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Landslide Types and Processes

Landslides in the United States occur in all 50 States. The primary regions of landslide occurrence and potential are the coastal and mountainous areas of California, Oregon, and Washington, the States comprising the intermountain west, and the mountainous and hilly regions of the Eastern United States. Alaska and Hawaii also experience all types of landslides.

Landslides in the United States cause approximately $3.5 billion (year 2001 dollars) in damage, and kill between 25 and 50 people annually. Casualties in the United States are primarily caused by rockfalls, rock slides, and debris flows. Worldwide, landslides occur and cause thousands of casualties and billions in monetary losses annually.

The information in this publication provides an introductory primer on understanding basic scientific facts about landslides—the different types of landslides, how they are initiated, and some basic information about how they can begin to be managed as a hazard.

La Conchita, coastal area of southern California. This landslide and earthflow occurred in the spring of 1995. People were evacuated and the houses nearest the slide were completely destroyed. This is a typical type of landslide. *Photo by R.L. Schuster, U.S. Geological Survey.*

TYPES OF LANDSLIDES

The term “landslide” describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. The materials may move by falling, toppling, sliding, spreading, or flowing. Figure 1 shows a graphic illustration of a landslide, with the commonly accepted terminology describing its features.

The various types of landslides can be differentiated by the kinds of material involved and the mode of movement. A classification system based on these parameters is shown in figure 2. Other classification systems incorporate additional variables, such as the rate of movement and the water, air, or ice content of the landslide material.

Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief. In low-relief areas, landslides occur as cut-and-fill failures (roadway and building excavations), river bluff failures, lateral spreading landslides, collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and open-pit mines. The most common types of landslides are described as follows and are illustrated in figure 3.

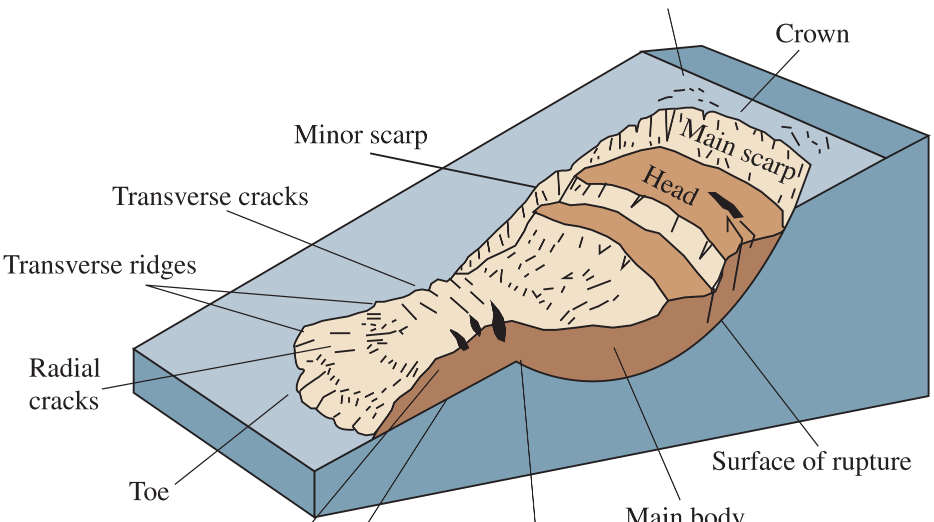

Figure 1. An idealized slump-earth flow showing commonly used nomenclature for labeling the parts of a landslide.

SLIDES: Although many types of mass movements are included in the general term “landslide,” the more restrictive use of the term refers only to mass movements, where there is a distinct zone of weakness that separates the slide material from more stable underlying material. The two major types of slides are rotational slides and translational slides.

Rotational slide: This is a slide in which the surface of rupture is curved concavely upward and the slide movement is roughly rotational about an axis that is parallel to the ground surface and transverse across the slide (fig. 3A).

Translational slide: In this type of slide, the landslide mass moves along a roughly planar surface with little rotation or backward tilting (fig. 3B). A *block slide* is a translational slide in which the moving mass consists of a single unit or a few closely related units that move downslope as a relatively coherent mass (fig. 3C).

FALLS: Falls are abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs (fig. 3D).

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TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow	Debris flow	Earth flow
		(deep creep)	(soil creep)	
COMPLEX	Combination of two or more principal types of movement			

Figure 2. Types of landslides. Abbreviated version of Varnes' classification of slope movements (Varnes, 1978).

Separation occurs along discontinuities such as fractures, joints, and bedding planes, and movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water.

TOPPLES: Toppling failures are distinguished by the forward rotation of a unit or units about some pivotal point, below or low in the unit, under the actions of gravity and forces exerted by adjacent units or by fluids in cracks (fig. 3E).

FLOWS: There are five basic categories of flows that differ from one another in fundamental ways.

a. Debris flow: A debris flow is a form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope (fig. 3F). Debris flows include <50% fines. Debris flows are commonly caused by intense surface-water flow, due to heavy precipitation or rapid snowmelt, that erodes and mobilizes loose soil or rock on steep slopes. Debris flows also commonly mobilize from other types of landslides that occur on steep slopes, are nearly saturated, and consist of a large proportion of silt- and sand-sized material. Debris-flow source areas are often associated with steep gullies, and debris-flow deposits are usually indicated by the presence of debris fans at the mouths of gullies. Fires that denude slopes of vegetation intensify the susceptibility of slopes to debris flows.

b. Debris avalanche: This is a variety of very rapid to extremely rapid debris flow (fig. 3G).

c. Earthflow: Earthflows have a characteristic "hourglass" shape (fig. 3H). The slope material liquefies and runs out, forming a bowl or depression at the head. The flow itself is elongate and usually occurs in fine-grained materials or clay-bearing rocks on moderate slopes and under saturated conditions. However, dry flows of granular material are also possible.

d. Mudflow: A mudflow is an earthflow consisting of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles. In some instances, for example in many newspaper reports, mudflows and debris flows are commonly referred to as "mudslides."

e. Creep: Creep is the imperceptibly slow, steady, downward movement of slope-forming soil or rock. Movement is caused by shear stress sufficient to produce permanent deformation, but too small to produce shear failure. There are generally three types of creep: (1) seasonal, where movement is within the depth of soil affected by seasonal changes in soil moisture and soil temperature; (2) continuous, where shear stress continuously exceeds the strength of the material; and (3) progressive, where slopes are reaching the point of failure as other types of mass movements. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges (fig. 3I).

LATERAL SPREADS: Lateral spreads are distinctive because they usually occur on very gentle slopes or flat terrain (fig. 3J). The dominant mode of movement is lateral extension accompanied by shear or tensile fractures. The failure is caused by liquefaction, the process whereby saturated, loose, cohesionless sediments (usually sands and silts) are transformed from a solid into a liquefied state. Failure is usually triggered by rapid ground motion, such as that experienced during an earthquake, but can also be artificially induced. When coherent material, either bedrock or soil, rests on materials that liquefy, the upper units may undergo fracturing and extension and may then subside, translate, rotate, disintegrate, or liquefy and flow. Lateral spreading in fine-grained materials on shallow slopes is usually progressive. The failure starts suddenly in a small area and spreads rapidly. Often the initial failure is a slump, but in some materials movement occurs for no apparent reason. Combination of two or more of the above types is known as a complex landslide.

LANDSLIDE CAUSES

1. Geological causes
   a. Weak or sensitive materials
   b. Weathered materials
   c. Sheared, jointed, or fissured materials
   d. Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth)
   e. Contrast in permeability and/or stiffness of materials

2. Morphological causes
   a. Tectonic or volcanic uplift
   b. Glacial rebound
   c. Fluvial, wave, or glacial erosion of slope toe or lateral margins
   d. Subterranean erosion (solution, piping)
   e. Deposition loading slope or its crest
   f. Vegetation removal (by fire, drought)
   g. Thawing
   h. Freeze-and-thaw weathering
   i. Shrink-and-swell weathering

3. Human causes
   a. Excavation of slope or its toe
   b. Loading of slope or its crest
   c. Drawdown (of reservoirs)
   d. Deforestation
   e. Irrigation
   f. Mining
   g. Artificial vibration
   h. Water leakage from utilities

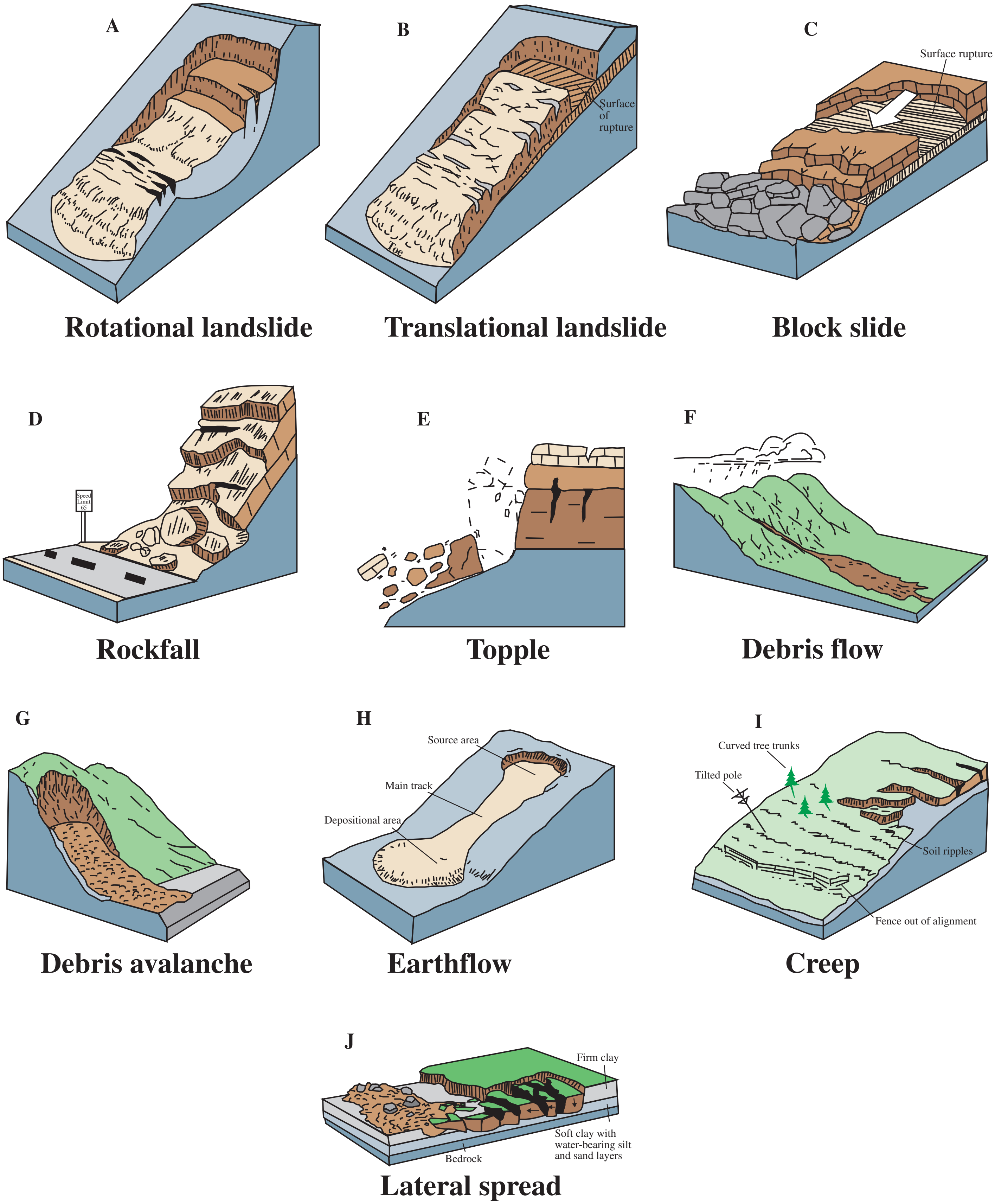

Figure 3. These schematics illustrate the major types of landslide movement that are described in the previous pages. For additional information on these processes and where to find photos, please see "Where to Go For More Information" at the end of this fact sheet.

Although there are multiple types of causes of landslides, the three that cause most of the damaging landslides around the world are these:

Landslides and Water

Slope saturation by water is a primary cause of landslides. This effect can occur in the form of intense rainfall, snowmelt, changes in ground-water levels, and water-level changes along coastlines, earth dams, and the banks of lakes, reservoirs, canals, and rivers.

Landsliding and flooding are closely allied because both are related to precipitation, runoff, and the saturation of ground by water. In addition, debris flows and mudflows usually occur in small, steep stream channels and often are mistaken for floods; in fact, these two events often occur simultaneously in the same area.

Landslides can cause flooding by forming landslide dams that block valleys and stream channels, allowing large amounts of water to back up. This causes backwater flooding and, if the dam fails, subsequent downstream flooding. Also, solid landslide debris can "bulk" or add volume and density to otherwise normal streamflow or cause channel blockages and diversions creating flood conditions or localized erosion. Landslides can also cause overtopping of reservoirs and/or reduced capacity of reservoirs to store water.

Landslides and Seismic Activity

Many mountainous areas that are vulnerable to landslides have also experienced at least moderate rates of earthquake occurrence in recorded times. The occurrence of earthquakes in steep landslide-prone areas greatly increases the likelihood that landslides will occur, due to ground shaking alone or shaking-caused dilation of soil materials, which allows rapid infiltration of water. The 1964 Great Alaska Earthquake caused widespread landsliding and other ground failure, which caused most of the monetary loss due to the earthquake. Other areas of the United States, such as California and the Puget Sound region in Washington, have experienced slides, lateral spreading, and other types of ground failure due to moderate to large earthquakes. Widespread rockfalls also are caused by loosening of rocks as a result of ground shaking. Worldwide, landslides caused by earthquakes kill people and damage structures at higher rates than in the United States.

Landslides and Volcanic Activity

Landslides due to volcanic activity are some of the most devastating types. Volcanic lava may melt snow at a rapid rate, causing a deluge of rock, soil, ash, and water that accelerates rapidly on the steep slopes of volcanoes, devastating anything in its path. These volcanic debris flows (also known as lahars) reach great distances, once they leave the flanks of the volcano, and can damage structures in flat areas surrounding the volcanoes. The 1980 eruption of Mount St. Helens, in Washington triggered a massive landslide on the north flank of the volcano, the largest landslide in recorded times.

Landslide Mitigation—How to Reduce the Effects of Landslides

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of a site and by making inquiries to planning and engineering departments of local governments. They can also obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazard potential of a site, built or unbuilt.

The hazard from landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increases when ground water is prevented from rising in the landslide mass by (1) covering the landslide with an impermeable membrane, (2) directing surface water away from the landslide, (3) draining ground water away from the landslide, and (4) minimizing surface irrigation. Slope stability is also increased when a retaining structure and/or the weight of a soil/rock berm are placed at the toe of the landslide or when mass is removed from the top of the slope.

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This fact sheet is available online at
http://pubs.usgs.gov/fs/2004/3072/

Where to go for more information

1. The U.S. Geological Survey Landslide Program has information, publications, and educational information on its Web site. Please see:
http://landslides.usgs.gov
or phone toll-free:
1-800-654-4966

2. For general information about slides, debris flows, rock falls, or other types of landslides in your area, contact your city or county geology or planning office. In addition, all 50 States have State Geological Surveys that can be accessed through a link at the USGS Web site,
http://landslides.usgs.gov

3. For an assessment of the landslide risk to an individual property or homesite, obtain the services of a State-licensed geotechnical engineer or engineering geologist. These professionals can be found through the membership listings of two professional societies, the American Society of Civil Engineers (ASCE), *http://www.asce.org* and the Association of Engineering Geologists *http://www.aegweb.org*. Often, personnel in State or county planning or engineering departments can refer competent geotechnical engineers or engineering geologists.

4. For more information about the design and construction of debris-flow mitigation measures which may include debris basins, debris fences, deflection walls, or other protective works, consult your city or county engineer, local flood-control agency, or the U.S. Department of Agriculture, Natural Resources Conservation Service:
http://www.ncgc.nrcs.usda.gov/

5. For photos of landslide types please see:
http://landslides.usgs.gov/html_files/nlic/nlicmisc.html

6. For more detailed information: two excellent publications that very clearly describe the processes of landslides were consulted for this fact sheet:

Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L., and Krizek, R.J., eds., Landslides—Analysis and control: National Research Council, Washington, D.C., Transportation Research Board, Special Report 176, p. 11–33.

Turner, Keith A., and Schuster, Robert L., 1996, Landslides—Investigation and mitigation: Transportation Research Board, National Research Council, National Academy Press.