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Introduction

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.

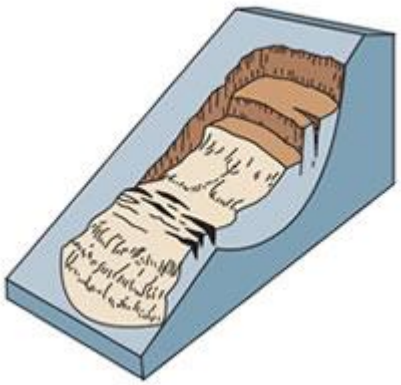
Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief. In low-relief areas, landslides occur as cut-and-fill failures (roadway and building excavations), river bluff failures, lateral spreading landslides, collapse of mine-waste piles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

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.

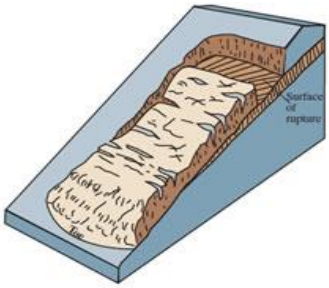
Rotational slide

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.



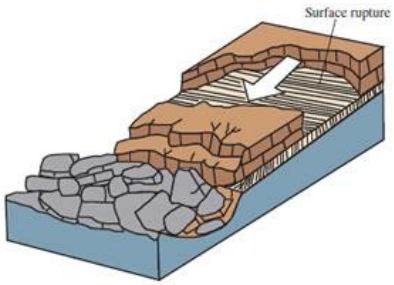
Translational slide

In this type of slide the landslide mass moves along a rough planar surface with little or backward tilting



Block slide

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



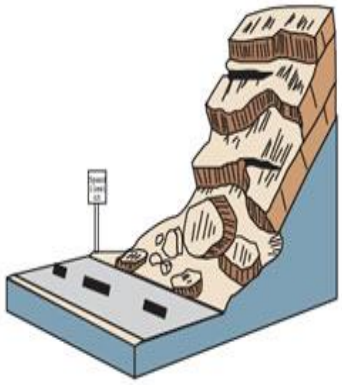
Falls

A rockfall is a sudden fall or collapse of a large mass of material from a precipitous position. Rockfalls occur along cliffs or very steep slopes where masses of rock can detach and begin a free-fall, often combined with a bouncing or rolling descent. No slip-plane or surface of flow is involved.

Rockfalls are rapid, and because of their speed and sudden occurrence, they are very dangerous. They often occur in the spring as freeze-thaw actions loosen jointed rocks.

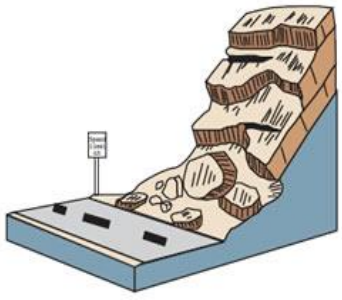
Rock fall

Falls are abrupt movements of masses of geologic materials such as rocks and boulders that become detached from steep slopes or cliffs. Separation occurs along discontinuities such as fractures, joints and bedding planes and movement occur 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.

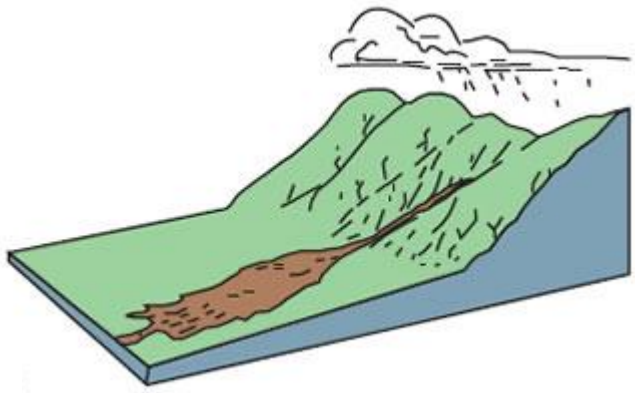


Flows

The basic categories of flows that differ from one another in fundamental ways

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. Debris flows include less than 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 proposition 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.



Earth flow

Earthflows have a characteristic “hourglass” shape. The slope material liquifies 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

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 mudslide.

Debris Avalanche

This is a variety of very rapid to extremely rapid debris flow.

Causes of Landslide

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

(1) water

(2) seismic activity and

(3) volcanic activity.

These are discussed in the sections below.

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 groundwater levels, and water level changes along coastlines, earth dams, and the banks of lakes, reservoirs, canals, and rivers.

Land sliding 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.

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.

Case Study 2019 Puthumala landslide

Puthumala, a plantation village near Meppadi is 20 kms away from Kalpetta in Wayanad district and is located at 1230 m above mean sea level. On 8th August 2019, due to heavy rainfall in the monsoon

season, severe floods and landslides affected the state of Kerala. A massive landslide occurred at the Puthumala village. The epicentre of the landside was 290-metre-high on the mountain which brought down 20 hectares of land pushing it to a distance of about 2 kms. The analysis of the rainfall data showed that in a span of just 24 hours before the landslide, the area received around 500 mm of intense rainfall. The Puthumala landslide started out as one of those smaller landslides which occurred deep inside the forest. However, the landslide turned catastrophic because the soil structure in the lower parts was fragile and soaked in rain. When rocks and soil crushed under pressure, it turned into a huge landslide. It was observed that large portion of the hill was collapsed and huge strip of valley land was filled with mud, rocks and debris. Some of the major factors for landslides in this region were high rainfall intensity resulting in the soil disintegration, deforestation, shallow soil depth resulted in water seeping into the cavities or soil piping, cardamom farming on the side of the mountain made the soil loose, vanishing stream length due to construction and occupation, unscientific construction and mining on the hill which changed the structure of the soil. In Puthumala, nearly 100 acres of tea plantation was washed away in the massive landslide. The village's primary livelihood depended on agriculture, with crops such as cardamom, pepper, coffee and tea. Based on the assessment of Soil conservation department of Wayanad District about 25,000 hectares area had lost the top fertile soil of 2 cm which would severely affect the agriculture production. Nearly, 40 ha of land was affected by land slide, land slip and silt deposit. The soil nutrients were washed away due to high intensity rainfall events in the region. As a result of landslide, soil covered the whole plantation of coffee and tea of 300 acres. The landslide sites are a part of the ecologically sensitive Western Ghats and they were on the list of areas vulnerable to landslides. In Wayanad, 102.6 km2 and 196.6 km2 area are under extremely landslide prone and moderately landslide prone respectively with some locations also vulnerable to soil piping effect. The landslide-prone regions are likely to increase in future due to the climate change. Therefore, it is necessary to regulate and prohibit unscientific constructions, regulate land development activities and functioning of quarries in landslide hazard prone areas of the district for preventing such disasters in future.

Volcanoes

A volcano is a mountain that opens downward to a reservoir of molten rock below the surface of the earth. Unlike most mountains, which are pushed up from below, volcanoes are vents through which molten rock escapes to the earth's surface. When pressure from gases within the molten rock becomes too great, an eruption occurs. Eruptions can be quiet or explosive. There may be lava flows, flattened landscapes, poisonous gases, and flying rock and ash that can sometimes travel hundreds of miles downwind.

Volcanic eruptions may be subtle or explosive and can produce dangerous lava flows, poisonous gases, and flying rocks and ash. Many volcanic eruptions are also accompanied by other natural hazards, such as earthquakes, landslides, debris flows, flash floods, fires and tsunamis.

They are typically located along the borders of the tectonic plates which sit on the lithosphere. When changes in pressure and density occur in the magma chamber beneath the volcano, it can force lower density lava and rocks to rise; sometimes explosively. More than 75% of the active volcanoes are within the Pacific 'Ring of Fire' - a band of volcanoes and ocean trenches where different plates meet. The Ring of Fire stretches along the western coast of South, Central and North America and then across to the eastern coast of Russia, China, and the entirety of Japan, the Philippines and many islands in the south Pacific Ocean.

While many volcanoes are located under the ocean, those on land can pose great danger to life depending on proximity to inhabited areas and the intensity of the eruption. Mount Vesuvius in Italy is a famous historical and modern example; the volcano destroyed two cities two thousand years ago, and today millions of people still live within close proximity of this active volcano.

Volcanoes are generally classified as being active, dormant or extinct based on their level of activity. Determining whether a volcano is active or not can be challenging, as volcanoes can be active under the surface with no outward signs on the surface. Historical records are important in this respect, as volcanoes that have erupted recently are generally likely to do so again but there may be years or centuries between periods of activity.

The different types of ("primary") eruptive events are:

- Pyroclastic explosions;
- Hot ash releases;
- Lava flows;
- Gas emissions;
- Glowing avalanches (gas and ash releases).

Secondary events are

- Melting ice, snow and rain accompanying eruptions are likely to provoke floods and hot mudflows (or lahars);
- Hot ash releases can start fires.

Volcano Case Study – Mt. Merapi

Mount Merapi is located in South East Asia in the country of Indonesia. It is on the island of Java. It is 1,700m high and has been erupting regularly since the 1500s.

The volcano is located on a destructive plate margin at a subduction zone and is part of the Pacific Ring of Fire.

Primary (caused directly by the volcano)	**Secondary** (result from primary effects)
Volcanic bombs and hot gases of up to 800°C spread over 11km away	Vegetable prices increased because of the damage to crops
Pyroclastic flows spread 3km down the mountain	Emergency shelters had to be moved over 15km away

Ash fell up to 30km away and 5km into the sky. 15km away, villages were under 30cm of ash	Danger area extended to 20km from the mountain and 278,000 people living in this area had to flee their homes
Sulphur Dioxide was blown across Indonesia and as far South as Australia	Planes were grounded in Western Australia because of the risk of damage to aircraft from the ash cloud
	Ash, rock and lava deposited on the sides of the volcano is still being washed down into towns by rainfall creating lahar (a mudflow that often flows along river valleys)

Impacts

Positive	Negative
Ash from the volcano will eventually lead to more fertile soils in the area	273 people were killed and 577 people were injured
A conservation area has been set up around the volcano where it is unsafe to live	The evacuation centres were overcrowded leading to poor sanitation, no privacy and serious disease risk
	People, particularly farmers, lost their homes and livelihoods
	360,000 people were displaced from their homes