Mass Wasting—Landscapes in Motion

Landslides can be just a nuisance...

...or costly (Slumgullion landslide, CO)...

Santa Tecla, El Salvador
January, 2001
Landslide in volcanic debris triggered by a 7.6 earthquake
1200 missing in Las Colinas neighborhood of Santa Tecla
Read more at: http://landslides.usgs.gov/research/other/centralamerica.php

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Why study landslides?
- characteristics of mass movements?
- causes of mass movements?
- factors determining areas, timing, conditions of slope stability?
- how to map mass-movement hazards?
- how do mass movements sculpt the landscape?

Guinsaigon landslide, 2/17/06
Leyte Is., Philippines
Trigger: rainfall, saturation
Lake formed when slow-moving landslide dammed a river.
Landslides—what are they? & why study them?

- Landslides are a **surfacial** process that move rock and rock fragments downslope. Streams, wind, and glaciers all shape surficial landscapes.

- "Landslide" is a generic term for **gravity-driven downslope movement** of rock and regolith.

- Falling, flowing, sliding masses of rock and regolith are found all across Earth.

Landslides...so what?

- **Catastrophic landslides are infrequent, but sometimes with great losses.** Can infrequency lead to a false sense of security?? It seems important to better understand them.

- In the U.S. alone, landslides have an impact on the order of 1 to 2 billion dollars annually—not to mention injury and loss of life.

What are the characteristics of mass movements?

- Distinguishing the materials in motion:
  - **Rock, versus debris, versus earth**
    - **Rock** is, of course, rock irrespective of size
    - **Debris** is coarse-grained; 20–80% being >2 mm in size
    - **Earth** 80% or more are <2 mm in size

The criteria of classification

- Types of motion
  - **Free fall** – just as it sounds, material falls through the air, or bounces, and rolls downslope
  - **Slide** – material (either rock or regolith) that slides along a rupture surface
  - **Flow** – continuous movement of rock, regolith, or both that behaves as a high-viscosity liquid

- Rates of motion
  - **Extremely slow** (~1 mm/year)... to very rapid (>100 km/hour)

Classification of mass movements

<table>
<thead>
<tr>
<th>Name</th>
<th>Sub-type</th>
<th>Material</th>
<th>Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FALL</td>
<td>N/A</td>
<td>Rock fragments</td>
<td>Extremely fast ~32 ft/sec (fastest type of mass movement)</td>
</tr>
<tr>
<td>SLIDE (landslide)</td>
<td>Rotational (slump)</td>
<td>Unconsolidated sediments</td>
<td>Slow (~10')</td>
</tr>
<tr>
<td></td>
<td>Translational slide</td>
<td>Rock blocks</td>
<td>Fast (10')</td>
</tr>
<tr>
<td>FLOW</td>
<td>Debris avalanche</td>
<td>Rock fragments</td>
<td>Very fast (1-10)</td>
</tr>
<tr>
<td></td>
<td>Debris flow</td>
<td>Course loose sediments</td>
<td>Moderately fast</td>
</tr>
<tr>
<td></td>
<td>Mud flow</td>
<td>Loose fine sediments (mud)</td>
<td>Fast</td>
</tr>
<tr>
<td></td>
<td>Earth flow</td>
<td>Loose fine sediments</td>
<td>Slow</td>
</tr>
<tr>
<td></td>
<td>Soil</td>
<td>Still</td>
<td>Very slow</td>
</tr>
</tbody>
</table>

There are many tables more or less like this. See fig. 15.2 in book
Creep

Very slow flow is called creep. At left is an example of rock creep, while at right we see evidence of earth creep in the curved tree trunks.

Fig 15.8

Rock fall

A famous recent fall event. New Hampshire’s “Old Man of the Mountain” succumbed to the forces of nature in May 2003.

Fig 15.3

Falls are very fast but limited in scope

- Often damage roadways
- Rarely kill people other than climbers

A planar slide surface in California.

Material slides down the steeply inclined bedding planes and into the ocean. This road closes frequently due to rock slides. Rupture surfaces often follow a preexisting orientation that is prone to weakness, like the sedimentary bedding planes shown here.

Fig 15.5

Rupture surfaces

- Slides move along a rupture surface
- May be a planar surface like a bedding plane, or a rock joint or fault
- Can also be a curved surface
  - Commonly on unconsolidated soil or regolith
  - The mass rotates along the curved break
  - Such a rotational slide is called a slump
Shallow-translational landslide—Orting WA

Slump-earthflow
“backward rotational”

An earth slump in NY. Note in the inset below the back-tilted trees and pavement which shows rotational movement.

La Conchita Slump-earthflow, Calif.

Failed hillside at Chehalis, Washington

Caused by 1996 storms

The main features of a rotational landslide

Characteristic features:
Earthflow in the Sutter Buttes

Debris avalanche
Debris avalanche in Nicaragua. Debris avalanches are mixtures of materials that flow rapidly downslope though a debris avalanche behaves as a fluid mass, it generally contains very little water.

Mount St. Helens May 18, 1980, seconds after the beginning of the eruption. Photo by Gary Rosenquist from Bear Meadow, ~11 km northeast of the volcano.

Unzen Volcano, Japan, showing path of 1991 pyroclastic flow and surge that killed 39 including Maurice and Katia Krafft and vulcanologist Harry Glicken.
Madison Canyon, Montana, 1959

An earthquake-triggered landslide dammed lake.

Glacier Lake, WA, south of Packwood, circa AD 1500?

Spider Lake, SE Olympic Mountains

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Day Lake

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Parts of maps 79 (above) and 88 (right) of Lewis and Clark (Moulton, 1983) showing the area of the “Quicksand River” (Sandy River) and nearby areas along the Columbia River. These maps also show camps used by the party between Oct. 28, 1805 and April 6, 1806.

“Landslip above the Cascades”, Paul Kane, 1847, Stark Museum of Art
Watercolor on paper

Ponding to 240 ft:
Backwater to John Day R. confluence
Volume: 7 billion cubic meters
Fill in 10-25 days (1996 and 2001)

Flows
Flows are much like they sound. Rock and/or regolith moving as an uncohesive mass much as a liquid. In (a) below we see wet sand and gravel flowing as a slurry, while in (b), this debris flow is made of rock, wood, and other materials entrained as it flowed.
Van Trump debris flow going over Comet Falls at Mount Rainier

Stevens Creek debris flow—Columbia Gorge

debris flows Grand Canyon

Mount Rainier from Sunrise

The summit collapsed to generate the Osceola Mudflow about 5,000 yr B.P. The Columbia Crest cone grew in the crater formed by the collapse, one of the world’s 20 largest lahars. The Osceola buried a native American site in Enumclaw.

Lahars, or volcanic debris flows

Electron Mudflow—A.D. 1502

Enumclaw artifacts; Gerald Hedlund photo
Red dots show buried trees near Mount Rainer

Complex flows
This started as a large curved-base slide (a slump), but materials broke up as it rotated and slid, becoming a flow.

15.1 What are the characteristics of mass movements?
- Mass movements are downslope movement of rock, regolith, or both due solely to gravity.

The three characteristics used to describe mass movements are
1) the material (rock, debris, earth),
2) the type of movement (fall, slide, flow)
3) the velocity (fast, slow).

Further notes
Falls free fall down steep slopes.
Slides move along surfaces of rupture, planar or curved.
Flows behave as a viscous fluid even though no water may be present.

Even more notes
Landscape features such as scarps, surface cracks, tilted/bent trees, bumpy topography, and talus provide clues to the occurrence and type of mass movement.

Some mass-movement events may involve more than one process. Rock and regolith initially separate along a rupture surface, but the slide-displaced materials may fall or flow.
15.2 What causes mass movements?

Under the conditions below, a brick on a board will slide if tilted far enough. What does this mean? 1) Increasing slope favors motion or slope instability. Next, we may sand the board and find it moves more easily. 2) Smoother surfaces favor motion and slope instability, and if we wet the board, it moves easier still. 3) The presence of water favors motion and slope instability.

So slope angle, smoothness of surface, and presence of water all seem to enhance the tendency to slide down a slope.

Fig 15.11

Gravity is the driving force: on any slope there is a component of gravity parallel to the sloping surface and this part increases as slope increases. Thus, the steeper the slope, the more downward force.

Fig 15.12

Friction and cohesion are resisting forces to gravity. Friction is an opposing force when two surfaces are in contact that increases with the "roughness" of contacting surfaces. Friction also varies with slope angle, as it is a function of mass and gravity. Cohesion is an attractive force between particles at the atomic level. Loose sand or gravel have little cohesion, but clay particles, with charged surfaces, have high cohesion.

Fig 15.13

Movement occurs when the driving force (downslope part of gravity) is greater than the resisting forces (friction and cohesion). For any sloped system there is a critical angle that, if exceeded, will result in movement.

Fig 15.14

On a rocky slope, usually there are faults, joints, bedding planes, or some combination thereof. The fractured rock is stable if the friction along joints and bedding planes, and cohesive forces between blocks, is greater than the downslope component of gravity. When some part of this system changes, it becomes unstable and mass movement results.

Fig 15.15

In the case of regolith, much of the resisting force is in the cohesion and friction between particles, as well as the friction and cohesion between the regolith and the bedrock surface below. When particles lose contact with one another, the bulk resistive force is effectively gone and movement results.
15.2 What causes mass movements?

Mass movements occur if the gravitational force is stronger than the resistive strength of the rock or regolith.

The resisting strength is the sum of all frictional resistance to movement and the cohesion between minerals in the rock or regolith.

The magnitude of the gravitational force directed parallel to the slope is greater at steeper angles.

15.3 What factors determine slope stability?

**Water:** Small amounts increase cohesion, but add too much and it causes particles to lose contact with one another, reducing both friction and cohesion.

**Angle of repose:** This is the maximum angle of a stable slope as determined by the friction, cohesion, and particle shape.

**Vegetation:** Roots penetrate regolith and tend to bind particles together as well as absorb water. They are a stabilizing force on slopes. Here we see the result of vegetative loss due to fire and the resultant mass movement.
15.3 What factors determine slope stability?

However, in an arid region the lack of vegetation due to available moisture lends to unstable slopes. Weathered fragments fall or wash away quickly with nothing to bind them. Mass movements are typically falls and slides.

- Abundance of water
- The composition and texture of materials
- The presence and orientation of planar features in the rock that may form rupture surfaces
- The steepness of the slope, the amount of weathering, and vegetation.

15.4 When do mass movements occur?

Peru, 1970: earthquakes trigger debris avalanches around Nevado Huascaran. The mixture of regolith, rock, and ice buried the town of Yungay, killing 18,000.

A lahar in the Philippines in the wake of the eruption of Mt. Pinatubo (c. 1991). A lahar is a mixture of debris and ash saturated with water either from rain or from rapidly melted snow and ice from atop the volcano. Lahars such as this buried whole cities, and in total they deposited a volume in the Philippines that would cover Washington D.C. to a depth of three stories.

15.5 How do we know ... how to map mass-movement hazards?

A flowchart that addresses different aspects of the landscape. This is the sort of tool that hazard managers use to assess the potential of landslides.