New Topic: SLOPES

Colluvial - Related to Hill-Slope or Mountain-Slope Processes, Especially Those Driven Directly by Gravity

Colluvium - Gravity Driven Deposits

U.S. Landslide Risk

Landslides by U.S. Region

- California 40% of U.S. damage
- West Virginia 13% of U.S. damage
  - $100-300/person/yr
  - ≈ UTAH

WV Has 1st or 2nd Highest Landslide Damage Per Capita
Regional Causes of Landslides

- **Steep Topography**
  - Mountains
  - Incision by Rivers in Last 1 MY

- **Materials**
  - Red Shales - Expansive Clays

- **Stupid or Ignorant People**
  - Oversteepening of Slopes
  - w/o Geotechnical Consulting

Landslide Video Clips

Debris Slide on Sultan River, Dec 11, 2004
http://www.kayakingsucks.com/sultan/sultan.html

Kinki Landslide

http://video.yahoo.com/video/pjy?vid=ba123439578b6b8304eaeaf2e2d614d434

Huge landslide Japan's Kinki region of the Nara Prefecture in August 2004 after heavy rains in the region.

Video by Japanese Ministry of Land

Landslide blocked a major mountain roadway, but nobody was injured in the incident.
In 1978 near Rissa, Norway, a landslide devastated an area of 0.127 sq miles, which included 7 farms. The slide contained about 7 to 8 million cubic yards of debris - the biggest slide in Norway in this century. Of the 40 people caught in the slide area, only 1 died.

The cause of this landslide was later determined to be the failure of a quick clay (marine clay) that was triggered by the excavation and stockpiling of 900 cu yards of soil placed by the shore of Lake Botnen. The stockpiled soil was generated by excavation work from the construction of a new wing being added to an existing barn. Note the relationship between the volume of the slide (~7.5 million yards) to the volume of the excavation that triggered it (~900 yards) - a ratio of over 8,000.

The slide started at the lake shoreline and developed retrogressively landward, occurring over a period of 6 minutes. About 70-90 m of shore slid into the lake.

The AVI clips below show portions of the slide in progress as filmed from a nearby vantage point. Look at the houses in the video clips to get a sense of the size of the failure - in the second clip, you can see houses and barns being carried away by the slide.

**Part 1:** Note the speed with which the landslide is moving

**Part 2:** Note that the slide is moving over great distances even though the ground is virtually flat

---

**Campbell & others (1986)**

Classification

*after Varnes*

<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Rock</th>
<th>Debris</th>
<th>Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Rock Fall</td>
<td>Debris Fall</td>
<td>Earth Fall</td>
</tr>
<tr>
<td>Topple</td>
<td>Rock Topple</td>
<td>Debris Topple</td>
<td>Earth Topple</td>
</tr>
<tr>
<td>Planar Slide</td>
<td>Rock Slide</td>
<td>Debris Slide</td>
<td>Earth Slide</td>
</tr>
<tr>
<td>Rotational Slide</td>
<td>Rock Slump</td>
<td>Debris Slump</td>
<td>Earth Slump</td>
</tr>
<tr>
<td>Flow</td>
<td>Rock Flow</td>
<td>Debris Flow</td>
<td>Earth Flow</td>
</tr>
<tr>
<td>Avalanche</td>
<td>Rock Avalanche</td>
<td>Debris Avalanche</td>
<td>Earth Avalanche</td>
</tr>
</tbody>
</table>
### Basic Landslide Classification

<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock</td>
<td>“Soil”</td>
</tr>
<tr>
<td></td>
<td>Debris</td>
</tr>
<tr>
<td></td>
<td>Earth</td>
</tr>
</tbody>
</table>

- **Material**
  - “Rock” = Bedrock
  - “Soil” = Unconsolidated Material
  - Debris: >20 % Big Stuff (>2 mm)
  - Earth: <20 % Big Stuff (>2 mm)

### Landslides

<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Rock</th>
<th>“Soil”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Debris</td>
<td>Earth</td>
</tr>
</tbody>
</table>

- Fall
- Topple
- Planar Slide
- Rotational Slide
- Flow
- Avalanche
<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Rock</th>
<th>“Soil”</th>
<th>Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Rock Fall</td>
<td>Debris Fall</td>
<td>Earth Fall</td>
</tr>
<tr>
<td>Topple</td>
<td>Rock Topple</td>
<td>Debris Topple</td>
<td>Earth Topple</td>
</tr>
<tr>
<td>Planar Slide</td>
<td>Rock Slide</td>
<td>Debris Slide</td>
<td>Earth Slide</td>
</tr>
<tr>
<td>Rotational</td>
<td>Rock Slump</td>
<td>Debris Slump</td>
<td>Earth Slump</td>
</tr>
<tr>
<td>Slide</td>
<td>Rock Flow</td>
<td>Debris Flow</td>
<td>Earth Flow</td>
</tr>
<tr>
<td>Avalanche</td>
<td>Rock Avalanche</td>
<td>Debris Avalanche</td>
<td>Earth Avalanche</td>
</tr>
</tbody>
</table>

**ROCK FALL:**

Talus = Landform (= Block Apron)

Scree = Deposit = Sediment (= Block Mantle)

70 Ton Boulder: “Mon” Blvd., 10 March 1994

S. Kite Photo
Ice Mountain Talus, W.Va.
S. Kite Photo

S. Kite Photo

Landslides - Topple

**Landslides**

<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Rock Fall</th>
<th>Debris Fall</th>
<th>Earth Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar Slide</td>
<td>Rock Slide</td>
<td>Debris Slide</td>
<td>Earth Slide</td>
</tr>
<tr>
<td>Rotational Slide</td>
<td>Rock Stump</td>
<td>Debris Stump</td>
<td>Earth Stump</td>
</tr>
<tr>
<td></td>
<td>Rock Flow</td>
<td>Debris Flow</td>
<td>Earth Flow</td>
</tr>
<tr>
<td></td>
<td>Rock Avalanche</td>
<td>Debris Avalanche</td>
<td>Earth Avalanche</td>
</tr>
</tbody>
</table>

**Landslides**

SLIDE (Translational)

Rock Slides may Parallel Weakness

SLUMP (Rotational Slide)
Slump: the typical WV landslide. Slump scarp is at the head, and earthflow is at the toe. (Illustration by Paul Queen, WV Geol. Surv.)

Debris Slides, Venezuela, Dec 1999

La Conchita, California
Slump

http://www.wvgs.wvnet.edu/
www/geohaz/geohaz3.htm
Slump in McClure Pass, CO.

Tully Landslide, New York, 1994
<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Rock</th>
<th>“Soil”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Debris</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Earth</td>
</tr>
<tr>
<td>Fall</td>
<td>Rock Fall</td>
<td>Debris Fall</td>
</tr>
<tr>
<td>Topple</td>
<td>Rock Topple</td>
<td>Debris Topple</td>
</tr>
<tr>
<td>Planar Slide</td>
<td>Rock Slide</td>
<td>Debris Slide</td>
</tr>
<tr>
<td>Rotational Slide</td>
<td>Rock Slump</td>
<td>Debris Slump</td>
</tr>
<tr>
<td>Flow</td>
<td>Rock Flow</td>
<td>Debris Flow</td>
</tr>
<tr>
<td>Avalanche</td>
<td>Rock Avalanche</td>
<td>Debris Avalanche</td>
</tr>
</tbody>
</table>

“FLOW” is Confined to Channel or Hollow

Debris Flow: “Slurry” Consistency

Part of Water Flood – Debris Flood – Debris Flow Continuum

AVALANCHE: Trapped Air &/or Water Reduces Friction

Snow Avalanche

Debris Avalanche: Rapidly "Sliding" Debris - Typically Originates as Debris Slide
Twin Run & Simmons Run Debris Flows, Nov. 1985

November 1985 Debris Flow Track, Twin Run, Pendleton Co., WV

Superelevation of Debris Flow, Twin Run
QUESTIONS ON DEBRIS FLOW VIDEOTAPES

Define Debris Flow
What are the triggers for debris flows?
What Source Area Conditions favor Debris Flow?
Describe the 3 phases of a typical debris flow?
Describe the sedimentology and geomorphology of debris flows.
The Coast and Williams videotape predates the USGS Landslide Classification (Campbell, & Others, 1986)
Which examples in the video are not true debris flows?
What happens to woody debris in a debris flow
What happens to large rocks in a debris flow?
Can you tell a debris flow from a flood flow deposit?

Gros Ventre Landslide, Wyoming.

Photo taken in 1937 of landslide triggered by rainfall & snowmelt in 1925, slide dammed the Gros Ventre River, creating a lake that later drained catastrophically when the landslide dam failed, killing people downstream.

Gros Vente Slide, Wyoming

Thistle Slide, Utah

Slumgullion Earth flow-slide Colorado

$400 million


http://www.ldeo.columbia.edu/edu/dees/ees/ies2/masswasting/sld001.html
Landslides
Debris Flow - Avalanche Hazard
Seattle Area
Creep

SOLIFLUCTION: Soil Flow
Gelifluction: Solifluction Associated with Frozen Ground

Frozen Soil

\[0^\circ\text{C}\]

Thawed Soil

Winter

Summer

Permafrost Zone

Landslides

<table>
<thead>
<tr>
<th>Type of Motion</th>
<th>Rock</th>
<th>“Soil”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rock</td>
</tr>
<tr>
<td>Fall</td>
<td>Rock Fall</td>
<td>Debris Fall</td>
</tr>
<tr>
<td>Topple</td>
<td>Rock Topple</td>
<td>Debris Topple</td>
</tr>
<tr>
<td>Planar Slide</td>
<td>Rock Slide</td>
<td>Debris Slide</td>
</tr>
<tr>
<td>Rotational Slide</td>
<td>Rock Slump</td>
<td>Debris Slump</td>
</tr>
<tr>
<td>Flow</td>
<td>Rock Flow</td>
<td>Debris Flow</td>
</tr>
<tr>
<td>Avalanche</td>
<td>Rock Avalanche</td>
<td>Debris Avalanche</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Earth</td>
</tr>
<tr>
<td>Fall</td>
<td>Earth Fall</td>
<td></td>
</tr>
<tr>
<td>Topple</td>
<td>Earth Topple</td>
<td></td>
</tr>
<tr>
<td>Planar Slide</td>
<td>Earth Slide</td>
<td></td>
</tr>
<tr>
<td>Rotational Slide</td>
<td>Earth Slump</td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td>Earth Flow</td>
<td></td>
</tr>
<tr>
<td>Avalanche</td>
<td>Earth Avalanche</td>
<td></td>
</tr>
</tbody>
</table>
Coulomb Equation

\[ S = c + \sigma' \tan \Phi \]

Shear Strength =
Cohesion +
Effective Normal Force \( \times \)
Tangent of “Angle of Repose”

\( \Phi \) = Angle of Internal Friction
  = "Angle of Repose"

Plane Friction +
Interlocking Friction
\( \tan \Phi \) Increases from 0 to Infinity
as \( \Phi \) Increases from 0° to 90°
Normal Force ($\sigma'$) Influenced by Pore Pressure ($\mu$) In Wet Soils

\[ \sigma' = \sigma - \mu \]

$\mu > 0$ in saturated zone

$\mu < 0$ in unsaturated zone

Factor of Safety

Shear Strength/Shear Force

Bearing Capacity:
Load/Area Without Yield

Ultimate Bearing Capacity:
Load/Area Without Rupture

ATTERBERG LIMITS: Solid - Plastic - Liquid

Plastic: Continuous Deformation With Stress Without Rupture

Plastic Limit: Water Content at Which Solid Becomes Plastic

Liquid Limit: Water Content at Which Plastic Becomes Liquid
QUESTIONS ON DEBRIS FLOW VIDEOTAPES

Define Debris Flow
What are the triggers for debris flows?
What Source Area Conditions favor Debris Flow?
Describe the 3 phases of a typical debris flow?
Describe the sedimentology and geomorphology of debris flows.
The Coast and Williams videotape predates the USGS Landslide Classification (Campbell, & Others, 1986)
Which examples in the video are not true debris flows?
What happens to woody debris in a debris flow?
What happens to large rocks in a debris flow?
Can you tell a debris flow from a flood flow deposit?

Click here to answer these questions!

Props: DEBRIS FLOW VIDEOTAPES


Iverson, Richard M. 2001, Highlight from the Debris Flow Experiment Flume Studies, USGS informal document, 1 VHS videotape.

CALTRANS Rock Fall Video

http://www.maccaferri-canada.com/Scan123.jpg
Suggested Priorities of an International Landslide Hazard Program

ILRG poll of 300 members in 1992
(not in exact order of priority)

1. Mapping
   A. Prepare landslide susceptibility maps
   B. Landslide inventories at 1:10,000 scale or larger
   C. Landslide inventories at 1:20,000 to 1:80,000 scale
   D. Recon landslide inventories at 1:100,000 to 1:500,000 scale

2. Sponsor workshops
   A. Local decision-maker awareness
   B. Teach geologists how to identify landslides
   C. International research conferences

3. Gather info on landslide costs

4. Develop more applications for use of existing landslide info