Mass Wasting:
The Work of Gravity
Earth – Chapter 15
Mass wasting: downhill quickly like an avalanche, or slowly like creep.
The Importance of Mass Wasting

• Slopes are the most common elements in our physical landscape
  – Slopes may appear to be stable, but all are under the influence of gravity
  – At one extreme movement may be gradual and practically imperceptible
  – At the other, it may consist of a roaring debris flow or thundering rock avalanche
The Importance of Mass Wasting

• Landslides as Geologic Hazards
  – A landslide is a sudden event where large quantities of rock and soil move down steep slopes
    • When people and communities are in the way, a natural disaster may result
    • The term landslide has no specific definition in geology
  – Mass wasting refers to the downslope movement of rock, regolith, and soil under the direct influence of gravity
The Importance of Mass Wasting

• The Role of Mass Wasting in Landform Development
  – Mass wasting is the geologic process that often follows weathering
    • Sediment is ultimately transported to the sea
  – Combined effects of mass wasting and running water produce stream valleys
    • The most common and conspicuous of Earth’s landforms
8 Oct 06, Kashmir
Feb 06, Leyte, P.I.
Sedimentary layers

Material eroded by running water

Shale

Shale

Shale

Metamorphic rocks

Weathered debris moved downslope by mass wasting

Colorado River

Geologist's Sketch
Excavating the Colorado Plateau
Excavating the Colorado Plateau
The Importance of Mass Wasting

• Slopes Change Through Time
  – Most rapid and spectacular mass-wasting events occur in areas of rugged, geologically young mountains
  – Mass wasting and erosional processes slowly change these rugged mountains to more subdued terrain
  – If dynamic internal processes did not continually produce regions having higher elevations, the system that moves debris to lower elevations would eventually cease
  – Gravity is the controlling force of mass wasting, but several other factors play important roles
Controls and Triggers of Mass Wasting

• The Role of Water
  – When sediment pores fill with water, cohesion among particles are destroyed
  – Water can lubricate materials
  – Water adds weight to a mass of material
    • Example: Colorado Front Range
Saturation Reduces Friction

Dry sand grains are bound mainly by friction with one another.

Small amounts of water increase the cohesion among sand grains.

Saturation reduces friction and causes the sand to flow.
Heavy Rains Trigger Debris Flow

Boulder, Colorado debris flows of September 2013
Controls and Triggers of Mass Wasting

• Oversteepened Slopes
  – Many situations where oversteepening takes place
    • Examples: stream valleys and human activities
  – Unconsolidated granular particles assume a stable slope at the angle of repose
    • The steepest angle at which a material can remain stable
    • Different for various materials
  – Oversteepened slopes are unstable and can trigger mass wasting
Unstable Slopes

lesson: “It’s not nice to fool Mother Nature!”
• Removal of Vegetation
  – Plants protect against erosions by binding soil and regolith together
    • Plants also shield the soil surface from raindrop impacts
  – Vegetation is removed by forest fire or by humans (timber, farming, development)
    • Wildfires are inevitable in the western United States
    • Fast-moving destructive debris flows triggered by intense rainfalls are some of the most dangerous post-fire hazards
Fire
Controls and Triggers of Mass Wasting

• Earthquakes as Triggers
  – Earthquakes and aftershocks can dislodge rocks and unconsolidated materials
  – Examples from California and China
    • 1994 Northridge earthquake in California triggered 11,000 landslides
    • 2008 earthquake in China caused landslides which created temporary dams and “earthquake-created” lakes
  – Liquefaction
    • During periods of ground shaking, water-saturated surface materials behave as fluid-like masses that flow
Earthquakes as Triggers
result of Hebgen Lake Earthquake, 1959 (Montana)
result of Hebgen Lake Earthquake, 1959 (Montana)
Landslides Without Triggers?

- Many rapid mass wasting events occur without a discernible trigger
- Slope materials gradually weaken over time—eventually if the strength falls below what is necessary to maintain slope stability, a landslide will occur
  - Timing of these events is random
  - Accurate prediction is impossible
Classification of Mass-Wasting Processes

• Two things to consider for classifying mass-wasting processes:

• Type of Material
  – *Debris, mud, and earth* are used if soil and regolith move
  – “Rock” is used if bedrock moves

• Type of Motion
  – Fall
    • The free fall of detached pieces is called a *fall*
    • *Talus slopes* are built by rock falls
Talus Slopes

In the mountains, mechanical weathering produces angular rock fragments that fall to the base of a cliff. Over time, a talus slope forms.

The large angular rock fragments and high angle of repose make talus slopes a challenging climb.
Classification of Mass-Wasting Processes

• Type of Motion
  – Slide
    • A **slide** occurs when there is a distinct zone of weakness separating the slide material from the underlying material
      – **Rotational slide**—surface of rupture is concave up
      – **Translational slide**—material moves along a flat surface
  – Flow
    • **Flow** occurs when material moves downslope as a viscous fluid
      – Most are saturated with water
Classification of Mass-Wasting Processes

• Rate of Movement
  – Fast
    • A rock avalanche is the most rapid type of mass wasting
      – Rocks float on air as they move downslope
  – Slow
    • Creep moves particles a few millimeters per year
    • A wide range of rates exists between these two extremes
Watch Out for Falling Rock!
The mass of rocky debris raced downslope on a cushion of compressed air.
Rapid Forms of Mass Wasting

• Slump
  – A slump is the movement of a mass of rock or unconsolidated material as a unit along a curved surface (rotational slide)
    • Can involve a single mass or multiple blocks
  – Occurs along oversteepened slopes
Slump
La Jolla

Soledad Mtn. Rd.

December 14th, 1961 (my 16th birthday)
What happened in 2006
(photos are one hour apart)
What happened in 2006
(photos are one hour apart)
Classic slump characteristics
Slump at Point Fermia, California
Rapid Forms of Mass Wasting

• Rockslide
  – A **rockslide** occurs when blocks of bedrock slide down a slope
    • A **debris slide** occurs when unconsolidated material slides down a slope
      – Generally very fast and destructive
      – Sometimes triggered by melting snow or rain
        • Most common during the spring
      – Sometimes triggered by earthquakes
        • New Madrid, Yellowstone, Gros Ventre
The side of the mountain gave way when the tilted sandstone bed, that had been cut through by the river, could no longer maintain its position atop the saturated bed of clay.

Even though the Gros Ventre rockslide occurred in 1925, the scar left on the side of Sheep Mountain is still a prominent feature.
Rapid Forms of Mass Wasting

• Debris Flow
  – A **debris flow** is a rapid form of mass wasting that involves the flow of soil and regolith with water (**mudflow** if the material is fine grained)
  – Tend to occur more frequently in semi-arid mountainous regions
    • Sudden rainfall or snowmelt washes large quantities of sediment into rivers
      – Lack of vegetation to anchor soil
  – Often confined to channels and canyons
The consistency of a debris flow ranges from that of wet concrete to a soupy mixture not much thicker than muddy water.

When the material is fine-grained, the event may be called a mudflow.
Caraballeda, Venezuela
Rapid Forms of Mass Wasting

• **Lahar**
  – Debris flows composed mostly of volcanic materials
    • Example: Mount St. Helens
  – Historically some of the most deadly volcanic hazards
    • Can occur during a volcanic eruption or when a volcano is quiet
    • Take place when highly unstable layers of ash and debris become saturated with water
    • Generally follow stream channels
Lahars at Redoubt Volcano and Mount St. Helens
Lahars at Redoubt Volcano and Mount St. Helens
Rapid Forms of Mass Wasting

• Earthflow
  – **Earthflows** form on hillsides in humid regions during heavy precipitation or snowmelt
    • Water saturates the soil and regolith
  – Commonly involve materials rich in clay and silt
    • Very viscous, move at slower rates than more fluid debris flows
  – Range in size from a few meters to more than a kilometer long and several hundred meters wide!
Slow Movements

• Creep
  – Creep is the *gradual* movement of soil and regolith downhill
    • Imperceptibly slow!
    • Aided by the alternate expansion and contraction of the surface material
    • Caused by freezing and thawing or wetting and drying
  – Causes fences and utility walls to tilt
Creep

Expansion caused by freezing

Contraction during thaws

Surface when frozen

Surface when thawed

Creep

Soil and regolith

Bedrock
Effects of Creep
Slow Movements

- **Solifluction**
  - *Solifluction* is the downslope movement of waterlogged soils
    - Literally: “soil flow”
    - Promoted by a deeper dense clay hardpan or impermeable bedrock layer
    - Common in regions underlain by permafrost
      - Occurs in the active layer, the zone above the permafrost
Solifluction Lobes Near the Arctic Circle in Alaska
Slow Movements

• The Sensitive Permafrost Landscape
  – Permafrost is permanently frozen ground
    • Summers are too short and cool to melt ice below the shallow surface
    • Deeper ground remains below 0°C (32°F) throughout the year
  – Extensive around the Arctic Ocean
    • Land use is regulated to prevent the permafrost from melting
 Distribution of Permafrost

In the continuous zone, the only unfrozen areas are beneath deep lakes or rivers.

In the higher-latitude portions of the discontinuous zone, there are only scattered areas of thawed ground. Moving southward, the percentage of unfrozen ground increases.
When Permafrost Thaws
• Submarine landslides are common and widespread in occurrence
• The most spectacular underwater landslides occur on the flanks of submarine volcanoes (called seamounts)
Submarine landslides

- Large slumps and debris flows scar the continental slopes along the margins of the United States
  - Triggered by the rapid buildup of unstable sediments, or by forces such as storm waves and earthquakes
  - Especially active near deltas
End of Chapter