



PHYS 3800: Physical Geology Chapter 13: Unsafe Ground: Landslides and Other Mass Movements



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Introduction

- Earth's surface is not terra firma; it is mostly unstable.
- Mass movement (or mass wasting) is:
 - Downslope motion of rock, soil, sediment, snow, and ice
 - Driven by gravity operating on any sloping surface
 - Characterized by a wide range of rates (fast to slow)



Fig. 13.3e

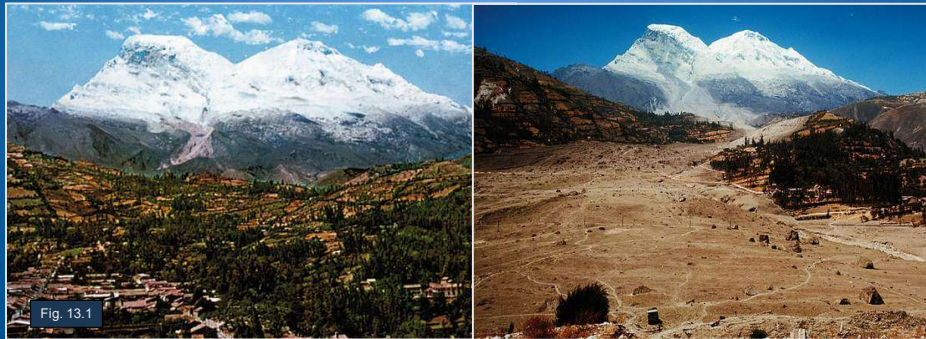
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Mass Movements

- Mass movements are a costly type of natural hazard.
 - A crucial component of the rock cycle
 - May often cause damage to living things and buildings.
- These hazards can produce catastrophic losses.
 - May 31, 1970: 18,000 people were buried in Yungay, Peru.



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Mass Movements

- Mass movements are important to the rock cycle.
 - The initial step in sediment transportation
 - A significant agent of landscape change
- All slopes are unstable; they change continuously.
- Mass movement is often aided by human activity.





Types of Mass Movement

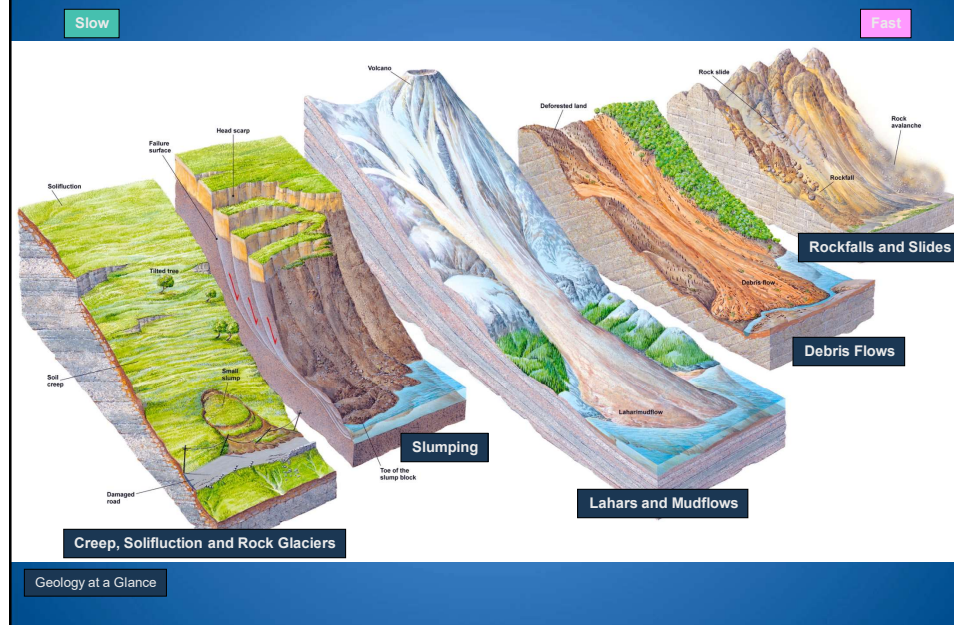
■ Classification is based upon four factors:

- The type of material (rock, regolith, snow, or ice)
- The velocity of movement (fast, intermediate, or slow)
- The nature of the mass (chaotic, coherent, or slurry)
- The movement environment (subaerial or submarine)



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Types of Mass Movement





Types of Mass Movement

- **Creep**—slow downhill movement of regolith
 - Due to seasonal soil expansion and contraction
 - Wetting and drying
 - Freezing and thawing
 - Warming and cooling
 - Grains are moved:
 - Perpendicular to slope upon expansion
 - Vertically downward by gravity upon contraction

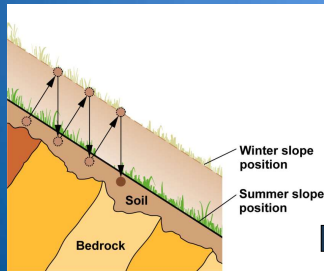
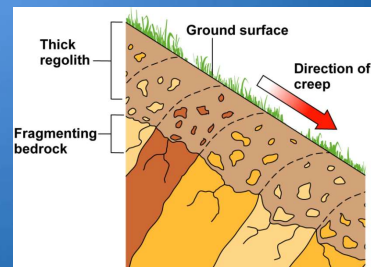


Fig. 13.2a, b



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Types of Mass Movement

- **Creep is evident from tilting of landscape features.**
 - Trees
 - Telephone poles
 - Retaining walls
 - Foundations
 - Tombstones



House with sagging foundation and cracked walls

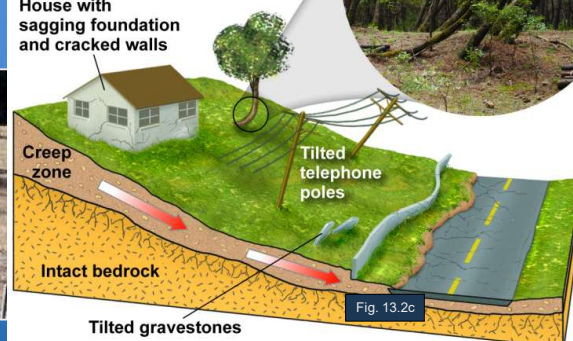


Fig. 13.2c



Types of Mass Movement

- **Solifluction**—low downhill movement of tundra
 - Melted permafrost slowly flows over deeper-frozen soil.
 - This process generates hillsides with solifluction lobes.



Fig. 13.2d

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Types of Mass Movement

- **Slumping**—sliding of regolith as coherent blocks
 - Slippage occurs along a spoon-shaped “failure surface.”
 - Display a variety of sizes and rates of motion.
 - Slumps have distinctive features:
 - ▶ Head scarp—upslope cliff face
 - ▶ Toe—material at base
 - ▶ Discrete faulted slices

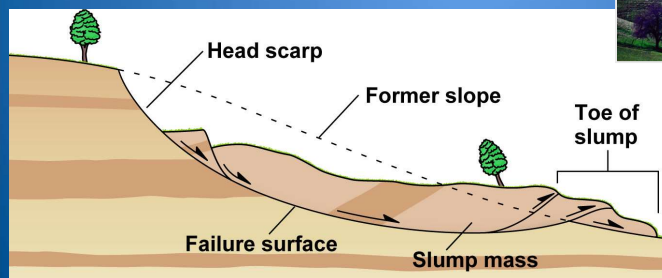
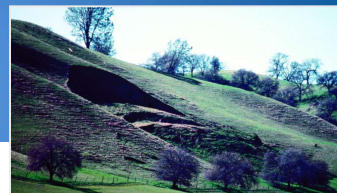


Fig. 13.3a, b



Types of Mass Movement

- Slumps are common along seacoasts & river cut banks.
 - Blocks that fall into water are often quickly eroded.
- Slumps can move slowly.
 - Can observe them develop
 - Reduces potential harm

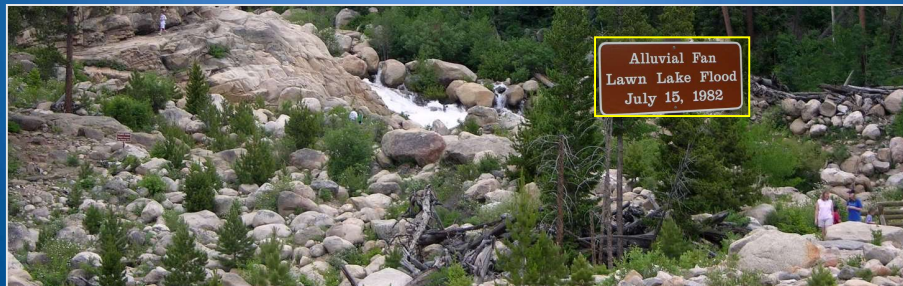


Fig. 13.3c, d

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Types of Mass Movement

- Mudflows, debris flows, and lahars—H₂O-rich movement
 - Move at a variety of speeds
 - Faster—more water or steeper slope angle
 - Slower—less water or lower slope angle
 - Tend to follow river channels down valley
 - Spread out into a broad lobe at the base of the slope
 - Able to carry huge boulders, houses, and cars





Types of Mass Movement

- Mudflows, debris flows, and lahars—H₂O-rich movement
 - Mudflow—a slurry of water and fine sediment
 - Common in tropical settings with abundant rainfall



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Types of Mass Movement

- Mudflows, debris flows, and lahars—H₂O-rich movement
 - Debris flow—a mudflow with many large rocks





Types of Mass Movement

- Mudflows, debris flows and lahars—H₂O-rich movement.

- Lahar—a special volcanic mud or debris flow
 - Volcanic ash (recent or ongoing eruptions) mixes with:
 - Water from heavy rains or melted glacial ice.



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Types of Mass Movement

- Lahar: Nevado del Ruiz volcano, Colombian Andes
- The volcano erupted the night of November 13, 1985.
 - Eruption melted some of the mountain's snowcap.
 - Meltwater mixed with ash and raced down river valleys.
 - Armero was buried, killing 20,000 residents in their sleep.



Fig. 5.18a



Types of Mass Movement

- Rock and debris slides—sudden movement downslope
 - Rock slide—a slide consisting of rock only
 - Debris slide—a slide comprised mostly of regolith
 - Movement down the failure surface is sudden and deadly.
 - Slide debris can move at 300 km per hour on a cushion of air.



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Types of Mass Movement

- Case study: The 1960 Vaiont Dam disaster, Italian Alps
 - Now we evaluate underlying geology for critical structures.
 - Limestone over shale in a deep synclinal gorge
 - Before:

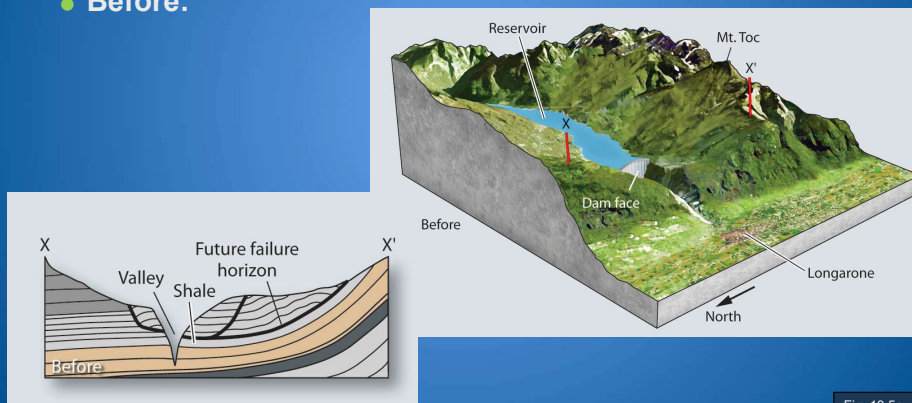


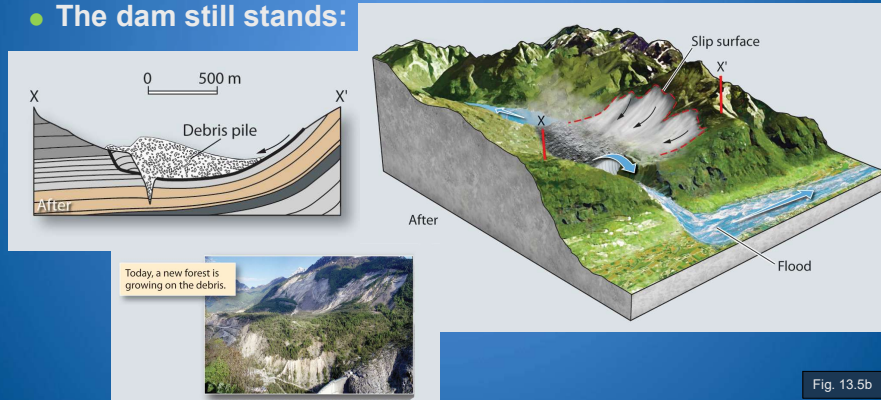
Fig. 13.5a



Types of Mass Movement

■ Case study: The 1960 Vaiont Dam disaster, Italian Alps

- October 9, 1963: 600 million tons of limestone slid into the reservoir.
- Resulting wave destroyed villages and killed 2,600 people.
- The dam still stands:



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Types of Mass Movement

■ Avalanches—turbulent clouds of debris and air

- Snow avalanche—oversteepened snow that detaches
- Move downhill with enormous force that flattens forests
- Tend to reoccur in clearly defined avalanche chutes
- Lethal to people caught in the way





Types of Mass Movement

- **Avalanches—turbulent clouds of debris and air**
 - Wet avalanches behave like a viscous slurry.
 - Hug the slope, entraining little air
 - Move relatively slowly (usually 30 km per hour)
 - Dry avalanches move cold, powdery snow.
 - Move above the ground surface on a layer of pressurized air
 - Move rapidly (up to 250 km per hour)



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Types of Mass Movement

- **Rockfalls and Debris Falls—vertical freefall of mass**
 - Bedrock or regolith falls rapidly downward
 - When blocks impact, they fragment and continue moving.
 - Talus blocks pile up at the base of the slope.



Fig. 13.7a, b

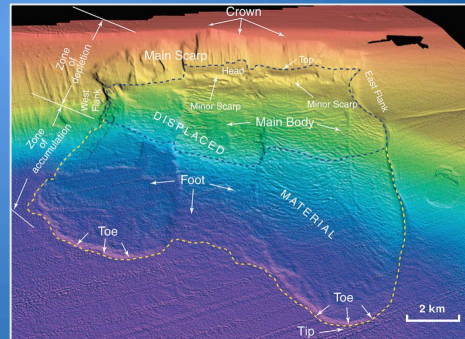


Types of Mass Movement

- Submarine mass movements often preserved by burial
 - Three types—based on degree of disintegration:
 - Submarine slumps—semicoherent blocks break and slip
 - Submarine debris flows—broken material moves as a slurry
 - Turbidity currents—sediment moves as a turbulent cloud
 - May be extremely large.



Fig. 13.8a, b



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Types of Mass Movement

- Gigantic submarine mass movements are documented.
 - Much larger than land-based mass movements
 - An important process for shaping land in tectonic settings
 - Mass movements tied to catastrophic tsunamis

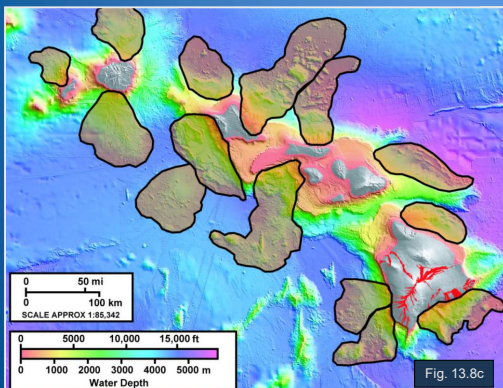


Fig. 13.8c



Why Do Mass Movements Occur?

- Mass movements require that earth materials:
 - Be subjected to topographic (slope) forces
 - Be weakened or loosened from their attachments
- Fragmentation and weathering
 - The upper crust is broken by jointing and faulting.
 - Chemical and physical weathering produces regolith.
 - Surface material is much weaker than solid crustal rock.



Fig. 13.9

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Why Do Mass Movements Occur?

- Slopes may be stable or unstable.
- Slope stability is a dynamic balance between two forces.
 - Downslope force—gravitational pull
 - Resisting force—material properties that resist motion.
- Slope failure occurs when downslope forces prevail.

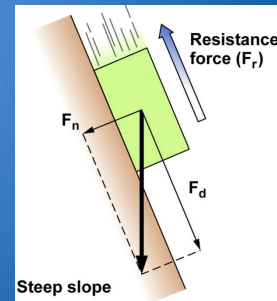
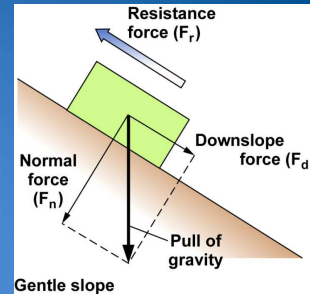




Slope Stability

- **Downslope forces = gravity**
 - The weight of Earth materials
 - The weight of added water
 - The weight of added structures
- **Resisting forces = material strength**
 - Cohesion
 - Chemical bonds
 - Electrical charges
 - Surface tension
 - Friction
- **Steeper slopes = larger forces**

Fig. 13.10



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Slope Stability

- **Loose granular material assumes a slope angle.**
 - “Angle of repose” is a material property due to:
 - Particle size and shape and the surface roughness.
 - Typical angles of repose:
 - Fine Sand: 35°
 - Coarse Sand: 40°
 - Angular Pebbles: 45°

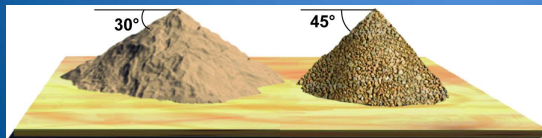


Fig. 13.11





Why Do Mass Movements Occur?

- Weak subsurface failure surfaces can initiate motion.
- Types of weak failure surfaces include:
 - Saturated sand or clay layers
 - Joints parallel to the land surface
 - Weak sedimentary bedding (shale, evaporites)
 - Metamorphic foliation planes

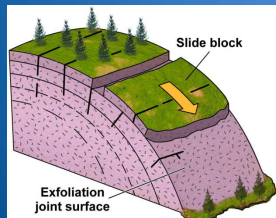
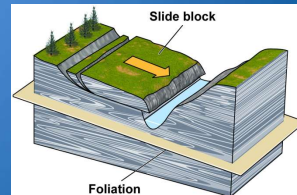
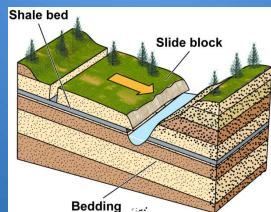


Fig. 13.12



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Why Do Mass Movements Occur?

- A destabilizing event usually triggers slope failure.
 - Triggers are both natural and anthropogenic.
 - Shocks, vibrations, and liquefaction
 - Changes in slope loads, steepness, and support
 - Changes in slope strength
- There may be no triggering event.





Why Do Mass Movements Occur?

- Shocks, vibrations, and liquefaction
 - Ground vibrations decrease material friction.
 - On an unstable slope, the downslope force takes over.
 - Vibrations are common.
 - Motion of heavy machinery or trains
 - Earthquakes
 - Vibrations can cause saturated sediments to liquefy.



Fig. 8.22c

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Why Do Mass Movements Occur?

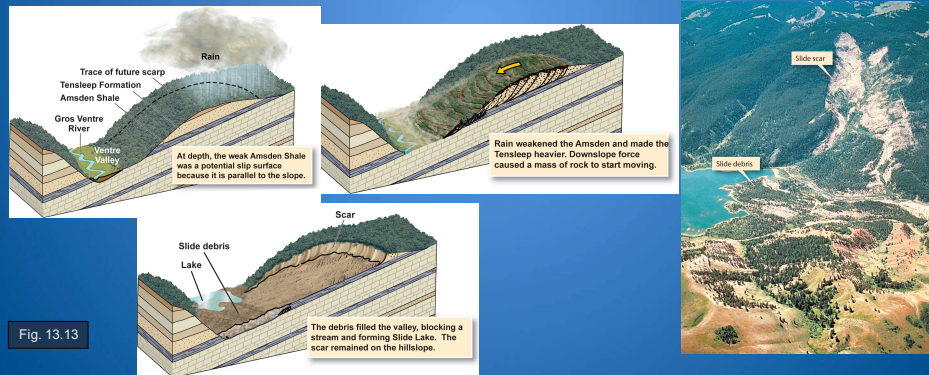
- Changes in characteristics can destabilize a slope.
 - Loading—adding weight to the top of a slope
 - Water—as rain or via humans (lawns, septic systems)
 - Materials—buildings, waste materials, fill, etc.
 - Angle—steepening a slope beyond the angle of repose
 - River incision
 - Excavation for buildings and roads





Why Do Mass Movements Occur?

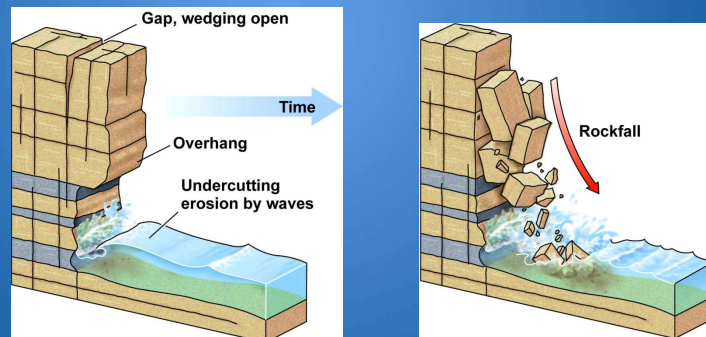
- Case Study: 1925 Gros Ventre Slide, Jackson Hole, Wyoming
- Gros Ventre River cut dipping beds on Sheep Mountain.
- Lubricated by rain, the slope failed on the Amsden Shale.
 - Around 40 million m³ slid 600 m, creating Slide Lake.



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Why Do Mass Movements Occur?

- Changes in characteristics can destabilize a slope.
 - Removing support—undercutting a slope leads to failure.
 - Natural—a river eroding the base of a slope
 - Human-induced—excavating the base of a slope





Why Do Mass Movements Occur?

■ Changes in slope strength

- Weathering—creates weaker regolith.
- Vegetation—stabilizes slopes. Removing vegetation:
 - Greatly slows removal of excess water
 - Destroys an effective stapling mechanism (roots)
 - Slope failures common after forest fires destroy vegetation



Fig. 13.3e

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Why Do Mass Movements Occur?

■ Changes in slope strength

- Water—reduces slope strength in several ways:
 - Adds a great deal of weight.
 - Water in pores pushes grains apart, easing disintegration.
 - Water lubricates grain contacts.
- Removing water, thereby, strengthens a failure surface.

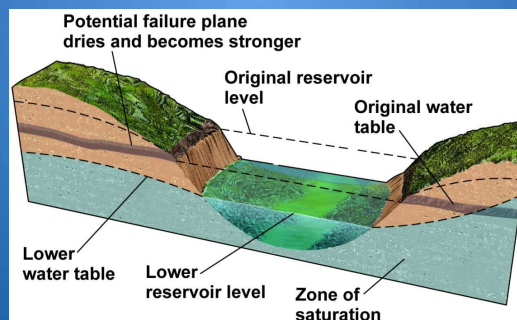


Fig. 13.17c



How Can We Protect Against Disaster?

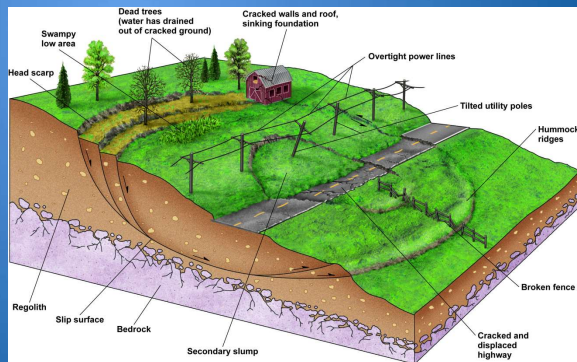
- Identifying regions at risk.
- Several factors are significant to mass movements:
 - Relief—steeper slopes have more mass movement.
 - Climate—more rainfall creates more water problems.



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Protecting Against Mass Movement

- Geologic mapping can identify regions at risk.
 - Highlight past failures (scarps, hummocky land, etc.)
 - Reveal currently unstable slopes:
 - Cracked and bulging ground
 - Measurable changes in surveyed land features
- GPS can detect slow movements.





Protecting Against Mass Movement

- Landslide potential mapping uses computer modeling.
 - Identifies areas of potential risk that may not show signs.
 - Assesses multiple factors:
 - Slope steepness
 - Strength of substrate
 - Degree of water saturation
 - Orientation of planar features
 - ✓ Bedding
 - ✓ Joints
 - ✓ Foliation
 - Vegetation cover
 - Heavy rain potential
 - Undercutting potential
 - Earthquake probability



Fig. 13.16

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Preventing Mass Movements

- Action can reduce mass-movement hazards.
 - Revegetation—adding plants has two positive effects:
 - It removes water by evapotranspiration.
 - Roots help to bind and anchor regolith.

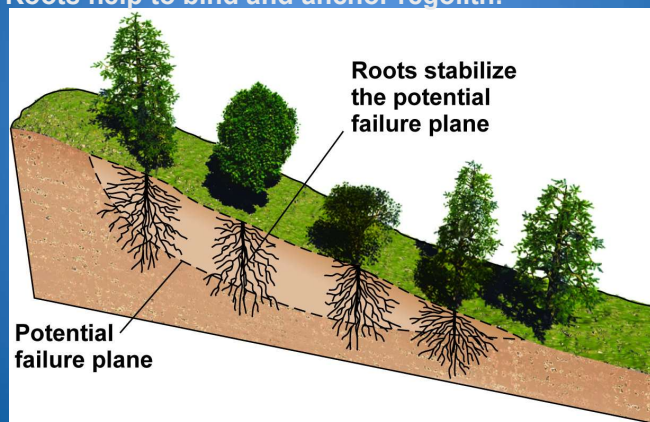


Fig. 13.17a



Preventing Mass Movements

- Action can reduce mass-movement hazards.
 - Redistributing mass by terracing.
 - Removes some of the mass loading a slope.
 - Catches debris.

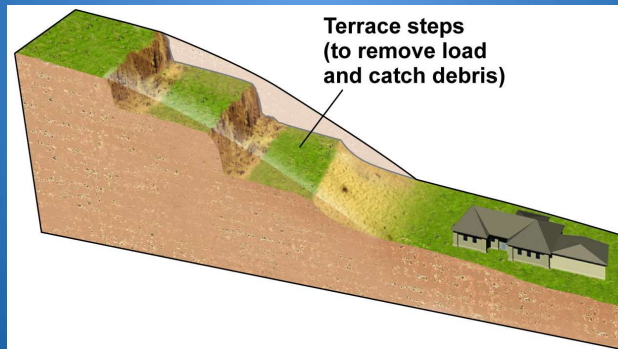


Fig. 13.17b

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Preventing Mass Movements

- Action can reduce mass-movement hazards.
 - Regrading—reshaping slopes below the angle of repose
 - Drainage—dewatering reduces weight; increases strength

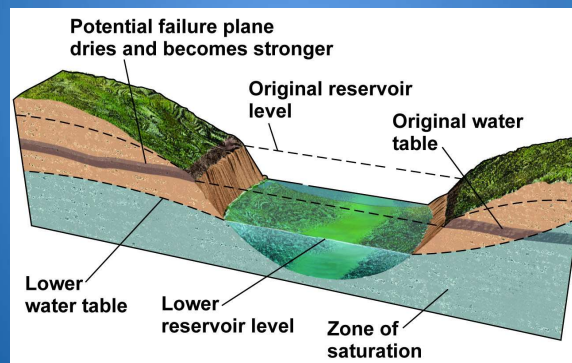


Fig. 13.17c



Preventing Mass Movements

- Action can reduce mass-movement hazards.
 - Slowing or eliminating undercutting—increases stability
 - Removing agent of erosion at the base of a slope
 - Reducing the effect of the agent of erosion (i.e., riprap)

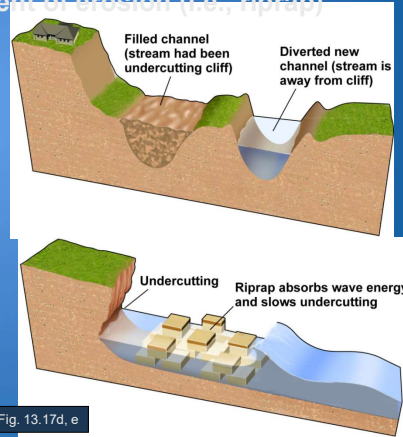
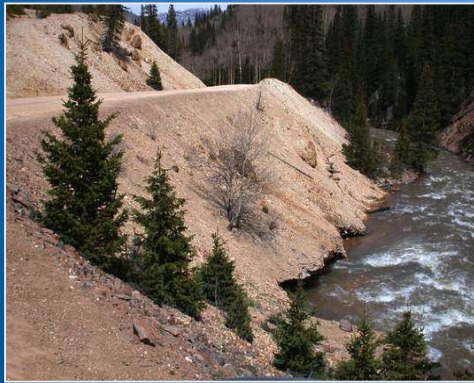


Fig. 13.17d, e

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Preventing Mass Movements

- Action can reduce mass-movement hazards.
 - Engineered structures—safety structures can be built to improve slope stability or to reduce movement hazards.
 - Retaining walls—barriers that pin the base and trap rock
 - Covers—fencing or coating that drapes over the outcrop

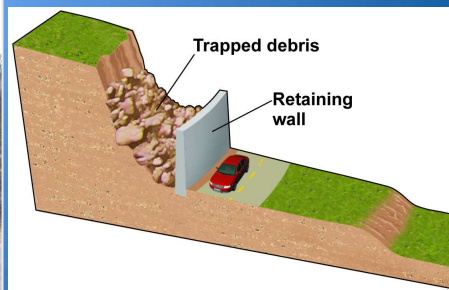


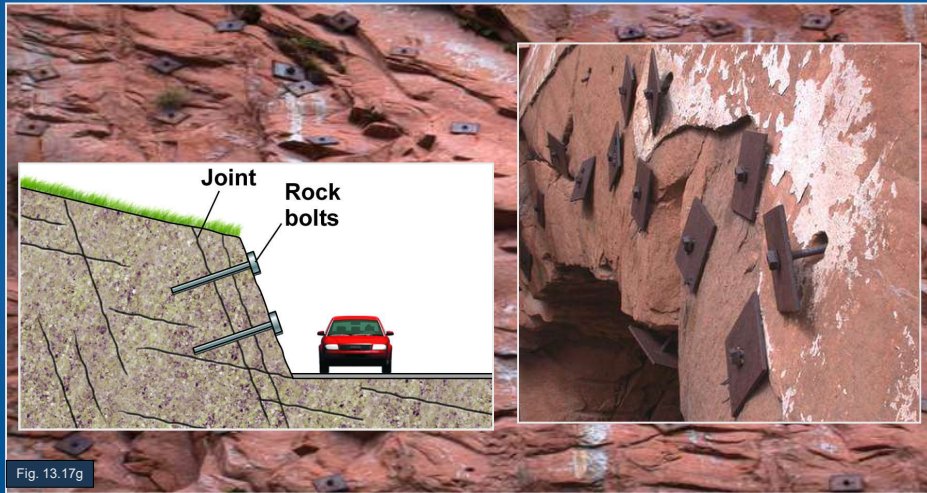
Fig. 13.17f



Preventing Mass Movements

- Engineered structures

- Rock staples—rods drilled into rock to hold loose facing.



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Preventing Mass Movements

- Engineered structures

- Avalanche sheds—structures that shunt avalanche snow
- Controlled blasting—surgical removal of dangerous rock





Useful Web Resources

- **USGS Landslide Hazards Program**
 - <http://landslides.usgs.gov/>
- **USGS Landslide Overview Map of the Conterminous United States**
 - <http://landslides.usgs.gov/learning/nationalmap/>