Mass Wasting

- *Mass wasting* is downhill movement of masses of bedrock, rock debris or soil, under the pull of gravity
- *Landslides* are much more costly over time in the U.S., in terms of both lives and dollars, than all other geologic and weather hazards combined
- Mass wasting is, with proper planning, perhaps the most easily avoidable of the major geologic hazards

Chapter 8

Mass Movement
(Mass Wasting)

Mass movements occur when the shearing stress acting on rocks or soil exceeds the shear strength of the material to resist it. Gravity provides the main component of shearing stress

Classification of Mass Wasting

- Mass wasting classification:
  - *Rate of movement*
    - Slow as< 1cm/year
    - Fast as >100 km/hour
  - *Type of material*
    - Start as solid bedrock
    - Start as loose *debris*
  - *Type of movement*
    - Flowage
    - Sliding
    - Falling

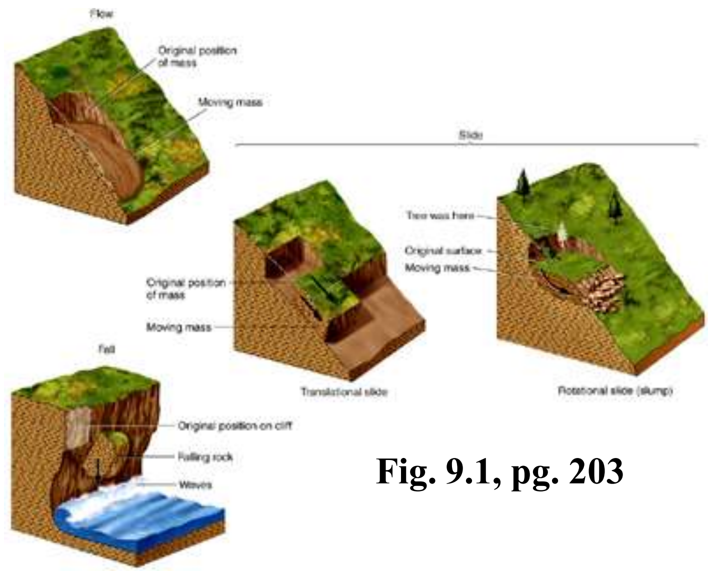


Fig. 9.1, pg. 203

Classification of Mass Wasting

- Types of movement
  - *Flow*
    - mass moves downhill as a viscous fluid
  - *Slide*
    - mass remains intact
    - slips along *well-defined surfaces*
      - ***Translational*** slide
        - » movement *parallel* to motion
      - ***Rotational*** slide (*slump*)
        - » movement along *a curved surface*
  - *Fall*
    - mass free-falls or bounces down a cliff

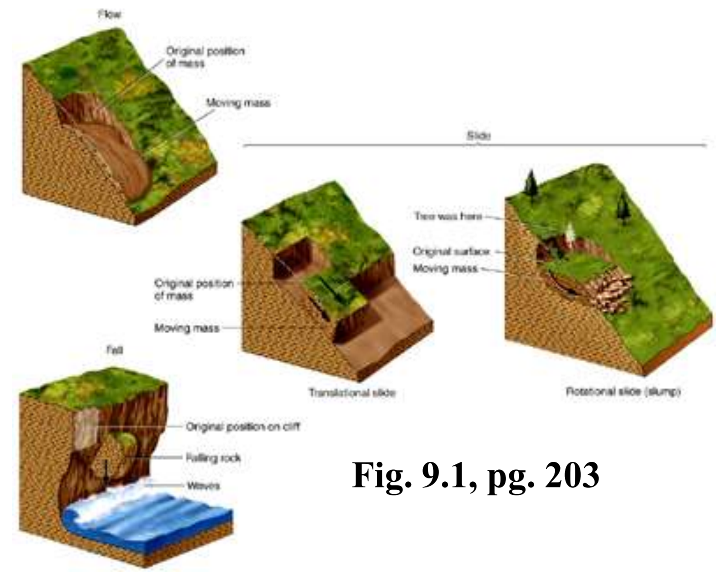
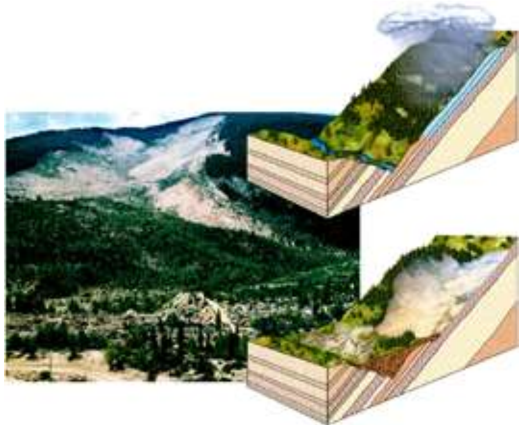
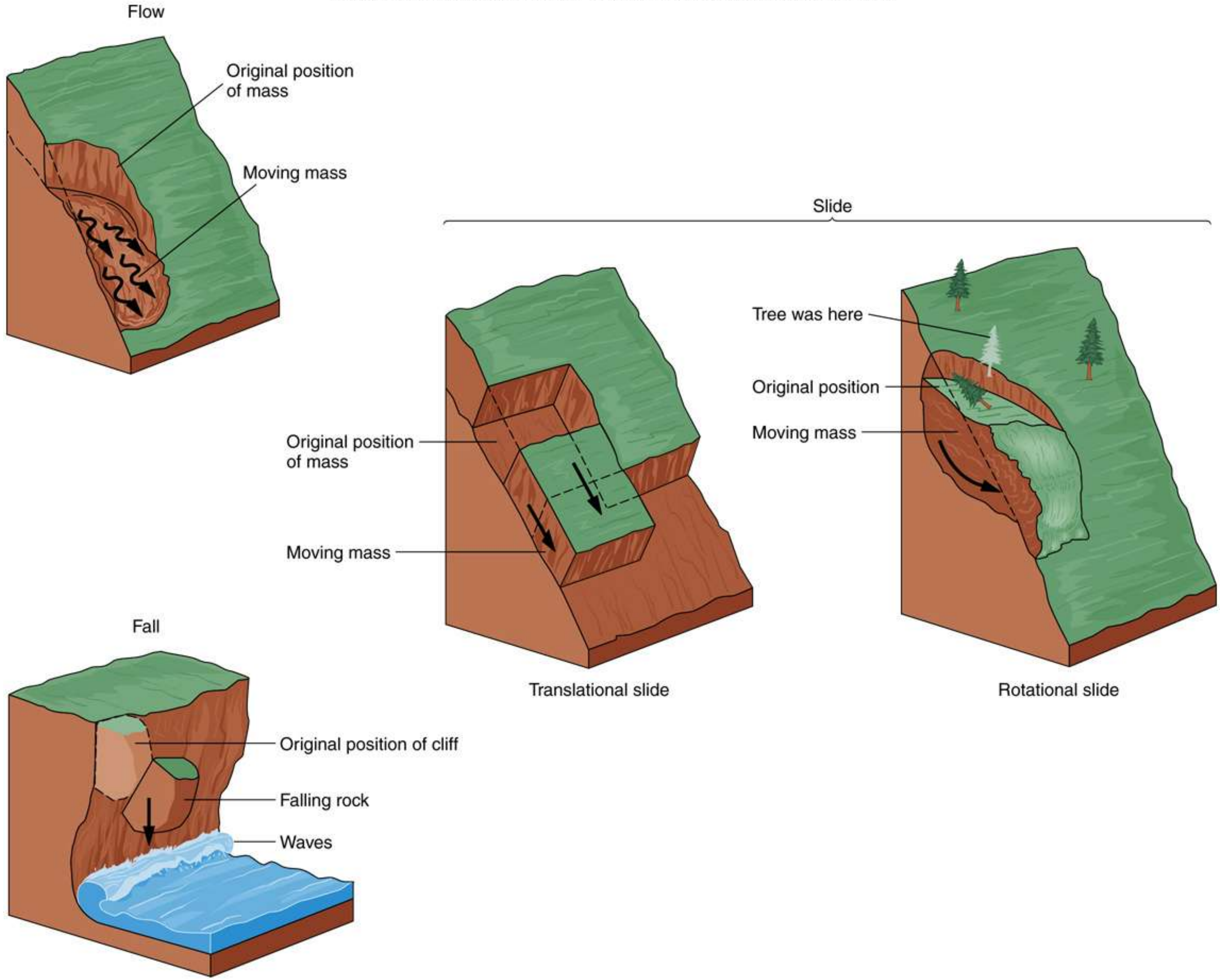


Fig. 9.1, pg. 203

Types of Mass Wasting

- *Rockfall* - when a block of bedrock breaks free and falls or bounces down a cliff
  - Commonly an apron of fallen rock fragments (*talus*) accumulates at cliff base
- *Rockslide* - the rapid sliding of a mass of bedrock along an inclined surface of weakness
- *Rock avalanche* - a very rapidly moving, turbulent mass of broken-up bedrock
- *Debris slide* - a coherent mass of debris moving along a well-defined surface
- *Debris fall* - a free-falling mass of debris



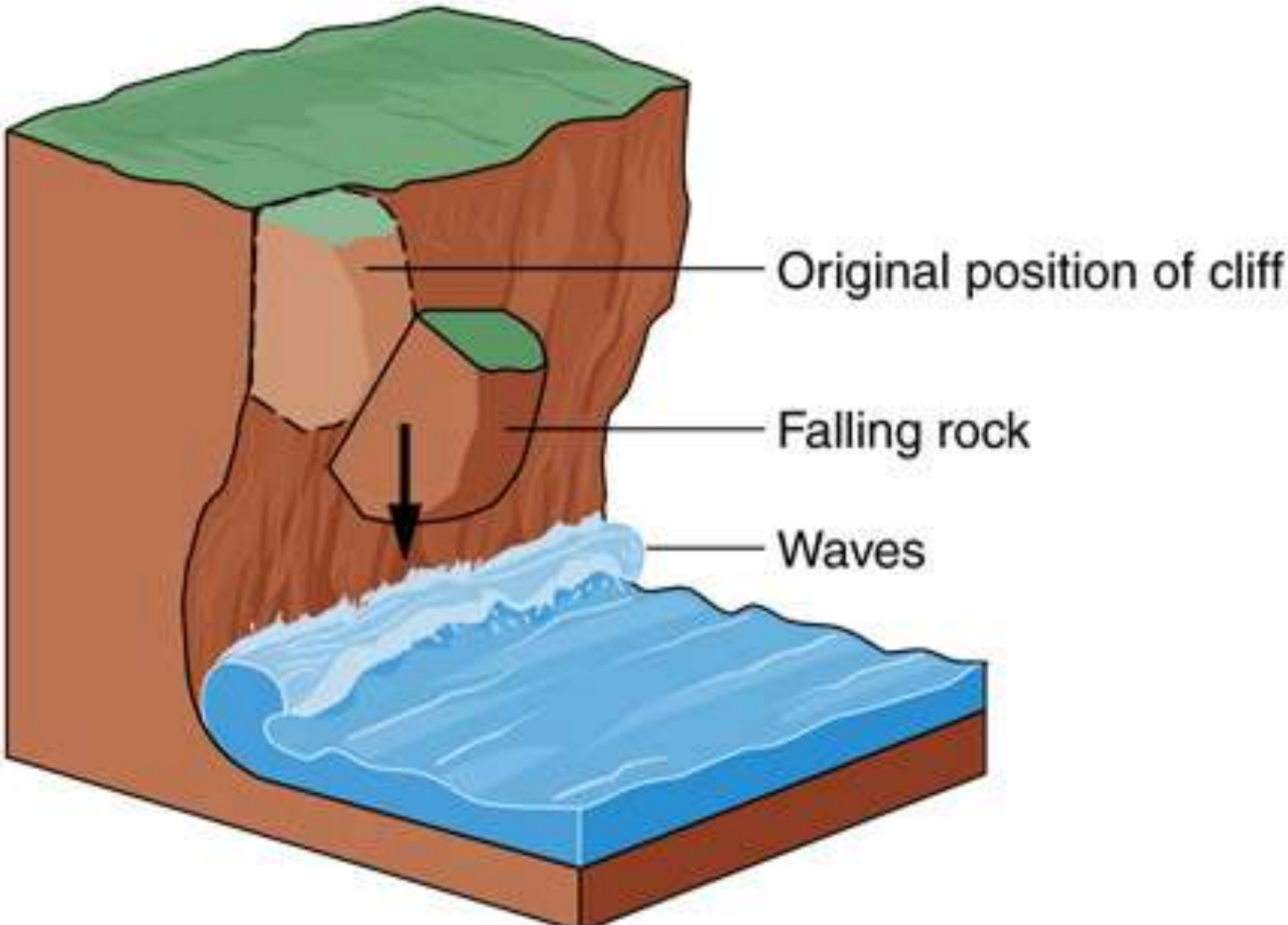

Flow
Original position of mass
Moving mass
Slide
Tree was here
Original position
Moving mass
Original position of mass
Moving mass
Translational slide
Rotational slide
Fall
Original position of cliff
Falling rock
Waves

Rockfall

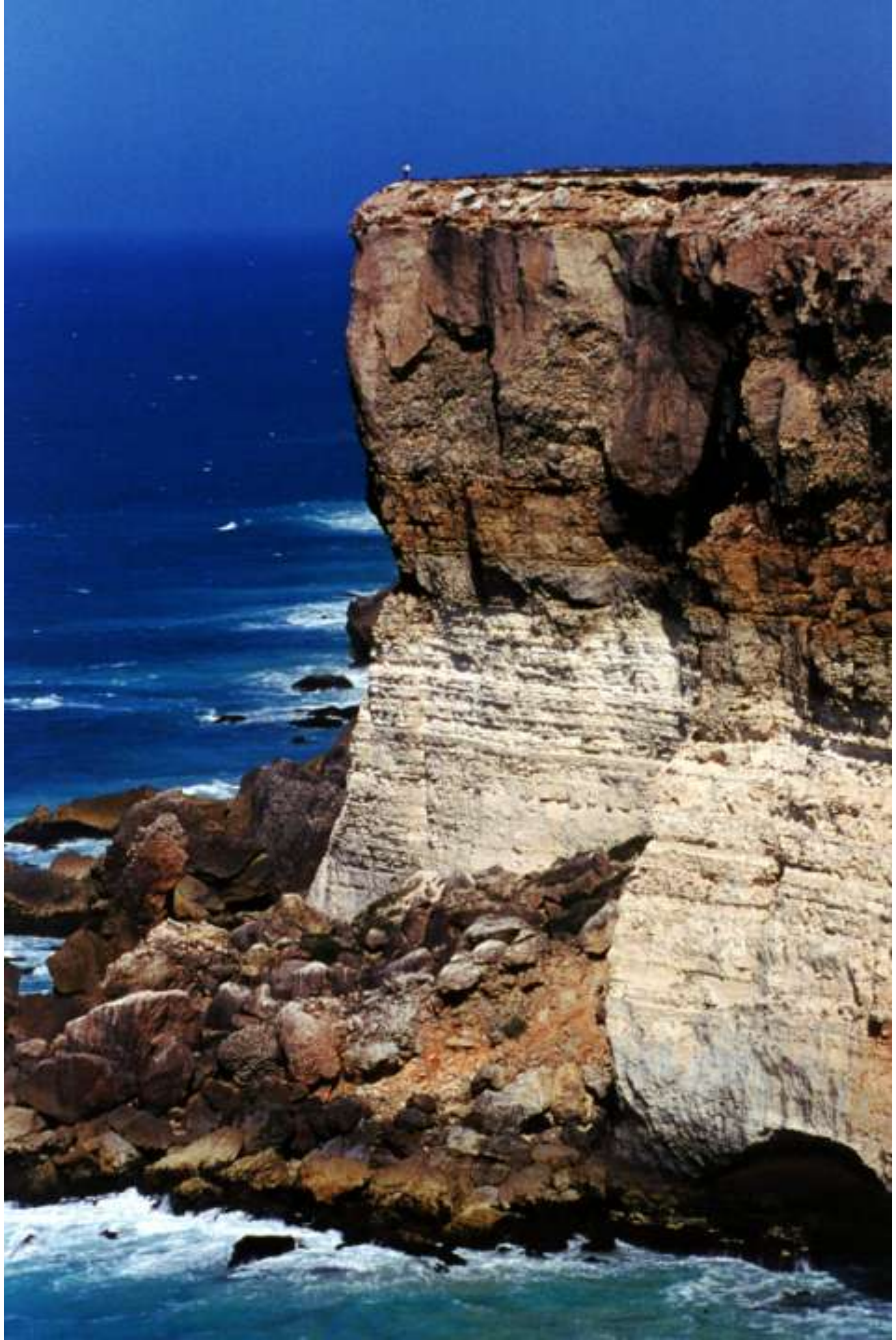
- ***Rockfall***
  - bedrock breaks loose, ***falls or bounces down a cliff***
  - often rock fragments (*talus*) accumulate at cliff base
  - ***Debris fall*** - falling ***debris***

Fig. 9.15 Talus

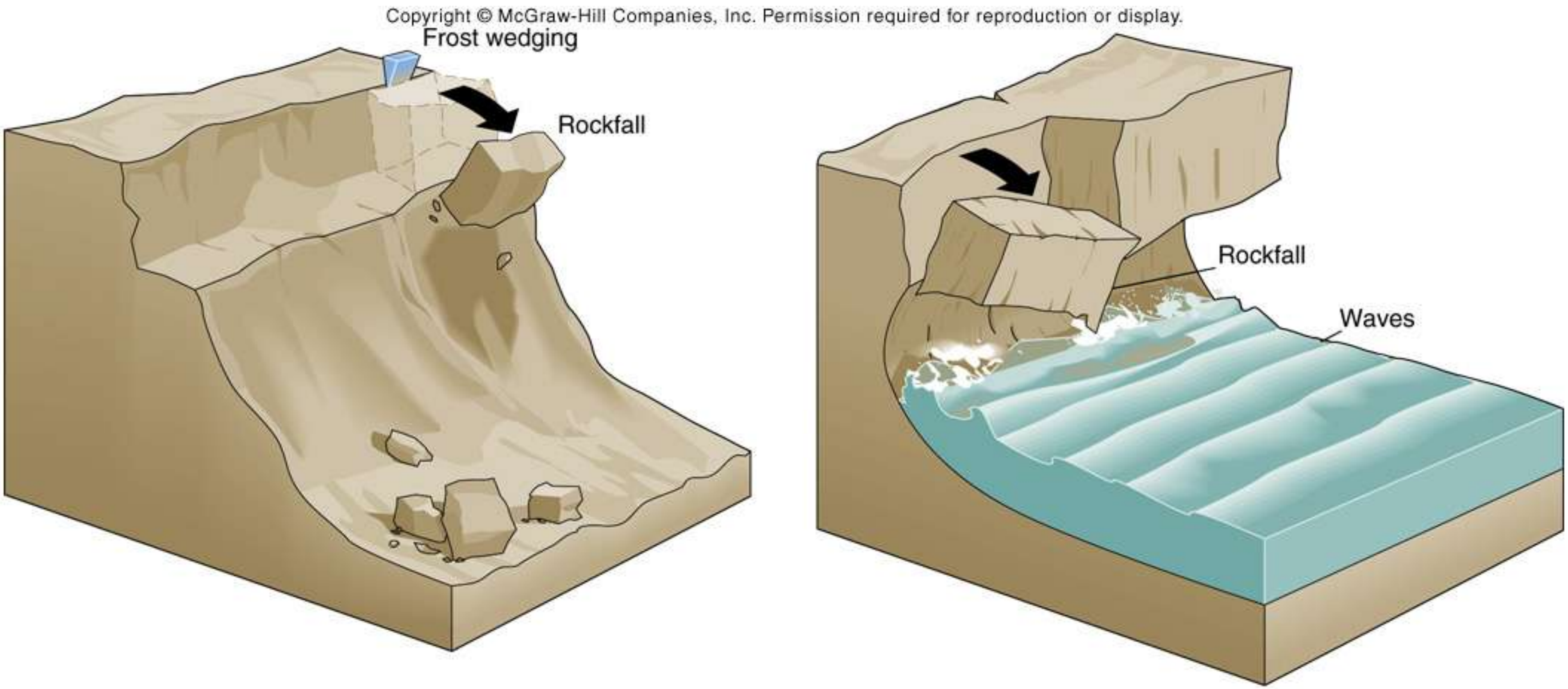
Fall



Rock Fall



Rockfalls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Frost wedging
Rockfall
Rockfall
Waves

Figure 8.13

Yosemite Valley CA rock slabs breaking loose

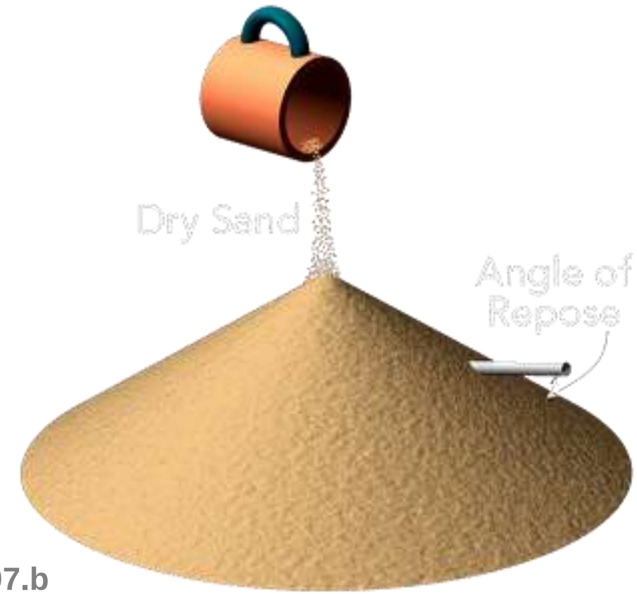
Photo by Ed Youmans

Slumping of loose material

A

B

Consider how steep a slope can be and remain stable

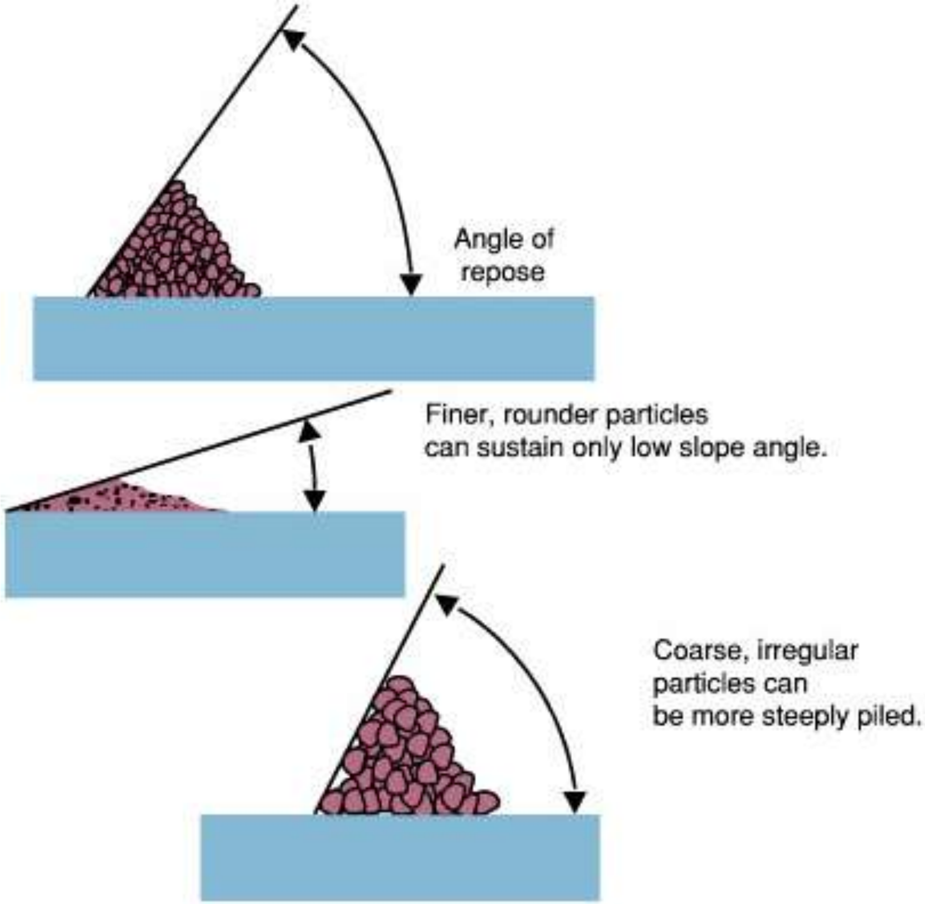


15.07.b

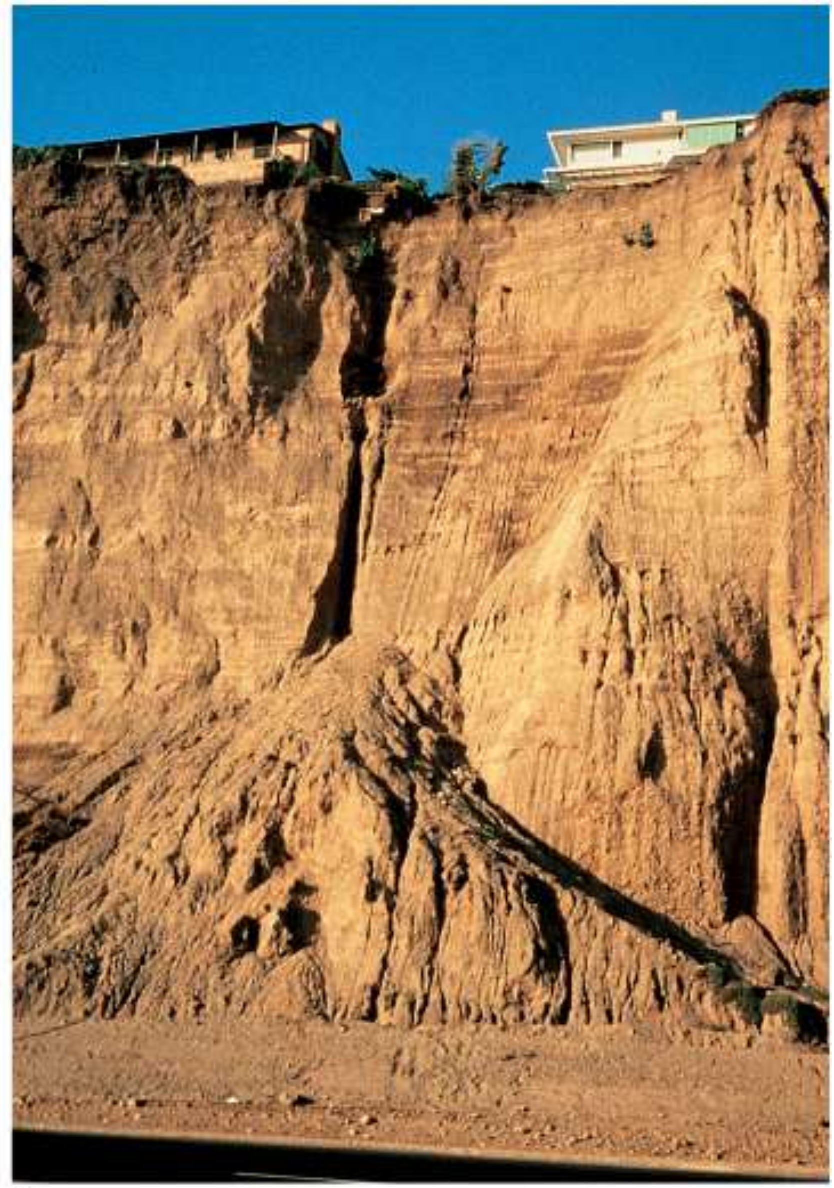
talus

talus

Angle of Repose



A



B

Rockslide

- ***Rockslide***
  - bedrock breaks loose, ***slides along inclined surface***
  - ***Rock avalanche***
    - ***very rapidly*** moving
    - ***broken-up bedrock***, a turbulent mass
  - ***Debris slide***
    - ***Very rapidly*** *moving*
    - *coherent* ***debris mass***, moves along a defined surface

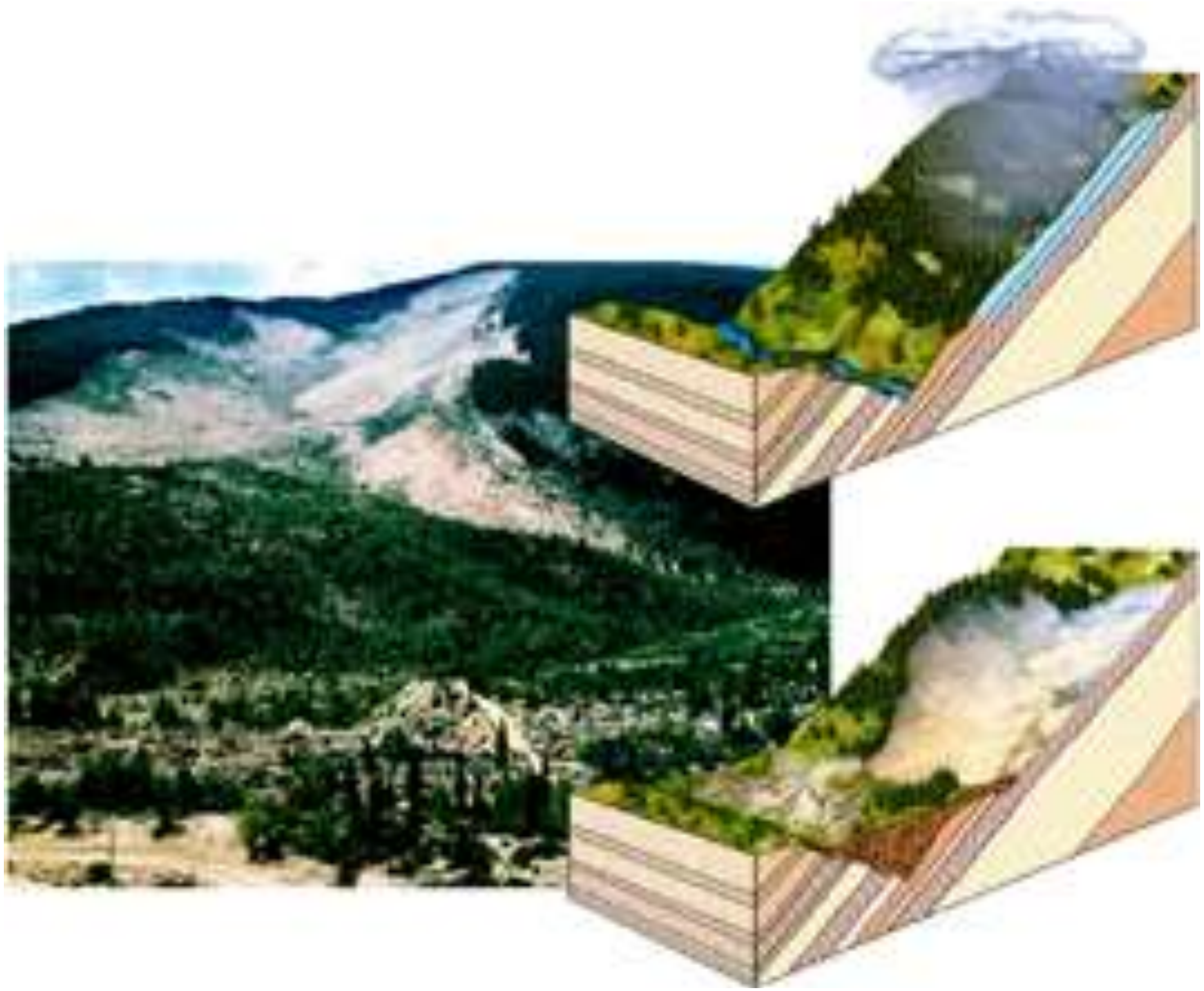
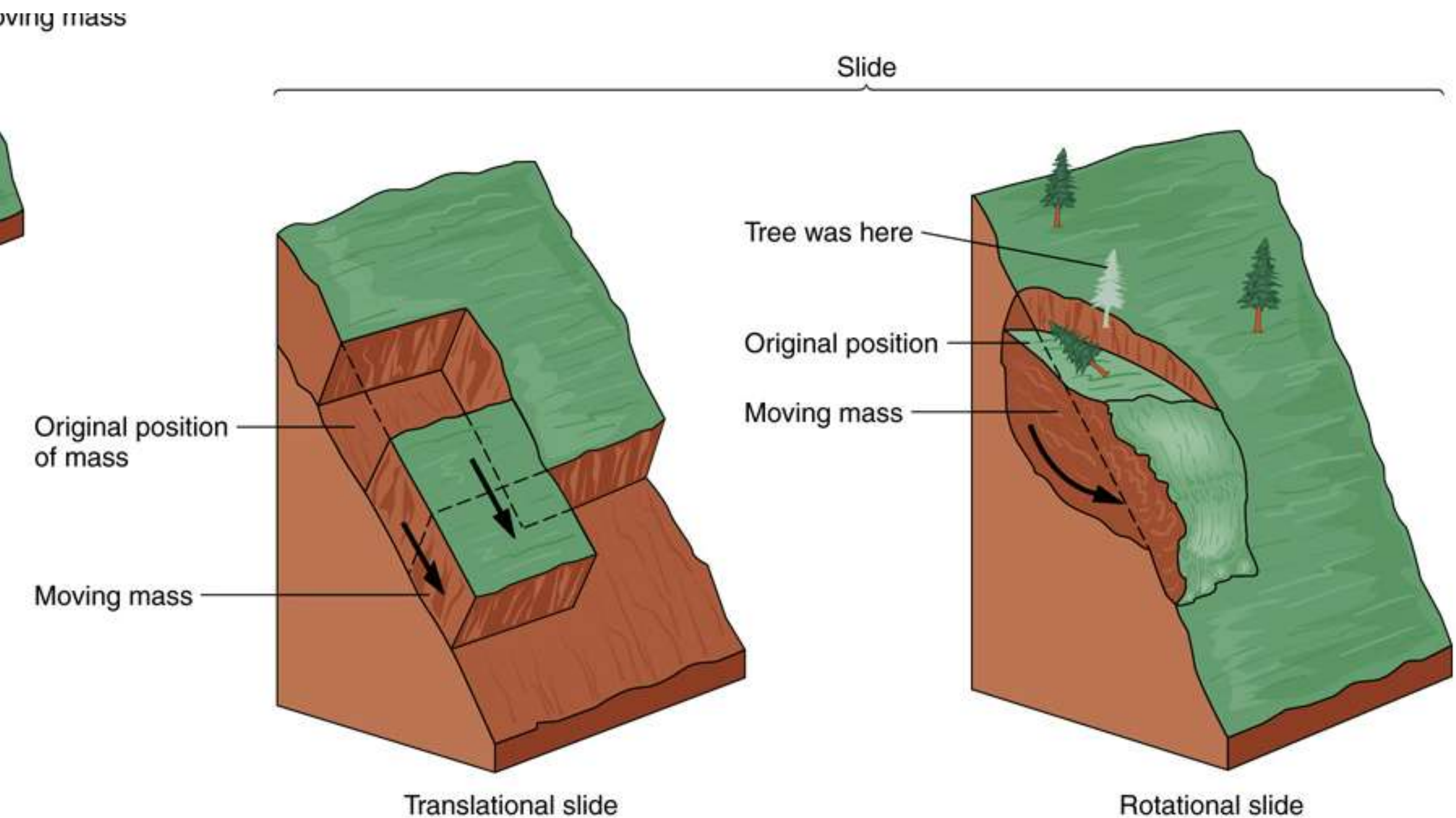


Fig. 9.18, Gros Ventre Slide, Wyoming


Slide
Original position of mass
Moving mass
Translational slide
Tree was here
Original position
Moving mass
Rotational slide

Geometry of a Rock Slide

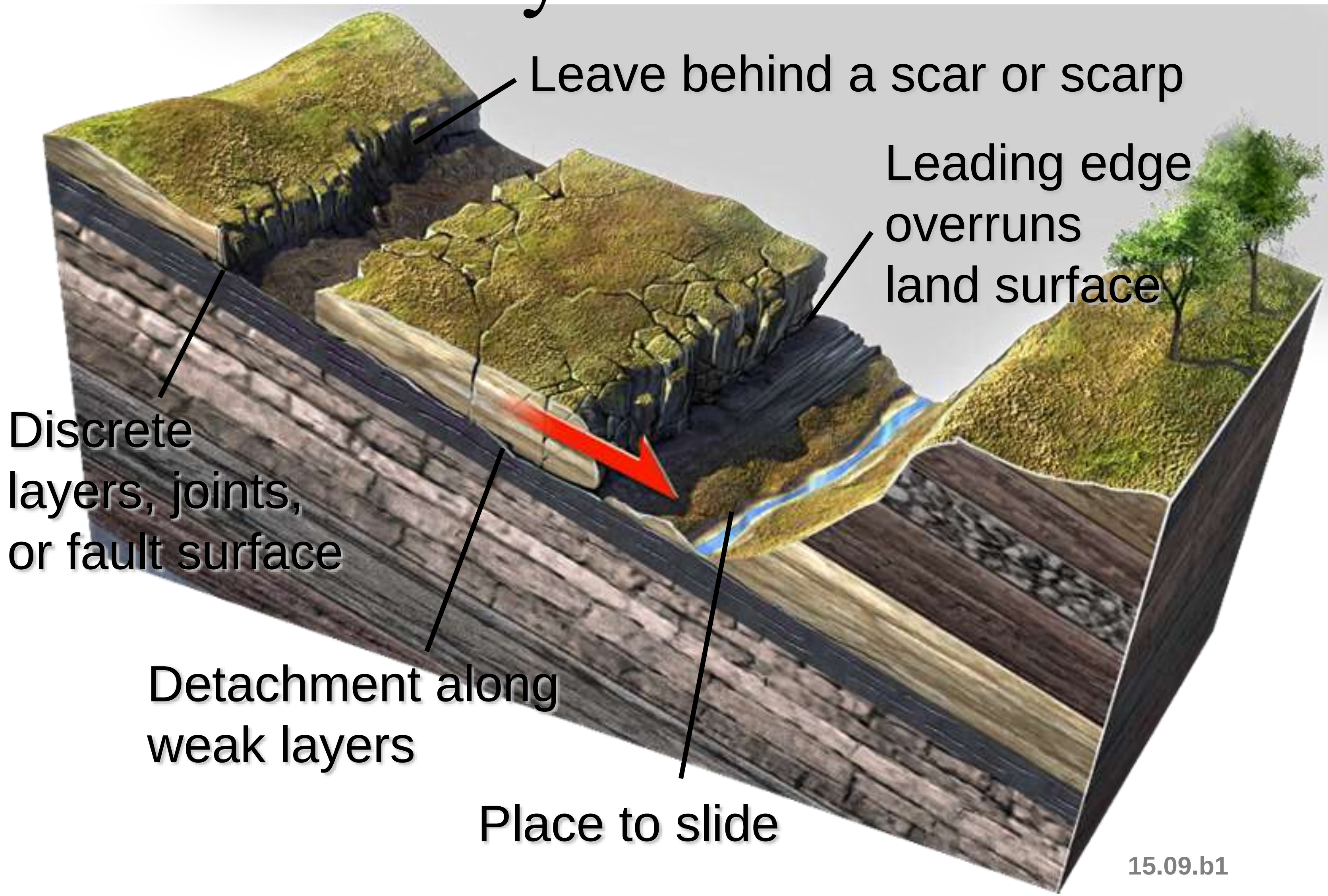


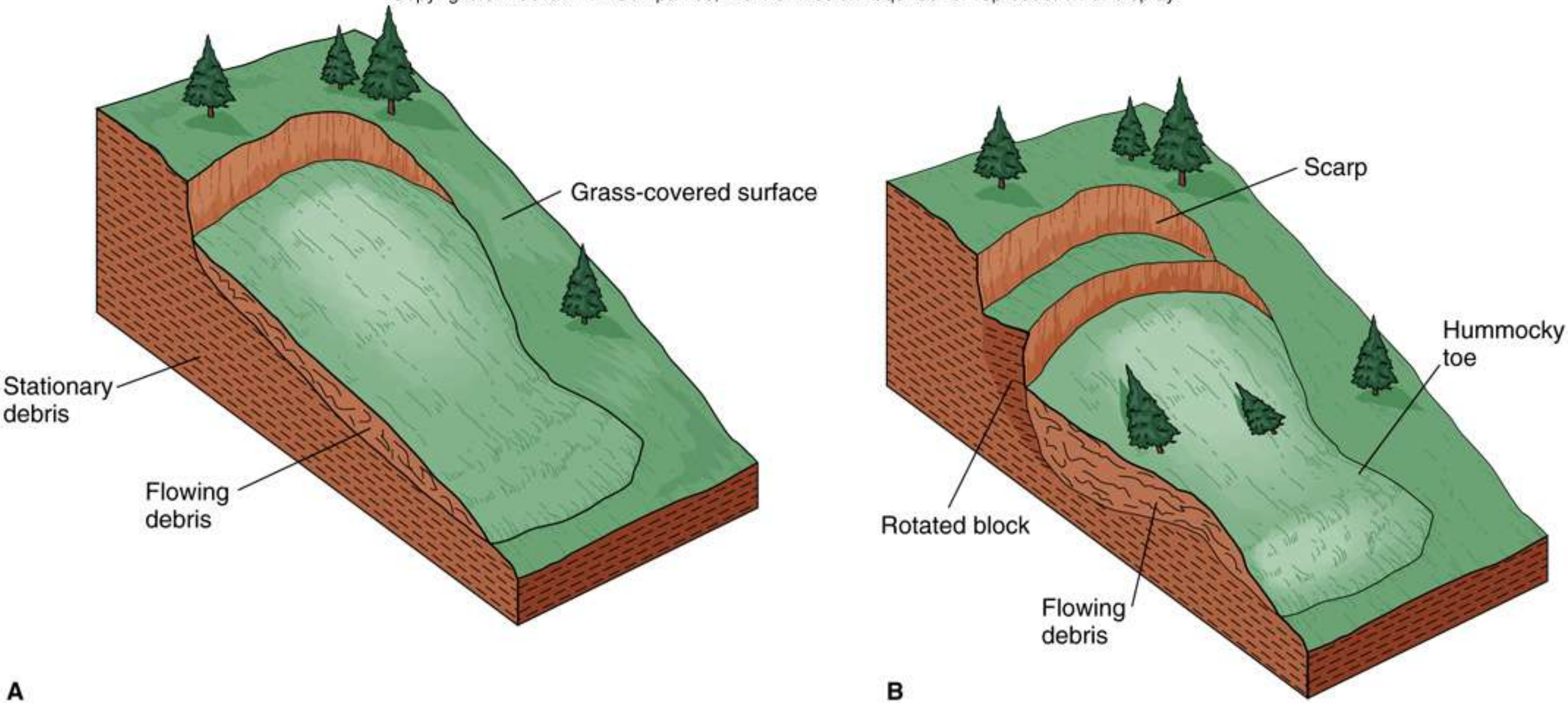
Figure 8.15

Types of Mass Wasting

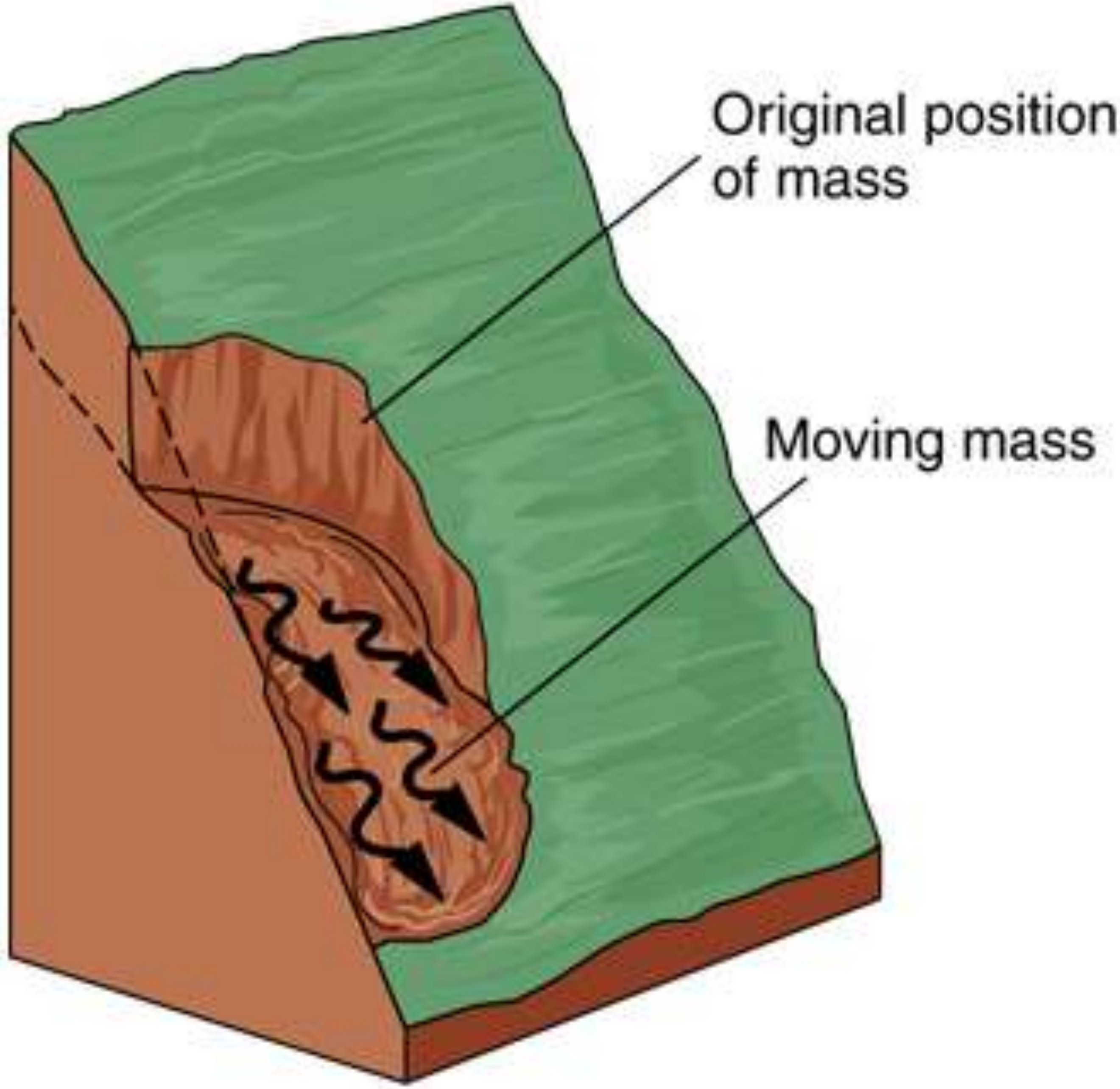
- ***Debris flow*** - mass motion by ***flowing***
  - ***Earthflow***
    - **slow or rapid** movement, as *viscous fluid*
    - common on steep hills, with thick debris cover, after heavy rains
    - ***Solifluction***
      - saturated debris moves above impermeable layer
  - ***Mudflow***
    - **rapid** movement, usually down a channel
    - mix of debris and water
    - common on steep *unvegetated* slopes, with thick debris cover, after heavy rains
    - stratovolcanoes with fresh ash layers are triggers
  - ***Debris avalanches***
    - **very rapid** (100s of km/hr), *turbulent*
    - mix of debris, water, *air*

Fig. 9.8, pg. 209

Fig. 9.13, pg. 213


Grass-covered surface
Stationary debris
Flowing debris
A
Scarp
Hummocky toe
Rotated block
Flowing debris
B

Flow



La Conchita, CA earthflow with rotational sliding (slumping) 1995

Landslides and La Conchita

15.10.m

Figure 8.5

Figure 8.7

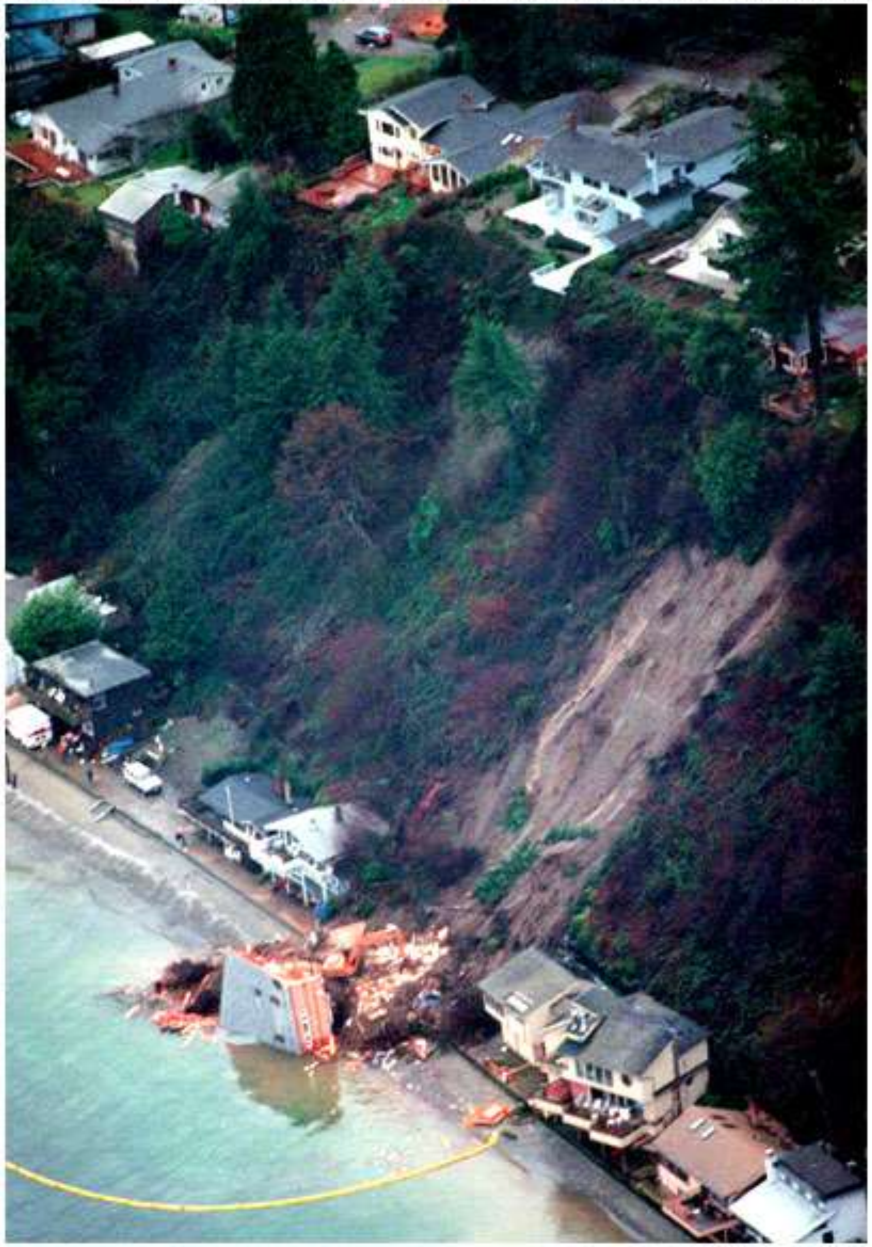
Figure 8.10

Figure 8.20

Figures 8.24 a and b

A B

Figure 8.37



Types of Mass Wasting

- **Creep** – slow, most active at the surface
- **Falls** – material free falls upon failure or undercutting, motion is rapid
  - Rockfalls are the most common form
- **Slumps** – material moves downslope accompanied by rotation
- **Slides** – material moves as cohesive unit along a clearly define surface
- **Flows** – material moves chaotically and in a disorganized fashion
- **Avalanches** or debris flow – involve a wide range of material involvement: trees, soil, and rock

Types of Mass Wasting

- ***Creep***
  - ***Very slow*** movement of soil or regolith
  - Major contributing factors:
    - water in soil
    - daily freeze-thaw cycles
  - Costly to maintain homes
    - foundations, walls, pipes crack and shift

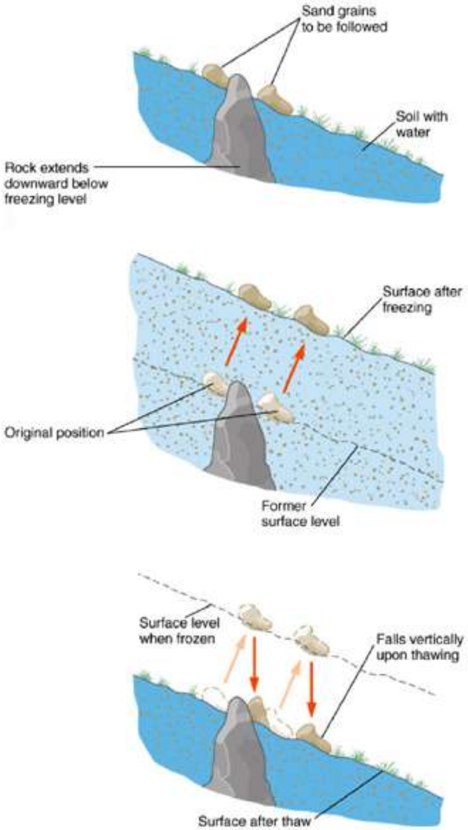
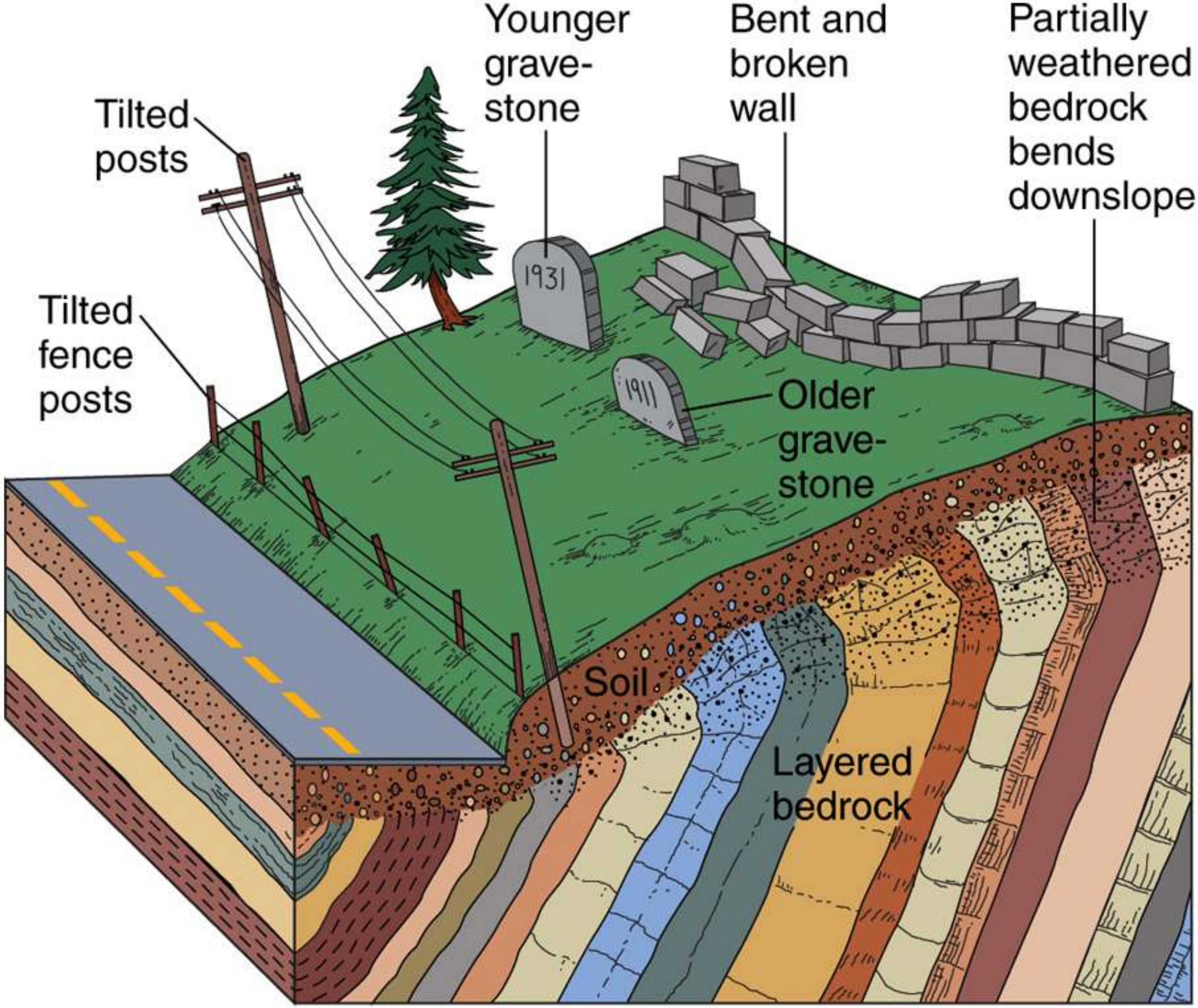
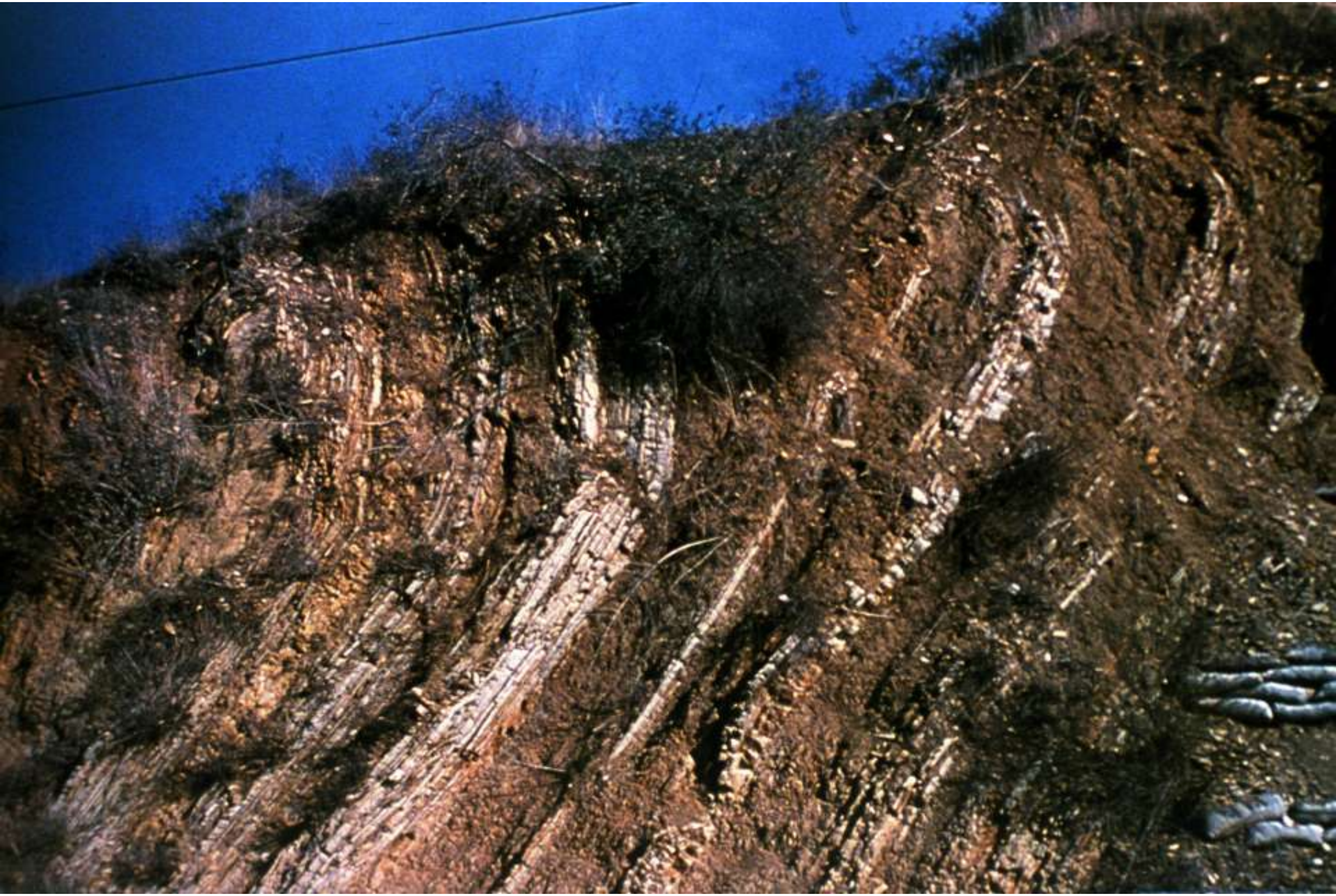
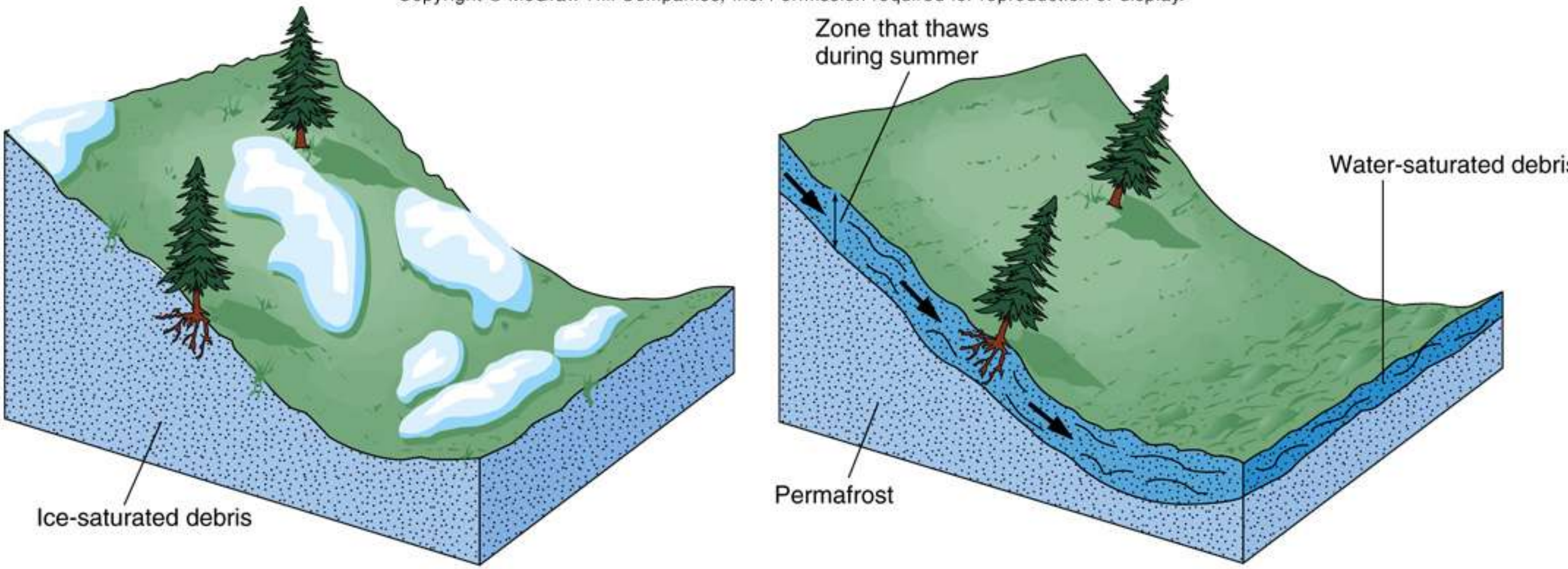


Fig. 9.6, pg. 208


Younger grave- stone
Bent and broken wall
Partially weathered bedrock bends downslope
Tilted posts
Tilted fence posts
1931
1911
Older grave- stone
Soil
Layered bedrock

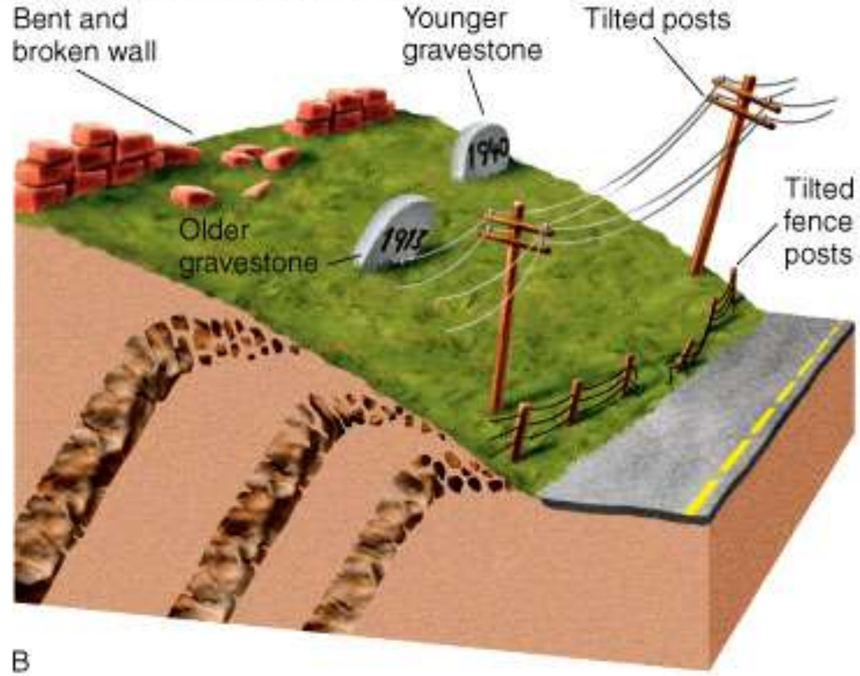




A Winter **B** Summer

Creep – club footed trees, walls & poles tilted downhill

A

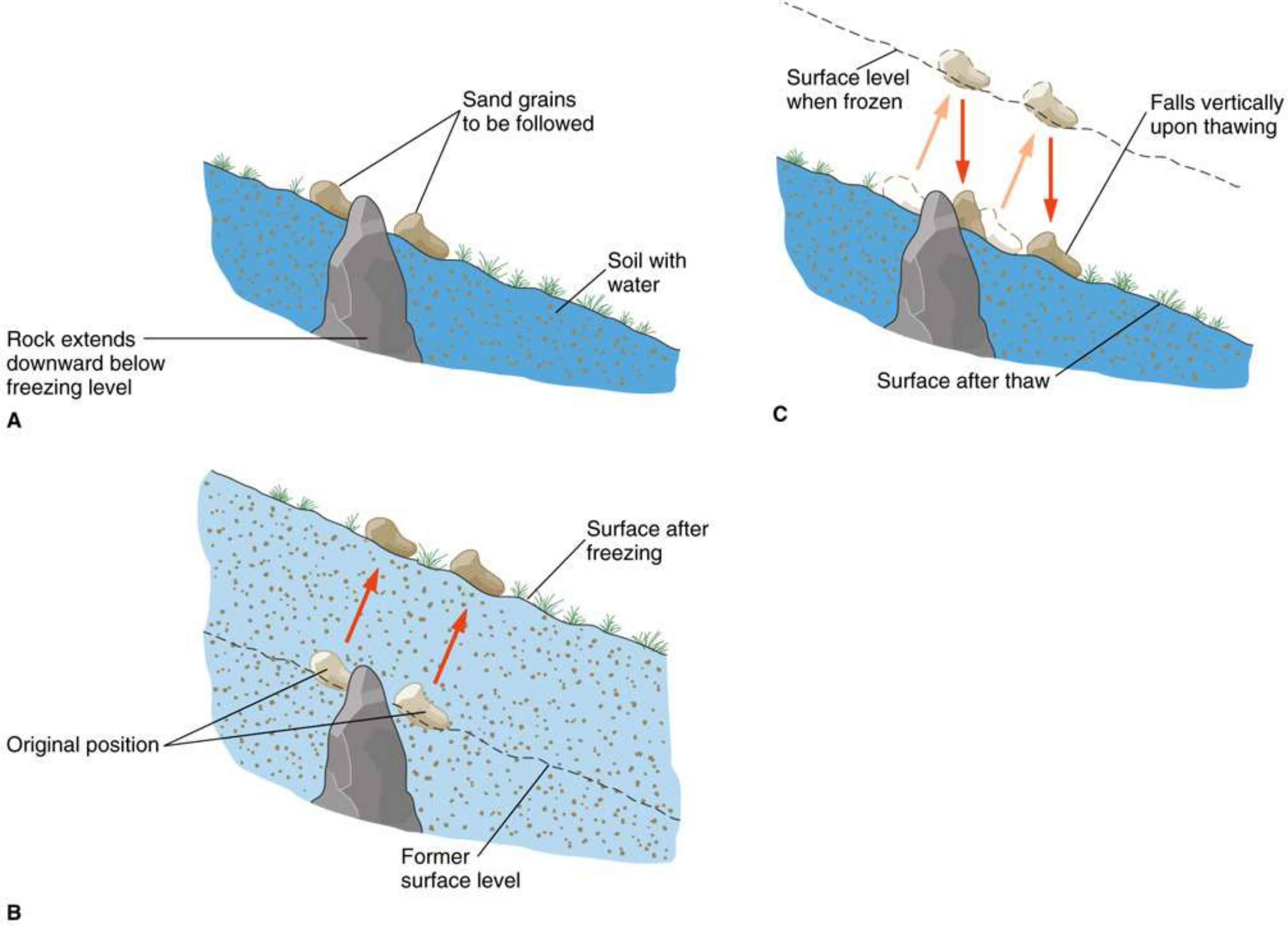


B

A

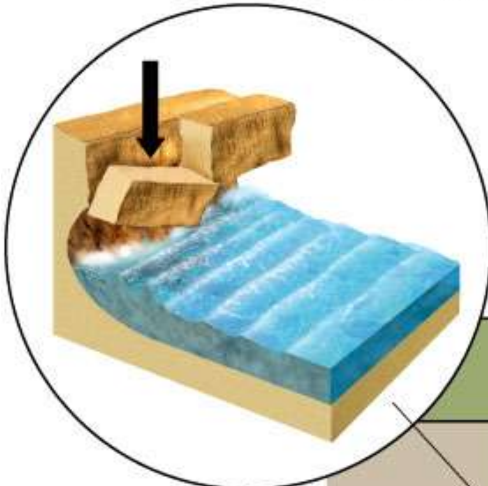
England – tilted old gravestones

Photo by C. C. Plummer



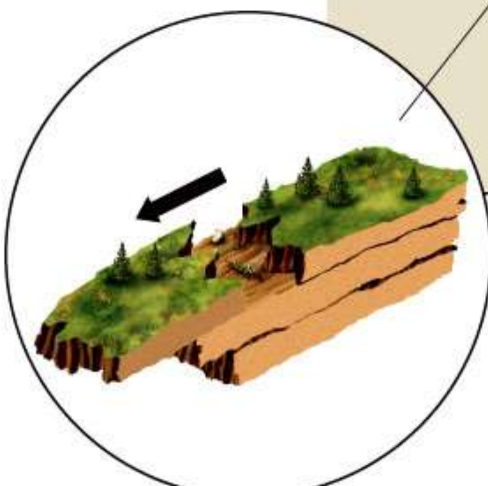
Sand grains
to be followed
Soil with
water
Rock extends
downward below
freezing level
A
Surface level
when frozen
Falls vertically
upon thawing
Surface after thaw
C
Surface after
freezing
Original position
Former
surface level
B

Types of Mass Movement



Types of Mass Movement and Typical Rates of Movement

	Material moves as coherent unit	Chaotic, incoherent movement
Free-falling motion	Rockfall Speed: Rapid (meters/second)	Soil fall (rare) Speed: Rapid (meters/second)
In contact with surface below	Slides: rockslide slump (soil) Speed: Highly variable (meters/year to meters/second)	Flows: snow avalanche debris avalanche nuée ardente earthflow mudflow lahar Speed: Rapid (meters/day to meters/second)



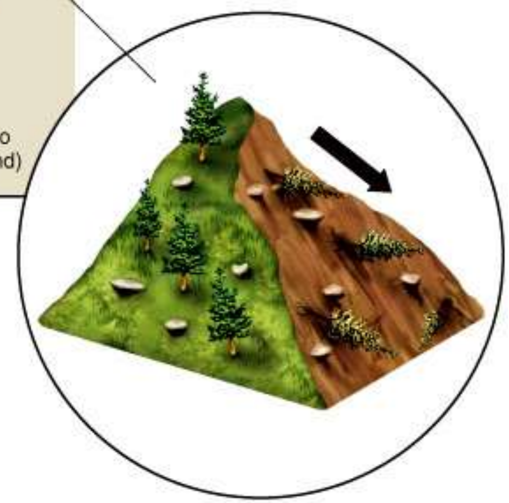


Table 9.2 Summary of Controls of Mass Wasting

Driving Force: Gravity

Contributing Factors	Most Stable Situation	Most Unstable Situation
Slope angle	Gentle slopes or horizontal surface	Steep or vertical
Local relief	Low	High
Thickness of debris over bedrock	Slight thickness (usually)	Great thickness
Orientation of planes of weakness in bedrock	Planes at right angles to hillside slopes	Planes parallel to hillside slopes
Climatic factors:		
Ice	Temperature stays above freezing	Freezing and thawing for much of the year
Water in soil or debris	Film of water around fine particles	Saturation of debris with water
Precipitation	Frequent but light rainfall or snow	Long periods of drought with rare episodes of heavy precipitation
Vegetation	Heavily vegetated	Sparsely vegetated

Triggering Mechanisms: (1) earthquakes; (2) weight added to upper part of a slope; (3) undercutting of bottom of slope.

Controlling Factors in Mass Wasting

- Gravity – driving force for mass wasting.
  - Shear force and normal force are resolvable effects of gravity.
  - Shear strength.

Controlling Factors in Mass Wasting

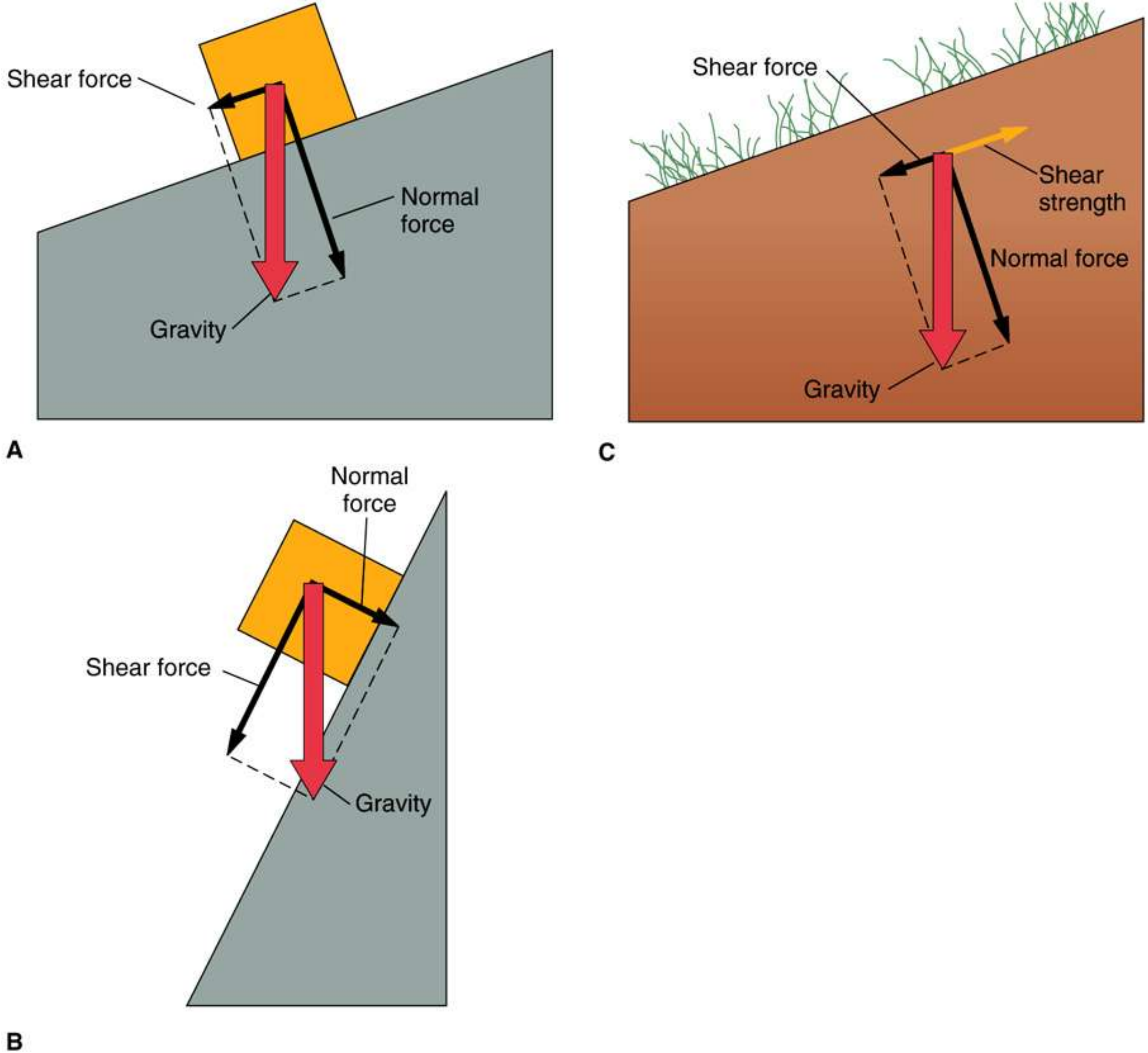
- Water – critical factor in mass wasting.

  - Increased pore pressure reduces shear strength.

  - Surface tension

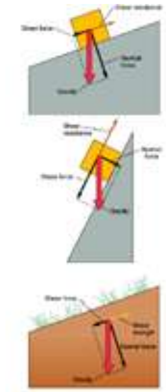
Factors Influencing Slope Stability

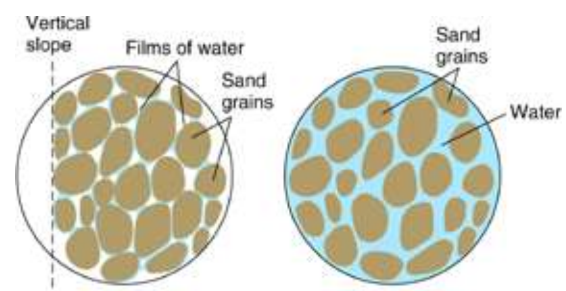
- The force of gravity acts to tear the mountains down. Gravity is the great leveler
- Mass Movement occurs anytime downward pull of gravity overcomes frictional forces resisting it
- **Shearing stress** is the down slope pull on the rock or debris
  - **Shear strength** is the resistance to the shear stress; once overcome movement will occur
- Factors that can overcome shear strength
  - Decrease friction
  - A process that reduces the shear strength of the actual material


Shear force
Normal
force
Gravity
A
Shear force
Shear
strength
Normal force
Gravity
C
Normal
force
Shear force
Gravity
B

Factors Controlling Mass Wasting

- Factors making mass wasting likely:
  - *Steep slopes*
    - Shear forces maximized by gravity
  - *Large relief*
    - (large elevation change from top of mountains/hills to valley floor)
  - *Thick layer(s) of loose rock, debris, soil*
  - *Presence of water*
    - Lubricates moving rocks/debris/soil
  - *Lack of vegetation*
    - No roots to hold rock/soil in place
  - *Seismic (earthquake) activity*





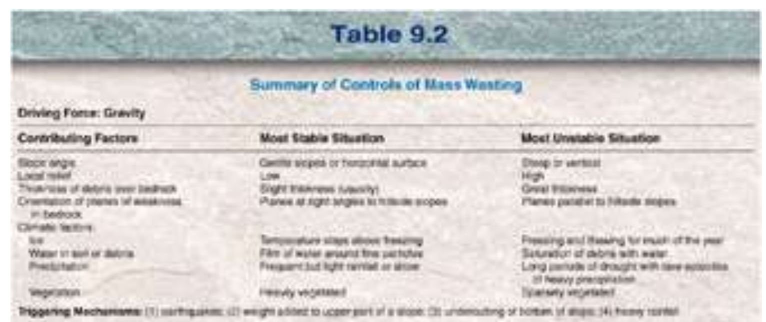


Table 9.2

Summary of Controls of Mass Wasting

Driving Force: Gravity

Contributing Factors	Most Stable Situation	Most Unstable Situation
Slope angle	Gentle slopes or horizontal surface	Steep or vertical
Local relief	Low	High
Thickness of debris over bedrock	Slight thickness (usually)	Great thickness
Orientation of planes of weakness in bedrock	Planes at right angles to hillside slopes	Planes parallel to hillside slopes
Climatic factors		
Ice	Temperature stays above freezing	Freezing and thawing for much of the year
Water in soil or debris	Film of water around fine particles	Saturation of debris with water
Precipitation	Frequent but light rainfall or snow	Long periods of drought with rare episodes of heavy precipitation
Vegetation	Heavily vegetated	Sparsely vegetated

Triggering Mechanisms: (1) earthquakes; (2) weight added to upper part of a slope; (3) undercutting of bottom of slope; (4) heavy rainfall

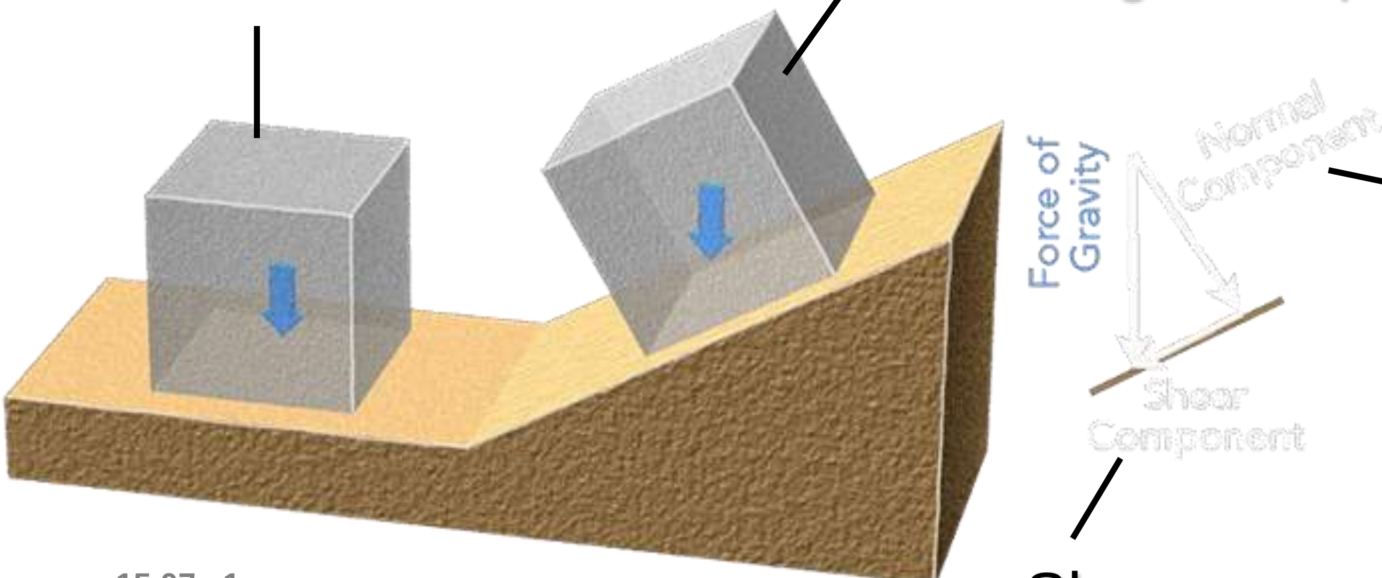
Effects of Slope and Materials

- All else being equal, the steeper the slope, the greater the shearing stress and therefore the greater the likelihood of slope failure
- **Angle of Repose** – maximum slope angle at which a material is stable
  - Reduce friction and material will move
    - Make the angle steeper
    - Fracture or weather the material (reduce shear strength)

Role of Gravity in Slope Stability

Gravity acts vertically so block will not move on a flat surface

Gravity pulls block at an angle so block can move on an angled slope

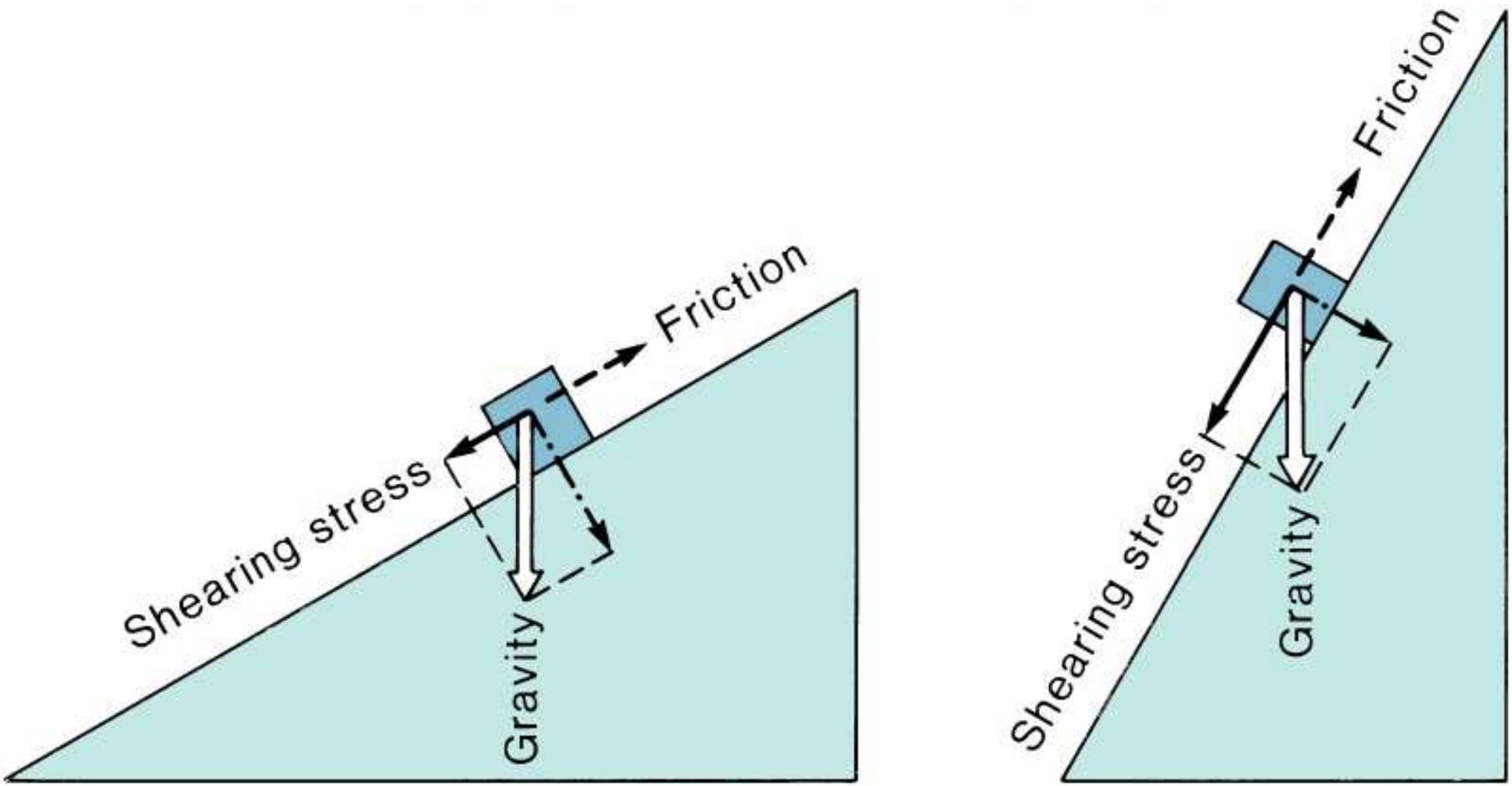


15.07.a1

Normal component pushes the block against the slope

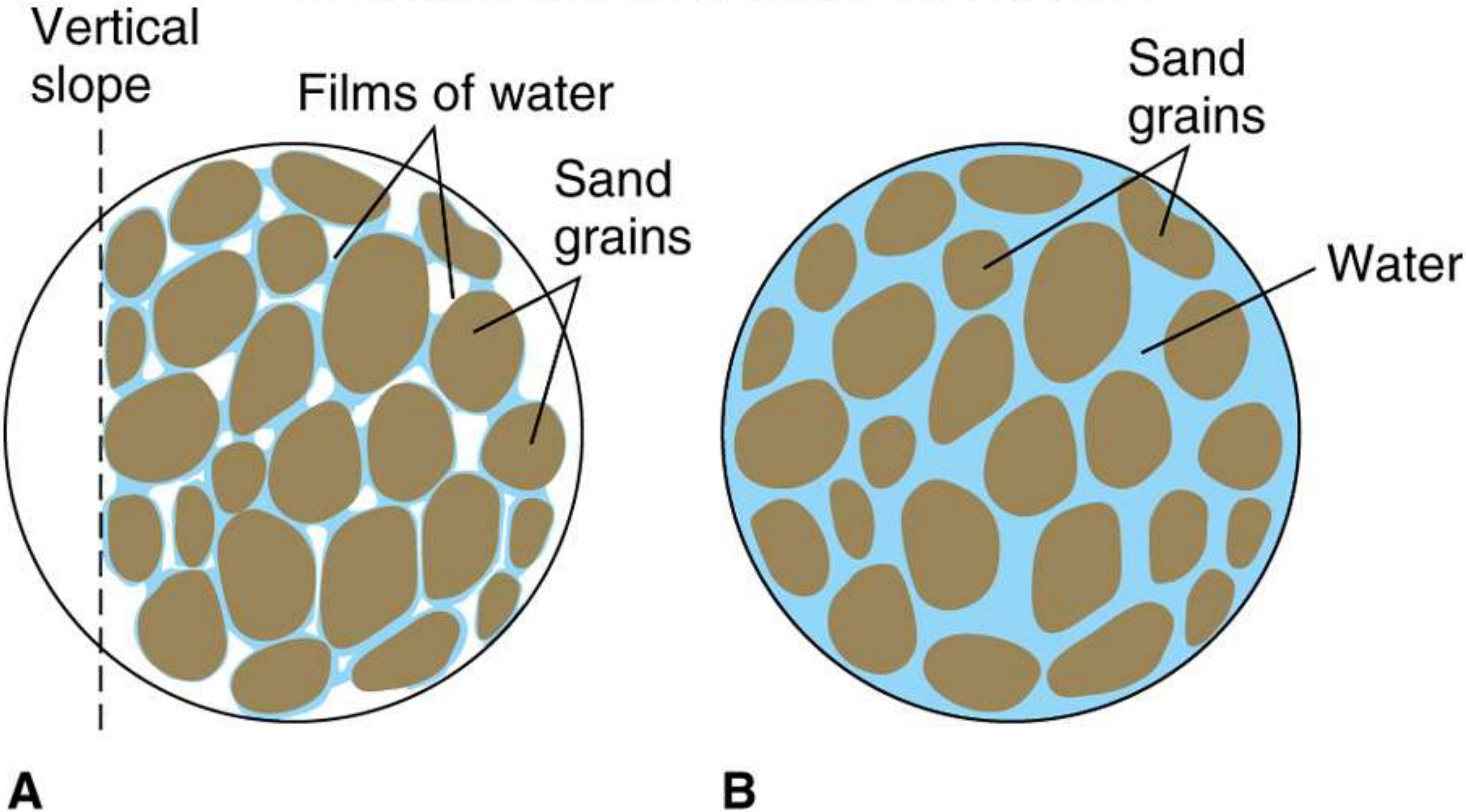
Shear component pushes block down slope

Steeper = Greater Shearing Stress



Effects of Fluids

- A variety of results occur with fluids:
  - Some surfaces will increase adherence
  - Other surfaces will reduce friction
  - Fluid infiltrating soil and sediment may increase pore pressure and promote movement
  - Frost heaving make weaken shear strength of a soil; movement may occur with next thawing
  - Earthquake vibration may reduce porosity and increase pore pressure of fluids and cause movement



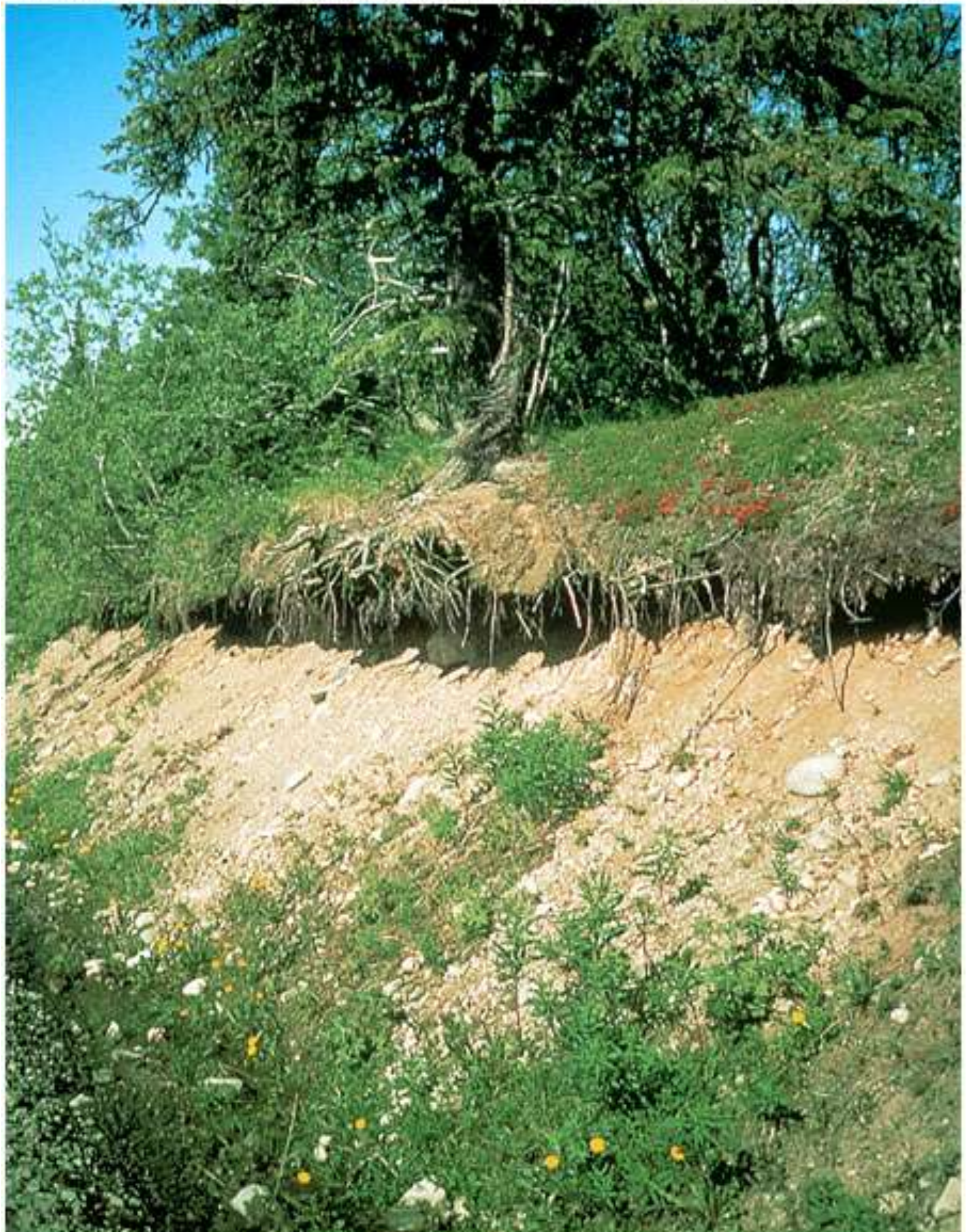
Unsaturated - holds

Saturated - flows

Effects of Vegetation

- Plant roots provide a strong interlocking network to hold unconsolidated rocks and sediment
- Vegetation removes moisture from the soil and may increase shear strength
  - Some plants may increase the shear stress, because of their bulk or shape, and cause movement

Figure 8.8



Earthquakes

- Landslides are a common consequence of an earthquake
  - Seismic waves passing through rock may stress and fracture it
    - Reduces shear strength
  - The loss of shear strength may result in immediate movement

Turnagain Heights Alaska EQ 1964

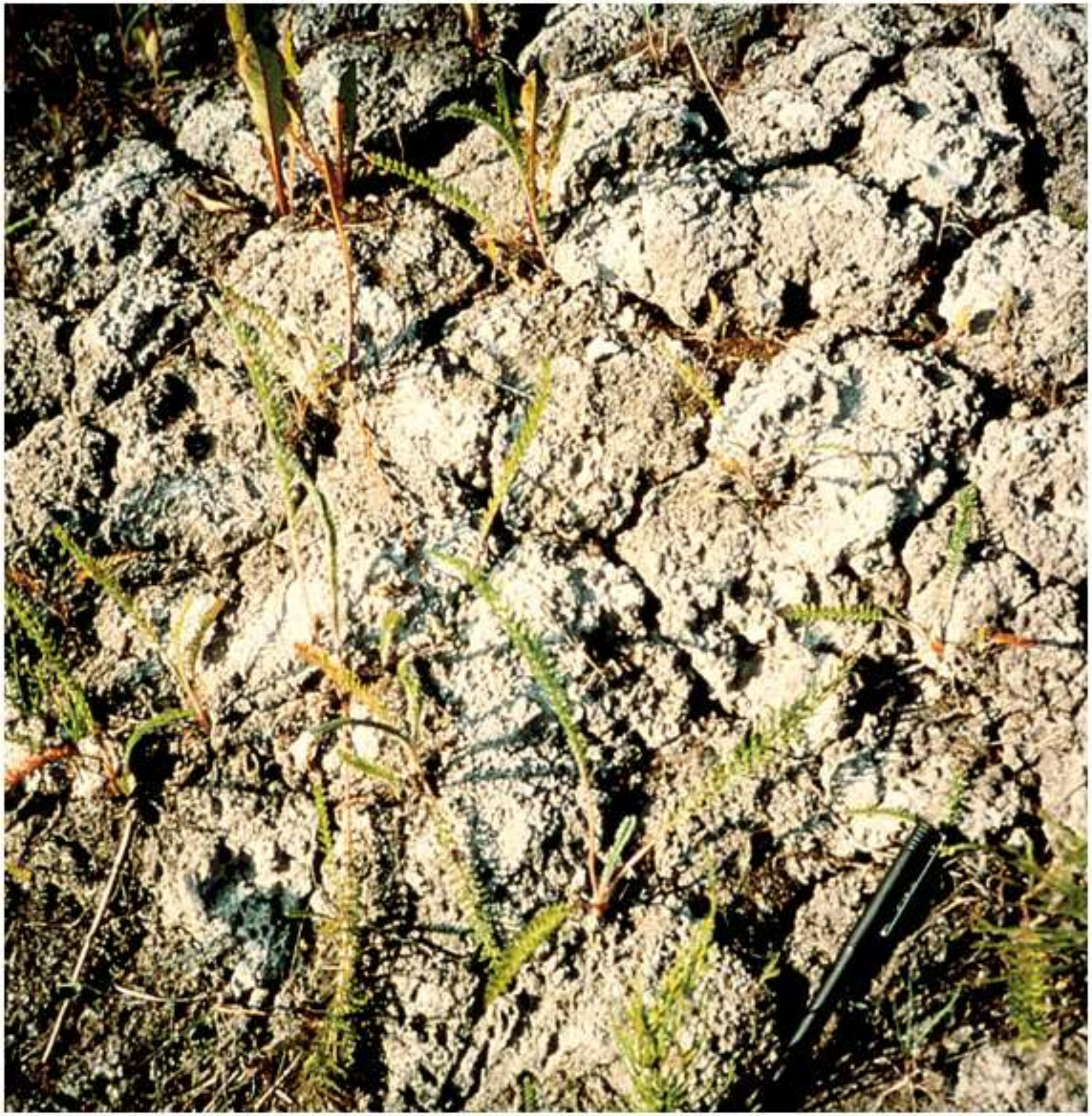
C

Quick Clays

- **Quick clays** are generally formed in polar latitudes
  – Glacial grinding of sediments produce a **rock flour** of clay-sized material
  – Usually, quick clays are deposited in marine environments and halite (salt) forms a binding glue
  – Seismic vibration may break apart the glue
  – Water, liberated by reduction in porosity, may wash away the salt
  – **Sensitive clays** are similar to quick clays but generally form in other localities and from volcanic ash
  – Sensitive clays may fail because of less energetic events
    - Passing automobiles

Figure 8.6

Expansive Soils



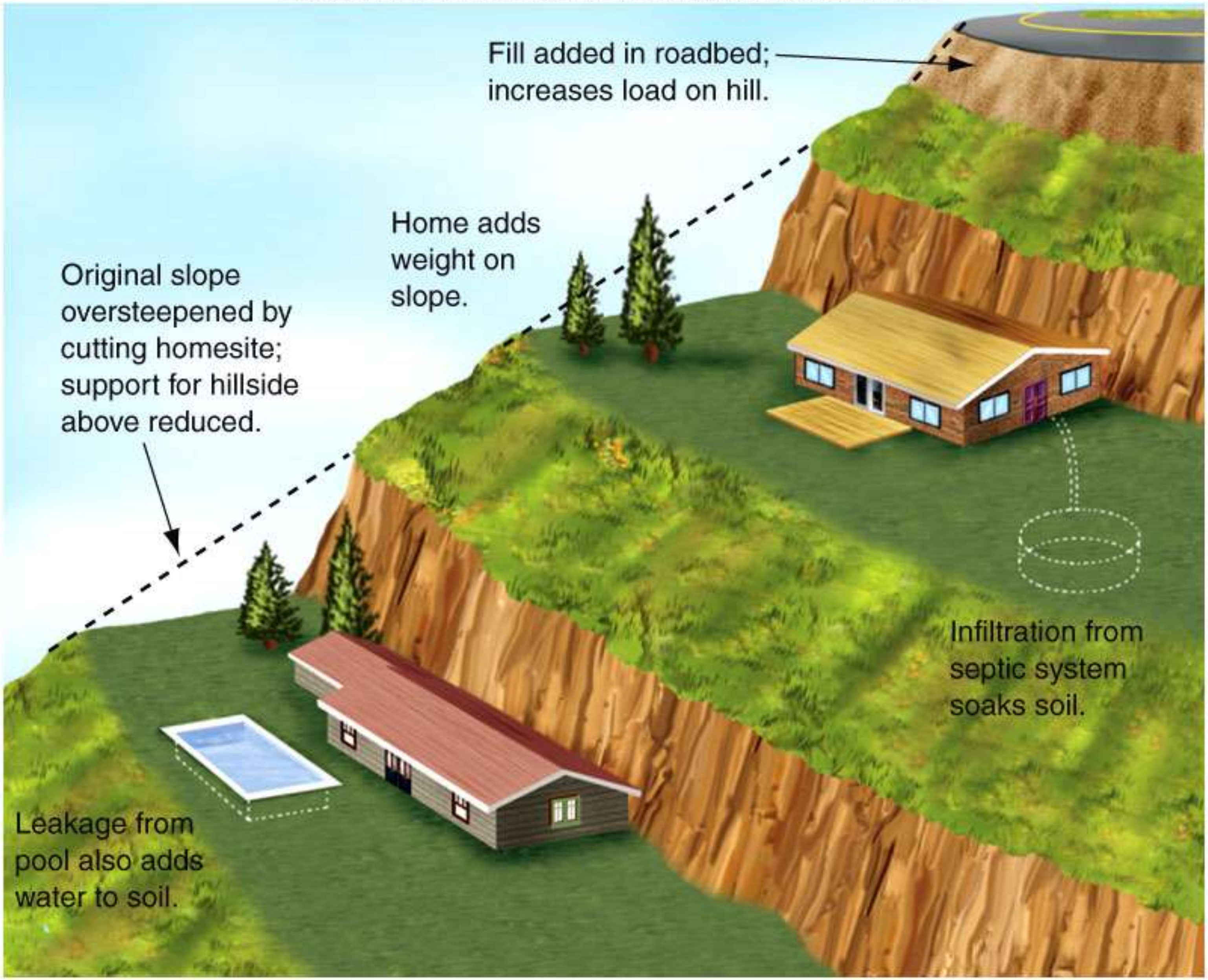
Solifluction – flow of water-saturated soil over impermeable material

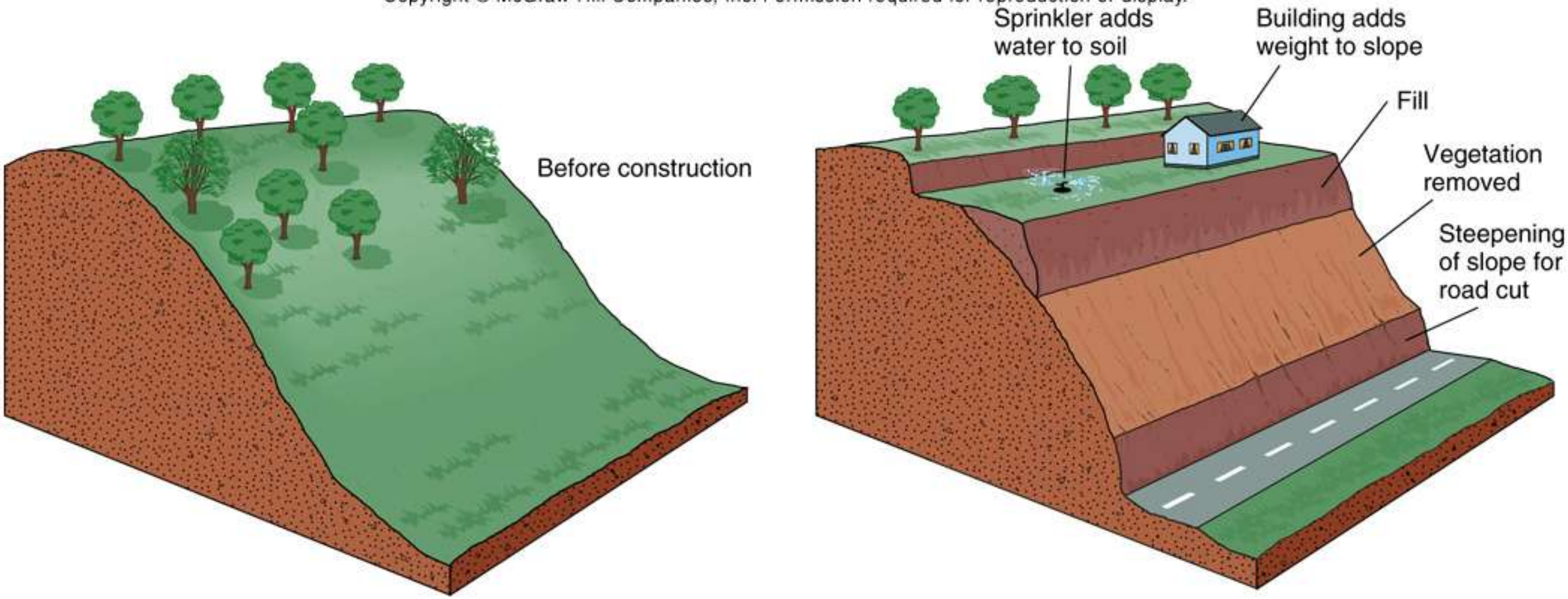
Permafrost terrain – top melts in summer, frozen in winter

Impact of Human Activities

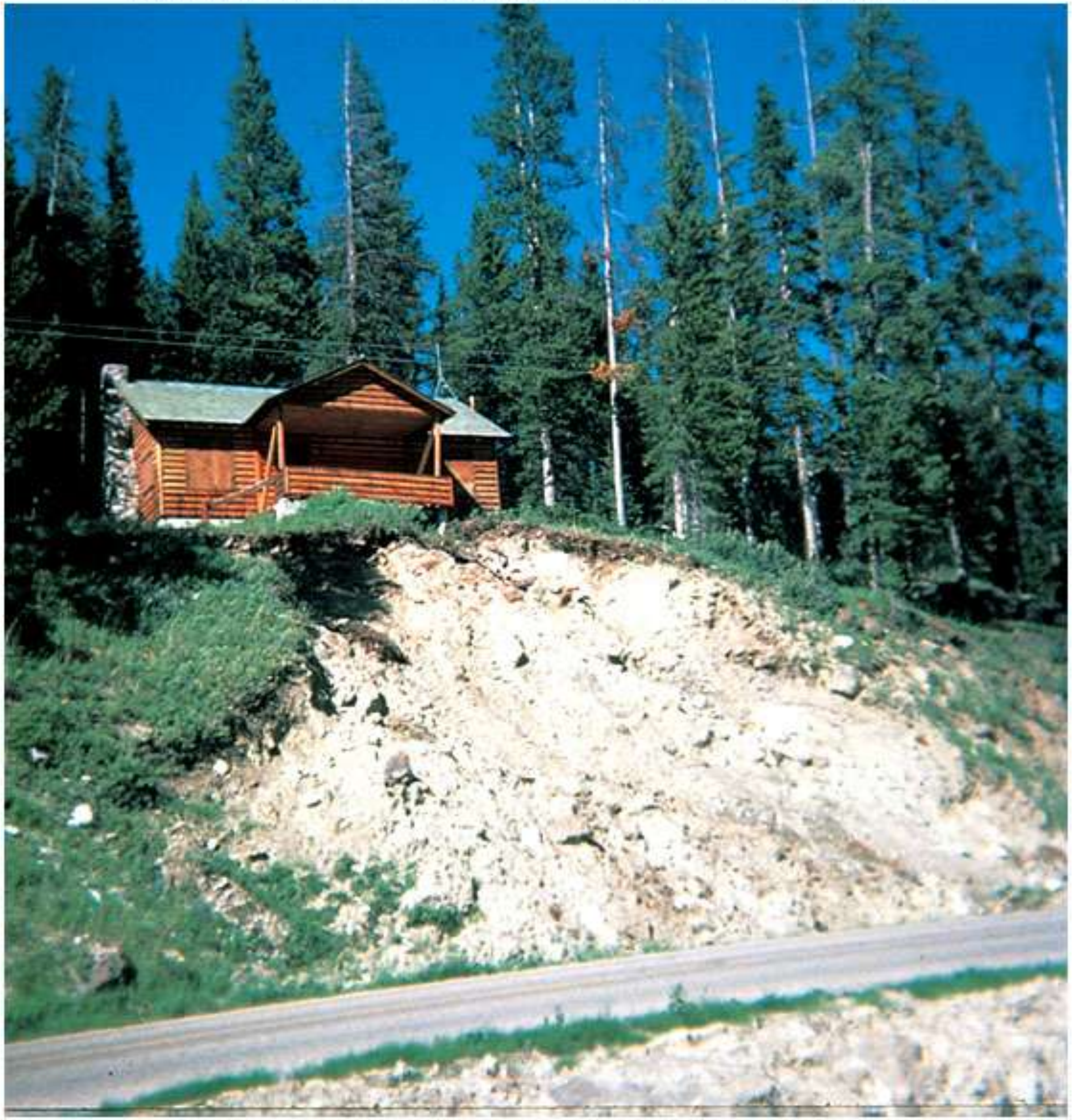
- Prevention
  - Vegetation tends to stabilize slopes
    - Re-plant areas affected by wildfire immediately
  - Avoid oversteepening of slopes
    - Increases shear stress and mass wasting hazards
    - Place additional supporting material at lower end of suspected area
    - Reduce the load on the slope
  - Avoid over watering scenarios
    - Leaking pools and water pipes, excess watering of landscape, or installing a poorly placed septic tank drain fields
  - Plan to build away from slopes with mass wasting potential

Cut and Fill Construction Pads




Before construction
Sprinkler adds water to soil
Building adds weight to slope
Fill
Vegetation removed
Steepening of slope for road cut

Undercutting slope by road construction



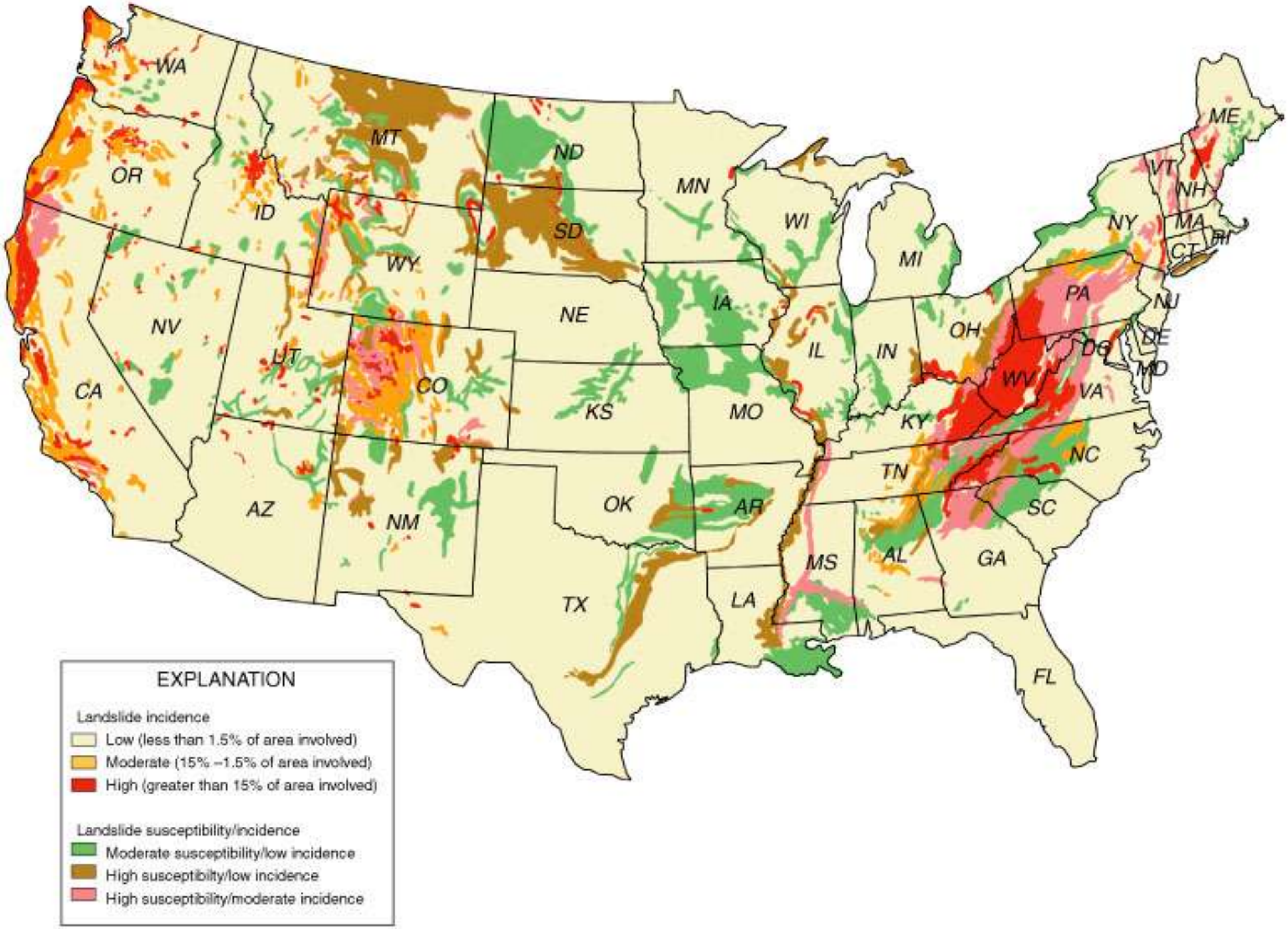
Figures 8.25 a and b

A

B

Debris Flow - Large Debris

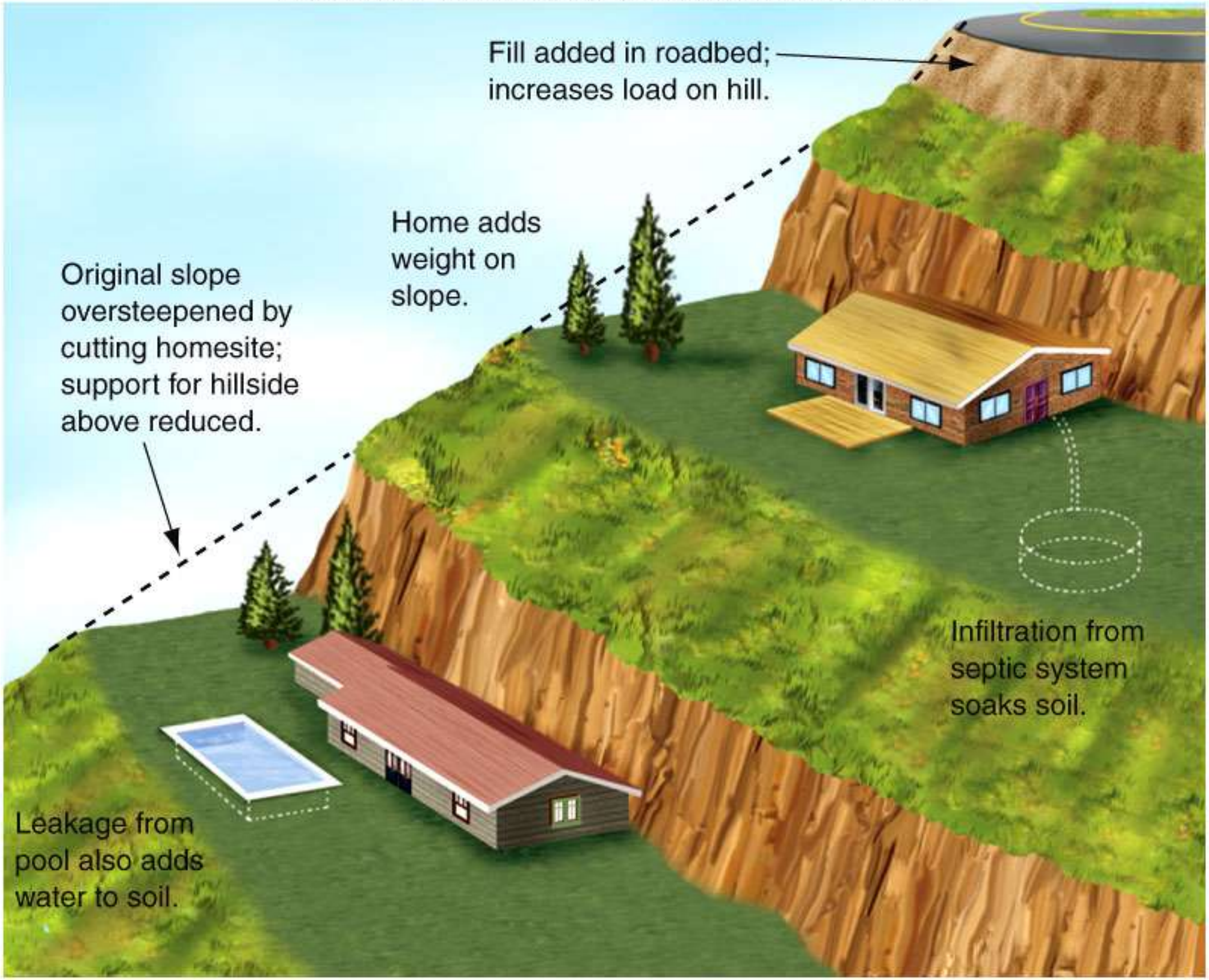
Landslide Incidence



Impact of Human Activities

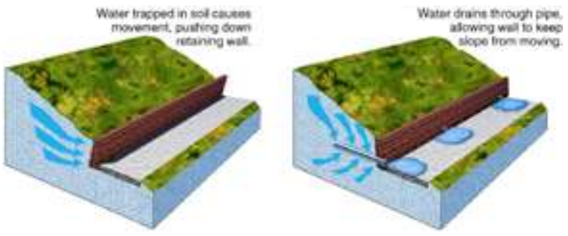
- More prevention
  - Avoid the most landslide-prone areas
  - Take steps to control mass-movement
  - Rely on geologic survey before construction
  - Build retention structures into slope
  - Plan fluid removal or moisture reduction strategies into projects
  - Drive piles or employ rock bolts on a potential unstable slope
  - Recognize the hazard

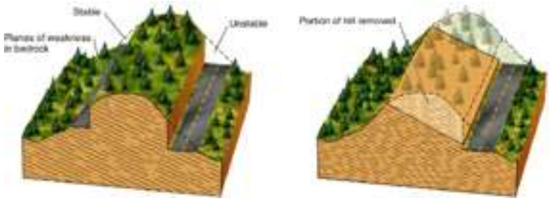
Figure 8.21

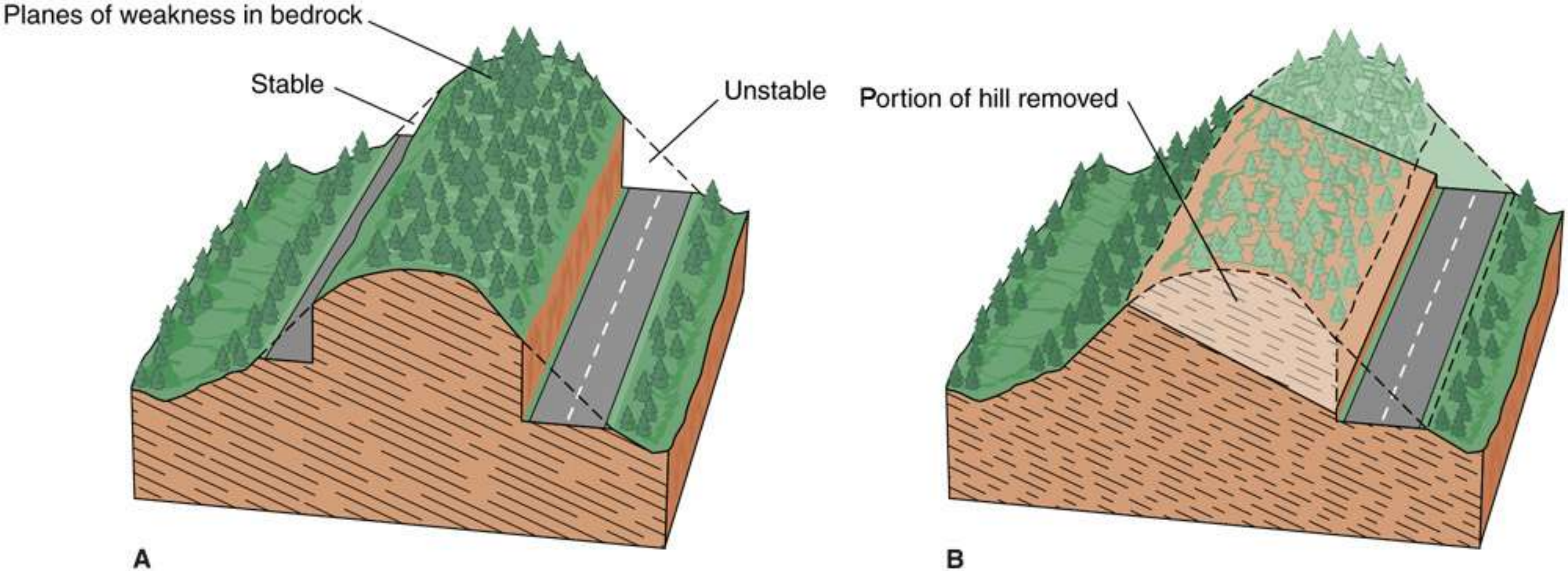

Fill added in roadbed; increases load on hill.
Home adds weight on slope.
Original slope oversteepened by cutting homesite; support for hillside above reduced.
Infiltration from septic system soaks soil.
Leakage from pool also adds water to soil.

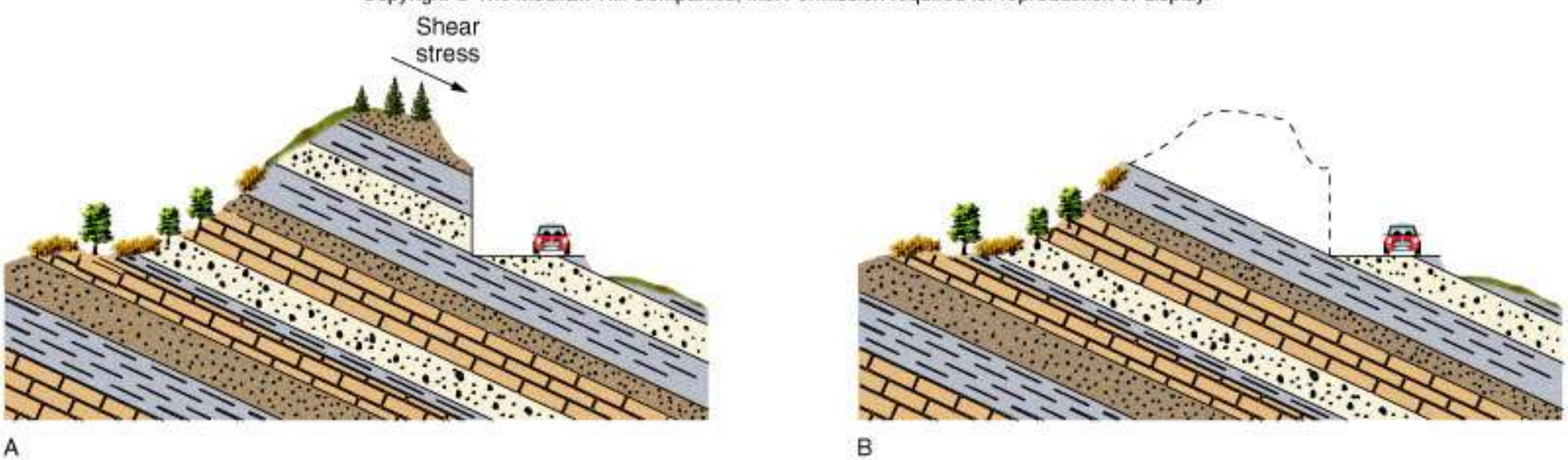
Preventing Landslides

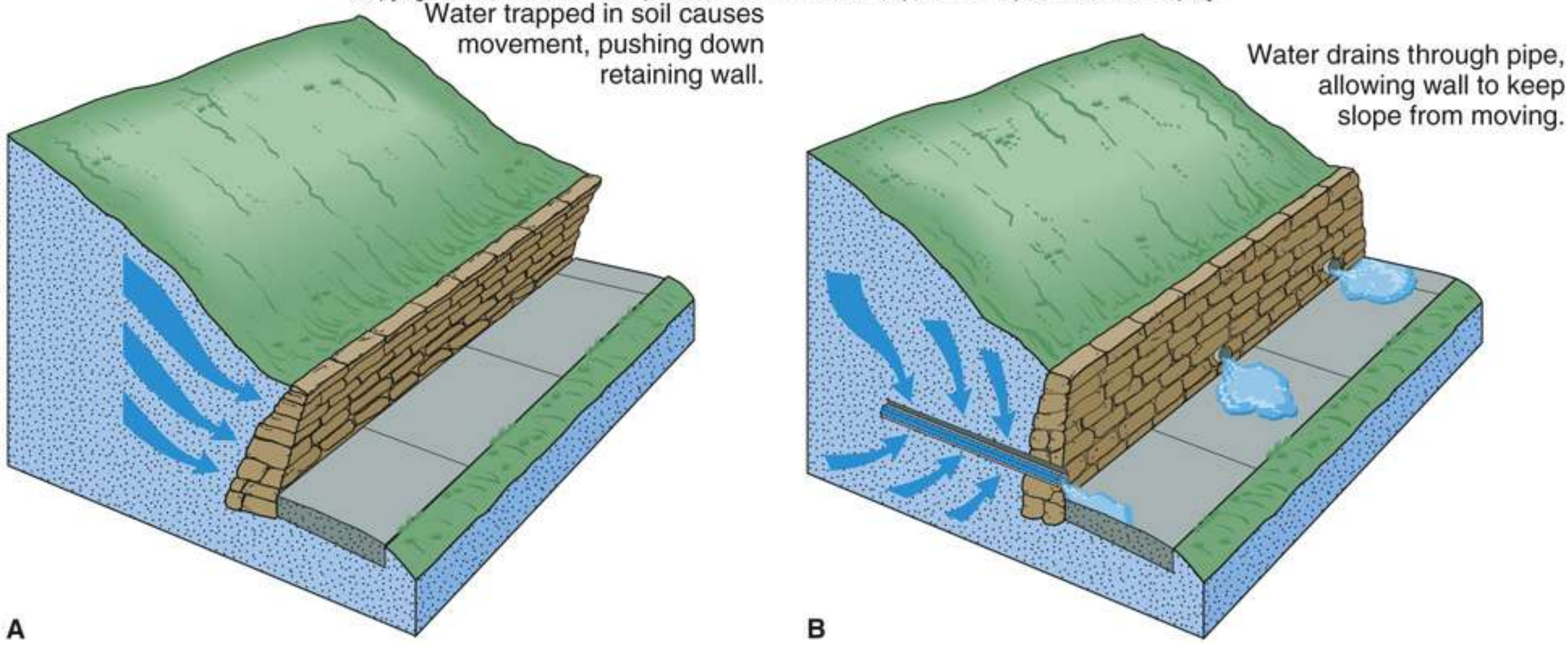
- *Preventing mass wasting of debris*
  - Construct *retaining wall* with drains
  - *Don't oversteepen* slopes during construction
- *Preventing rockfalls and rockslides on highways*
  - *Remove all rock that is prone to sliding*
  - *"Stitch" together outcrop*
- *Important to know the susceptibility of land to mass wasting before building any road or structure*






Planes of weakness in bedrock
Stable
Unstable
Portion of hill removed
A
B


Shear
stress
A
B


Water trapped in soil causes movement, pushing down retaining wall.
A
Water drains through pipe, allowing wall to keep slope from moving.
B

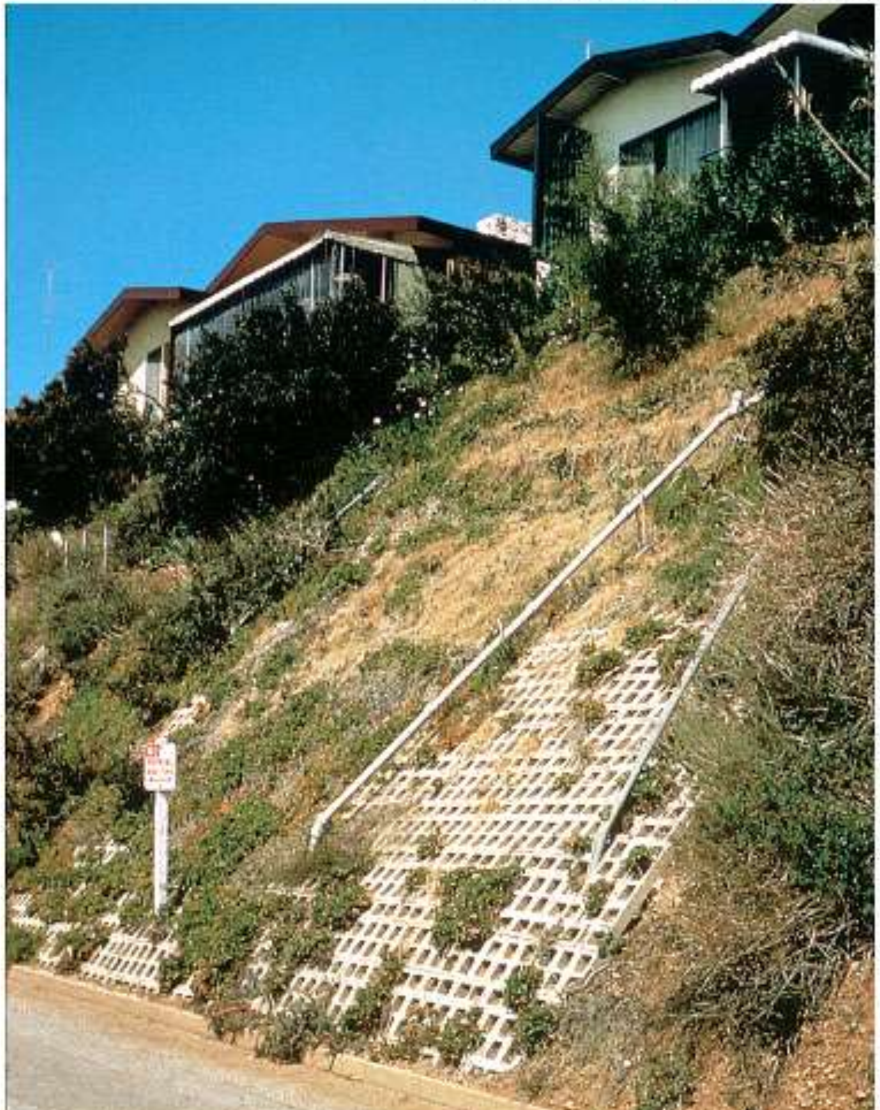
Figures 8.27 a, b, and c

A

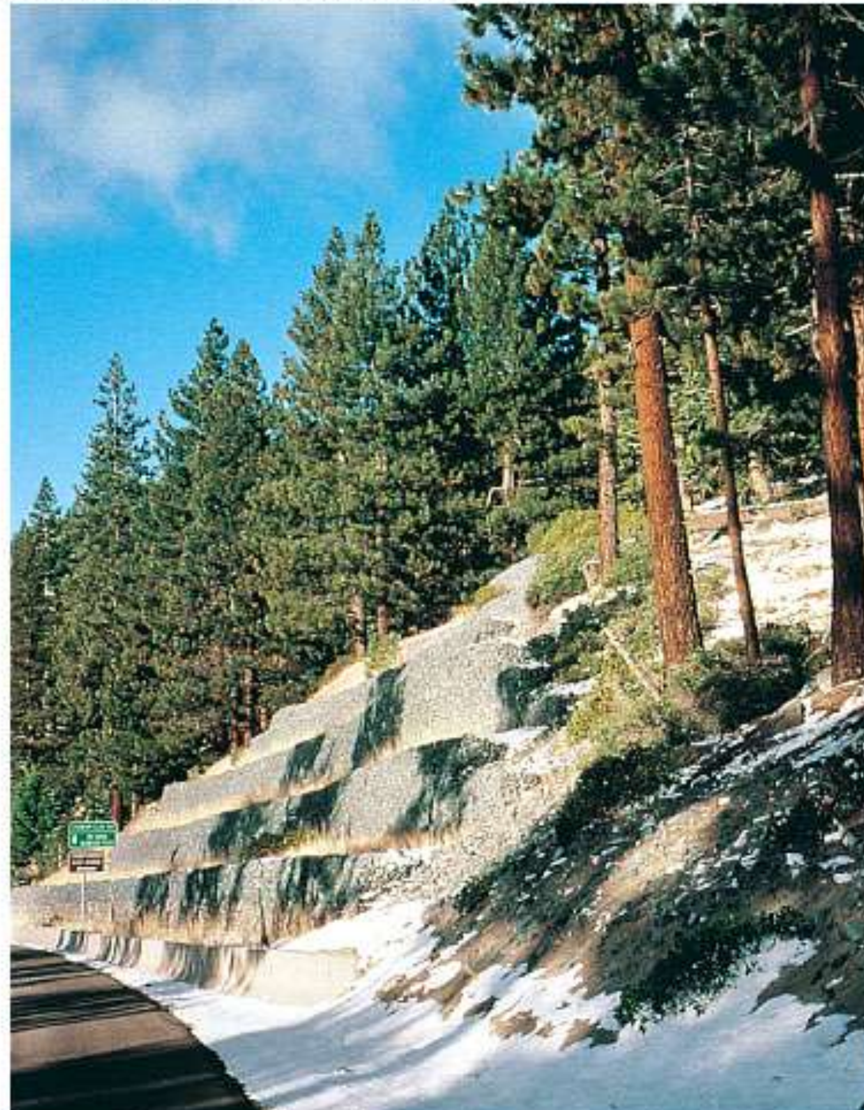
B

C

Slope stabilization

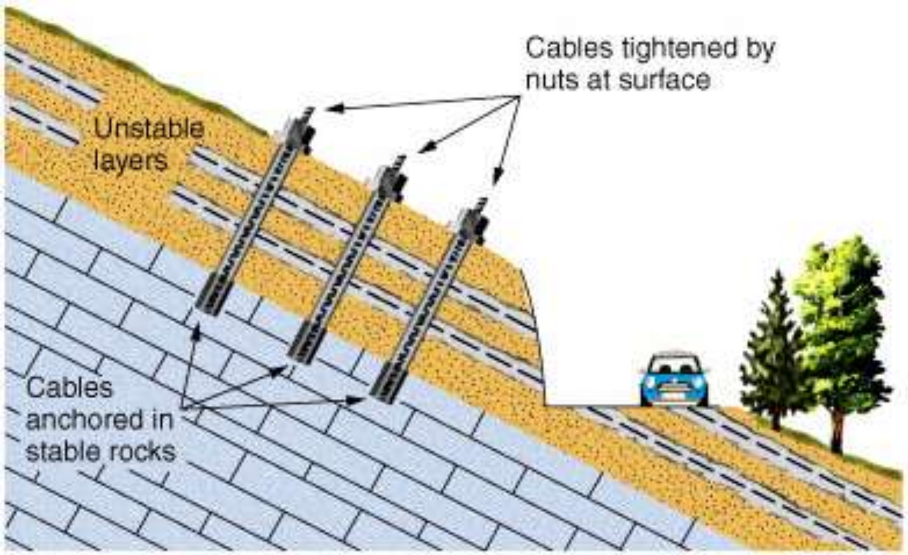


A

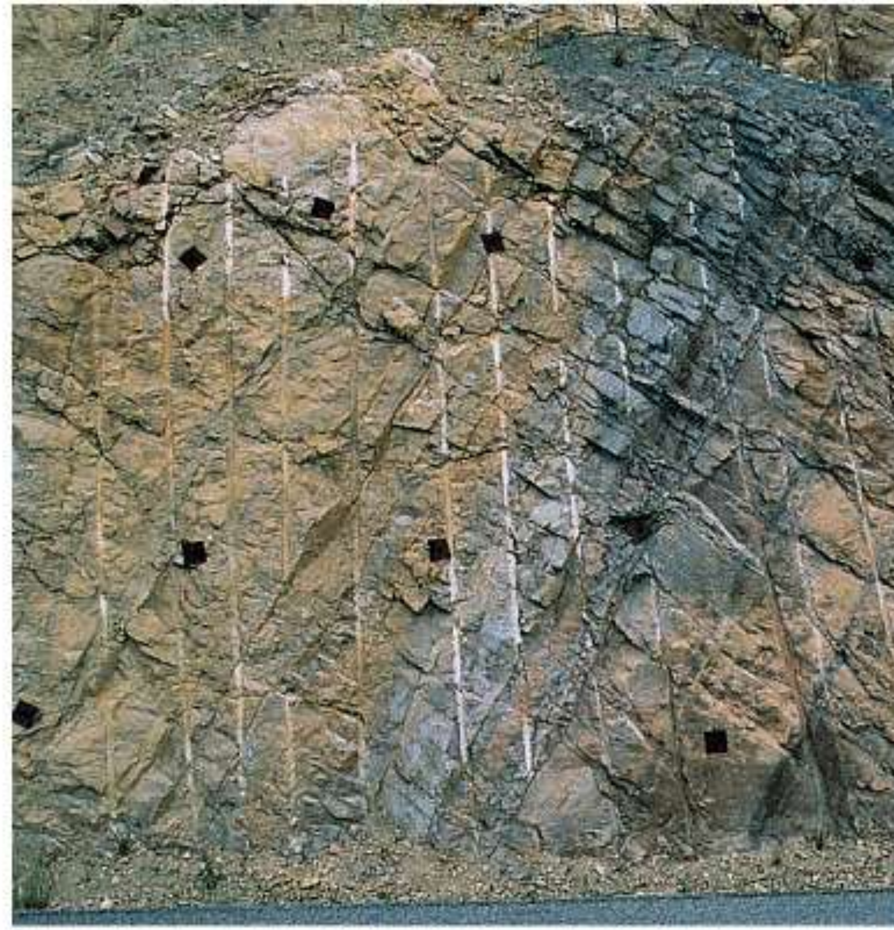


B

Rock Bolts



A



B

E

Photo by Paul G. Bauer

Table 9.2 Summary of Controls of Mass Wasting

Driving Force: Gravity

Contributing Factors	Most Stable Situation	Most Unstable Situation
Slope angle	Gentle slopes or horizontal surface	Steep or vertical
Local relief	Low	High
Thickness of debris over bedrock	Slight thickness (usually)	Great thickness
Orientation of planes of weakness in bedrock	Planes at right angles to hillside slopes	Planes parallel to hillside slopes
Climatic factors:		
Ice	Temperature stays above freezing	Freezing and thawing for much of the year
Water in soil or debris	Film of water around fine particles	Saturation of debris with water
Precipitation	Frequent but light rainfall or snow	Long periods of drought with rare episodes of heavy precipitation
Vegetation	Heavily vegetated	Sparsely vegetated

Triggering Mechanisms: (1) earthquakes; (2) weight added to upper part of a slope; (3) undercutting of bottom of slope.

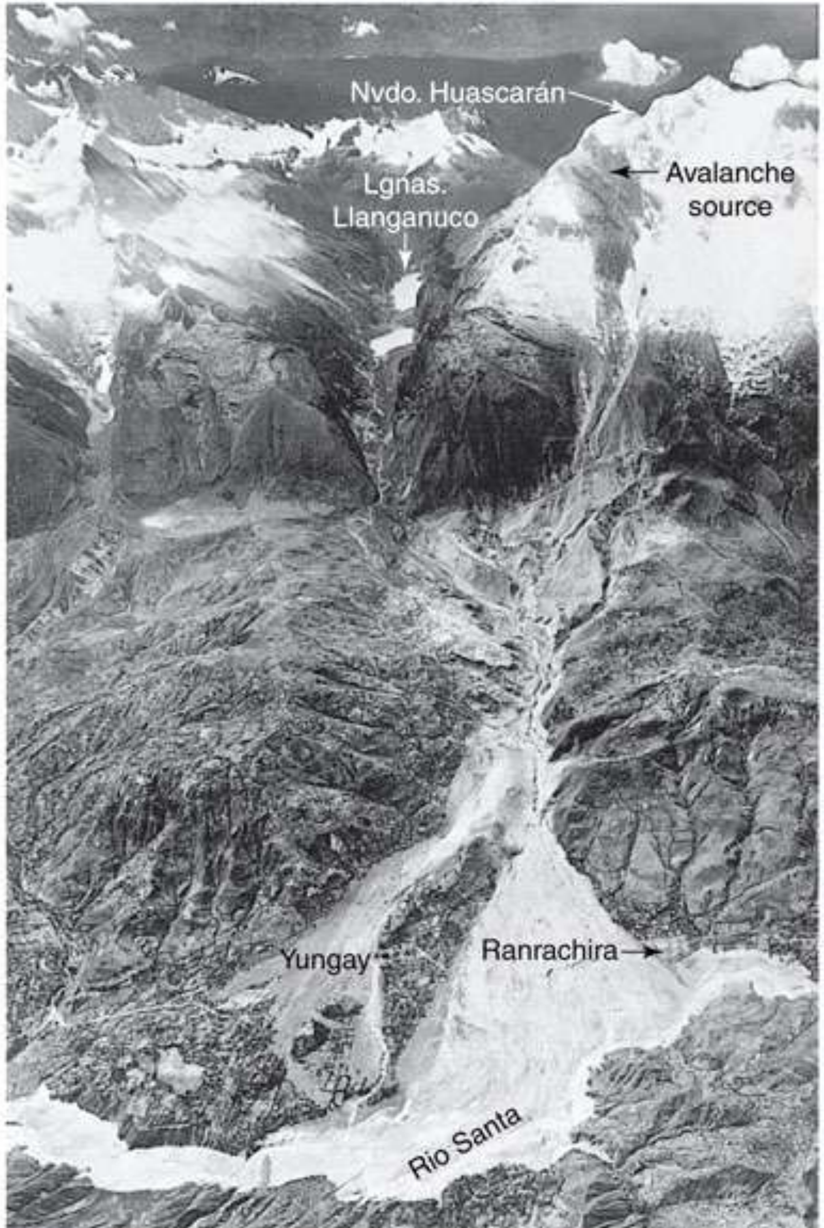
Figures 8.33 a and b

A

B

Toutle R. after 1980 Mt. St Helens

1970 debris avalanche Peru, buried Yungay



1970 debris avalanche, Yungay, Peru

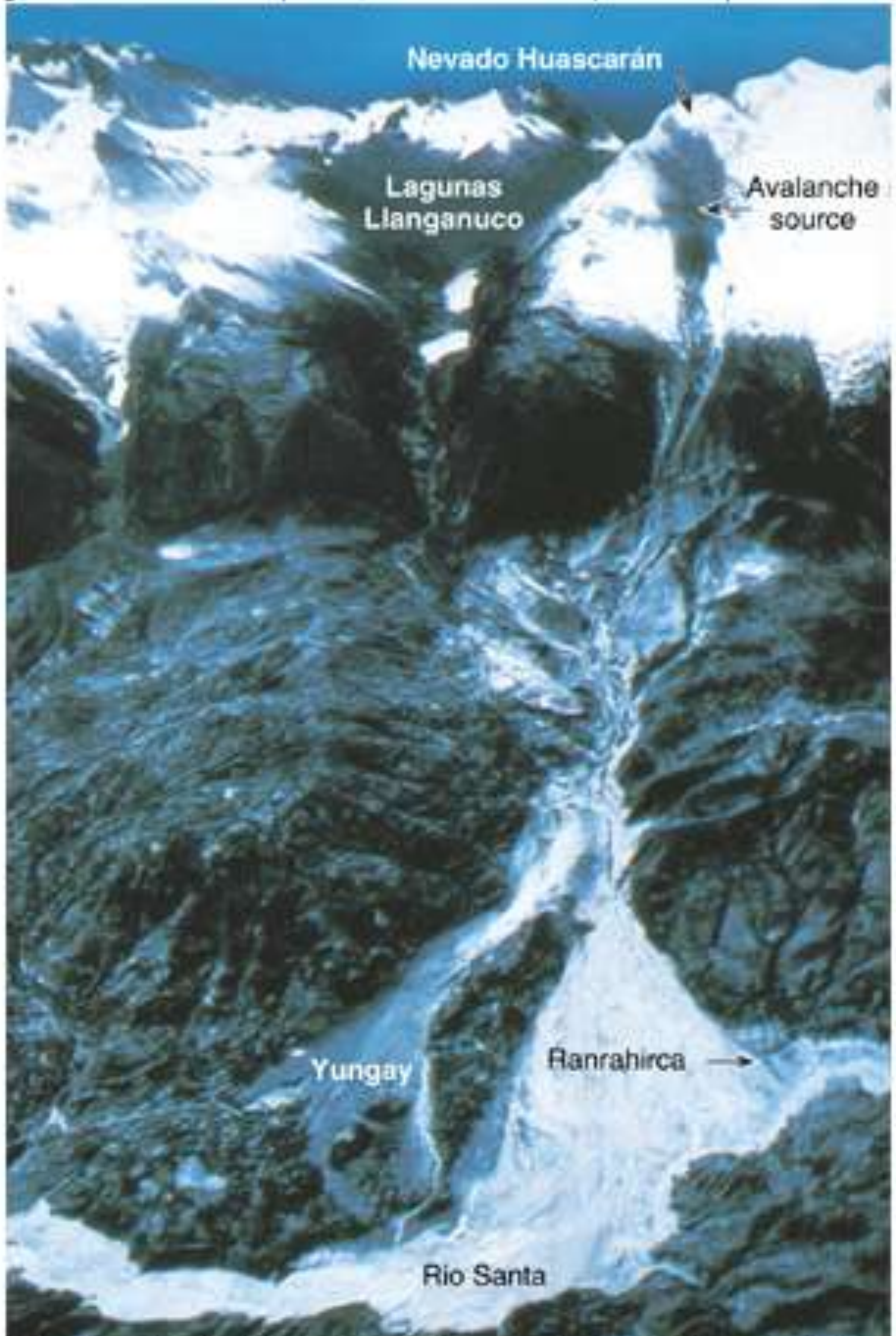
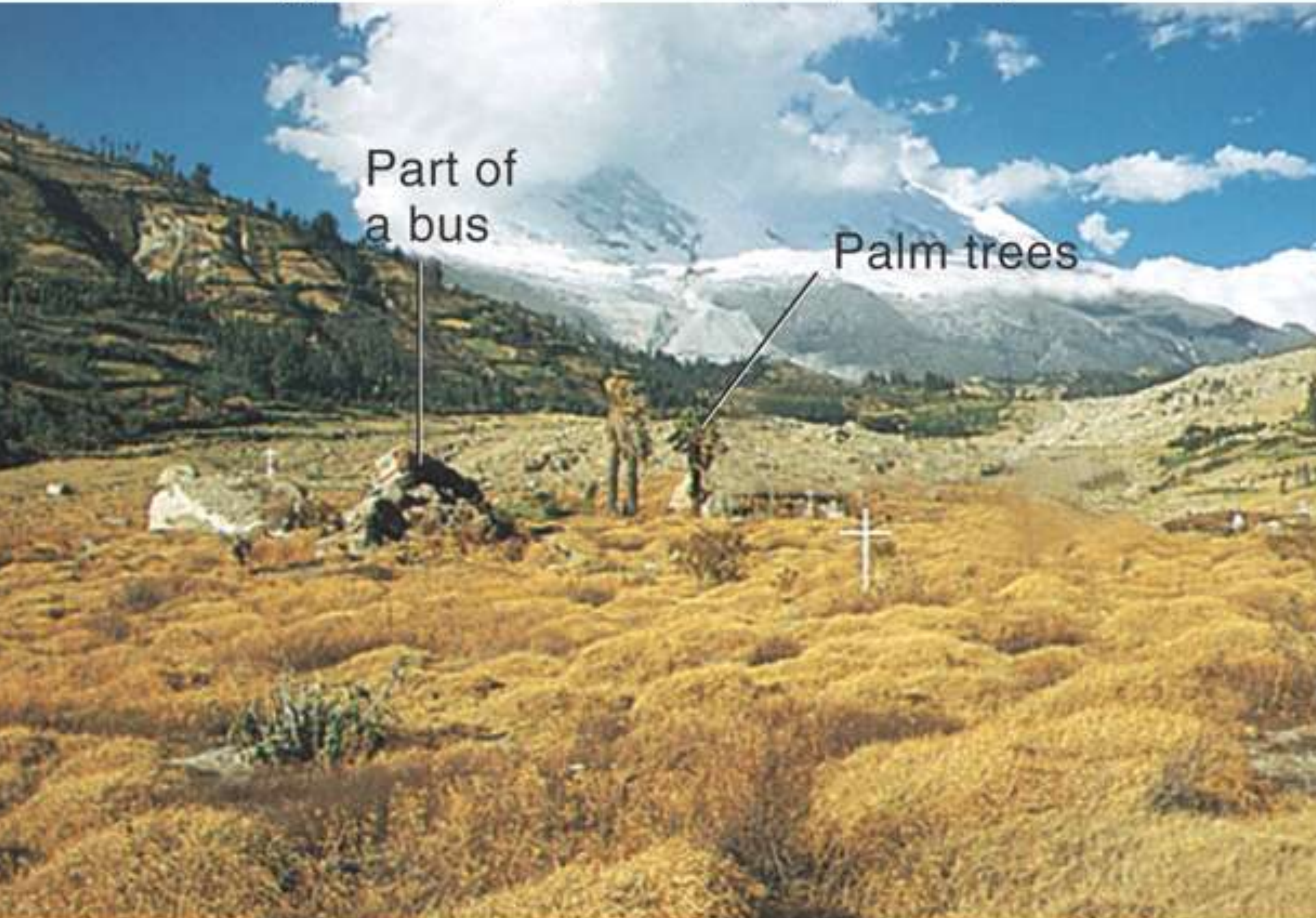


Photo by Servicio Aerofotografico de Peru, courtesy of U.S. Geological Survey

B Yungay Peru

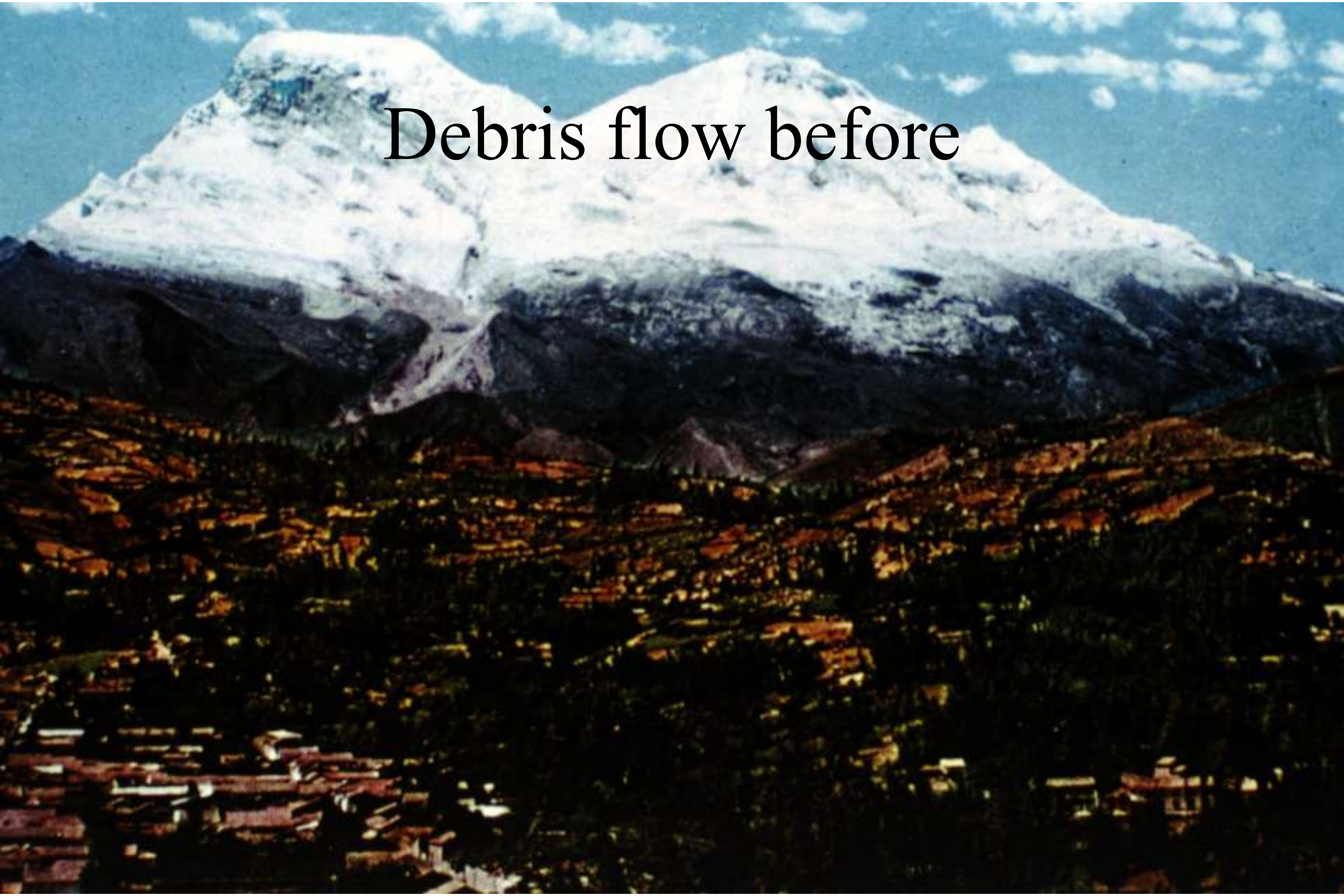
Photo by George Plafker, U.S. Geological Survey



Yungay Peru, 3 years later

Photo by C. C. Plummer

Debris flow before



Debris flow after

Observe some ways that slopes fail

15.08.a1

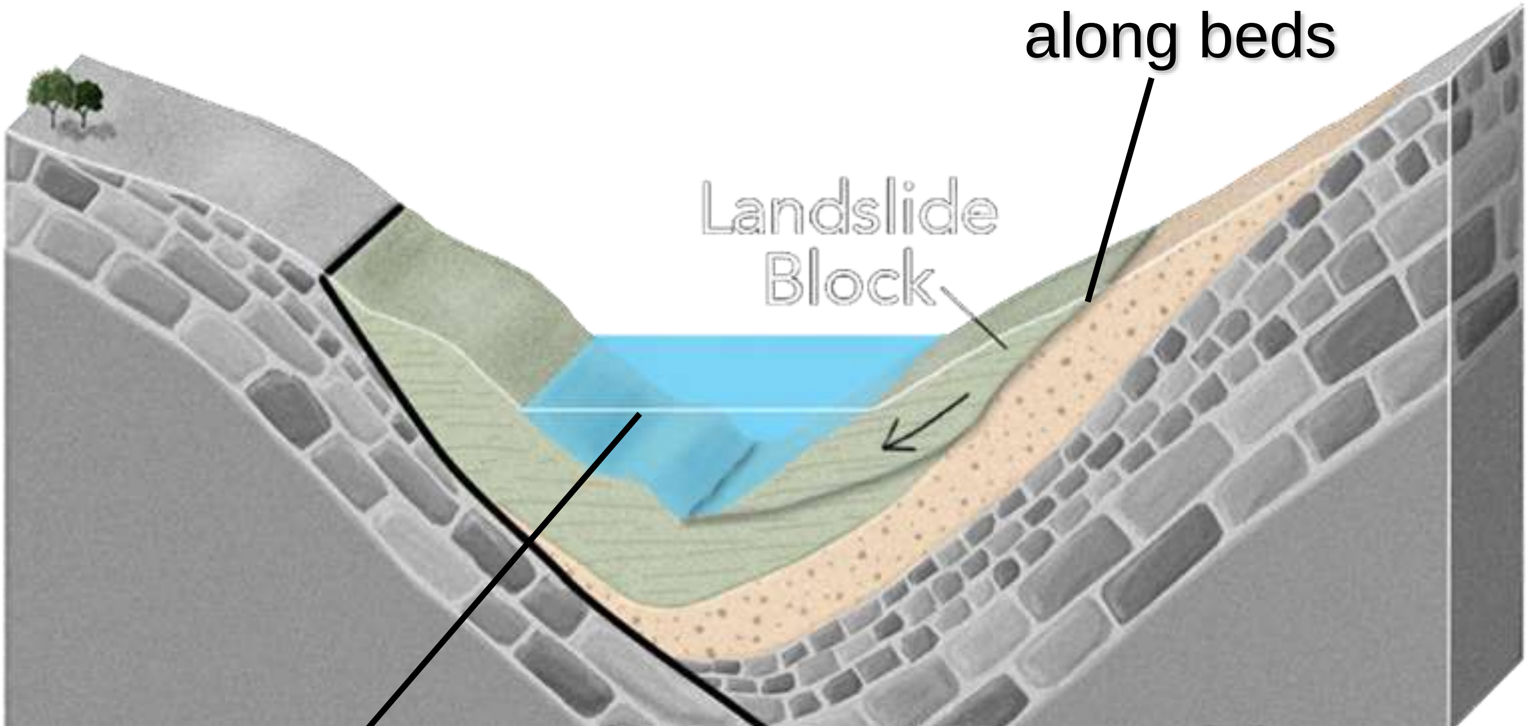
Classification of Slope Failures

Mechanism of Movement

Type of Material

Rate of Movement

Viaont Disaster, Italy



15.09.m1

Assessing Potential for Slope Failure

15.12.c

Past failures

Known problems

Steep slopes

Changes in slope

Conditions of material

Potential triggers

3D