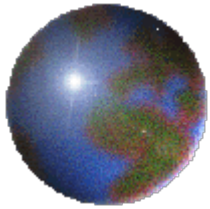


# Introduction to Physical Geology

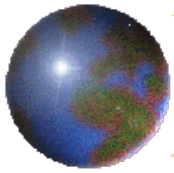


## Chapter 13 Mass Wasting






By Dr. Jia Hui

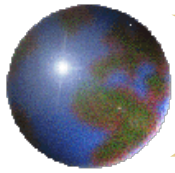
School of Earth Sciences and Engineering

Xi'an Shiyou University



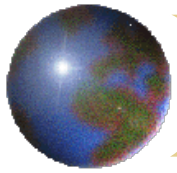
# Content

-  13.1 Mass Wasting
-  13.2 What Causes Mass Movement
-  13.3 Types of Mass Movement
-  13.4 Avoiding/preventing Mass Movement
-  13.5 Extraterrestrial Mass Movement



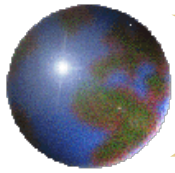
## *13.1 Mass Wasting*

- ✦ 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.



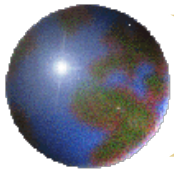
## *13.1 Mass Wasting*

- ✦ Process that transports Earth's materials downslope by the pull of gravity (landslide)
  - ◆ Friction, strength, and cohesiveness of materials resist mass movement
  - ◆ Angle of slope (sloppiness), water content, lack of vegetation, and biological disturbances enhance mass wasting
- ◆ Extent of damage and deaths from Mass Movement in the USA (1925-1975): 1 k/20 k (75 b\$ as compared to 20 b\$ for all others)

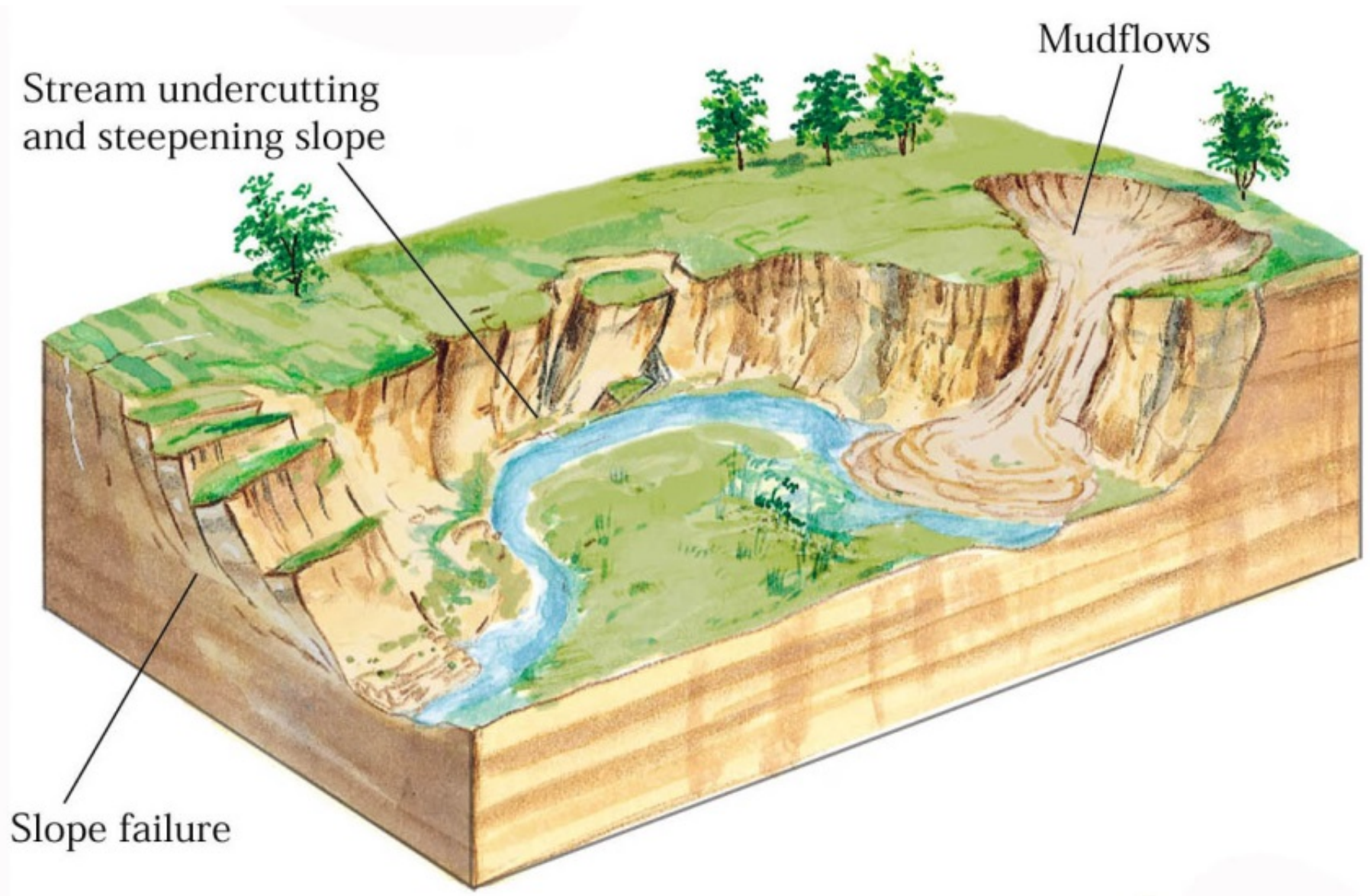


## *13.2 What causes Mass Movement*

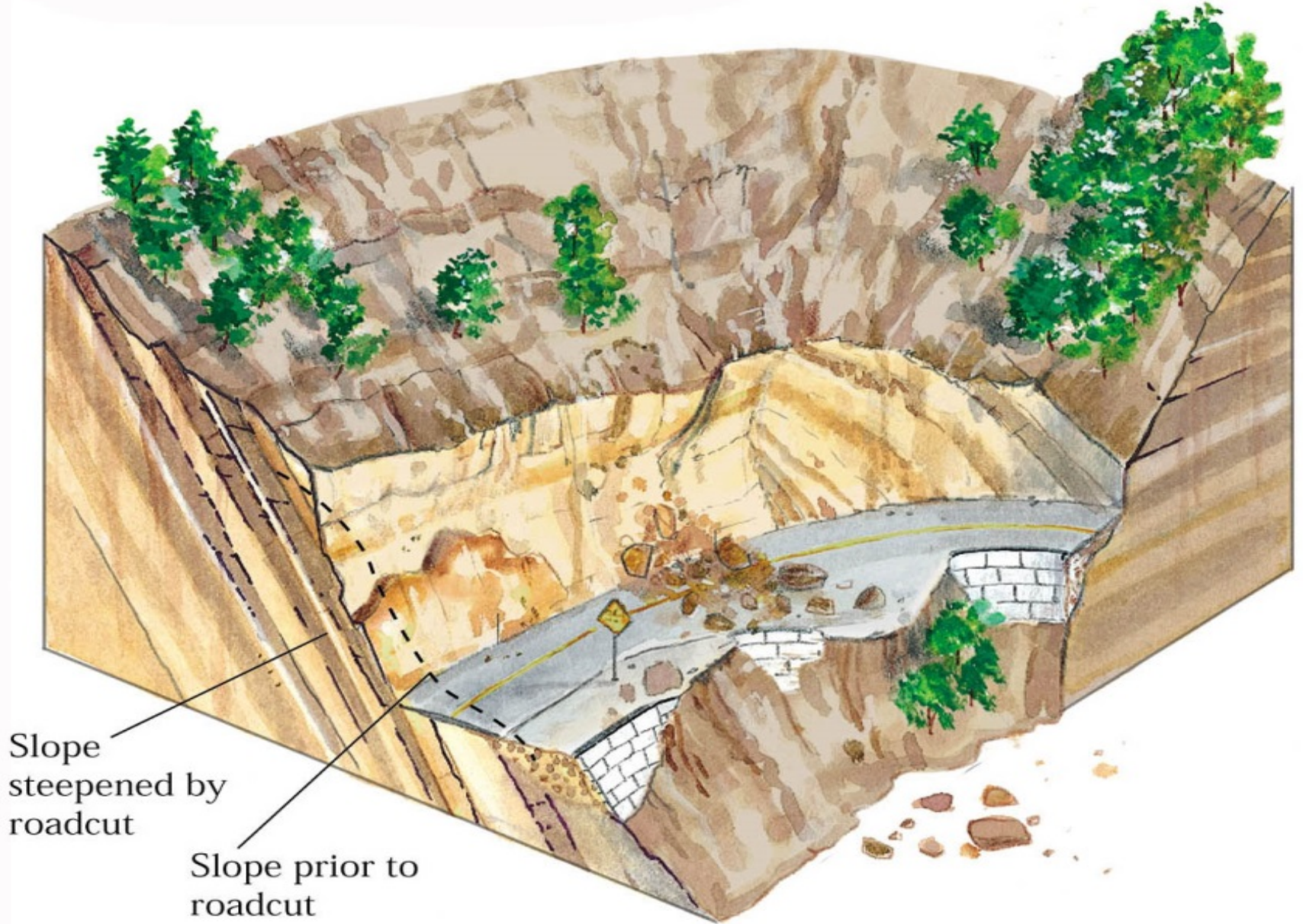
- ✚ Amount of Friction & Steeper slopes depend on:
  - Via Natural processes (Faulting, Folding and Tilting of strata), River cutting, Glacial Erosion & Coastal wave cutting
  - Via Human causes: Quarrying, Road cutting and Waste dumping

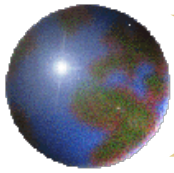


# *Processes that oversteepen slopes*



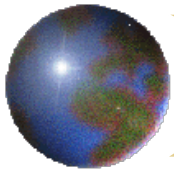
# *Processes that oversteepen slopes – contd.*



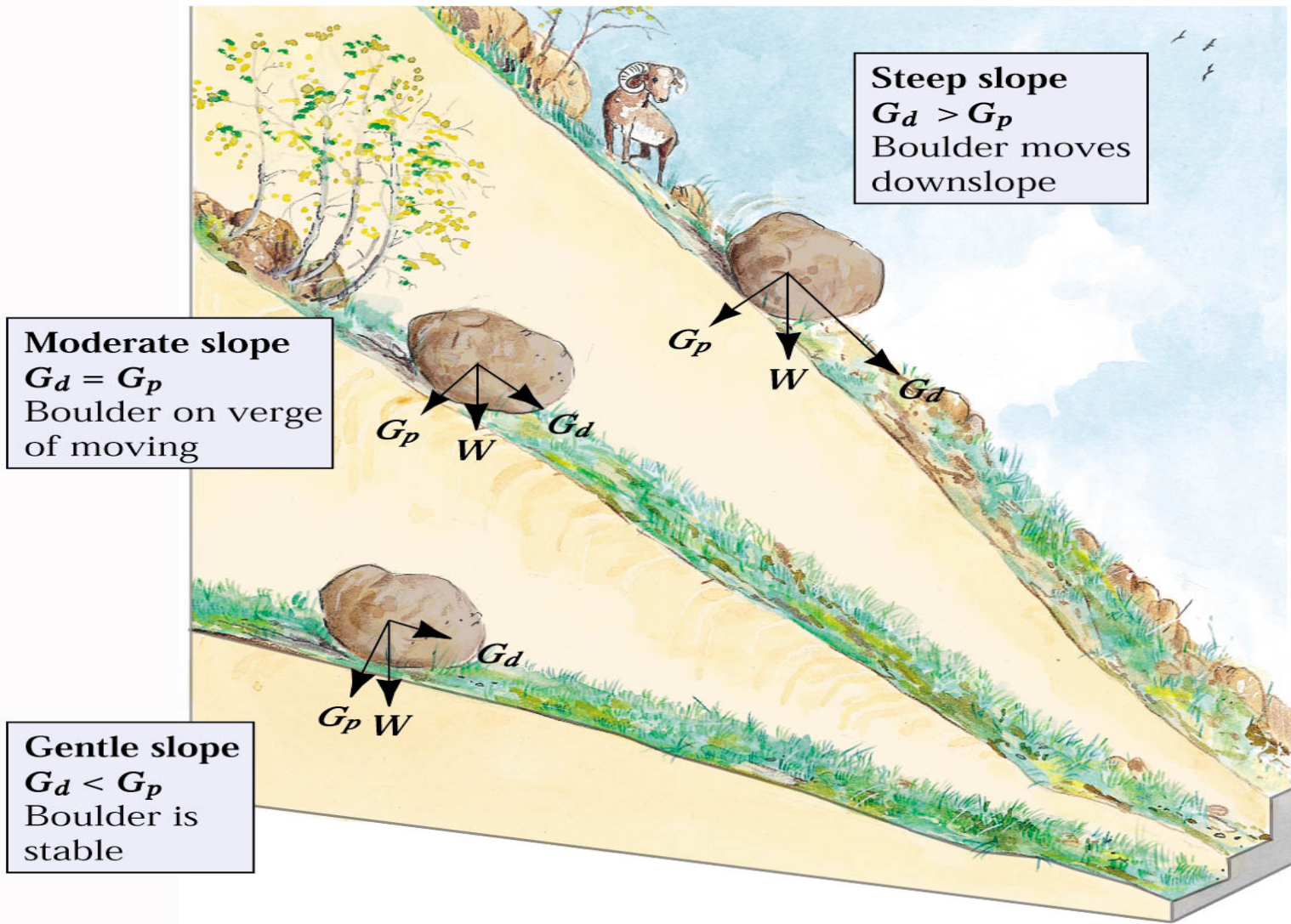


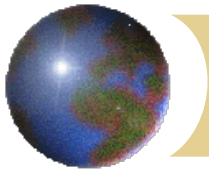
## *13.2 What causes Mass Movement*

- ✚ Principal Factor: Gravity
- ✚ Principal Resistance Factors: Friction, strength and cohesiveness of slope material
- ✚ Gravity Components:
  - ▣ Parallel to Slope ( $G_d$ )
  - ▣ Perpendicular to Slope ( $G_p$ )



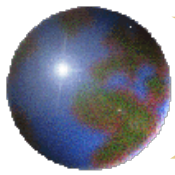
# Boulder on a hillside



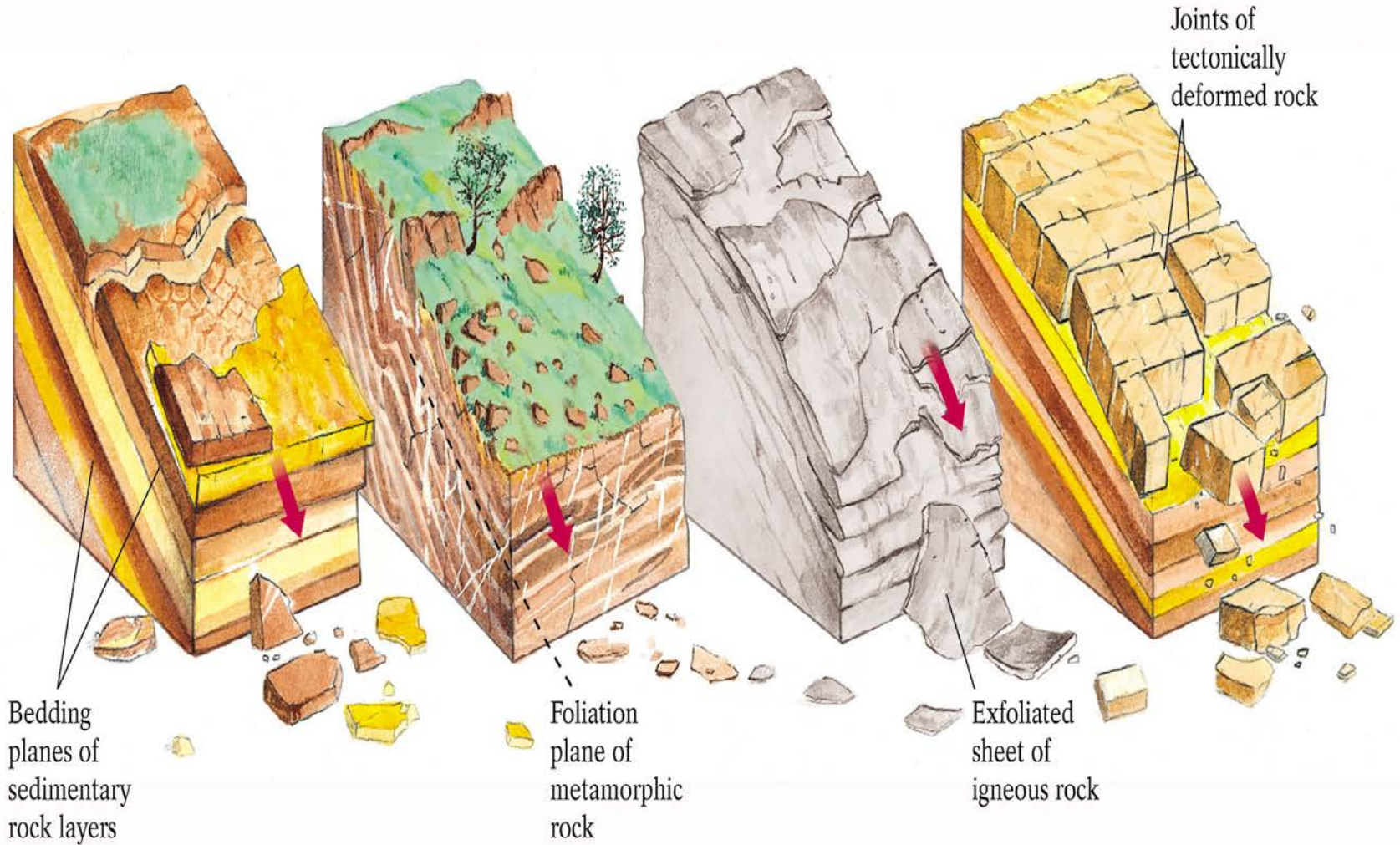


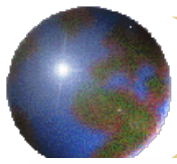
# *Slope Composition*

- ✱ Factors that can reduce rock stability are:
  - ✱ Breakage into networks of joints, fractures, or faults
  - ✱ Mechanical weathering processes
  - ✱ Sedimentary bedding planes
  - ✱ Cavities formed in soluble rock via dissolution
  - ✱ Igneous cooling joints (A joint pattern developed during cooling)
  - ✱ Foliated metamorphic rock with marked rock cleavage
  - ✱ Weakness planes parallel to slope

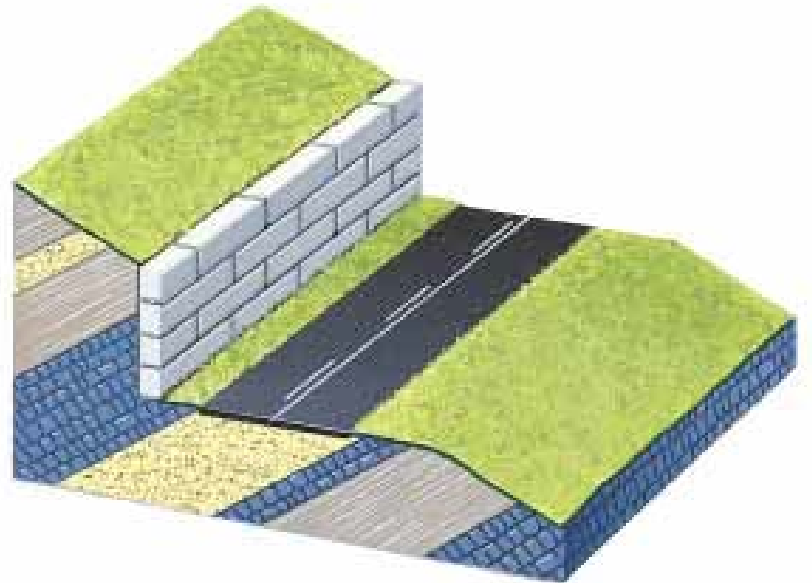
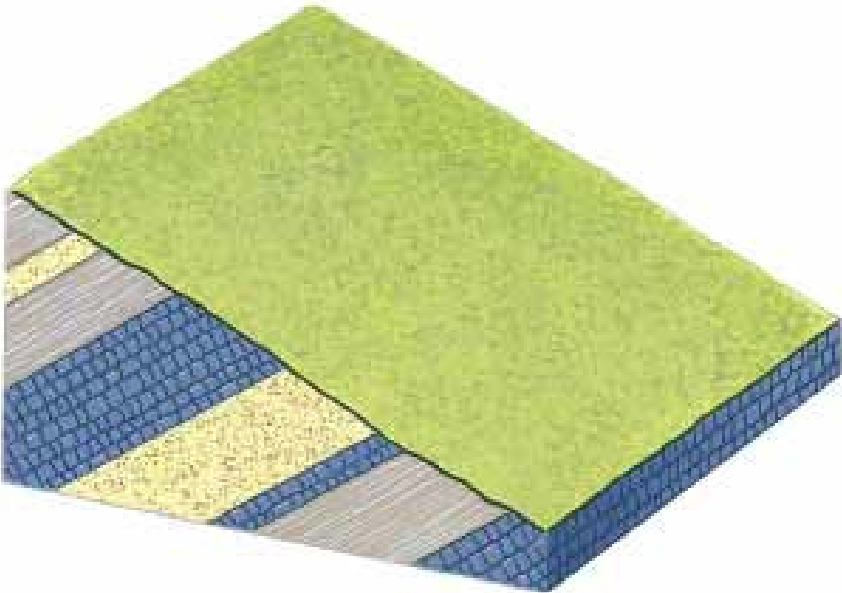
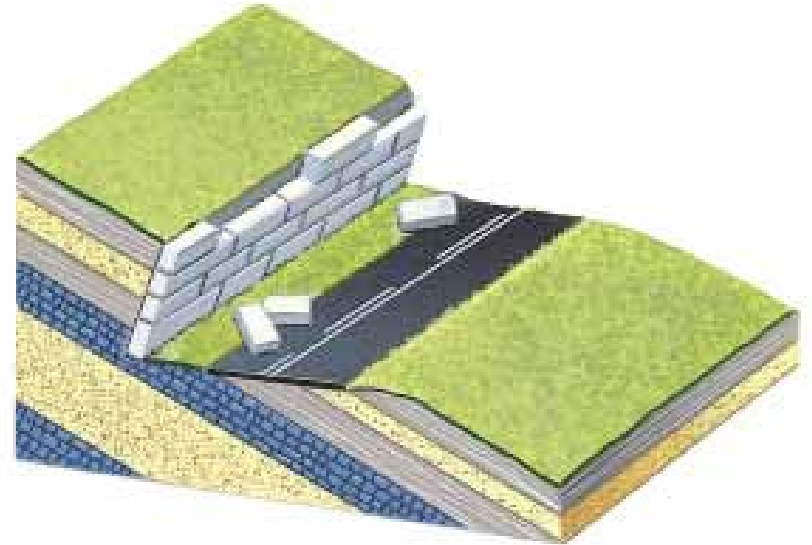
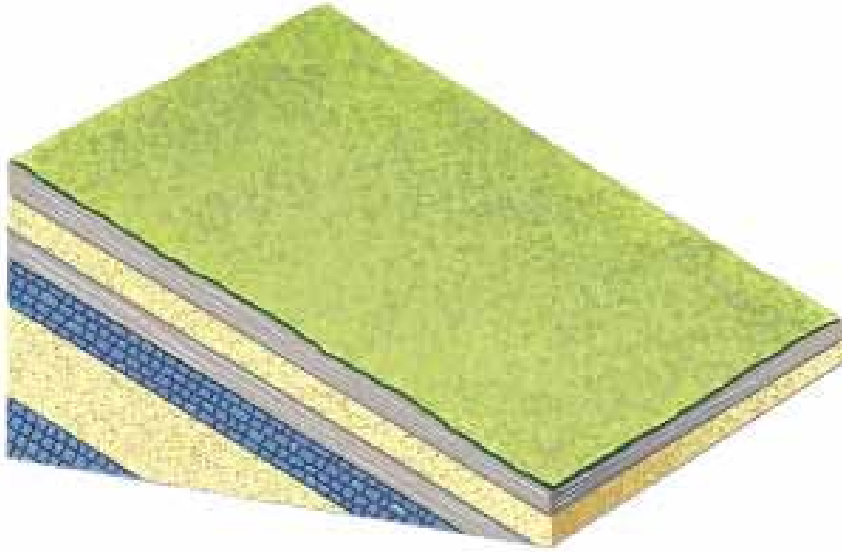


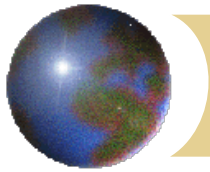
# *Slopes susceptible to mass movements*





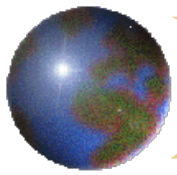
# *Slope Composition*





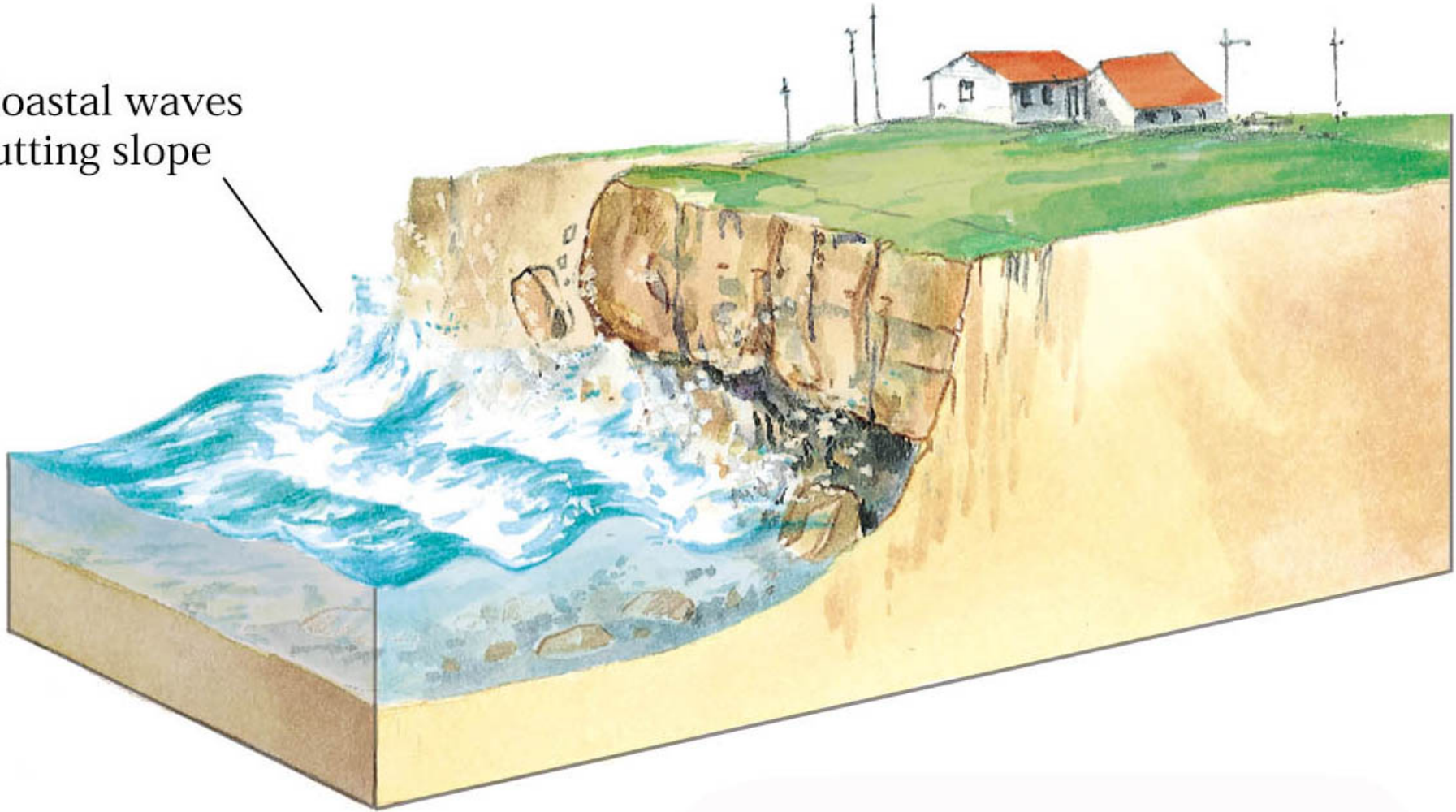
## *13.2 What causes Mass Movement*

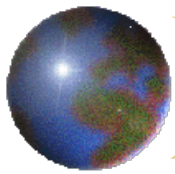
- \* Steepness of Slope
  - \* Stable only if friction is greater than  $G_d$
  - ◆ Faulting, folding, river cut, glacial, coastal wave create steep slope;
- ◆ Angle of repose (maximum slope angle at which a material is stable  $30-35^\circ$  for dry sand);
  - ◆ Different for different material; determined by particle size, shape and particle arrangement; for talus slopes  $>40^\circ$
- \* Composition of Material either promotes or resists mass wasting
  - ◆ Solid /Unconsolidated



# *Slope Composition*

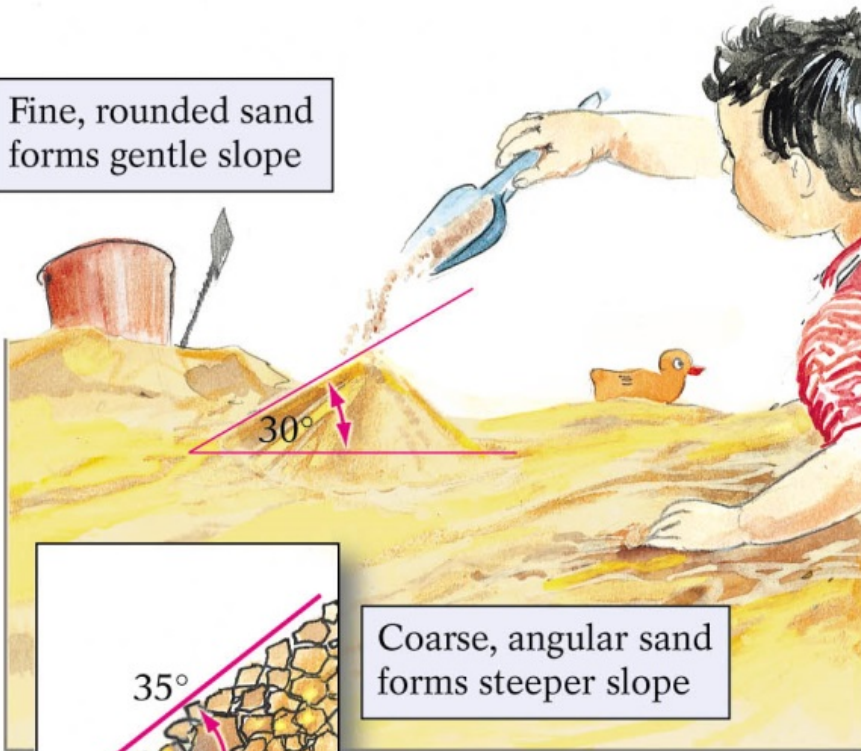
Coastal waves  
cutting slope



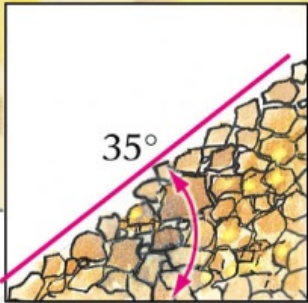


# Particle size and shape

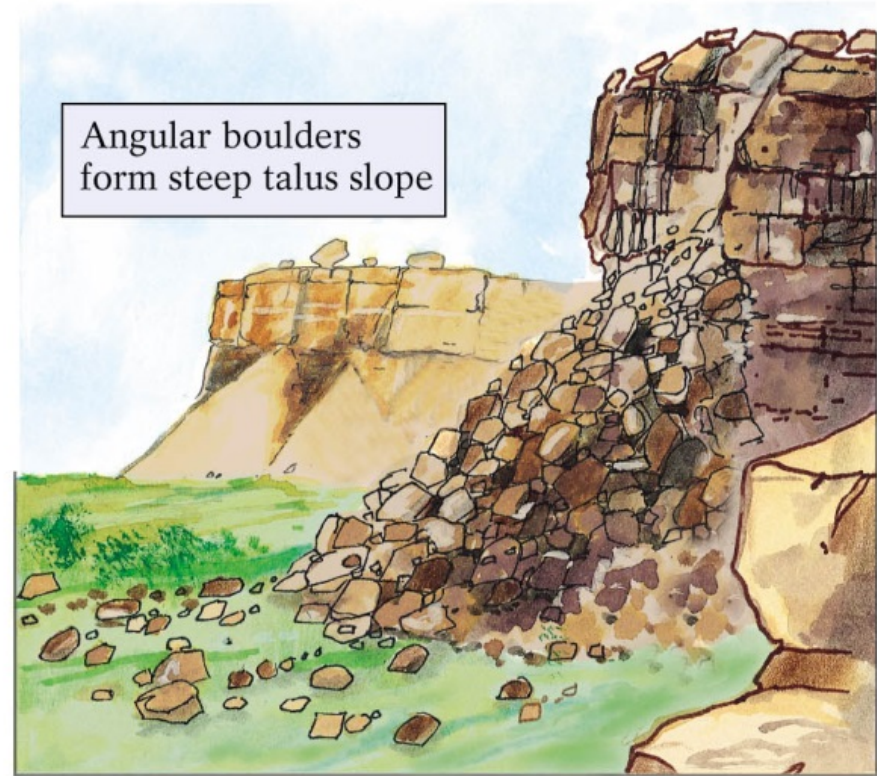
Fine, rounded sand forms gentle slope

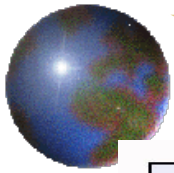


Coarse, angular sand forms steeper slope



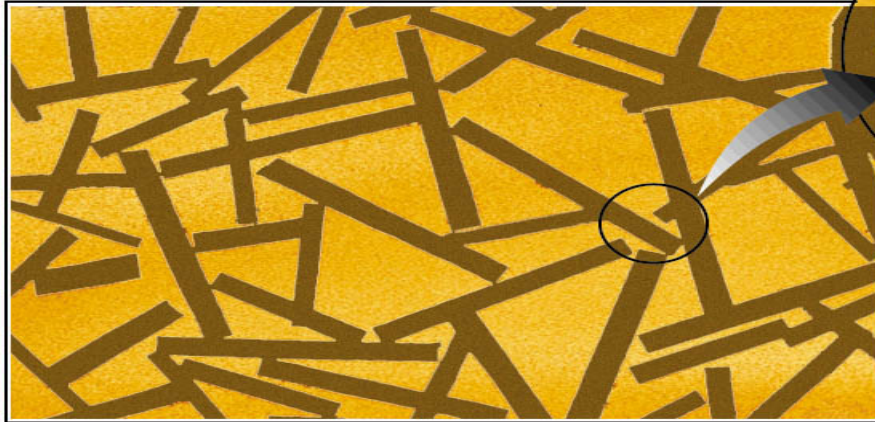
Angular boulders form steep talus slope



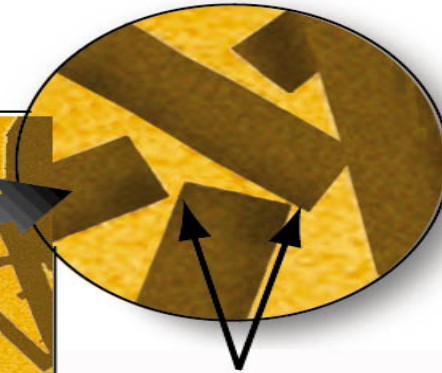


# Effect of particle arrangement on stability

Particles deposited rapidly form stable chaotic structure



**(a) More stable structure**

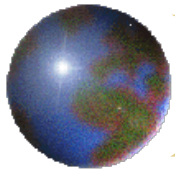


Friction  
at contact  
points



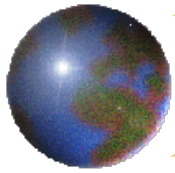
**(b) Less stable structure**

Particles deposited slowly form unstable layered structure that allows particles to slide past one another more easily



## *13.2 What causes Mass Movement*

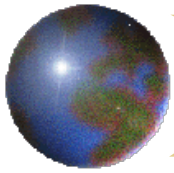
- ✿ Vegetation- lack of which promotes mass wasting (Binds and stabilizes loose, unconsolidated material)
  - ✿ Plant roots provide a strong interlocking network to hold unconsolidated rocks and sediment
  - ✿ Vegetation removes moisture from the soil and may increase shear strength
- ✿ Some plants may increase the shear stress, because of their bulk or shape, and cause movement



# *Causes of Mass Movement*

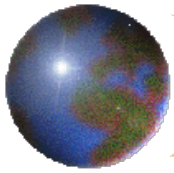
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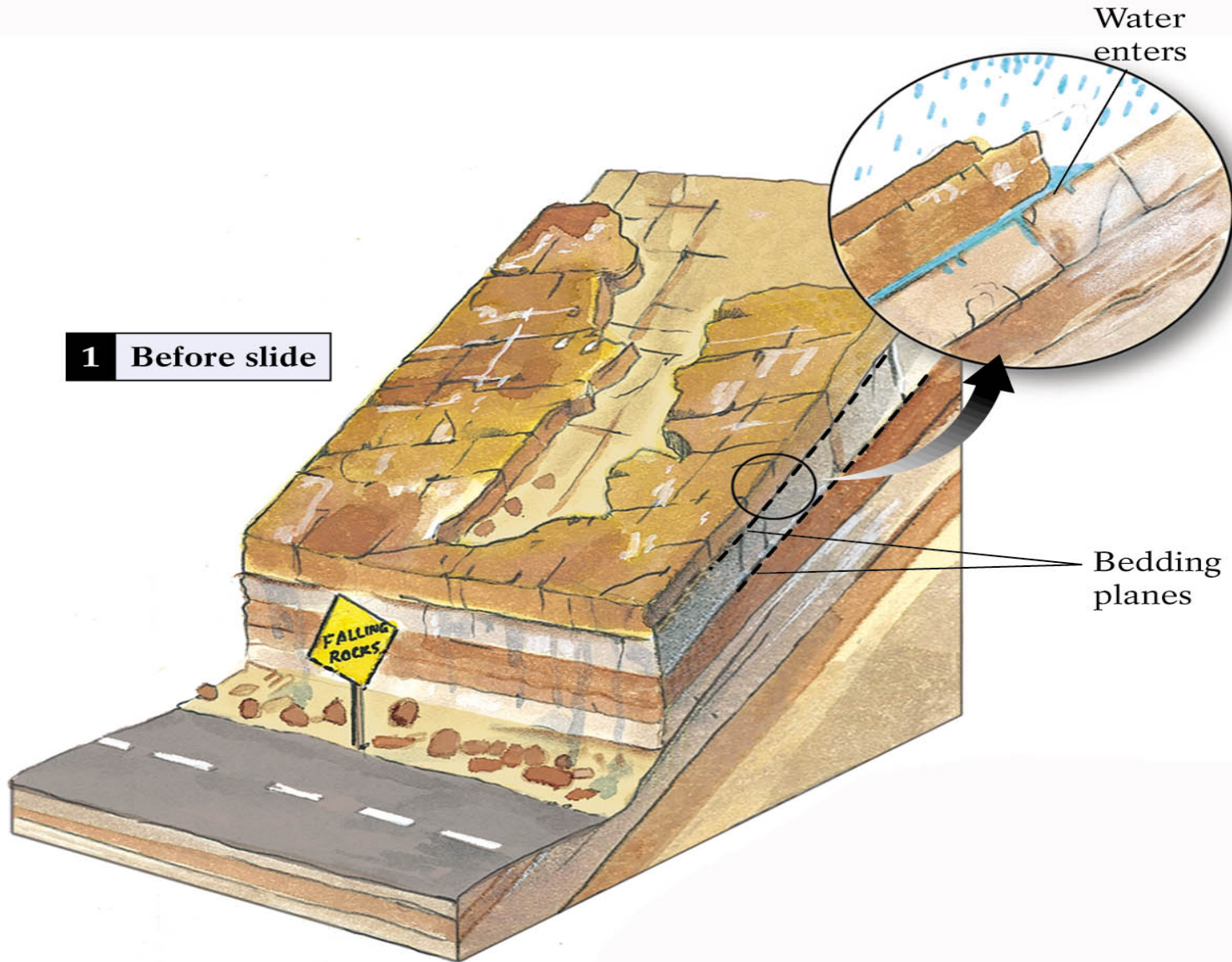


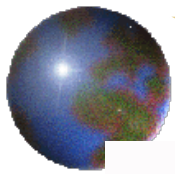
## *13.2 What causes Mass Movement*

- ❖ Water Content- increases weight of material and reduces friction between planes of weakness:
  - ❖ Small water increases cohesiveness
  - ❖ Excess of water reduces friction between surface materials and underlying rocks
  - ❖ Reduces cohesiveness – counteract some or all of  $G_p$  by buoying upward the weight of slope material



# *Water can cause failure in slopes of solid bedrock*

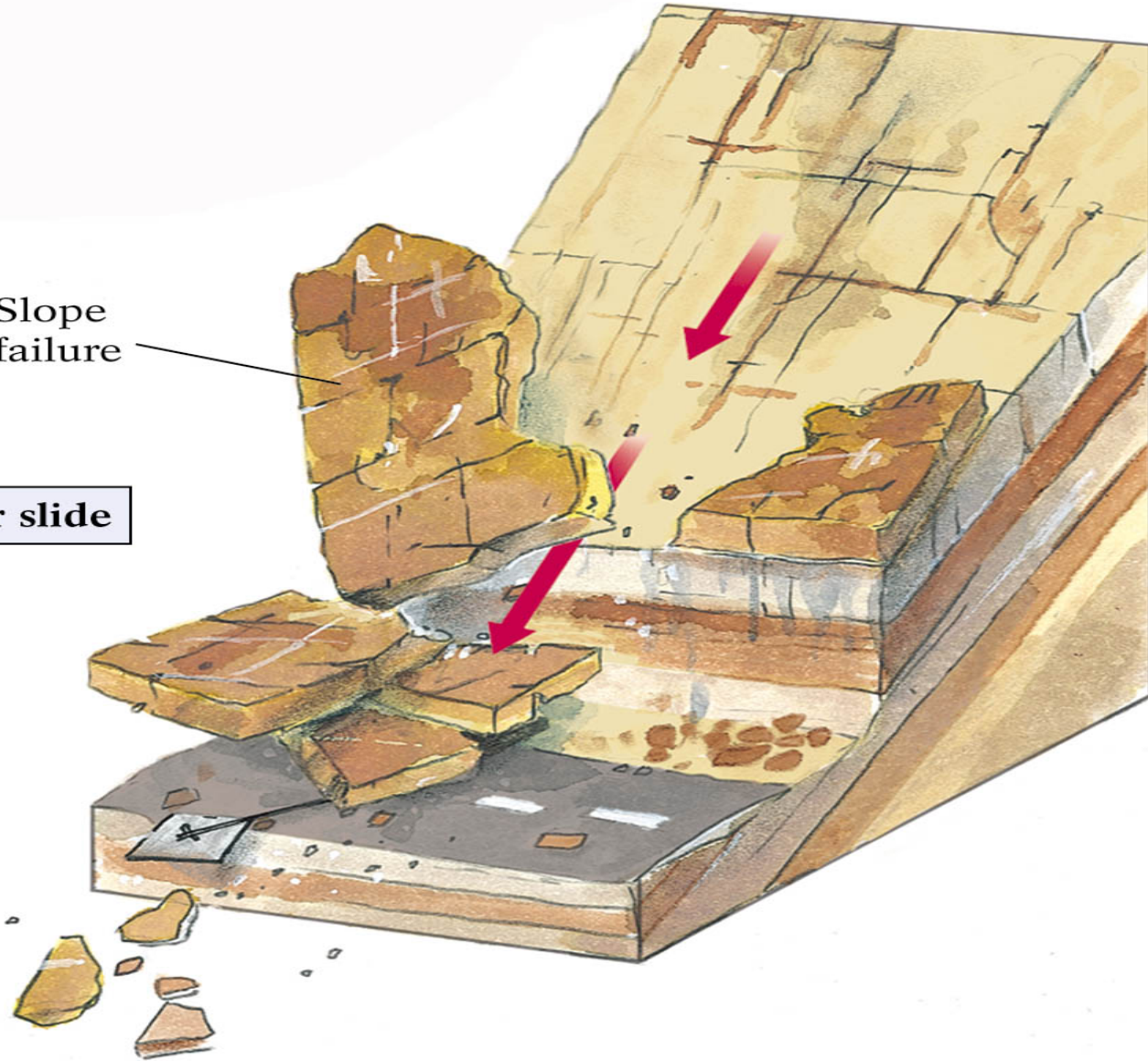


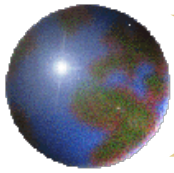


# *Effect of water – contd.*

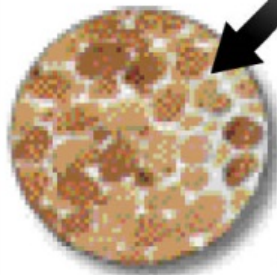
Slope failure

**2** After slide

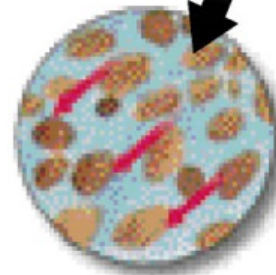




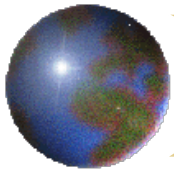
# *Saturation with water promotes mass movement*



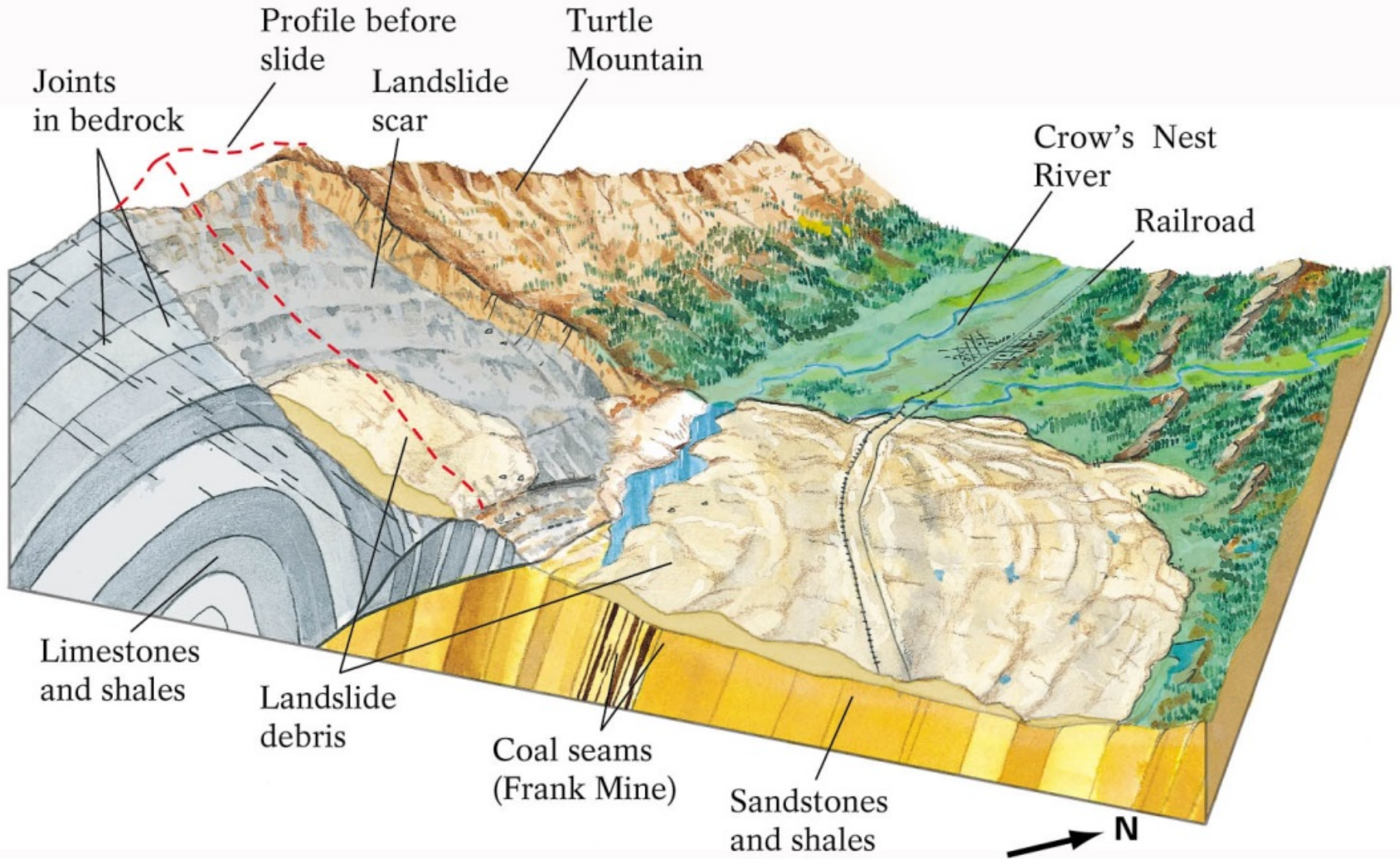
Stable when dry

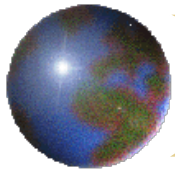


Slope fails when saturated



# *Turtle Mountain landslide*





## *13.2 What causes Mass Movement*

### ✚ Human/Other Disturbances

#### ✚ Triggers for Mass Movement Events

- Natural Triggers

- ◆ Climatic- torrential rains and snow melt

- ◆ Geologic- earthquakes and volcanic eruptions

- ◆ Landslides are a common consequence of an earthquake

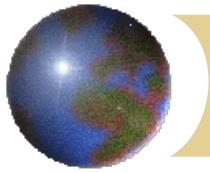
- ◆ Seismic waves passing through rock may stress and fracture it

- ◆ Reduces shear strength

- ◆ The loss of shear strength may result in immediate movement



C



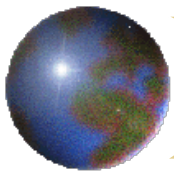
## *13.2 What causes Mass Movement*

### ✚ Human/Other Disturbances

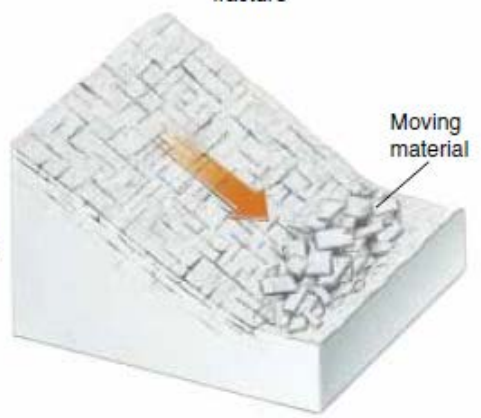
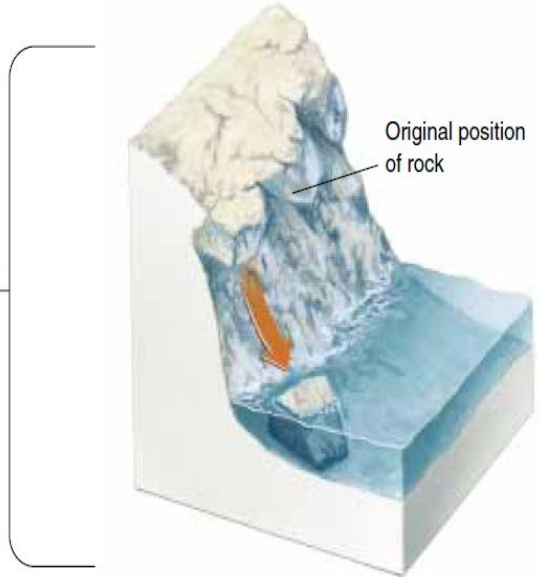
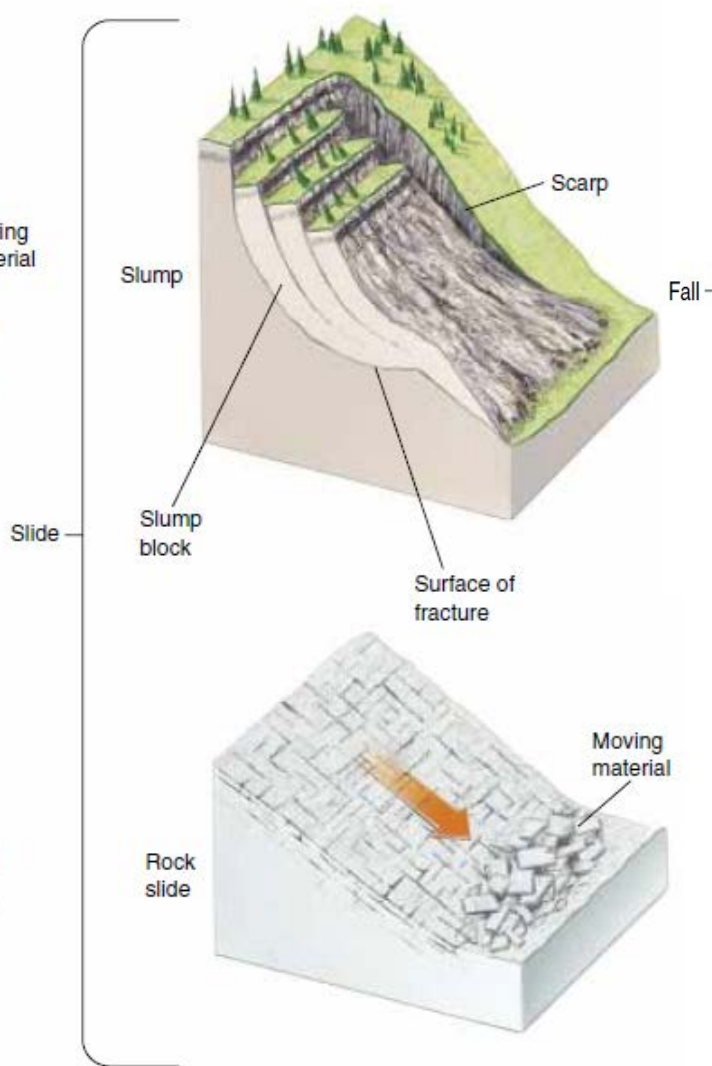
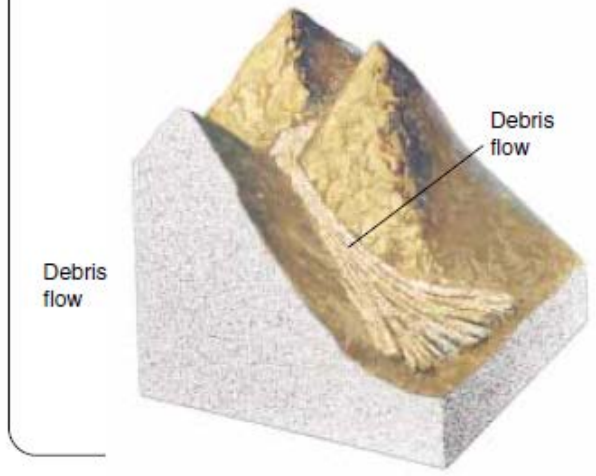
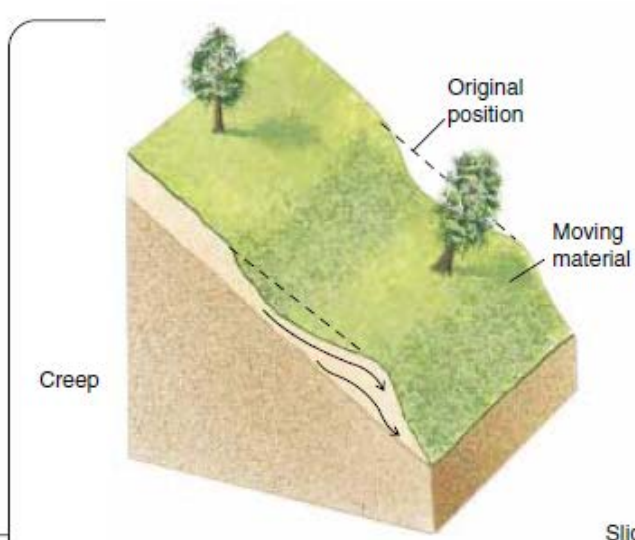
#### ✚ Triggers for Mass Movement Events

### ✚ Human-Induced Triggers

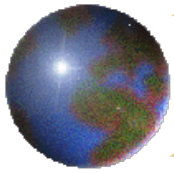
- ◆ Oversteeping of slopes- excavation
- ◆ Overloading- excess water, building, and other construction
- ◆ Deforestation/overgrazing of vegetation
- ◆ Loud noise- trains, aircrafts, blasting
- ◆ Lawn sprinkling



# 13.3 Types of Mass Movement



Flow, slide, and fall are the three categories of mass wasting.



## *13.3 Types of Mass Movement*

✱ Classification based on velocity & Composition

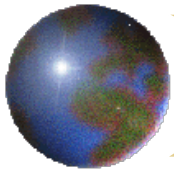
✱ Slow Mass Movement

✱ Creep: Slowest Mass movement (measured in mm or cm per year); affects unconsolidated materials

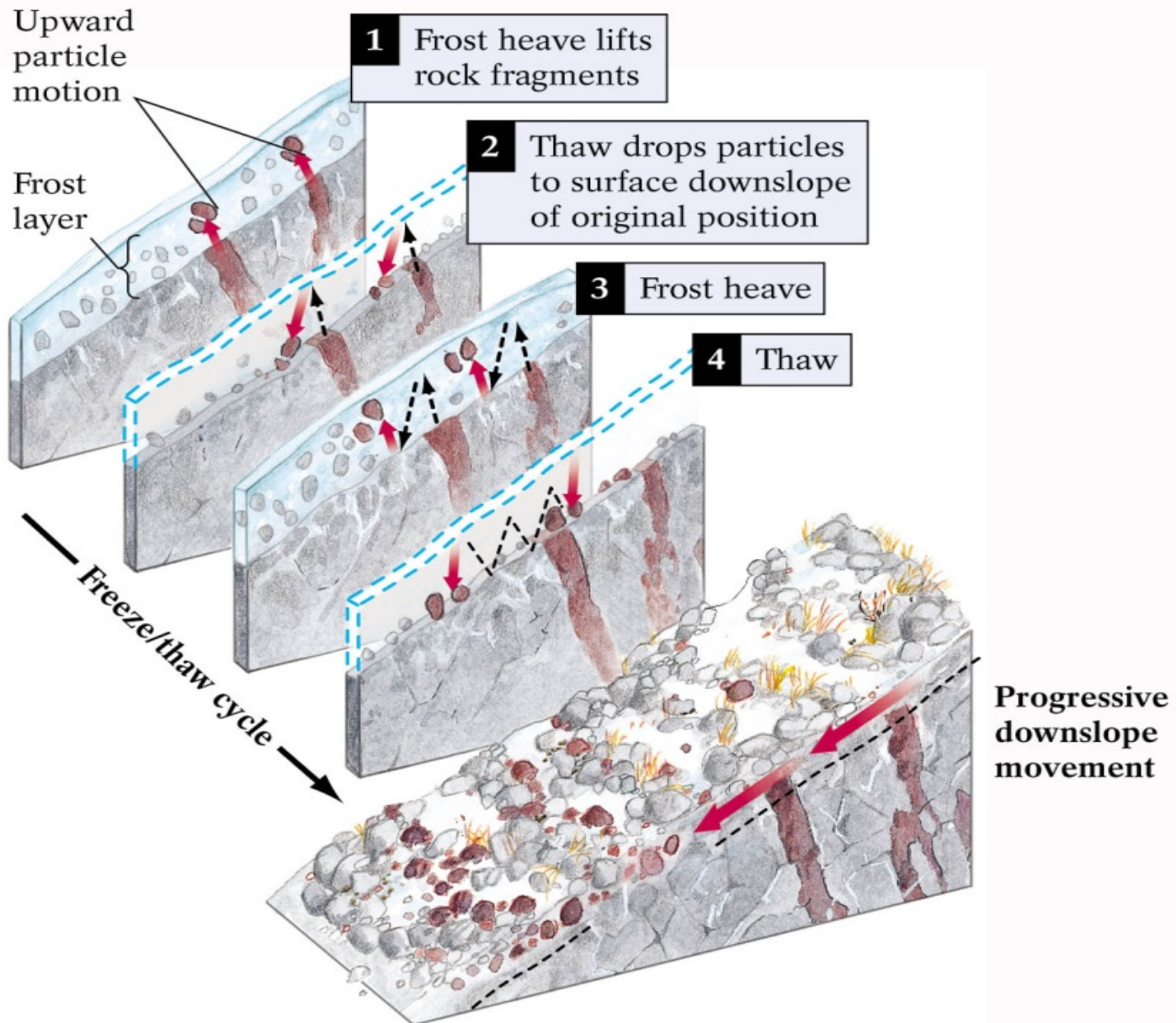
- under the influence of gravity, Individual particles move independently of one another

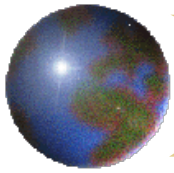
✱ Causes:

- ✱ Burrowing animals
- ✱ Trampling of animals
- ✱ Splashing of raindrops
- ✱ Swaying of plants and trees
- ✱ Freezing and Thawing
- ✱ Wetting and Drying of clays

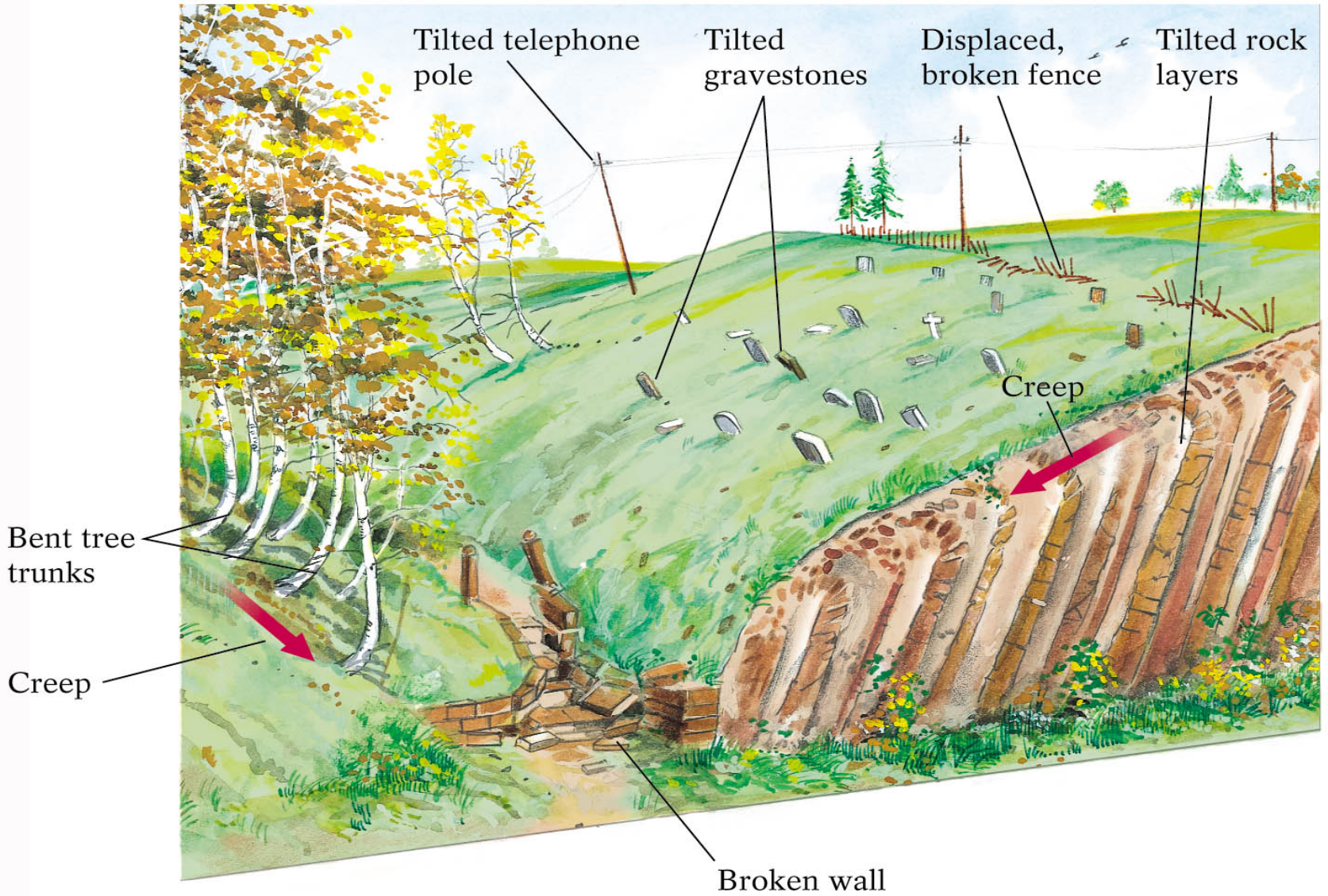


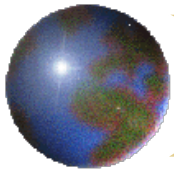
# *Frost-induced creep*





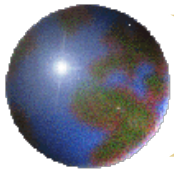
# Creep Effects



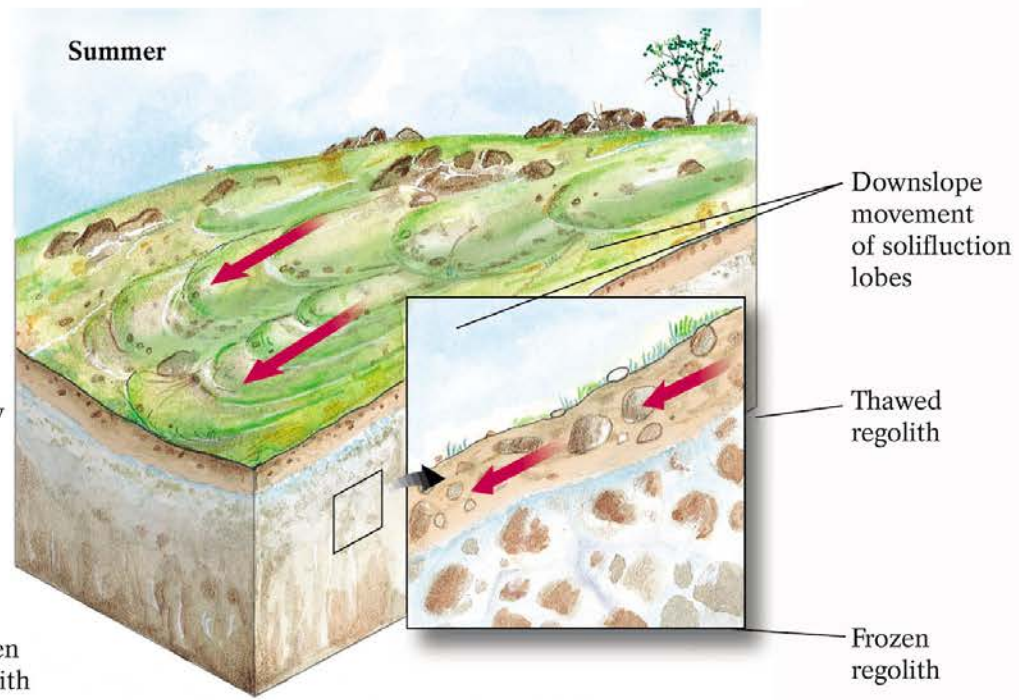
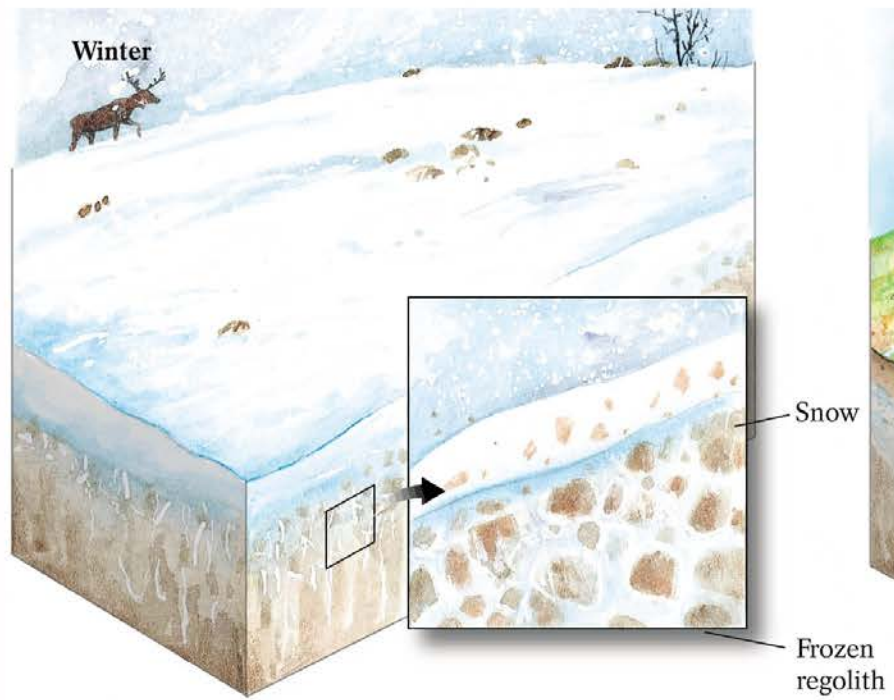


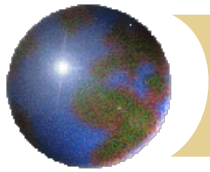
## *13.3 Types of Mass Movement*

- ✚ Solifluction: Special variety of creep, soil flow
  - ⊠ Comparatively fast form of creep
  - ⊠ Occurs in permafrost areas
  - ⊠ Indications of creep-tilted 'vertical' structures



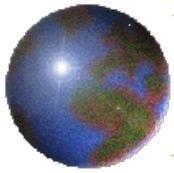
# Solifluction





# *Rapid Mass Movement*

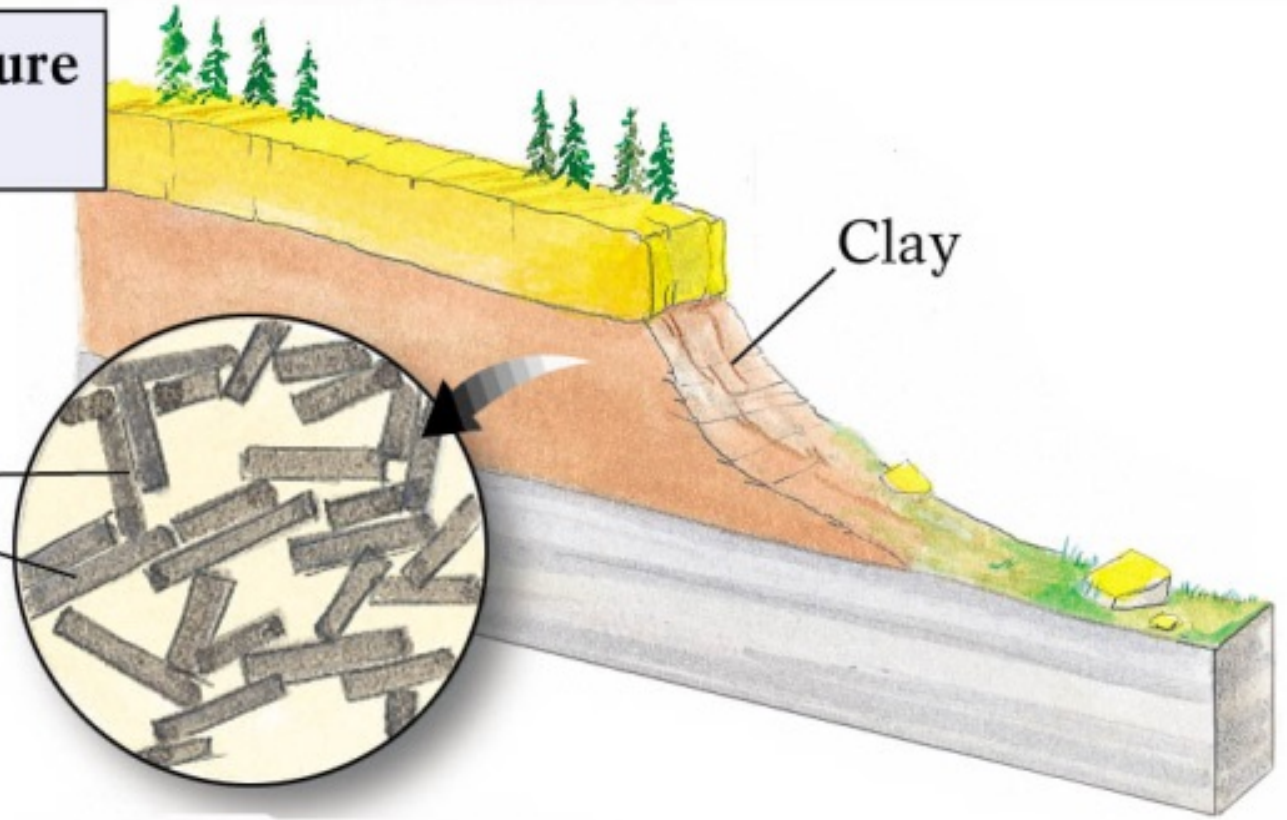
- \* Measured in km/hr or m/s; classified by types of motion; one type can evolve into another
- ✚ **Flows:** Material moves chaotically and in a disorganized fashion
  - ✚ Mixture of solid, unconsolidated particles that moves downslope like a viscous fluid
  - ✚ **Earthflows:** Relatively dry masses of clayey or silty regolith (~ meter/hour)
  - ✚ **Mudflows:** Swifter-flowing slurry of regolith mixed with water; likely to develop after heavy rainfalls
  - ✚ **Quick Clays:** Highly fluid mudflow
  - ✚ **Lahars:** Catastrophic mudflows (volcanic eruption: St. Helens)
  - ✚ **Debris Flows:** Triggered by the sudden introduction of large amounts of water; coarser than sand, often contain boulders
  - ✚ **Debris Avalanches:** Swiftest & Most dangerous mud flows

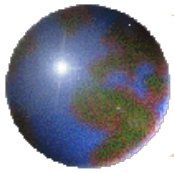


# *The development of quick-clay flows*

**1** Dry clay structure as deposited

Particles bound together by salt

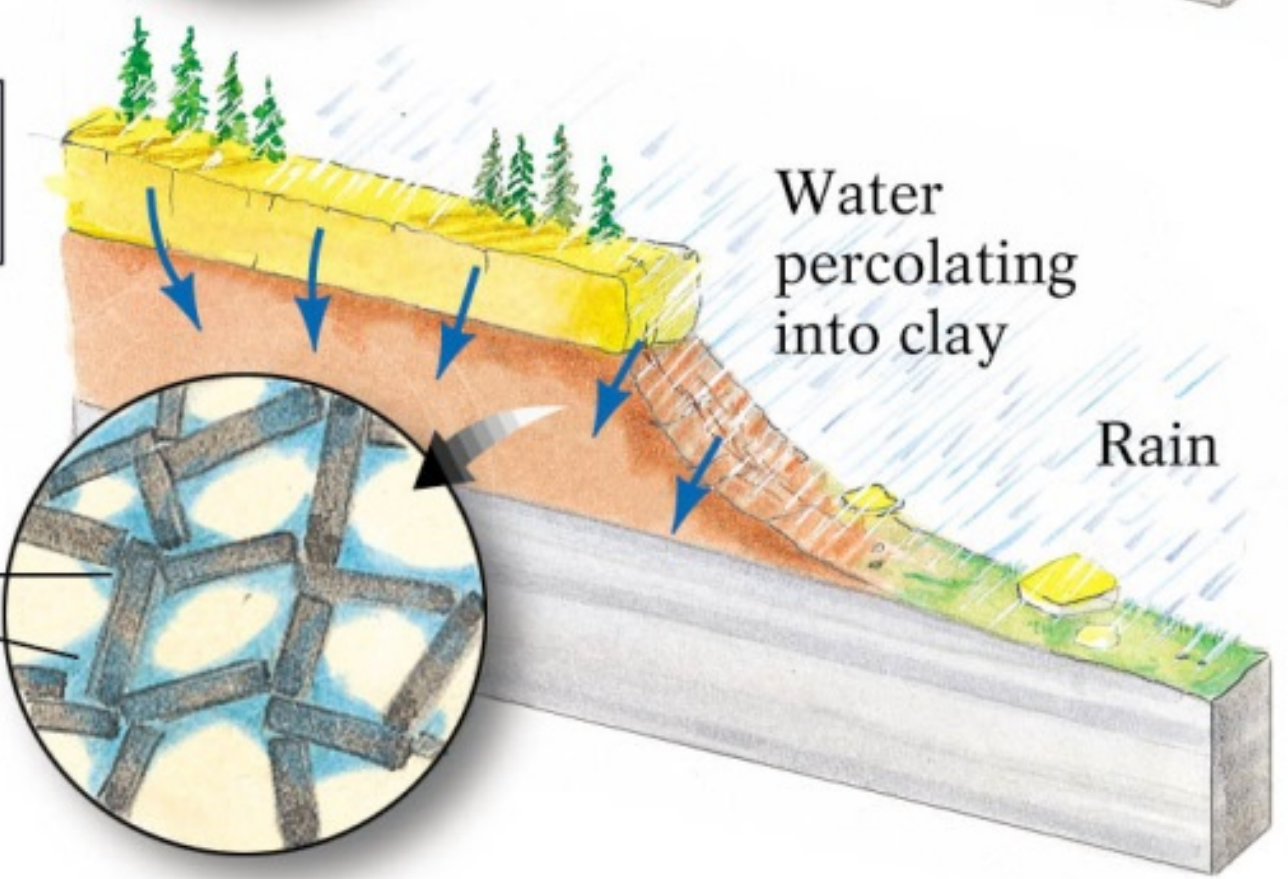




# *The development of quick-clay flows-contd.*

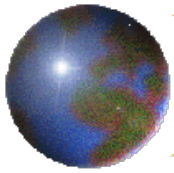
**2** Clay becoming saturated

Fresh water dissolves salt



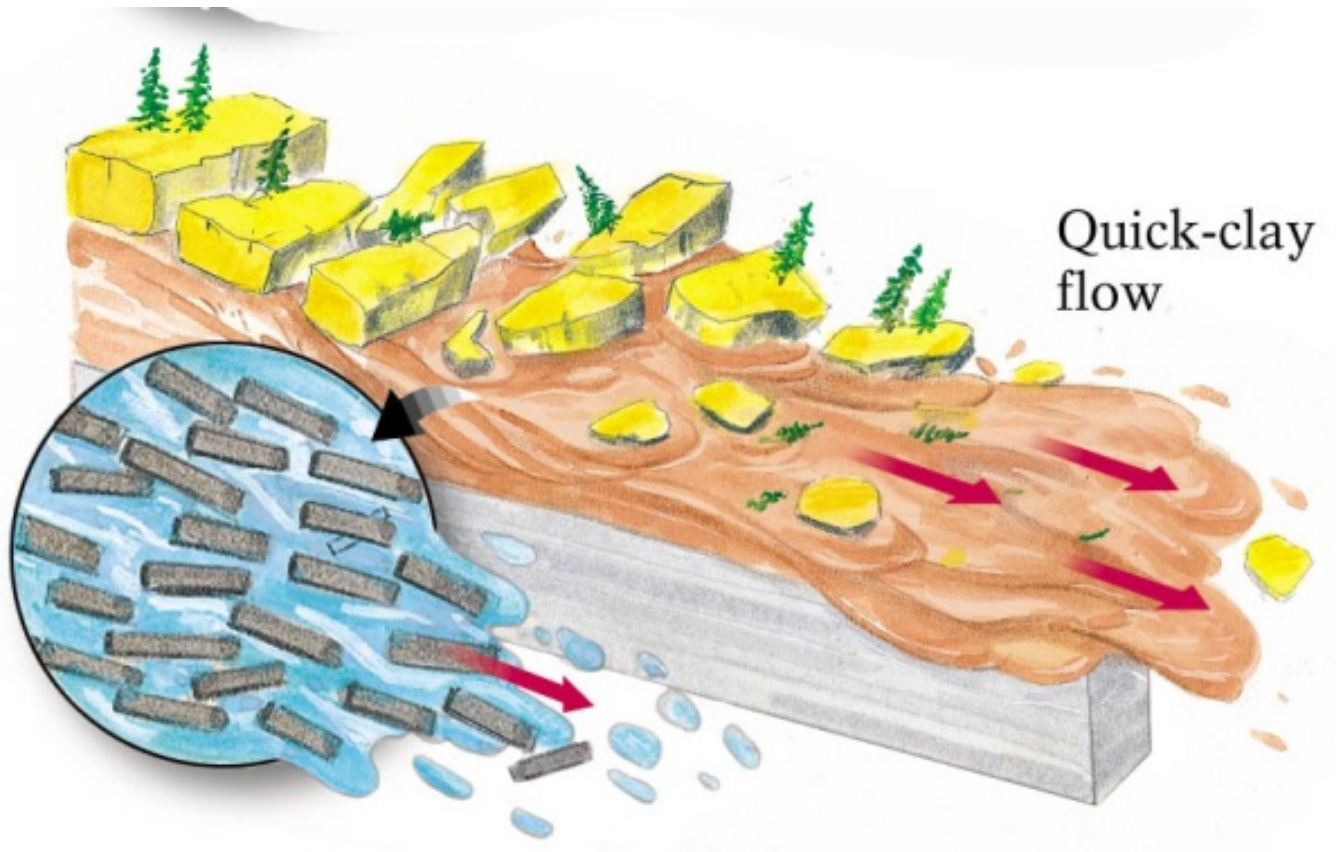
Water percolating into clay

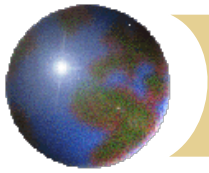
Rain



# *The development of quick-clay flows-contd.*

**3** Liquefied  
("quick") clay

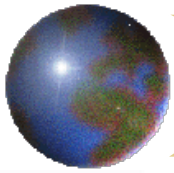




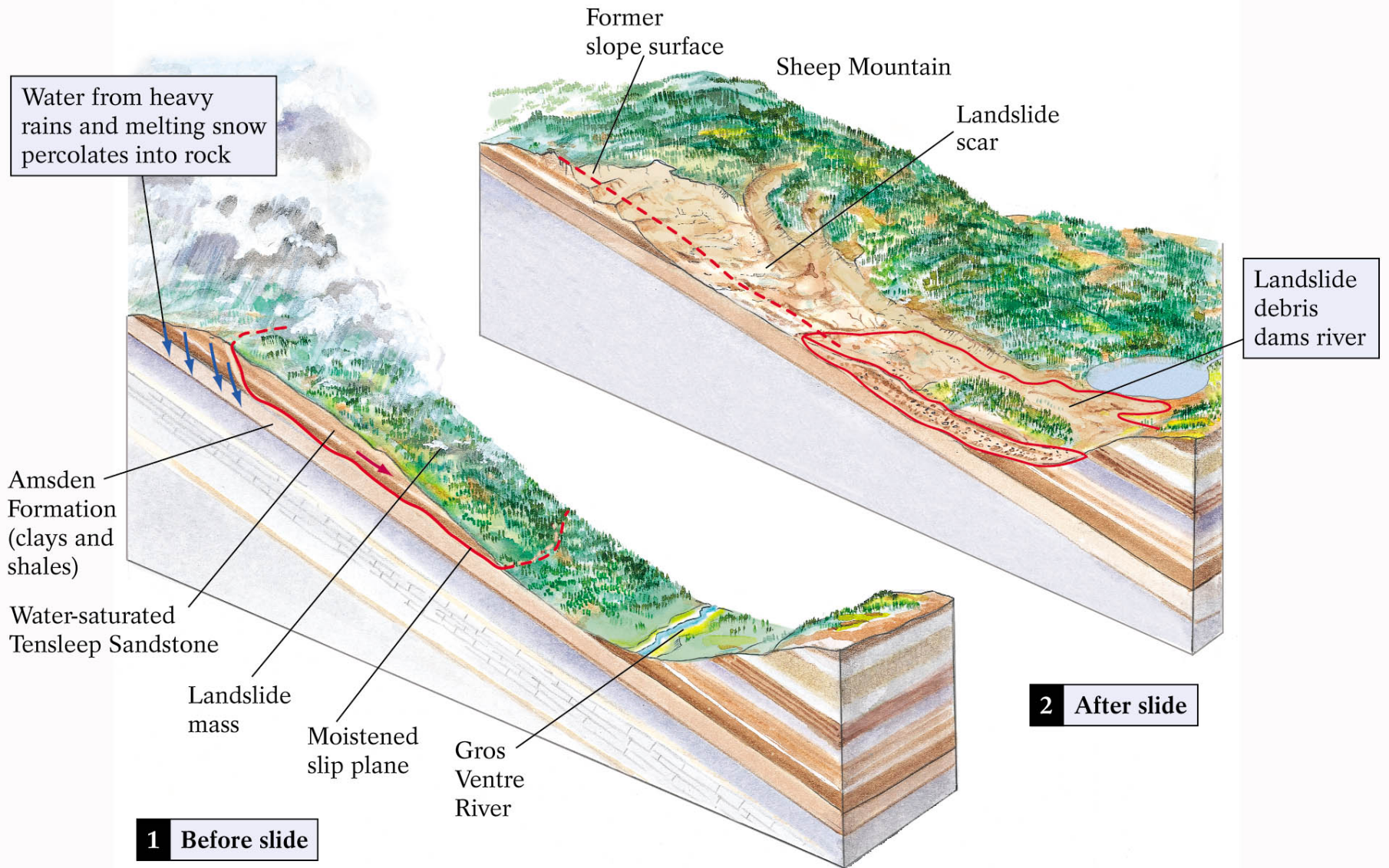
## *Rapid Mass Movement – contd.*

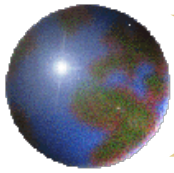
### ✦ Slides and Slumps:

- ✦ **Slides: Single intact mass of rock. Soil, or unconsolidated material moves along a preexisting plane of weakness**
  - Unconsolidated sediment: Between material types is slip plane
  - Solid Bedrock: within the rock, along planes of weakness
  - Sedimentary rock: Bedding planes
  - Plutonic igneous rocks: Large joint produced by exfoliation
  - Metamorphic rocks: Along foliation surfaces
- ✦ **Slumps: Slides with concave slip planes, material moves downslope accompanied by rotation– forms scarps (Steep, exposed cliff face that forms where the slump mass pulls away)**



# Sheep Mountain

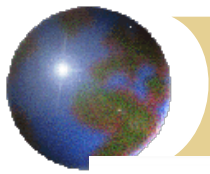




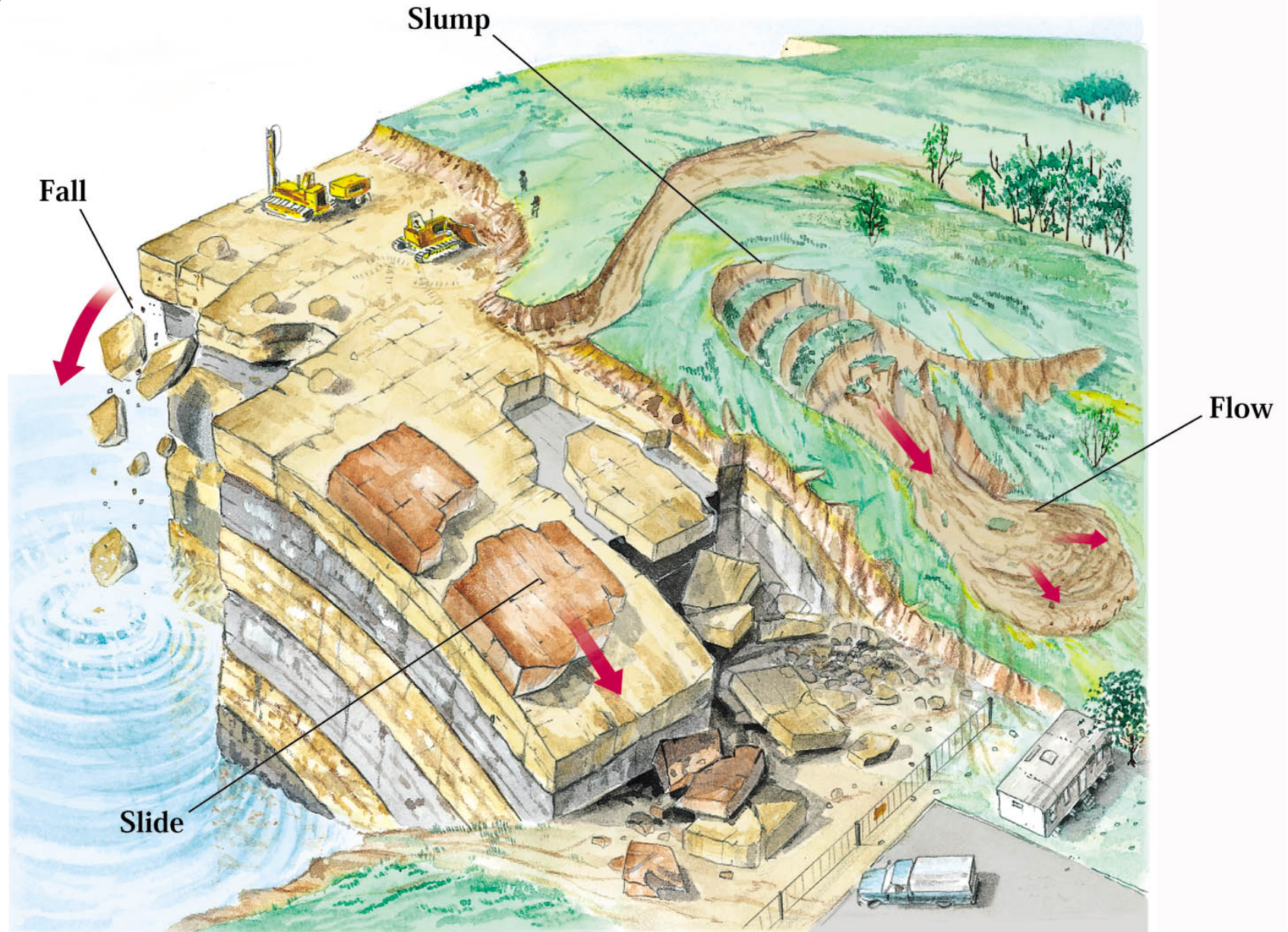
## *Rapid Mass Movement – contd.*

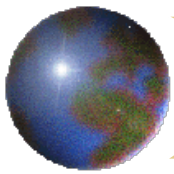
### ❏ Falls:

- Fastest type of rapid mass movement; rocks break free steep slope & plummet to the ground
- Material free falls upon failure or undercutting, motion is rapid
- Rockfalls are the most common form

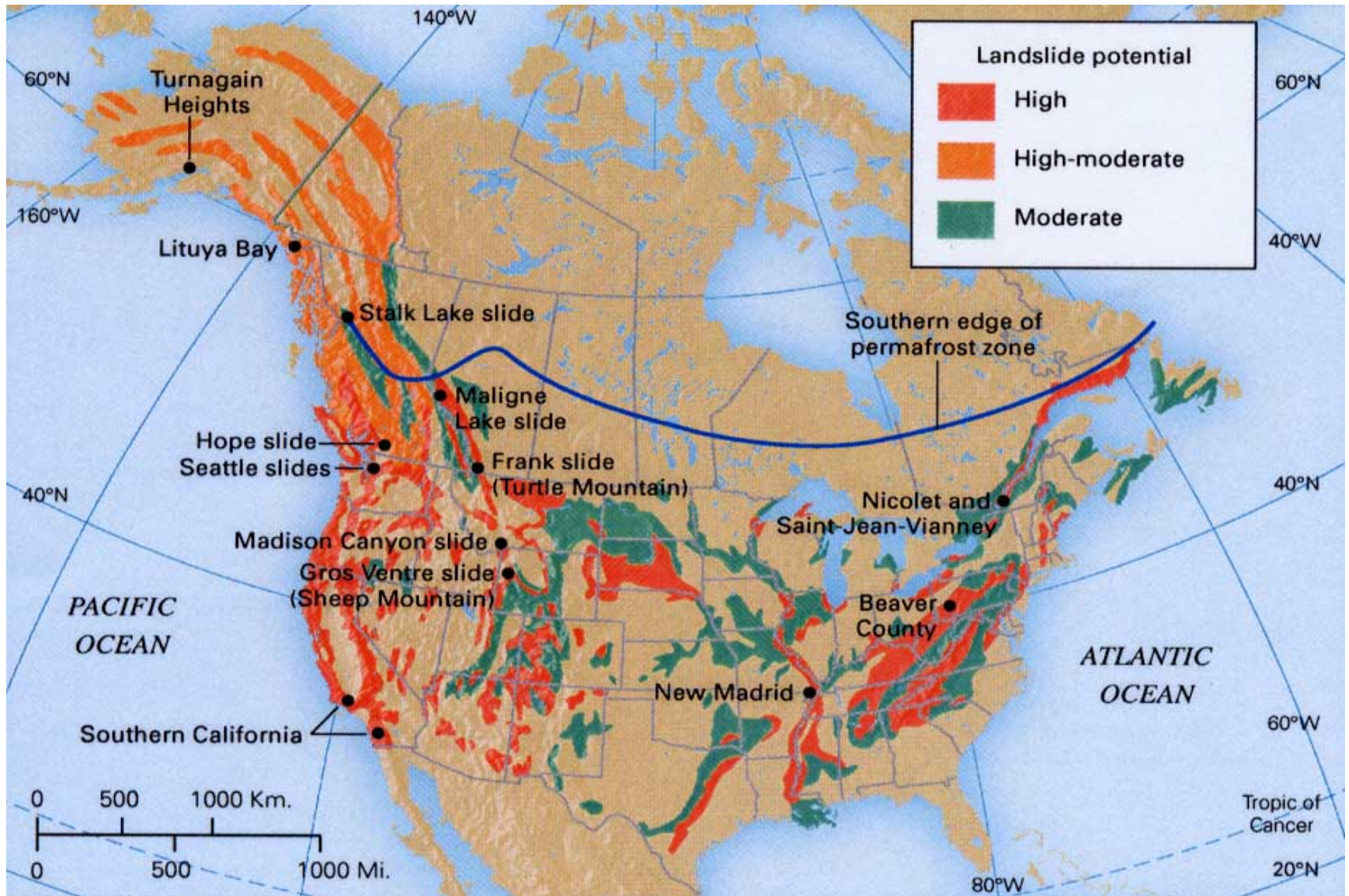


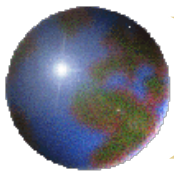
# *Rapid Mass Movement*



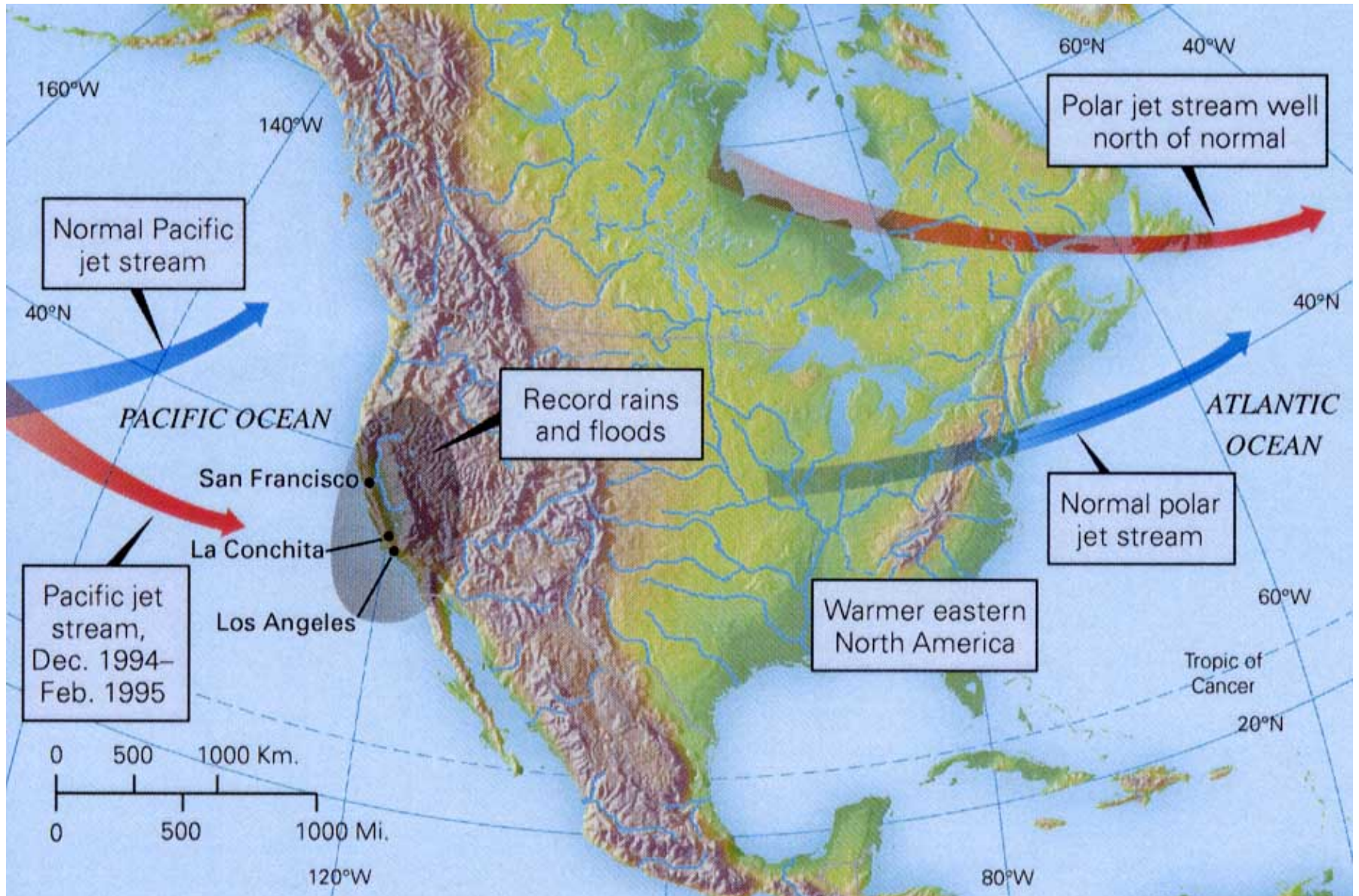


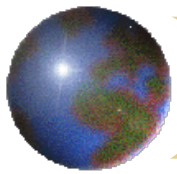
# Rapid Mass Movement map





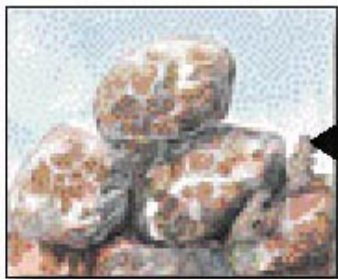
# Storm Tracks



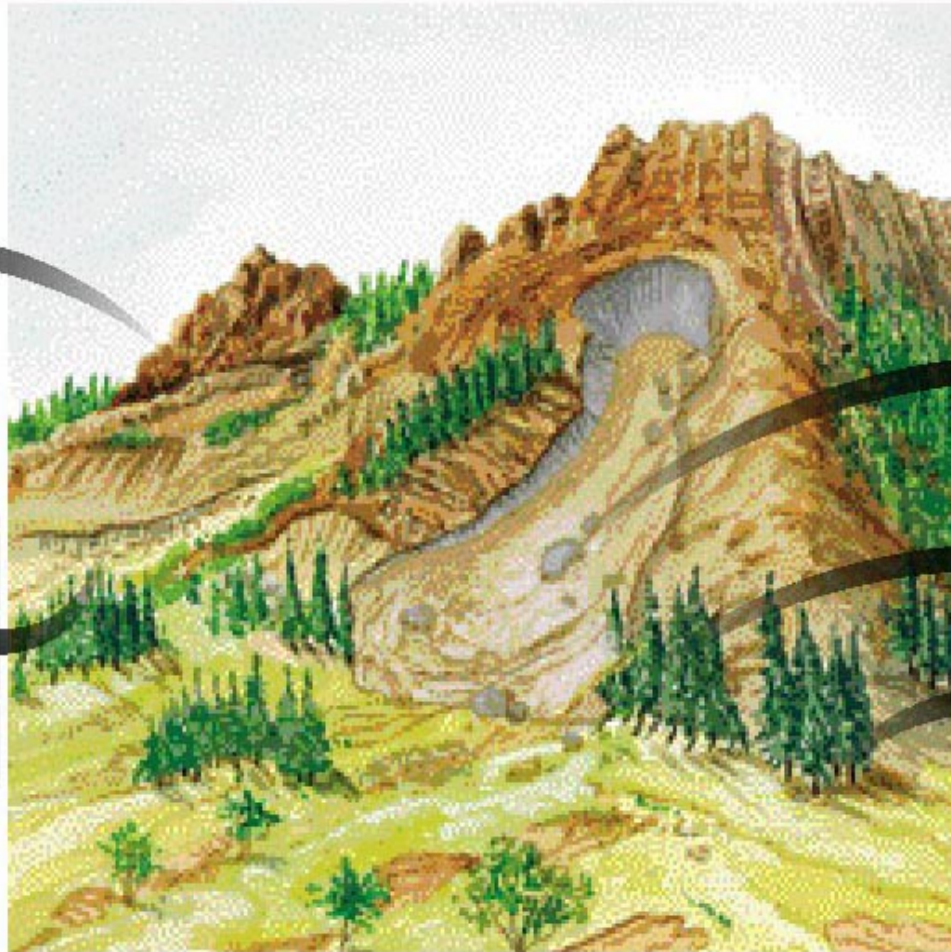


# Dating Mass Movement events

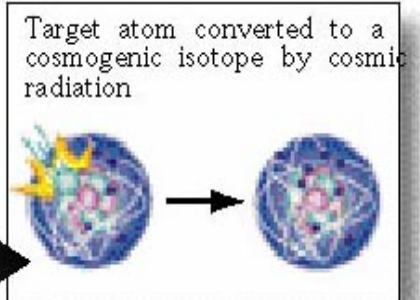
Lichenometry



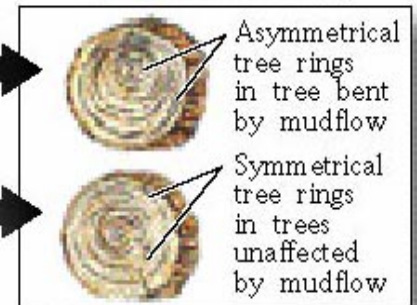
C-14 dating of organic material

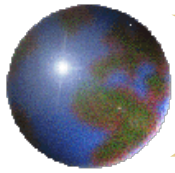


Surface-exposure dating



Dendrochronology





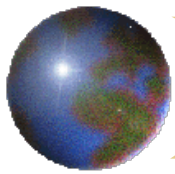
## *13.4 Avoiding/preventing Mass Movement*

### ✚ Avoiding

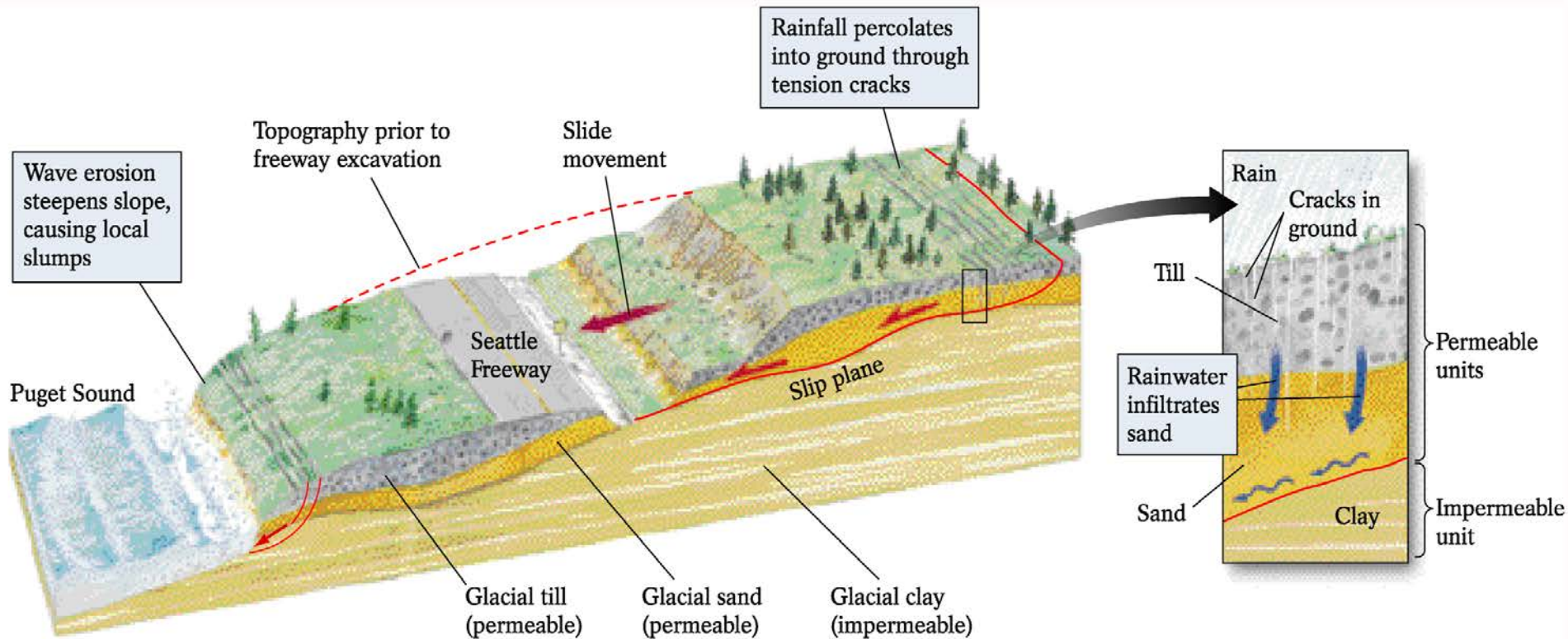
- ◆ Predicting mass movement
  - ◆ Terrain analysis (composition, layering, structure, water content and drainage), field visit, eye witness/recorded accounts
- ◆ Vegetation- over grazing, harvesting

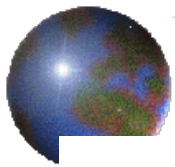
### ✚ Preventing

- ◆ Develop Prevention Plan
- ◆ Enhance Forces that Resist or Reduce forces of mass wasting
- ◆ Structural Approach- reduce slope (Modification: unloading, grading & removing material), Bolts and Pins
- ◆ Non-Structural Approach- tree, chemical stability



# Slide-prone geology



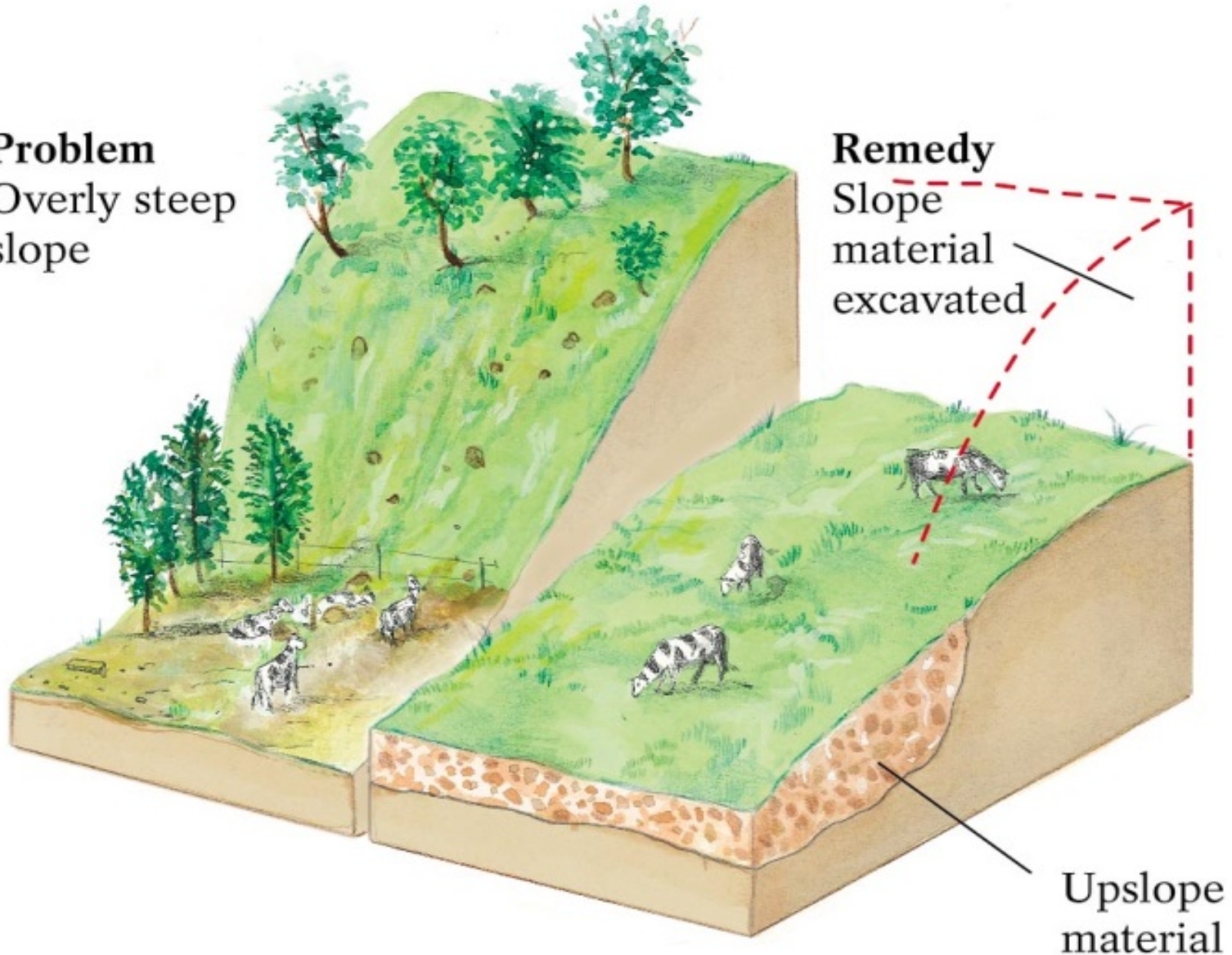


# Slide Prevention

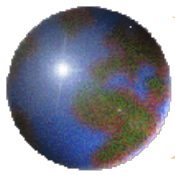
**Problem**  
Overly steep slope

**Remedy**

Slope material excavated

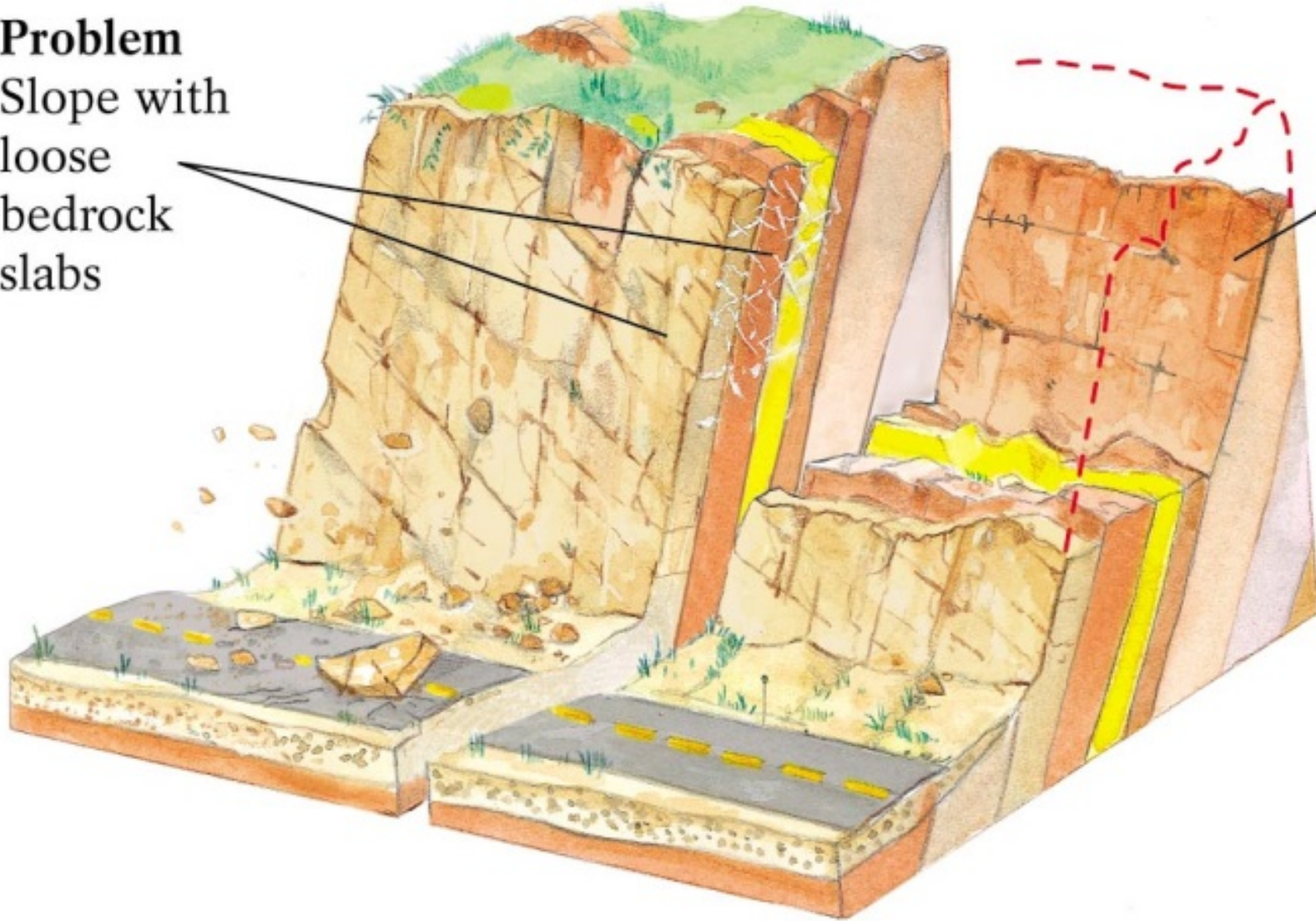


Upslope material

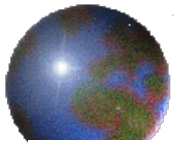


# *Slide Prevention – contd.*

**Problem**  
Slope with  
loose  
bedrock  
slabs

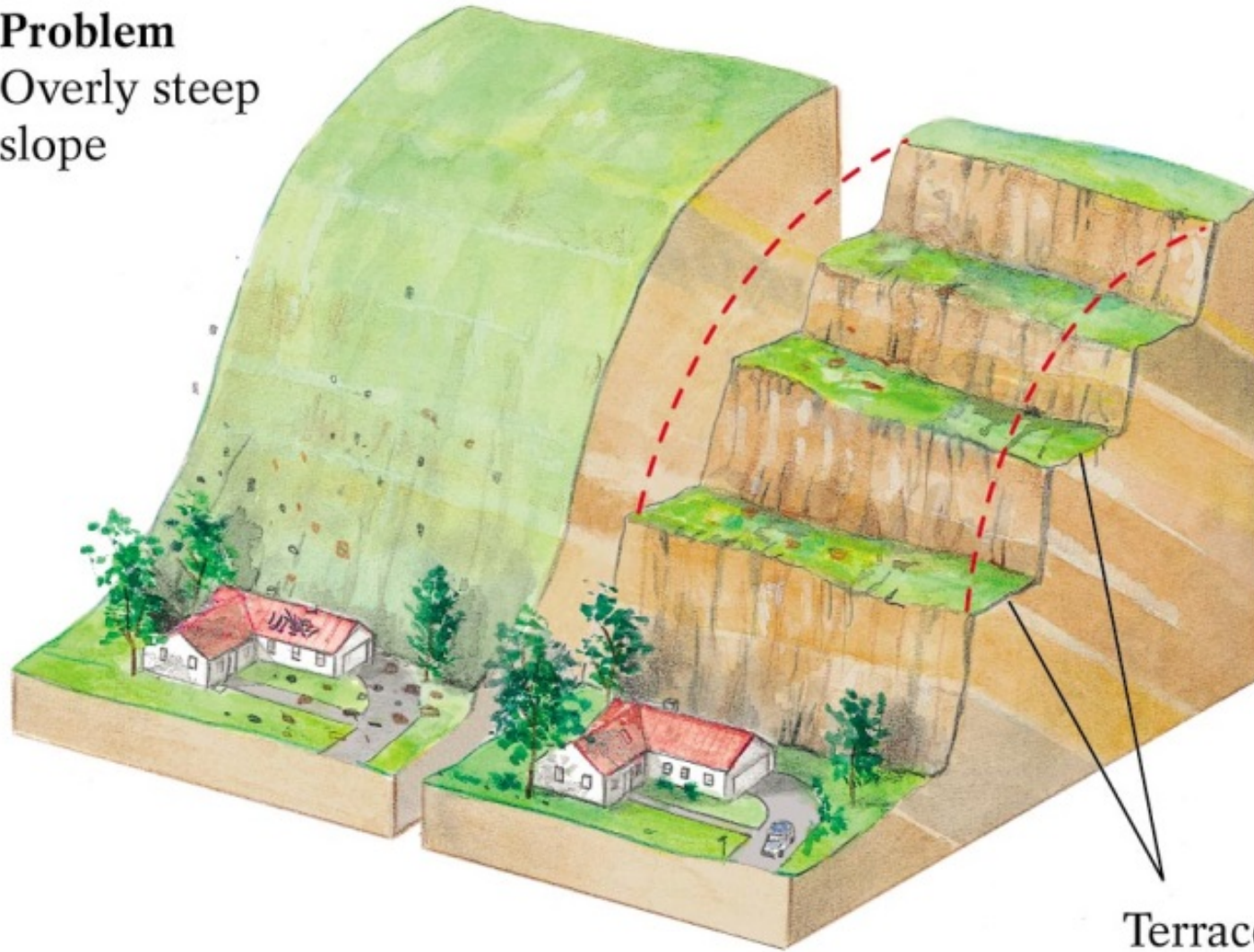


**Remedy**  
Loose  
bedrock  
slabs  
removed



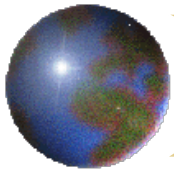
# Slide Prevention – contd.

**Problem**  
Overly steep  
slope

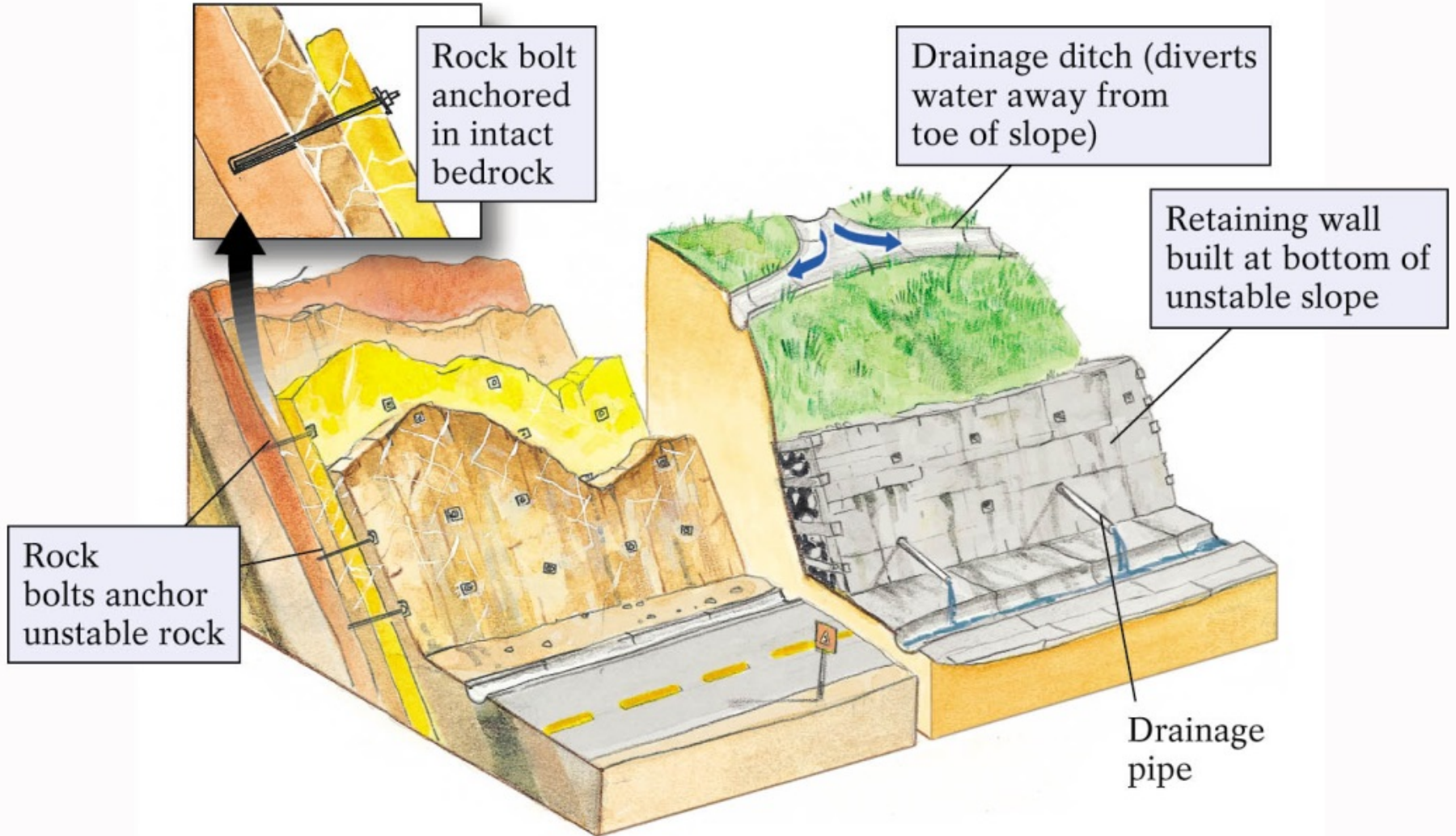


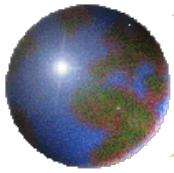
**Remedy**  
Stable slope  
with  
terraces

Terraces  
trap potential  
slide material



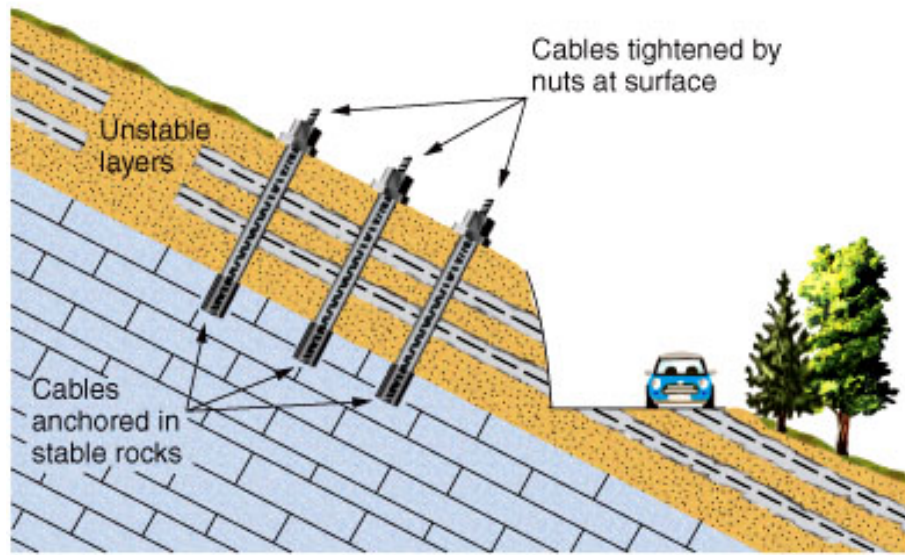
# *Structural supports to prevent slope failure*



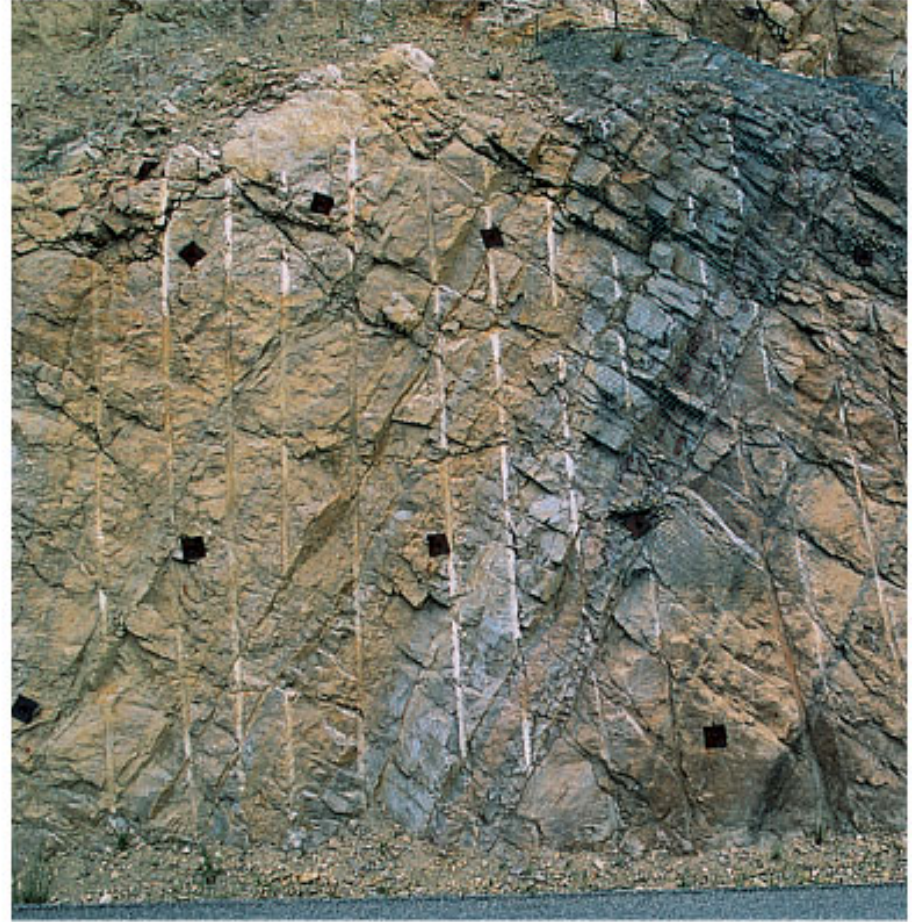


# *Structural supports to prevent slope failure*

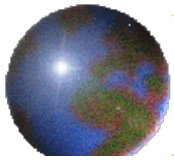
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A



B

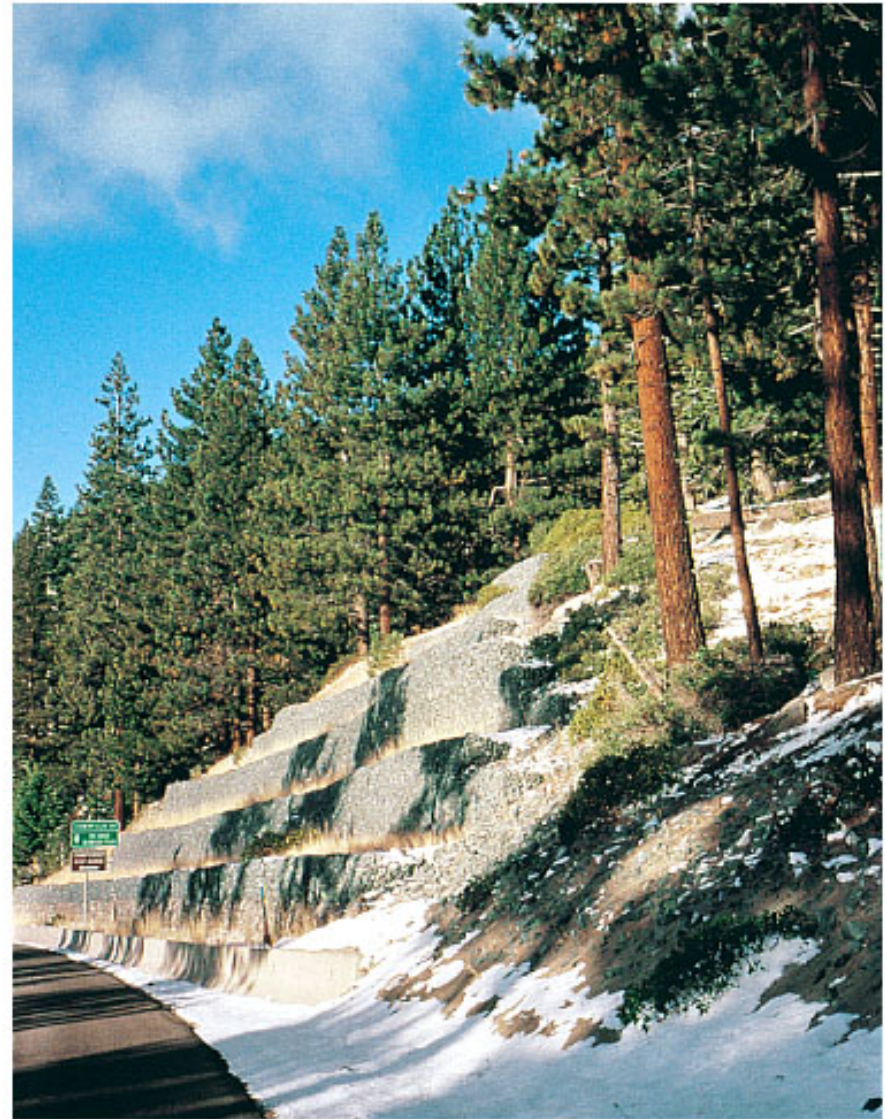


# *Structural supports to prevent slope failure*

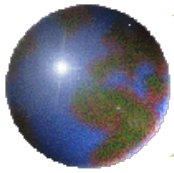
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A



B



## *13.5 Extraterrestrial Mass Movement*

- ✚ Mass movement on the Moon – by dry process
  - ▣ Triggered by Meteorites (which produces avalanches)

Mass movement on Mars:

Triggered by Meteorite impacts

Slides, slumps, and debris and mud flows reported