

GGY 2012

SURFACE PROCESS

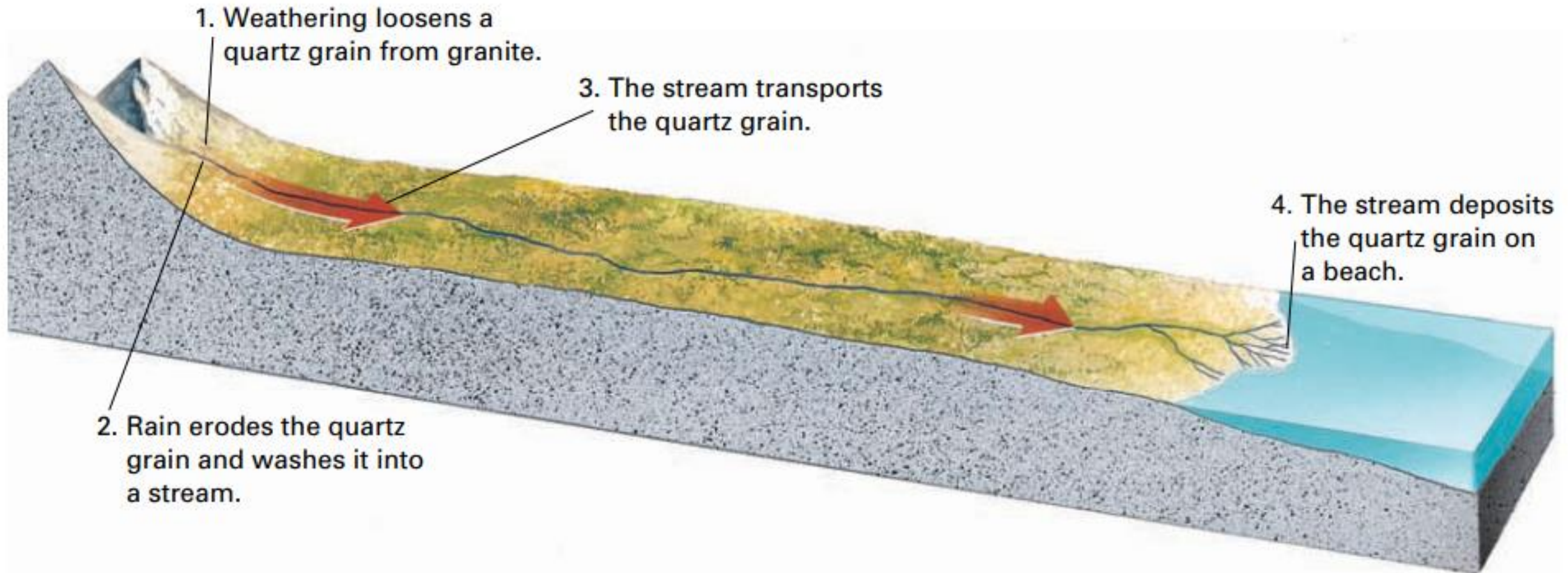
Dr. C. Phiri

WEATHERING, EROSION AND SOIL

- ✓ The processes that decompose rocks and convert them to loose gravel, sand, clay, and soil are called weathering
- ✓ Weathering involves little or no movement of the decomposed rocks and minerals. The weathered material simply accumulates where it forms
- ✓ Loose soil and other weathered material offer little resistance to rain or wind and are easily eroded. Thus erosion processes soon pick up and carry off weathered rocks and minerals
- ✓ Rain, running water, wind, glaciers, and gravity are the most common agents of erosion
- ✓ These agents (i.e., Rain, running water, wind, glacier and gravity) may then transport the weathered material great distances and finally deposit it as layers of sediment at Earth's surface

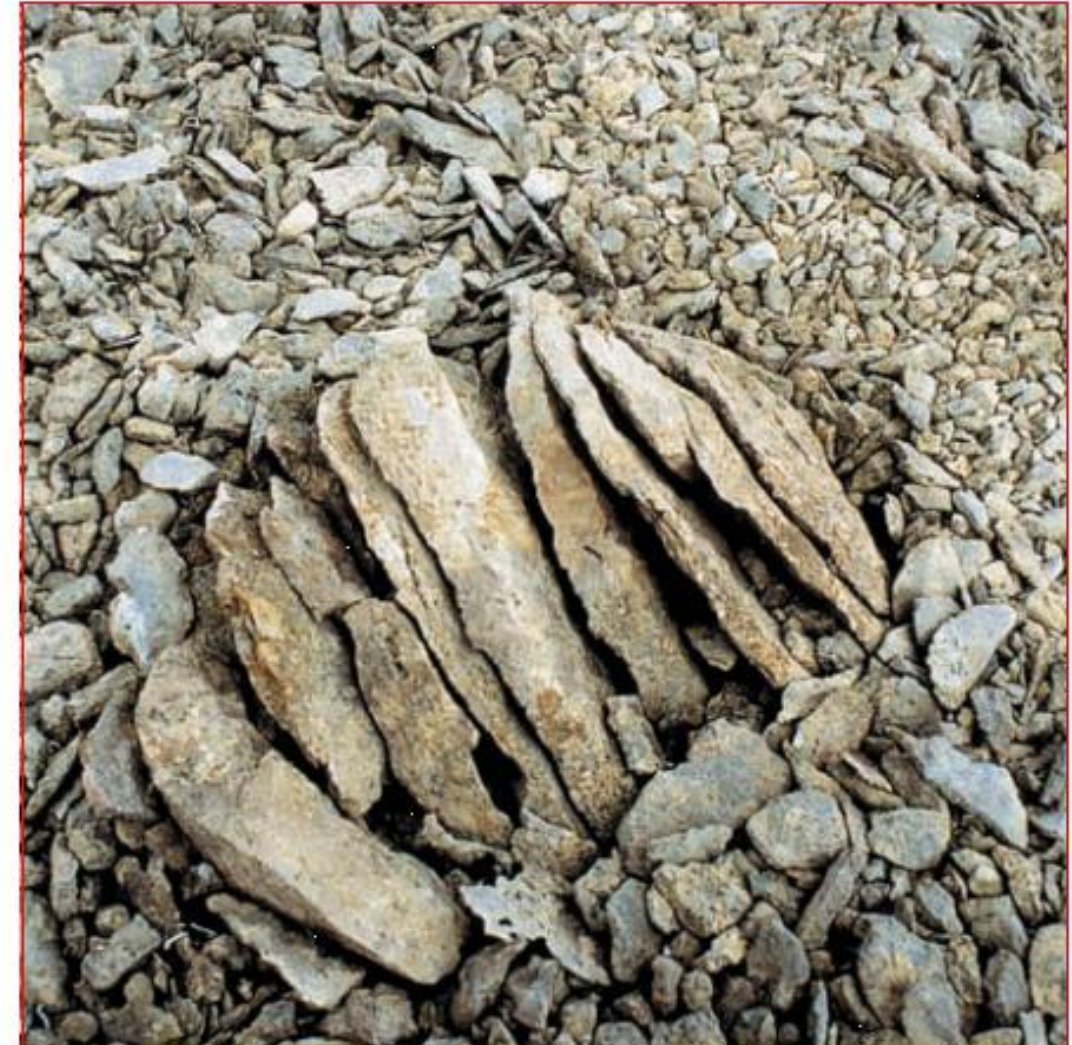
WEATHERING, EROSION AND SOIL

- ✓ Weathering, erosion, transport, and deposition typically occur in an orderly sequence. For example, water freezes in a crack in granite, weathering the rock and loosening a grain of quartz. A hard rain erodes the grain and washes it into a stream. The stream then transports the quartz to the seashore and deposits it as a grain of sand on a beach.



WEATHERING, EROSION AND SOIL

- ✓ Weathering occurs by both mechanical and chemical processes
- ✓ Mechanical weathering (also called physical weathering) reduces solid rock to small fragments but does not alter the chemical composition of rocks and minerals
- ✓ Chemical weathering occurs when air and water chemically react with rock to alter its composition and mineral content
- ✓ Chemical weathering is similar to rusting of a steel knife blade in that the final products differ both physically and chemically from the starting material



WEATHERING, EROSION AND SOIL

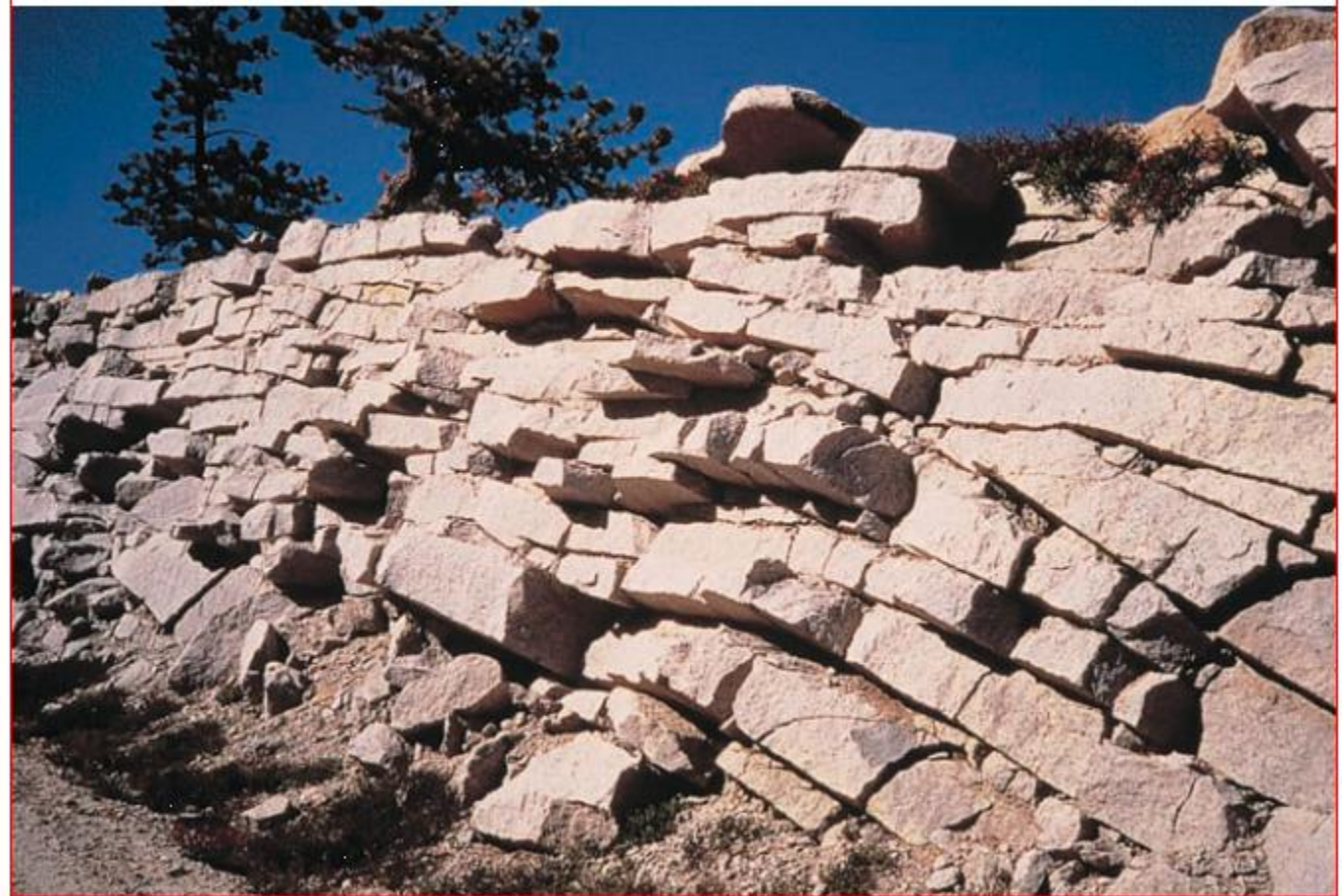
MECHANICAL WEATHERING

- Five processes cause mechanical weathering:
 - Pressure release fracturing
 - Frost wedging
 - Abrasion
 - Organic activity
 - Thermal expansion and contraction

WEATHERING, EROSION AND SOIL

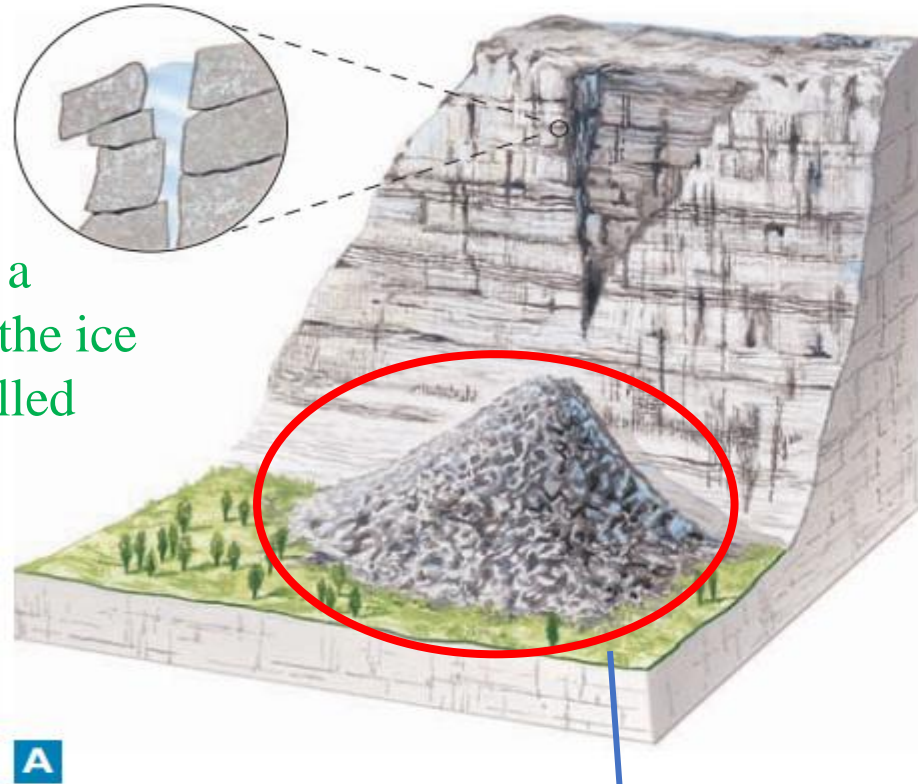
1. PRESSURE-RELEASE FRACTURING

- ✓ Many igneous and metamorphic rocks that formed at depth, but now lie at Earth's surface, have fractured in this manner



WEATHERING, EROSION AND SOIL

2. FROST WEDGING



A

Talus Cone



B

Courtesy of Graham R. Thompson/Jonathan Turk

- ✓ If water accumulates in a crack and then freezes, the ice expands in a process called frost wedging
- ✓ When the ice melts, rock fragments tumble from a steep cliff
- ✓ Large piles of loose angular rocks, called talus, lie beneath many cliffs

WEATHERING, EROSION AND SOIL

3. ABRASION

- ✓ Rocks, grains of sand, and silt collide with one another when currents or waves carry them along a stream or beach
- ✓ During these collisions, their sharp edges and corners wear away and the particles become rounded
- ✓ The mechanical wearing of rocks by friction and impact is called ABRASION
- ✓ Note that water itself is not abrasive—it is the collisions among rock, sand, and silt that round the rocks
- ✓ Wind hurls sand and other small particles against rocks, sandblasting cause unusual shapes due to **ABRASION**



Courtesy of Graham R. Thompson/Jonathan Turk



Courtesy of Graham R. Thompson/Jonathan Turk

WEATHERING, EROSION AND SOIL

4. ORGANIC ACTIVITY

- ✓ If soil collects in a crack in bedrock, a seed may fall there and sprout. The roots work their way into the crack, expand, and may eventually widen the crack
- ✓ City dwellers often see the results of this type of organic activity where tree roots raise and crack concrete sidewalks.



WEATHERING, EROSION AND SOIL

5. THERMAL EXPANSION AND CONTRACTION

- ✓ Rocks at Earth's surface are exposed to daily and yearly cycles of heating and cooling. They expand when they are heated and contract when they cool
- ✓ The forces generated by this thermal expansion and contraction may fracture the rock

WEATHERING, EROSION AND SOIL

CHEMICAL WEATHERING

The most important processes of chemical weathering are:

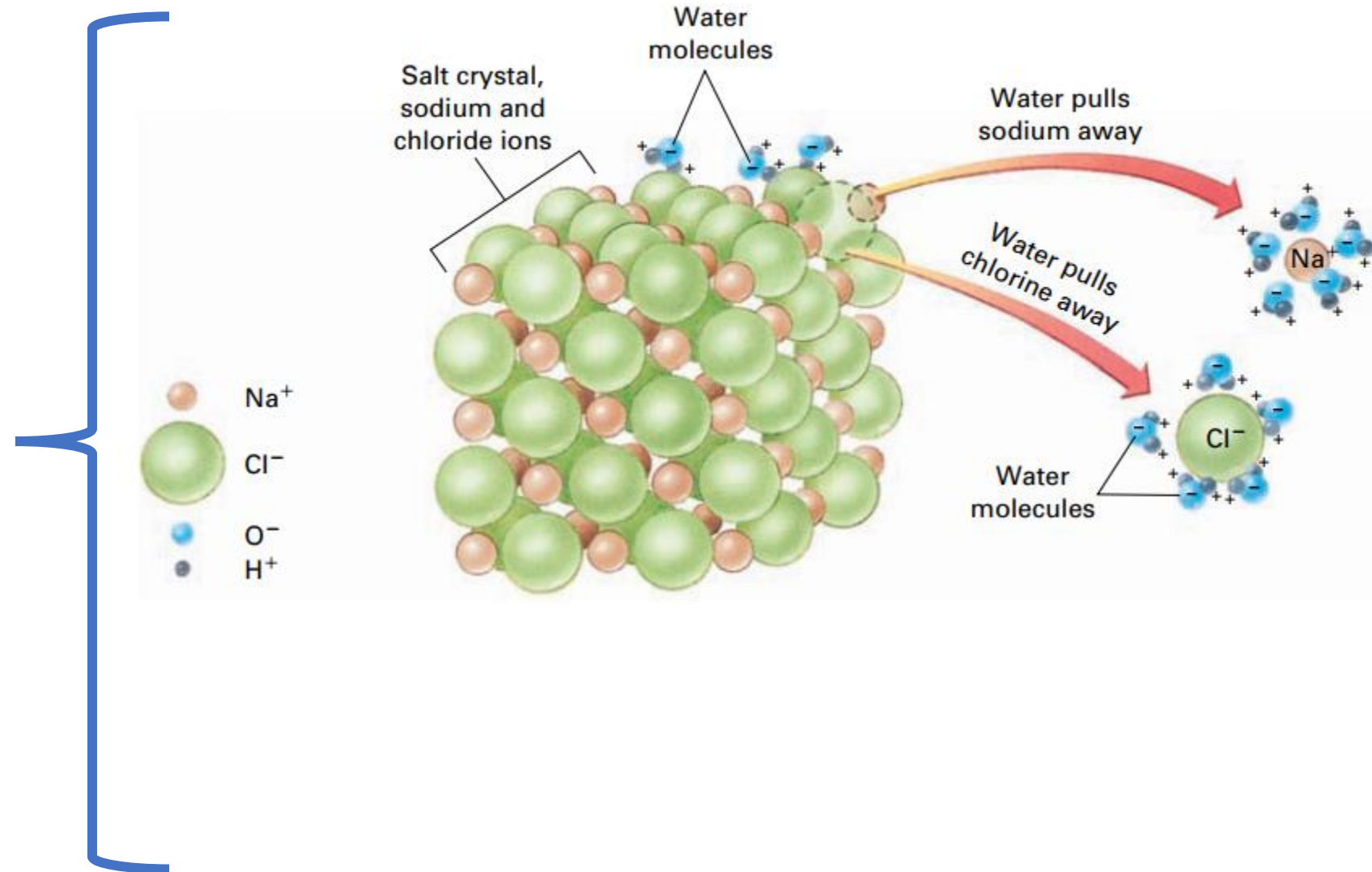
- Dissolution
- Hydrolysis
- Oxidation

WEATHERING, EROSION AND SOIL

❖ CHEMICAL WEATHERING

DISSOLUTION

✓ If you put a crystal of halite (rock salt, or table salt) in water, the crystals rapidly dissolve to form a solution. The process is called **DISSOLUTION**



WEATHERING, EROSION AND SOIL

❖ CHEMICAL WEATHERING

DISSOLUTION PROCESS

- ✓ Rocks and minerals dissolve more rapidly when water is acidic or basic
- ✓ An acidic solution contains a high concentration of hydrogen ions (H), whereas a basic solution contains a high concentration of hydroxyl ions (OH)
- ✓ For example, limestone is made of the mineral calcite (CaCO_3). Calcite barely dissolves in pure water but is quite soluble in acid. If you place a drop of strong acid on limestone, bubbles of carbon dioxide gas instantly form as the calcite dissolves



WEATHERING, EROSION AND SOIL

❖ CHEMICAL WEATHERING

HYDROLYSIS PROCESS

- ✓ In hydrolysis, water reacts with a mineral to form a new mineral with the water as part of its crystal structure. Most common minerals weather by *hydrolysis*
- ✓ When granite weathers, the feldspar and other minerals decompose to form clay but the unaltered quartz grains fall free from the rock



WEATHERING, EROSION AND SOIL

❖ CHEMICAL WEATHERING

OXIDATION PROCESS

- ✓ Many elements react with atmospheric oxygen. Iron rusts when it reacts with water and oxygen. Rusting is an example of a more general process called oxidation
- ✓ Iron is abundant in many minerals; if the iron in such a mineral oxidizes, the mineral decomposes
- ✓ When sulphide minerals oxidize during weathering, the sulfur reacts to form sulfuric acid, a strong acid

WEATHERING, EROSION AND SOIL

- ❖ **Bedrock** breaks into smaller fragments as it weathers, and much of it decomposes to clay and sand. Therefore, on most land surfaces, a thin layer of loose rock fragments, clay, and sand overlies bedrock. This material is called *RIGOLITH*
- ❖ Soil scientists define *soil* as upper layers of regolith that support plants.

Components of Soil

- ✓ *Soil* is a mixture of mineral grains, organic material, water, and gas. The mineral grains include clay, silt, sand, and rock fragments.
- ✓ *Clay* is so fine grained and closely packed that water, and even air, do not flow through a clay-rich soil readily, so plants growing in clay soils suffer from lack of oxygen
- ✓ In contrast to clay soil, *sandy soils* allows water and air flow easily. The most fertile soil is *loam*, a mixture of sand, clay, silt, and generous amounts of organic matter

WEATHERING, EROSION AND SOIL

- ❖ Minerals and organic matter in soils contain nutrients necessary for plant growth

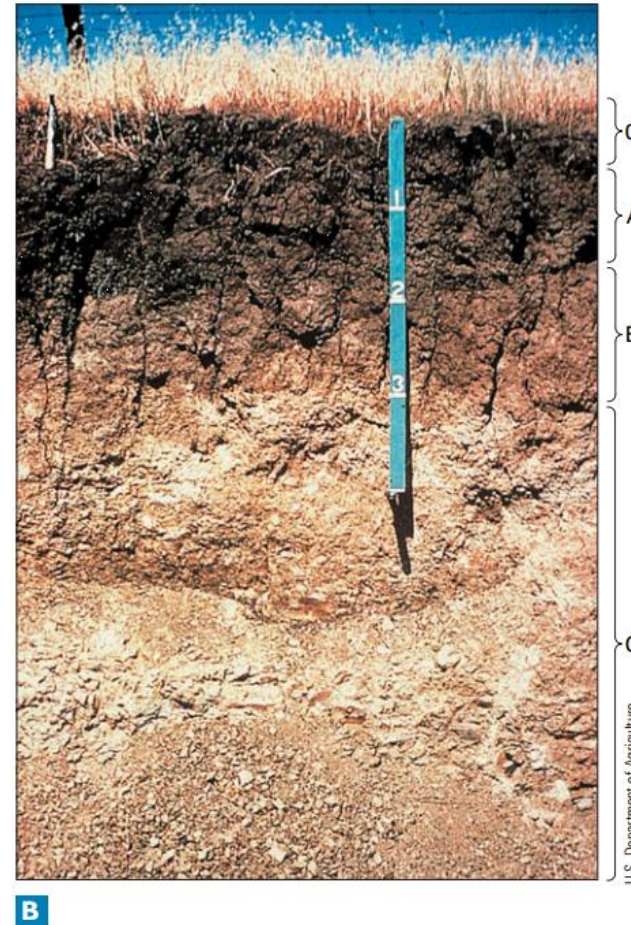
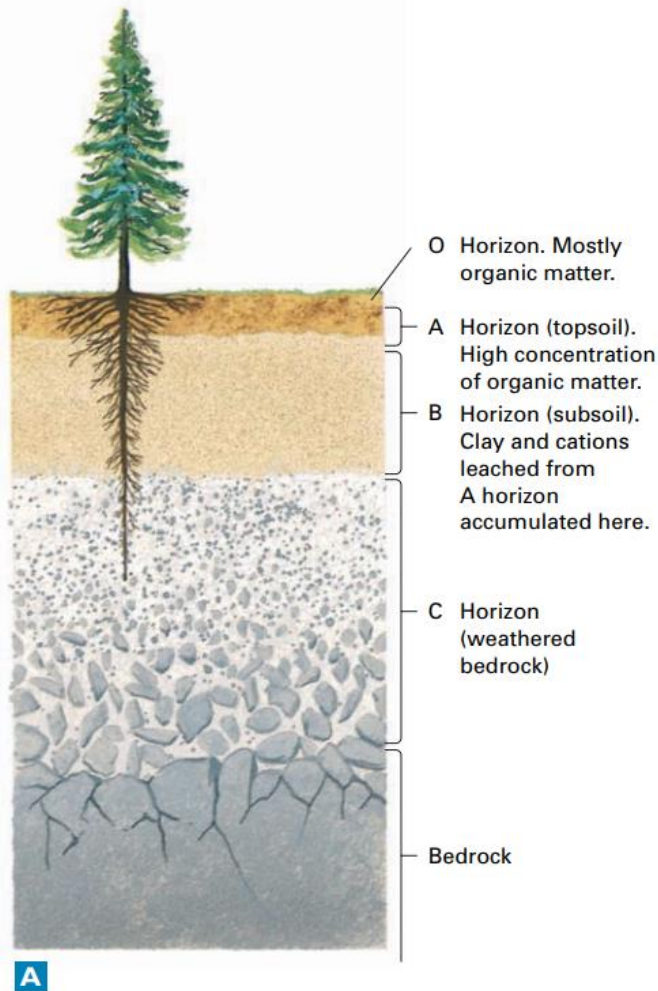
Table 10.1 Nutrients Essential for Plant Growth

Macronutrients from air and water		Micronutrients from soil
Carbon } Oxygen } Hydrogen }	The basic building blocks of all organic tissue	Iron Copper Manganese Boron Zinc Chlorine Molybdenum
Macronutrients from soil		
Nitrogen	Most critical element for growth of plant proteins	
Phosphorus	Important for metabolism and development of cell membranes	
Potassium	Maintains plant cell permeability	
Calcium	Important for plant cell walls	
Magnesium	Important for production of chlorophyll	
Sulfur	Required for synthesis of plant vitamins and proteins	

WEATHERING, EROSION AND SOIL

❖ Soil Horizons

✓ A typical well-developed soil consists of several layers called soil horizons



- **O horizon** is the uppermost layer named for its organic component. This layer consists mostly of litter and humus, with a small proportion of minerals
 - **A horizon**, is a mixture of humus, sand, silt, and clay
- NOTE:** The combined O and A horizons are called topsoil
- **B horizon** or subsoil, is a transitional zone between topsoil and weathered parent rock below
 - **C horizon**, consists of partially weathered rock that grades into unweathered parent rock (Bedrock). This zone contains little organic matter

WEATHERING, EROSION AND SOIL

- When rain falls on soil, it sinks into the O and A horizons, with weathering minerals, forming clay, and carrying dissolved ions to lower levels. This downward movement of water and dissolved ions is called leaching
- The A horizon is sandy because water also carries the clay downward but leaves the sand behind
- Water, dissolved ions, and clay from the A horizon accumulate in the B horizon

WEATHERING, EROSION AND SOIL

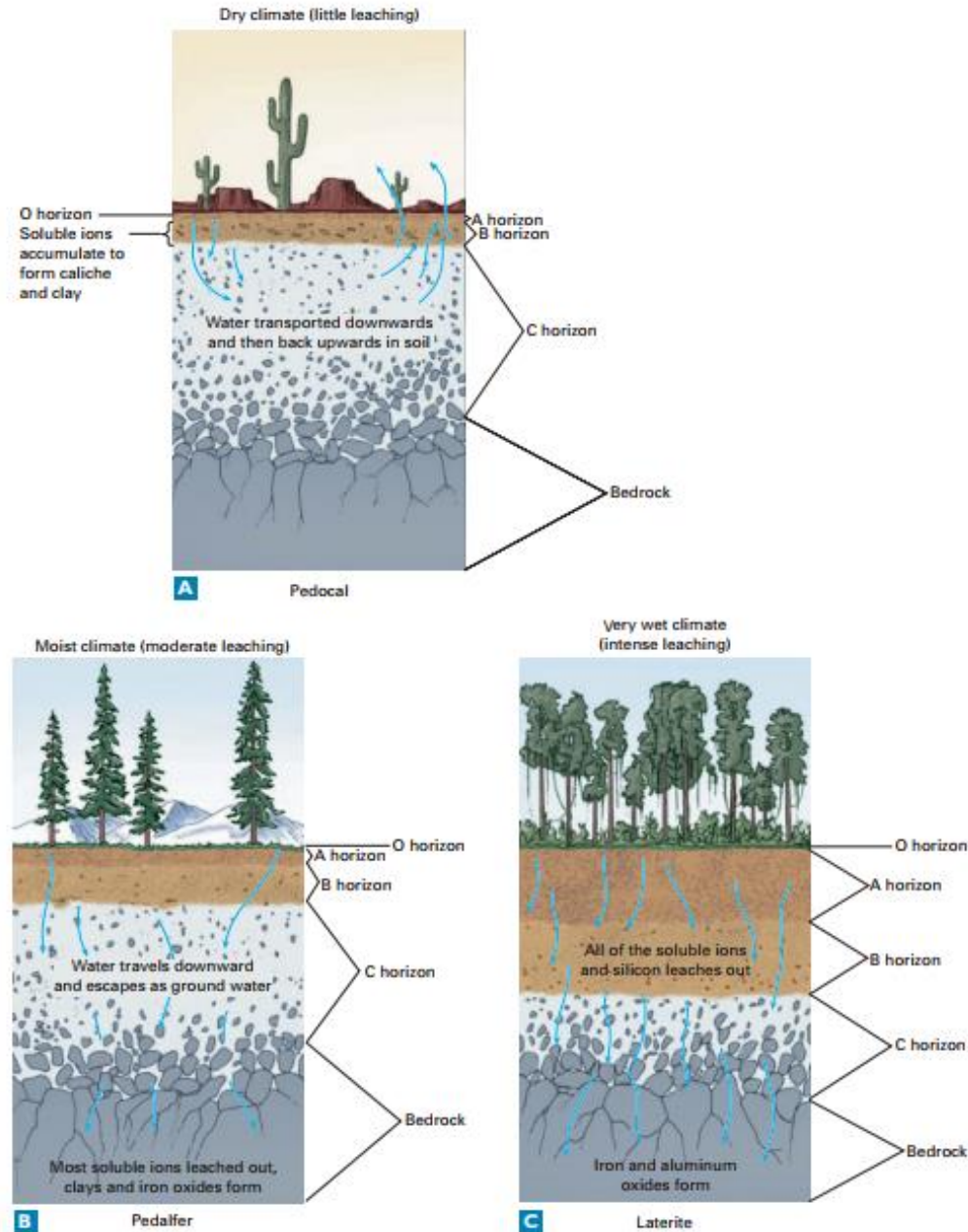
❖ *Factors that forms Soil*

1. Parent Rock: The texture and composition of soil depend partly on its parent rock. For example, when granite decomposes, the feldspar converts to clay and the rock releases quartz as sand grains. If the clay leaches into the **B horizon**, a sandy soil forms. **In contrast, because basalt contains no/little quartz, soil formed from basalt is likely to be rich in clay and contain only small amounts of sand**

2. Climate: Rainfall and temperature affect soil formation. Rain seeps downward through soil, but several other factors pull the water back upward. Roots suck soil water toward the surface, and water near the surface evaporates. The upward movement of water toward the soil is called **capillary action**

WEATHERING, EROSION AND SOIL

Effects of Climate



WEATHERING, EROSION AND SOIL

3. Time: Chemical weathering occurs slowly in most environments, and time is therefore an important factor in determining the extent of weathering.

4. Soil Transport: most of the soil was transported from elsewhere. Streams deposit sediment, wind deposits dust, and soil slides downslope from mountain-sides into valleys. These foreign materials mix with locally formed soil, changing its composition and texture

LANDSLIDES

- ❖ The word landslide is a general term for mass wasting and for the landforms created by mass wasting
- ❖ Mass wasting is the downslope movement of earth material, primarily caused by gravity
- ❖ Mass wasting occurs naturally in all hilly or mountainous terrain with steep slopes becoming especially vulnerable, and landslide scars common in the mountains
- ❖ Every year, small landslides destroy homes and farmland. Occasionally, an enormous landslide buries a town or city, killing thousands of people

LANDSLIDES

❖ Consider four examples of recent landslides that have affected humans:

A. A movie star builds a mansion on the edge of a picturesque California cliff. After a few years, the cliff collapses and the house slides into the valley



J. T. Gill, USGS

A

B. A ditch carrying irrigation water across a hillside in Montana leaks water into the ground



Courtesy of Graham R. Thompson/Jonathan Turk

B

C. Excavations for roads and high-rise buildings undercut the base of a steep hillside in Hong Kong. Suddenly, the slope slides, destroying everything in its path



Hong Kong Government Information Services

C

D. On January 10, 2005, a landslide destroys 36 houses and kills 10 people in the community of Southern California coast



© AP/Wide World Photos

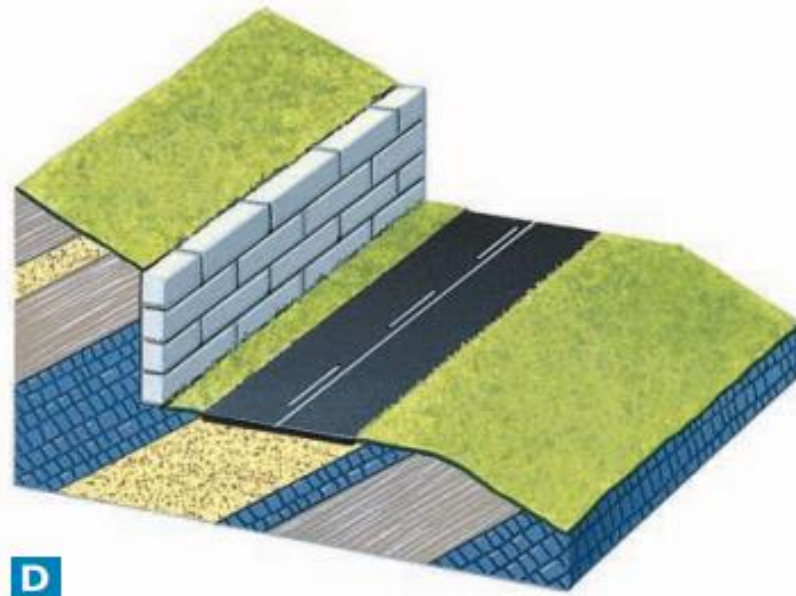
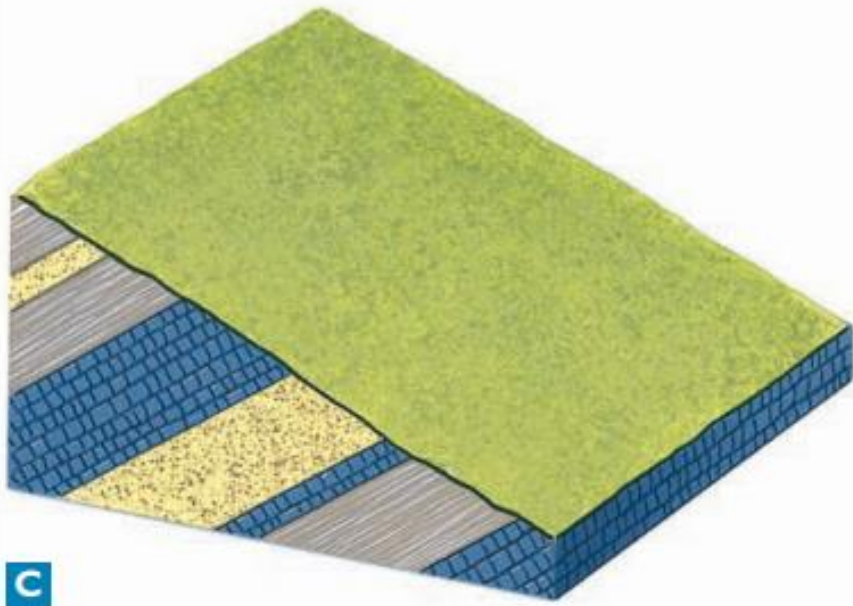
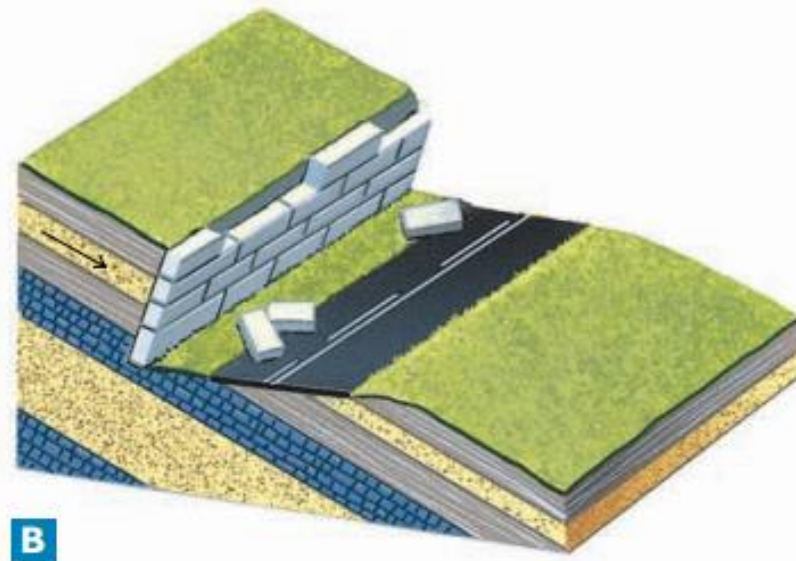
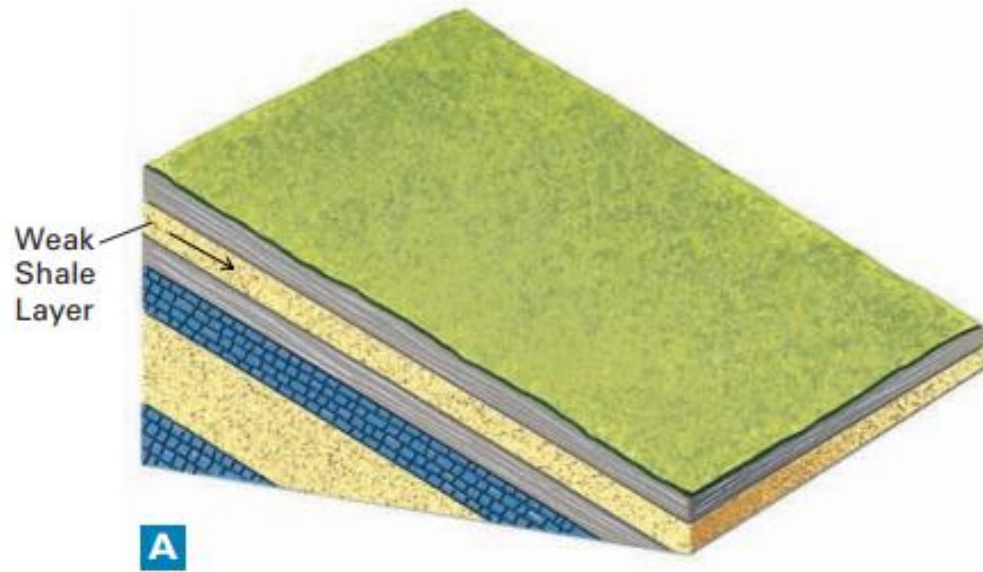
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LANDSLIDES

❖ Why Do Landslides Occur?

- ✓ **Steepness of the Slope**: Obviously, the steepness of a slope is a factor in mass wasting. If frost wedging dislodges a rock from a steep cliff, the rock tumbles to the valley below
- ✓ **Type of Rock and Orientation of Rock Layers**: If sedimentary rock layers dip in the same direction as a slope, the upper layers may slide over a layer of weak rock
- ✓ **The Nature of Unconsolidated Materials**: The angle of repose is the maximum slope or steepness at which loose material remains stable. If the slope becomes steeper than the angle of repose, the material slides. The angle of repose varies for different types of material
- ✓ **Water and Vegetation**: excess water lubricates the sand and adds weight to a slope. When some soils become water saturated, they flow downslope, just as the sand castle collapses
- ✓ **Earthquakes and Volcanoes**: An earthquake may cause a landslide by shaking an unstable slope, causing it to move

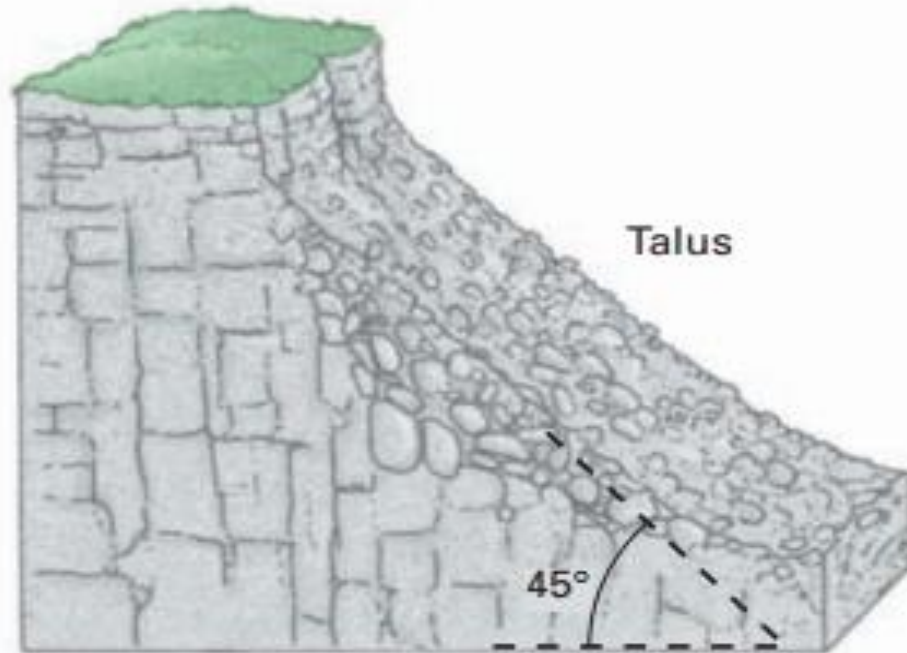
LANDSLIDES



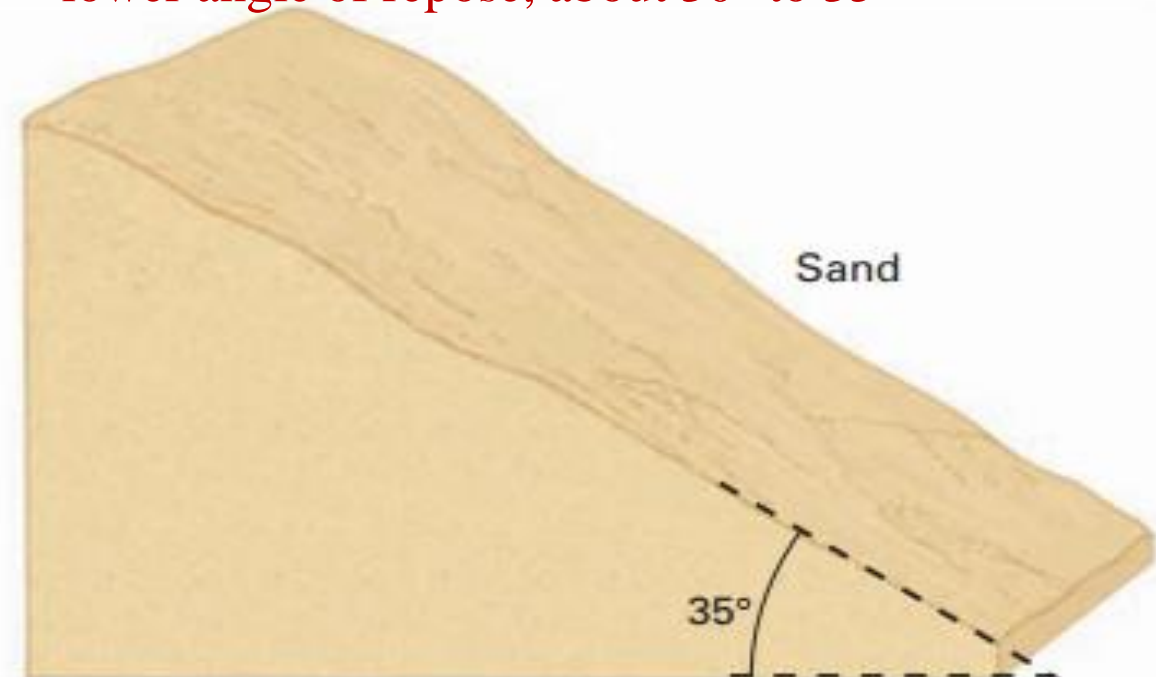
LANDSLIDES

❖ ANGLE OF REPOSE

- Talus typically has a steep angle of repose, up to 45°



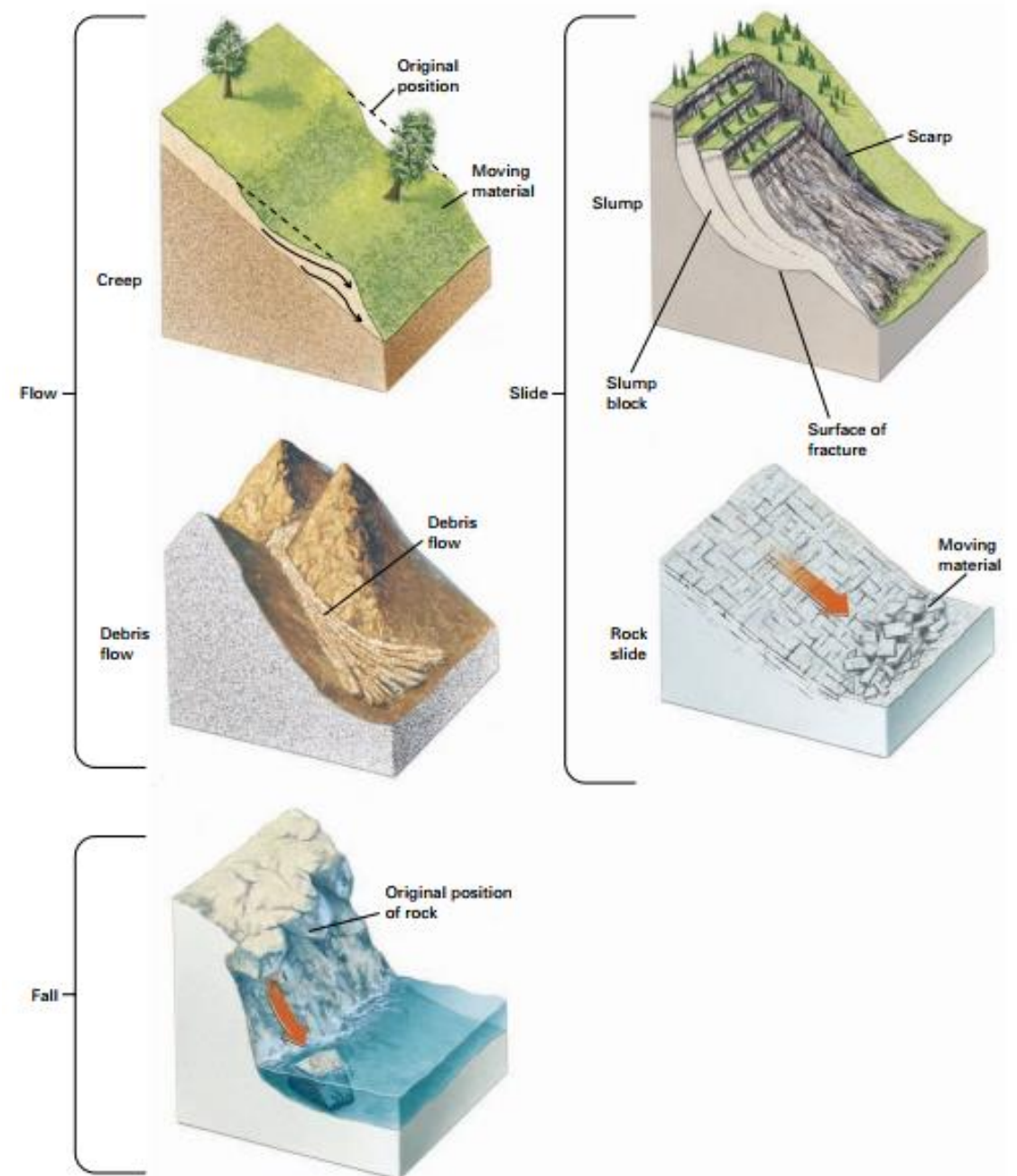
- Sand grains do not interlock and therefore have a lower angle of repose, about 30° to 35°



LANDSLIDES

❖ TYPES OF LANDSLIDES

- ✓ Landslides fall into three categories: flow, slide, and fall
- During flow, loose, unconsolidated soil or sediment moves as a fluid
- Movement of a coherent block of material along a fracture is called slide. Slide is usually faster than flow
- Rapid, free-falling motion is called fall. Fall is the most rapid type of mass wasting



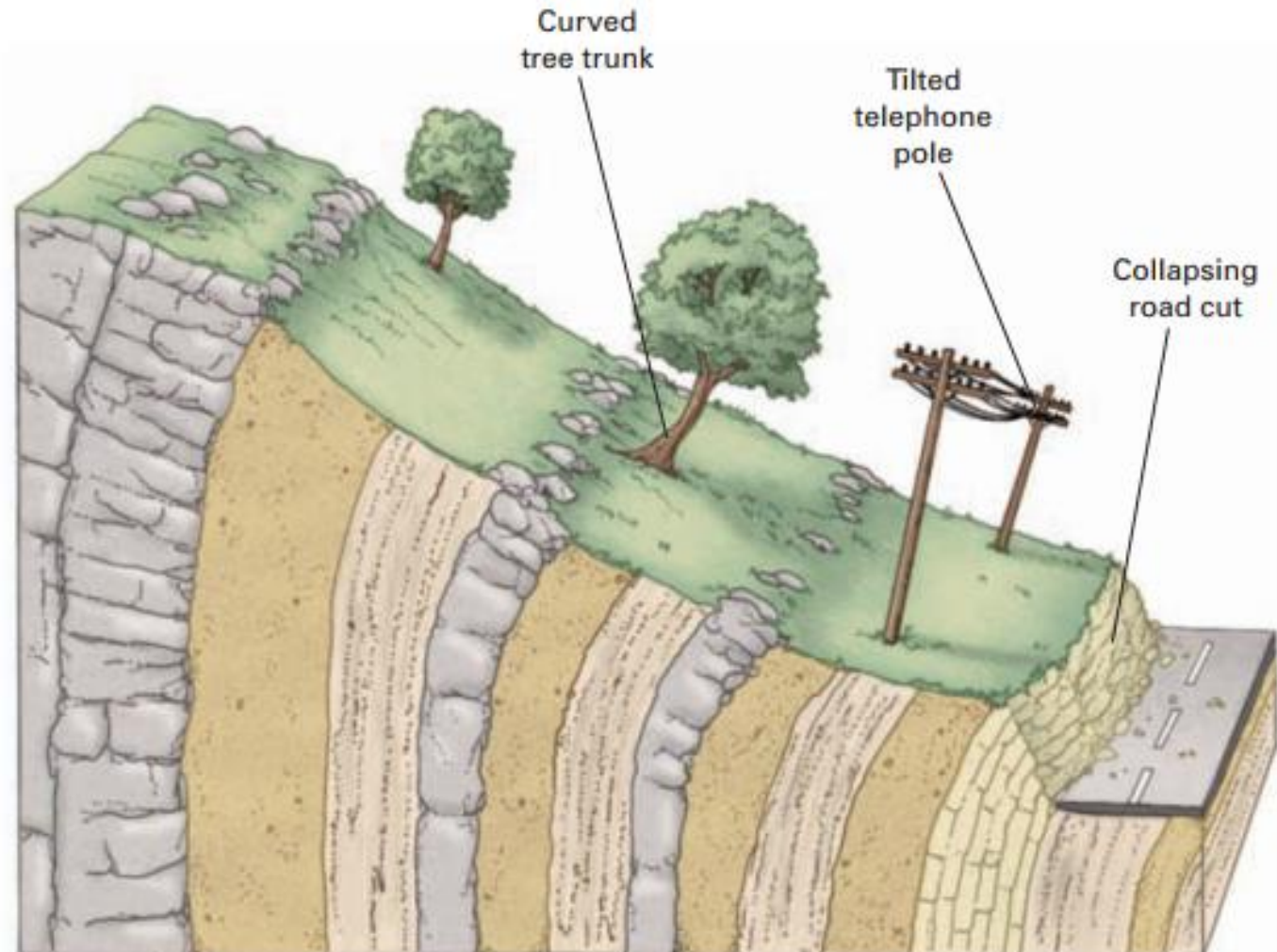
LANDSLIDES

❖ *TYPES OF LANDSLIDES*

□ **Flow**

✓ **Creep** is a type of flow. **Creep** is the slow, downhill flow of rock or soil under the influence of gravity. A creeping slope typically moves at a rate of about 1 centimeter per year, although wet soil can creep more rapidly

✓ During creep, the shallow soil or rock layers move more rapidly than deeper material moves. As a result, anything with roots or a foundation tilts downhill

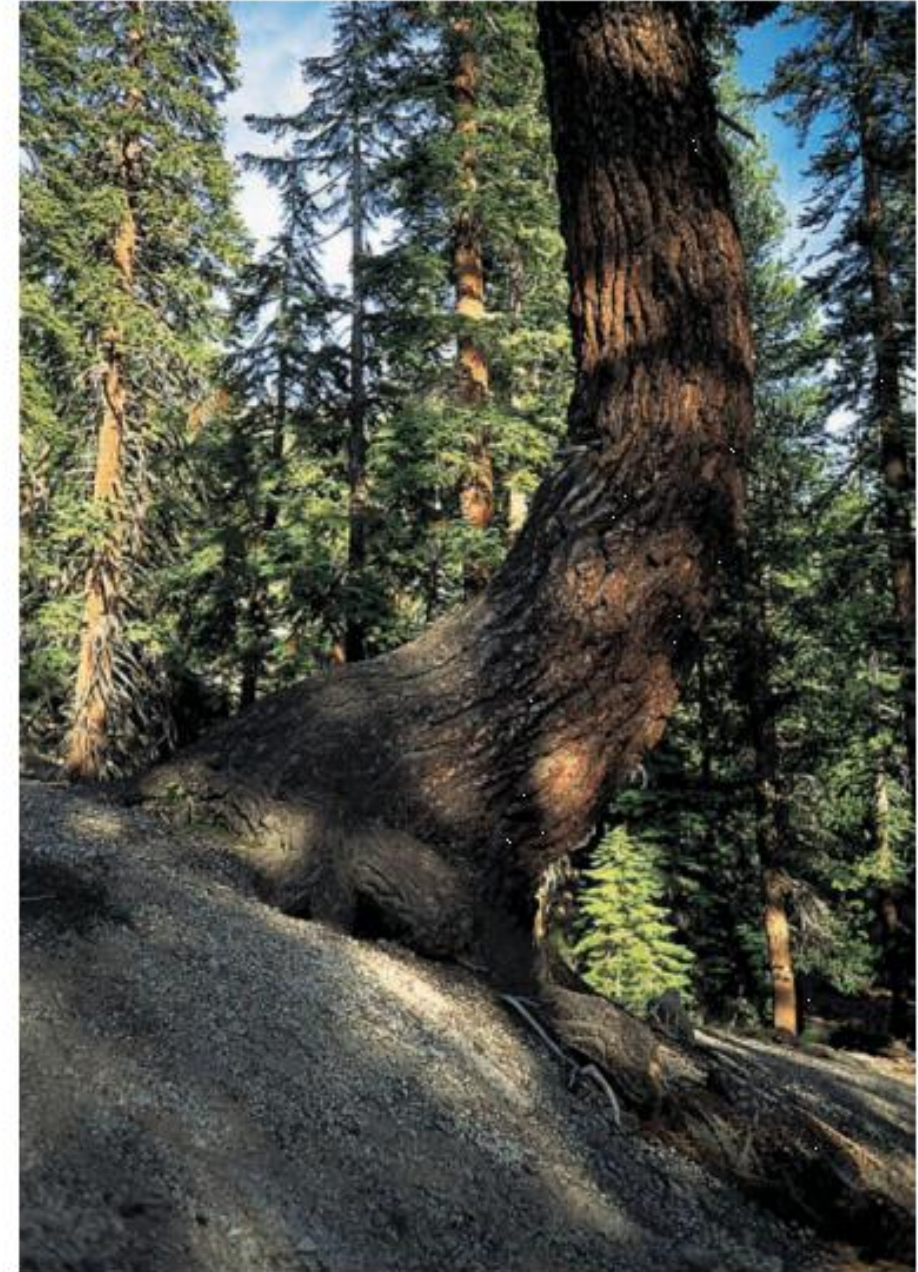


LANDSLIDES

❖ *TYPES OF LANDSLIDES*

□ **Flow**

- ✓ Trees have a natural tendency to grow straight upward. As a result, when soil creep tilts a growing tree, the tree develops a J-shaped curve in its trunk, called pistol butt



LANDSLIDES

❖ TYPES OF LANDSLIDES

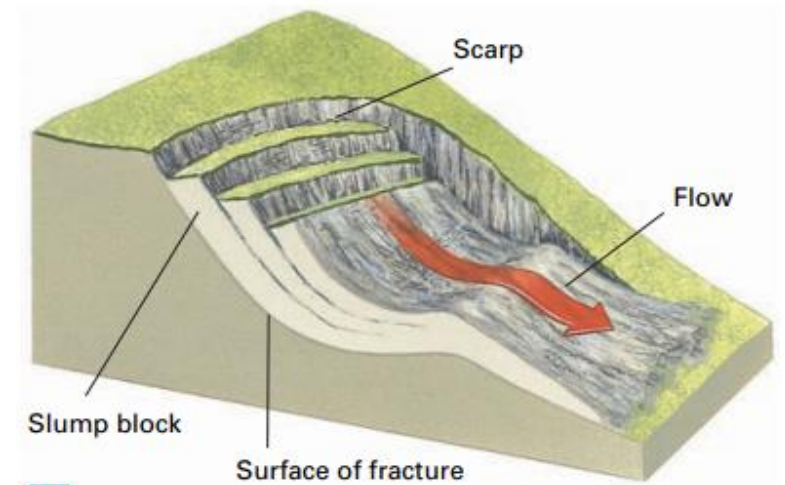
□ Slide

✓ Two types of slides occur: slump and rockslide

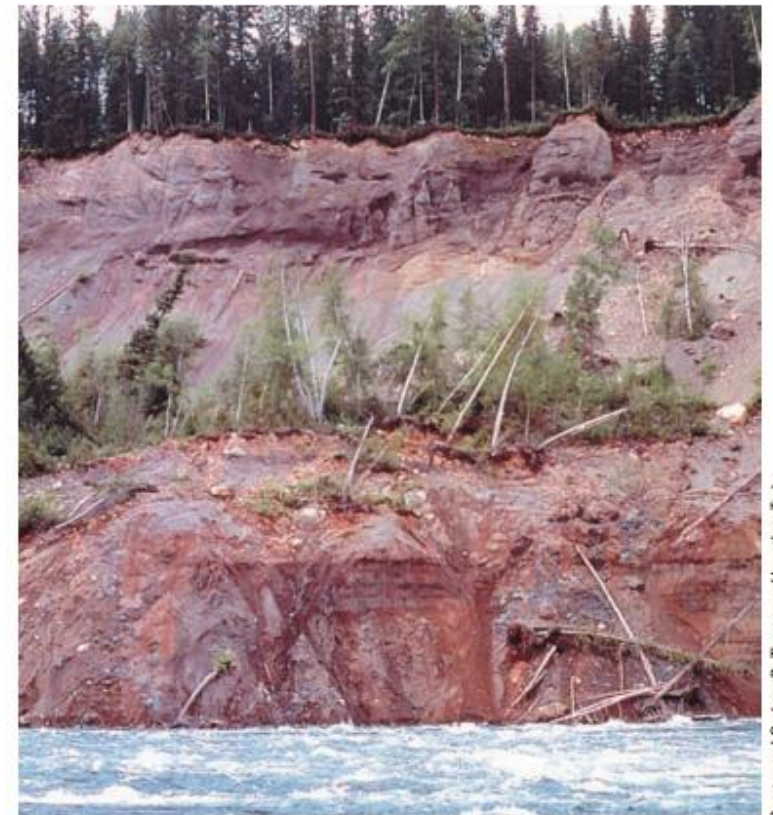
✓ A slump occurs when blocks of material slide downhill over a gently curved fracture in rock or regolith

Thus, one can distinguish slump from creep because slump tilts trees uphill, whereas creep tilts them downhill

✓ During a rockslide (or rock avalanche), bedrock slides downslope over a fracture plane. Characteristically, the rock breaks up as it moves and a turbulent mass of rubble tumbles down the hillside



A



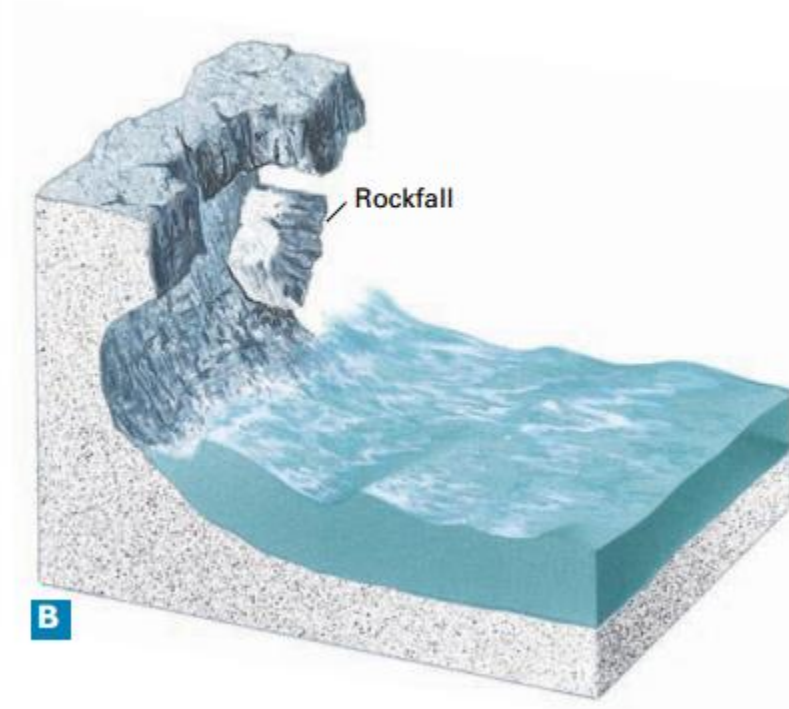
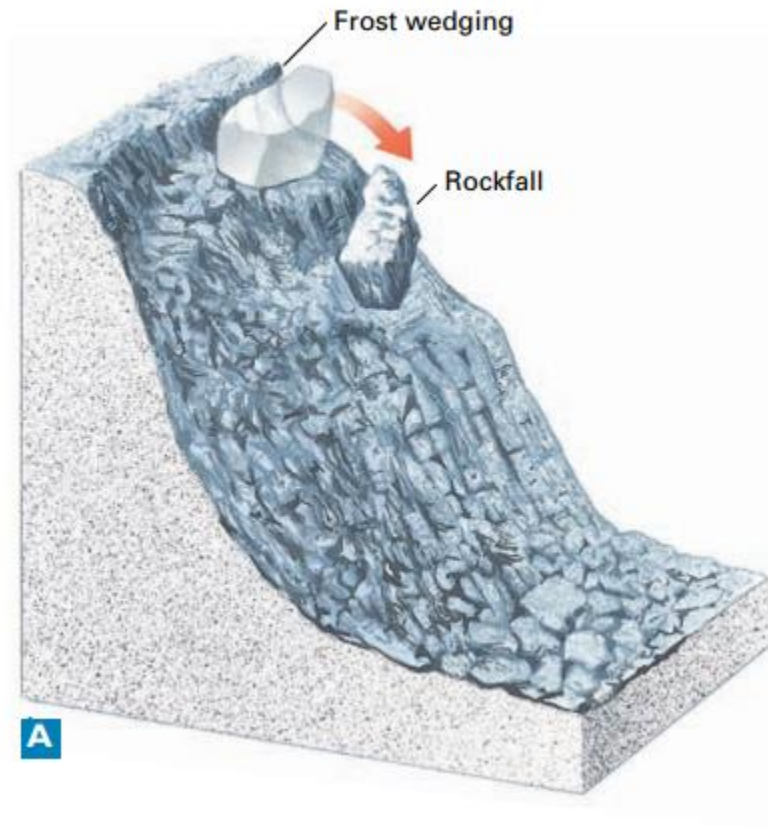
B

LANDSLIDES

❖ *TYPES OF LANDSLIDES*

□ **Fall**

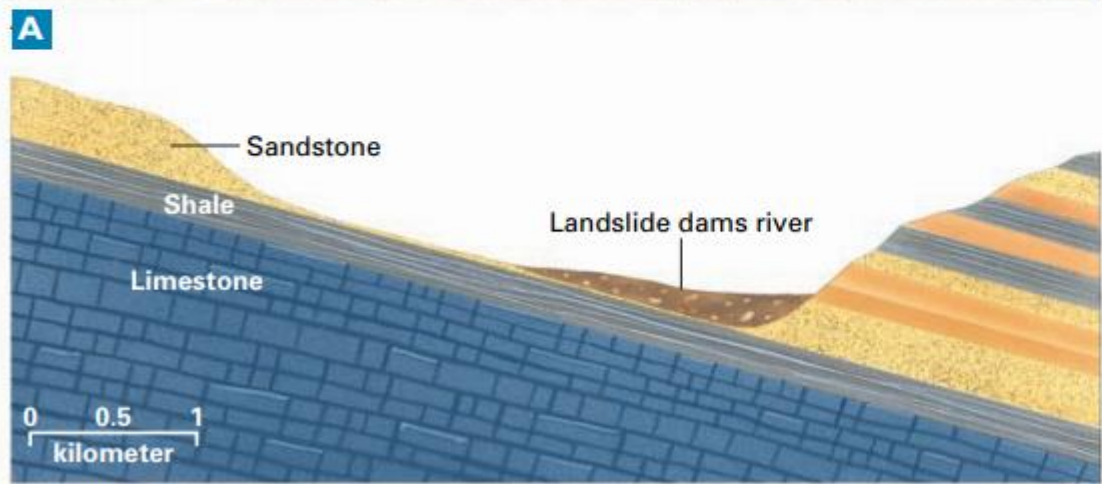
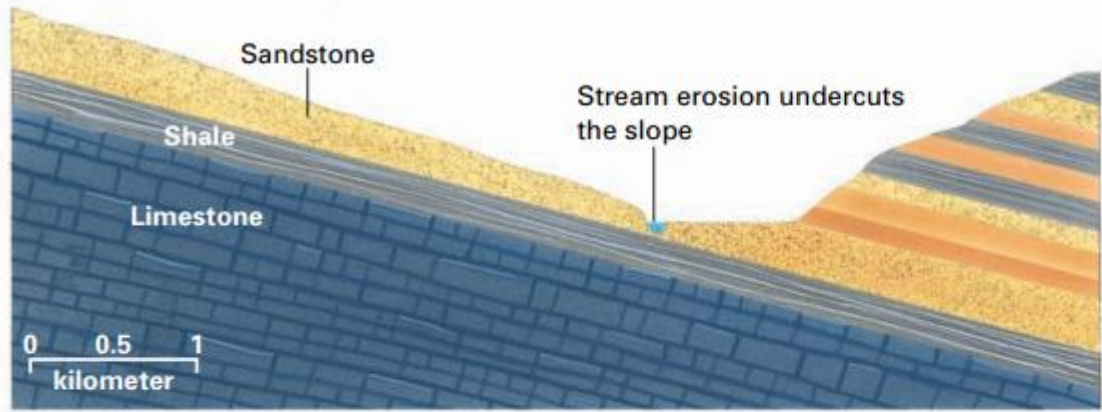
- ✓ Rocks from cliffs and cause rockfall.
Rockfall also occurs when ocean waves or a stream undercuts a cliff



LANDSLIDES

❖ TYPES OF LANDSLIDES

□ Fall



Courtesy of Graham R. Thompson/Jonathan Turk

A

B

LANDSLIDES

❖ *PREDICTING AND AVOIDING LANDSLIDES*

- ✓ One of the most important tools in evaluating landslide hazards is to understand that landslides commonly occur in the same area as earlier landslides because the geologic conditions that cause mass wasting tend to be constant over a large area and for long periods of time. Thus, if a hillside has slumped, nearby hills may also be vulnerable to mass wasting. In addition, landslides and mudflows commonly follow the paths of previous slides and flows. If an old mudflow lies in a stream valley, future flows may follow the same valley
- ✓ Geologists evaluate landslide probability by combining data on soil and bedrock stability, slope angle, climate, and history of slope failure in the area

Key Terms

weathering 233	exfoliation 239	salinization 245
erosion 233	regolith 239	pedalfer 245
mechanical weathering (physical weathering) 233	soil 239	laterite 245
chemical weathering 234	loam 240	bauxite 245
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dissolution 236	B horizon 242	fall 253
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For Review

1. Explain the differences among weathering, erosion, transport, and deposition.
2. Explain the differences between mechanical weathering and chemical weathering.
3. List five processes that cause mechanical weathering.
4. What is a talus slope? What conditions favor the formation of talus slopes?
5. List three processes that cause chemical weathering.
6. What is hydrolysis? What happens when granitic rocks undergo hydrolysis? What minerals react? What are the reaction products?
7. What are the components of healthy soil? What is the function of each component?
8. Characterize the four major horizons of a mature soil.
9. List six factors that control soil characteristics and briefly discuss each one.
10. Imagine that soil forms on granite in two regions, one wet and the other dry. Will the soil in the two regions be the same or different? Explain.
11. Explain how soils formed from granite will change with time.
12. What are laterite soils? How are they formed? Why are they unsuitable for agriculture?
13. List and describe each of the factors that control slope stability.
14. What is the angle of repose? Why is the angle of repose different for different types of materials?
15. How does vegetation affect slope stability?
16. Why is mass wasting common in deserts and semiarid lands?
17. How do volcanic eruptions cause landslides?
18. How do earthquakes cause landslides?
19. Discuss the differences among flow, slide, and fall. Give examples of each.
20. Compare and contrast creep and slump. What does a pistol-butt tree trunk tell you about slope stability?
21. Explain how trees are tilted but not killed by slump.
22. How do landslides reach and destroy towns and villages many kilometers from the steep slopes where the slides originate?