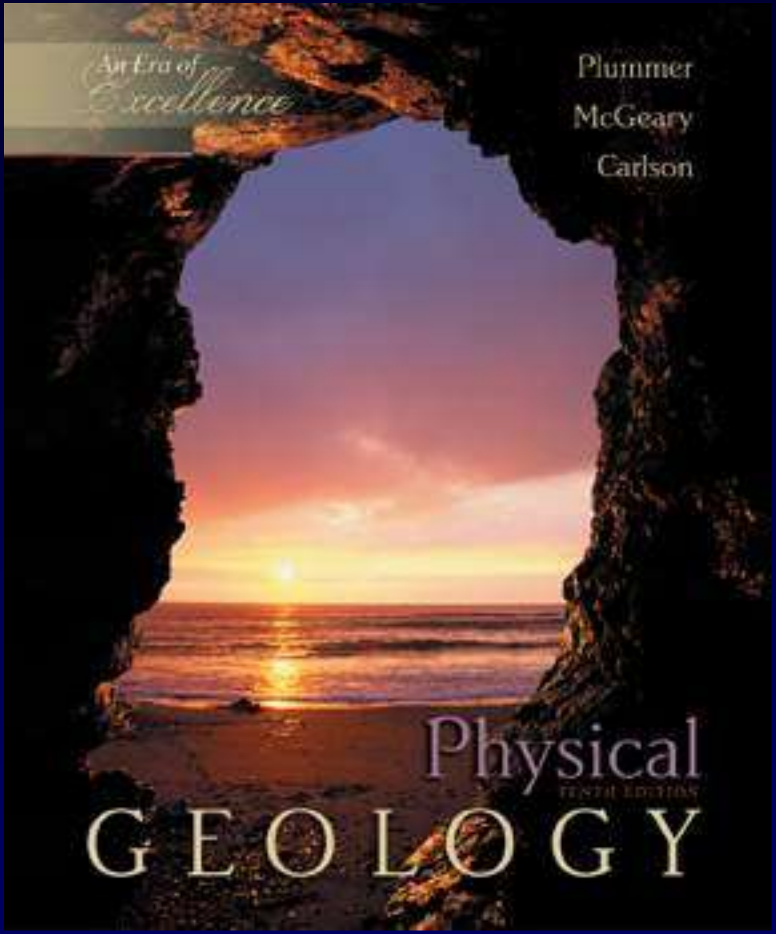
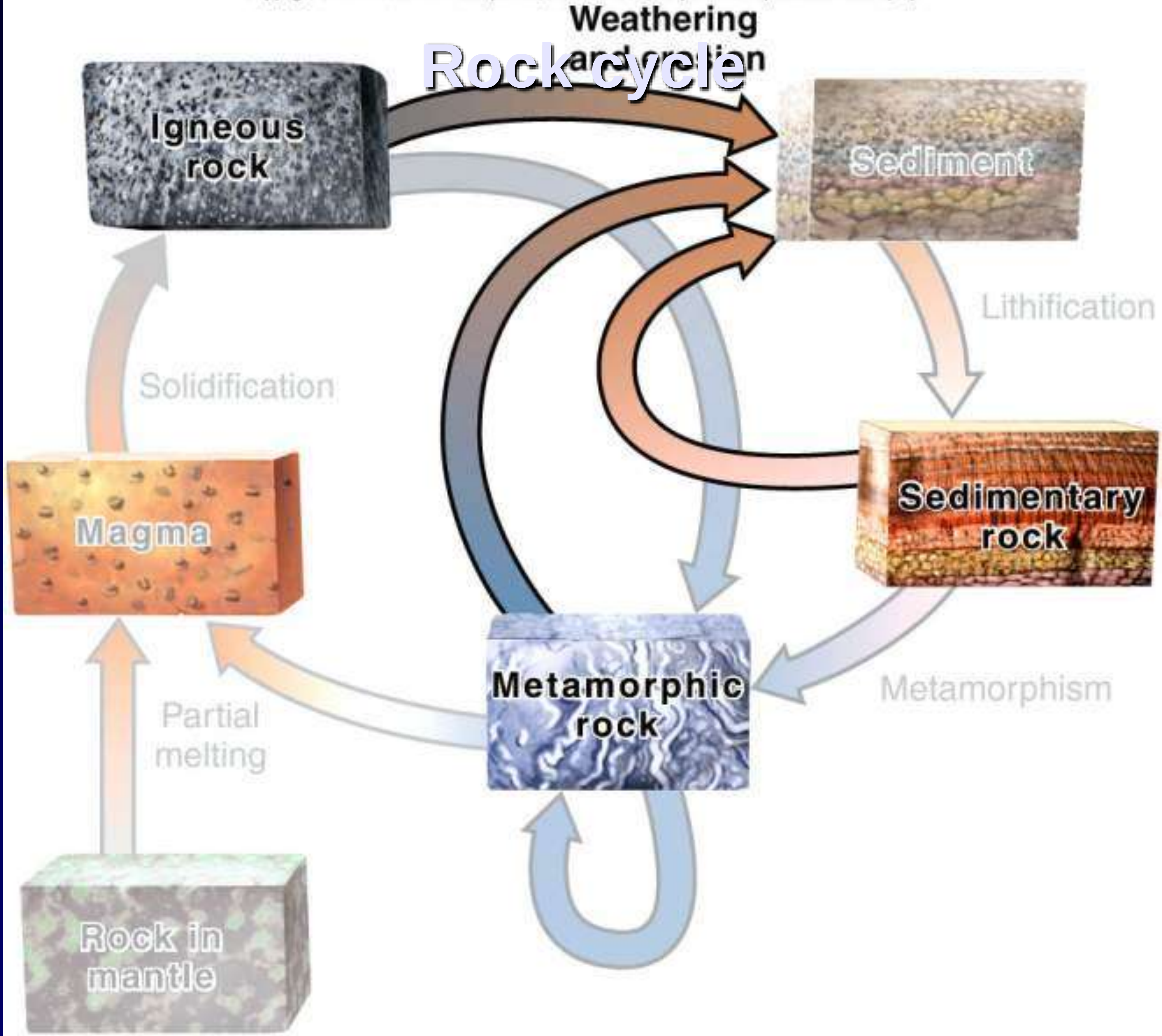
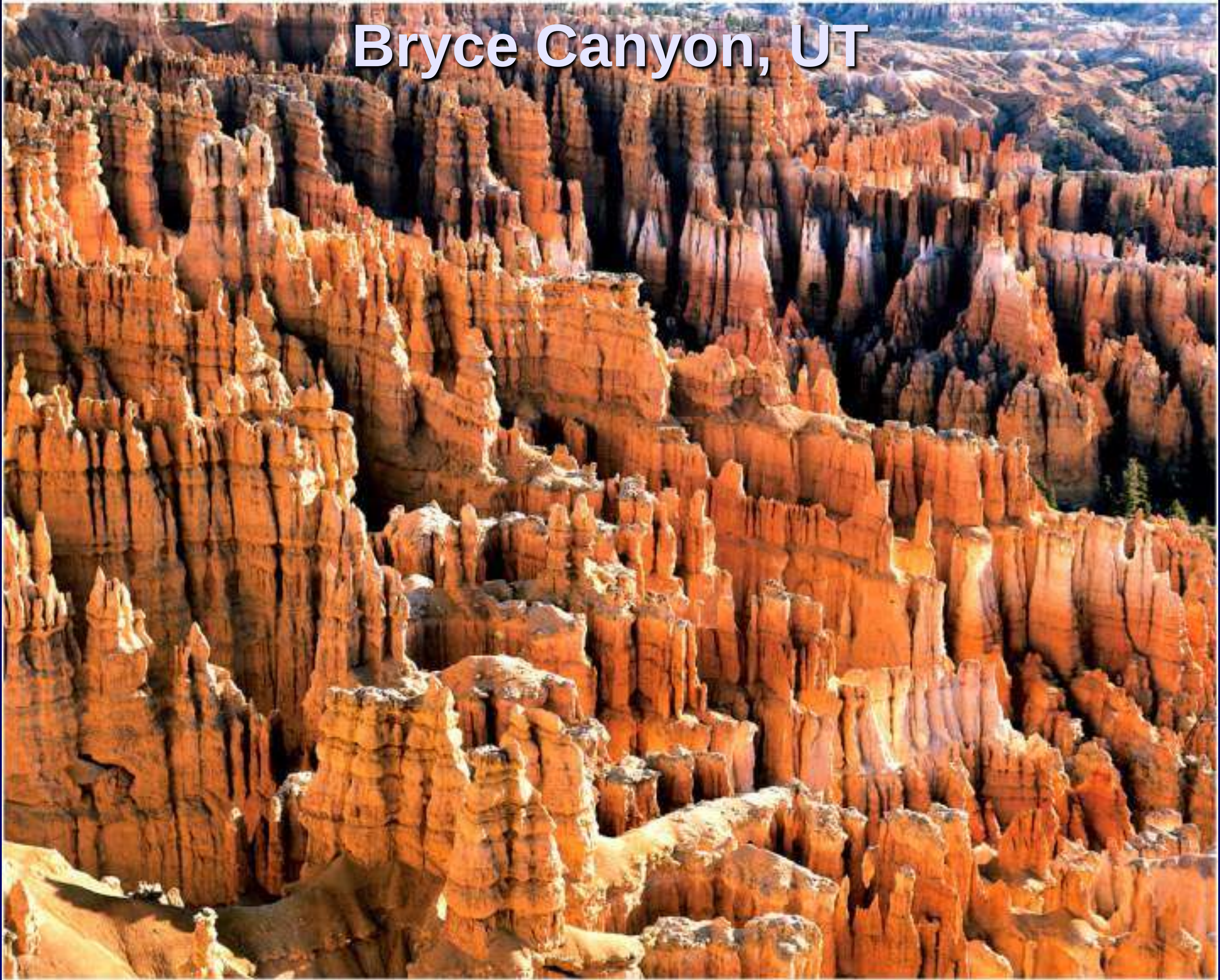
Chapter 5
Soils, Weathering



Rock cycle


Weathering
and erosion
Igneous rock
Sediment
Lithification
Solidification
Magma
Sedimentary rock
Metamorphic rock
Metamorphism
Partial melting
Rock in mantle

Bryce Canyon, UT



Weathering, Erosion, and Transportation

- Rocks exposed at Earth's surface are *constantly changed* by water, air, temperature variations and other factors
- *Weathering* is the group of destructive processes that change physical and chemical character of rocks at or near Earth's surface
- *Erosion* is physical picking up of rock particles by water, ice, or wind
- *Transportation* is the movement of eroded particles by water, ice, or wind

Weathering and Earth Systems

- *Solar system*
  - Earth-style weathering (water, ice, wind) is nearly unique to our planet, at present. Small amounts of weathering (primarily by wind) still occur on Mars, and water erosion appears to have been important there in the distant past.
- *Atmosphere*
  - Oxygen and carbon dioxide critical to chemical weathering
  - Water cycled through atmosphere is critical to chemical and mechanical weathering processes
  - Air in soils contributes to biological action that can produce chemical and mechanical weathering

Weathering and Earth Systems

- *Hydrosphere*
  - Water is necessary for *chemical weathering*
  - Oxygen dissolved in water *oxidizes iron* in rocks
  - Carbon dioxide dissolved in water creates *carbonic acid*
    - Primary cause of chemical weathering
  - Running water loosens and abrades particles
  - Glacial ice removes and abrades particles
  - Freeze/thaw cycling mechanically weathers
- *Biosphere*
  - Plant root growth widens cracks
  - Animal foot traffic and human activity mechanically weather
  - Decaying organic matter in soils produces acidic soil moisture

A

B

Types of weathering

Types of Weathering

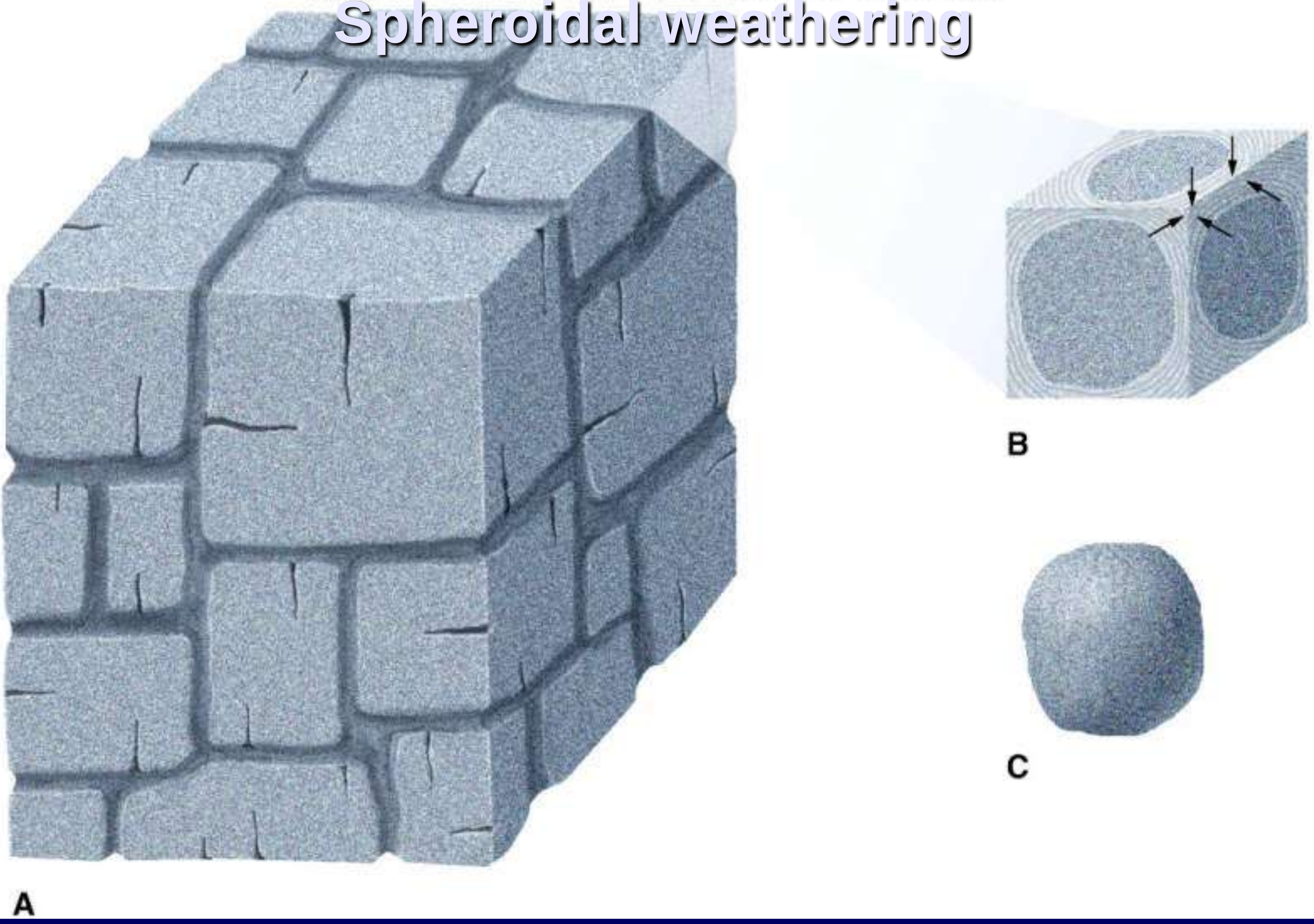
- *Mechanical weathering*
  - Physical disintegration
  - Frost action, pressure-release fracturing, plant growth, burrowing animals, salt wedging, thermal cycling
- *Chemical weathering*
  - Decomposition of rock from exposure to atmospheric gases (oxygen, water vapor and carbon dioxide)
  - New chemical compounds (minerals) form
  - Rate increased by increased rock surface area

Spheroidal weathering Salt R Can

Effects of Weathering

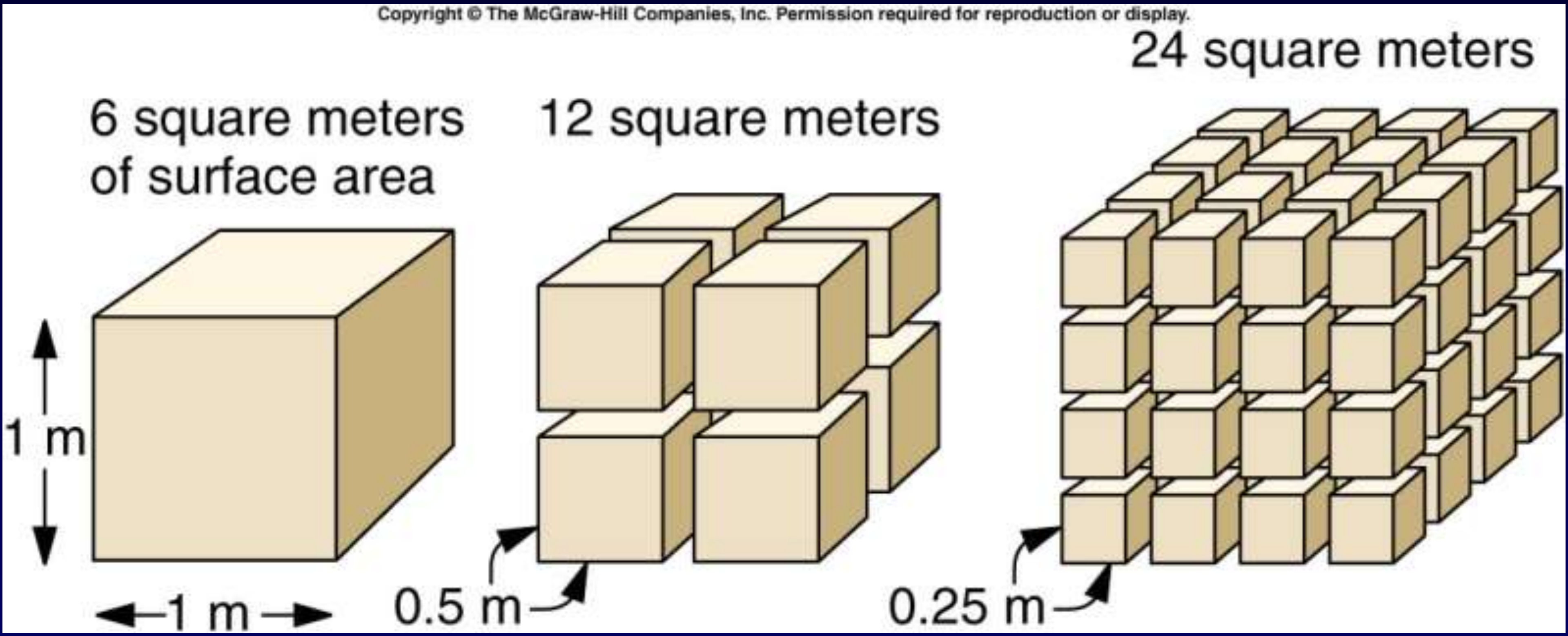
- Spheroidal wx – rock rounded by wx from an initially blocky shape. Rounded b/c chemical wx acts more rapidly or intensely on the corners and edges of a rock than on the smooth rock faces.

Spheroidal weathering

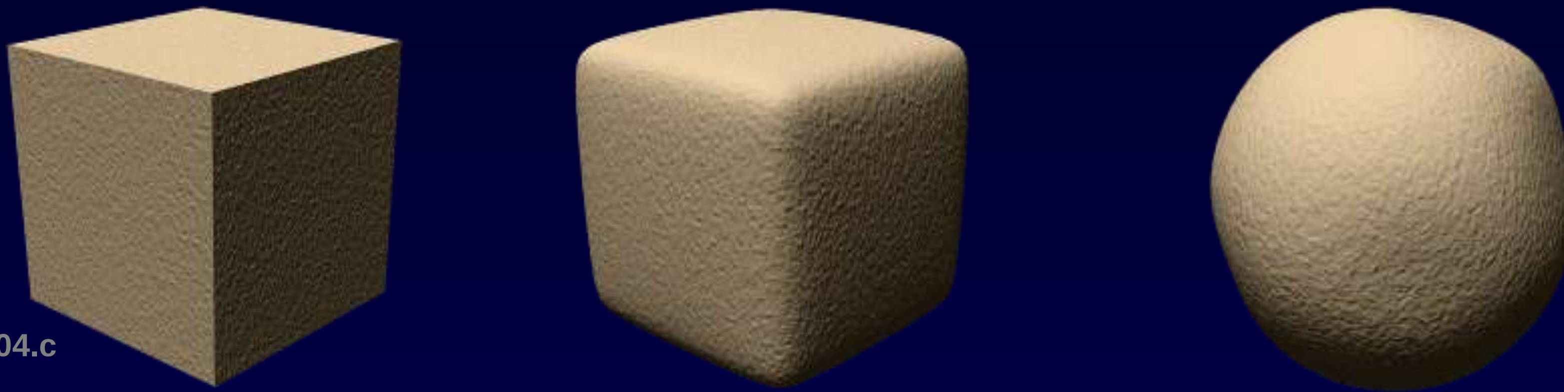


D

Increased surface area



Observe how weathering produces rounded features

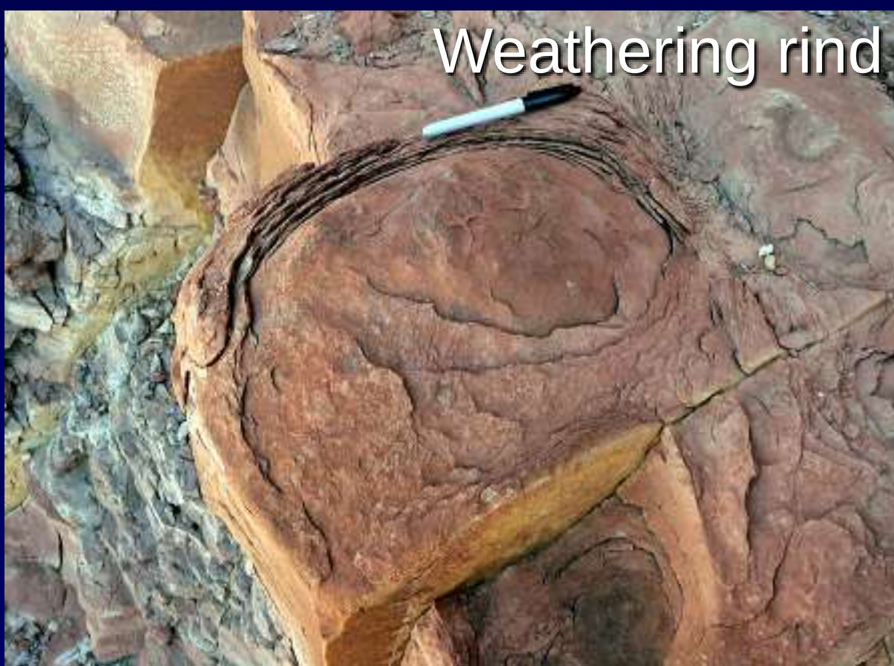


15.04.c

Sharp angular edges

Edges and corners begin to smooth

No sharp edges or angular features



Effects of Weathering

- Differential wx – term for varying rates of wx in an area where some rocks are more resistant to weathering than other.

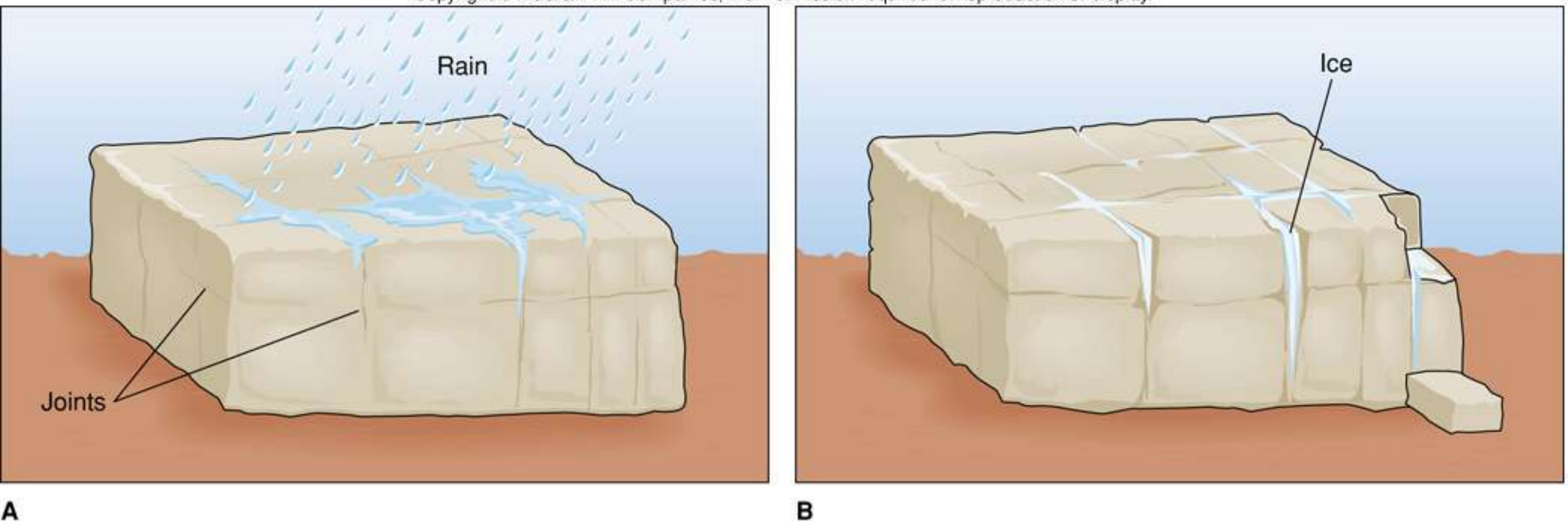
Mechanical weathering
Mechanical Weathering

- *Frost action*
  - Mechanic effect of freezing (and expanding) water on rocks
- *Pressure release*
  - Removal of overlying rock allows expansion and fracturing
- *Plant growth*
  - Growing roots widen fractures
- *Burrowing animals*
- *Thermal cycling*
  - Large temperature changes fracture rocks by repeated expansion and contraction

Frost

- Frost action – the mechanical effect of freezing water on rocks – frost wedging or frost heaving
  - Frost wedging = expansion of freezing water prys rock apart
    - Regions with many days of freezing and thawing
  - Frost heaving – lifts rock and soil vertically

Fig. 05.05



Mechanical Weathering

Frost wedging – the expansion of freezing water pries rx apart.

Joints – water that has trickled into a joint in a rx can freeze and expand by as much as 9% when the temp drops below 32°F. The expanding ice wedges the rx apart, extending the joint or even breaking the rx into pieces.


Frost wedging
A

Mechanical Weathering

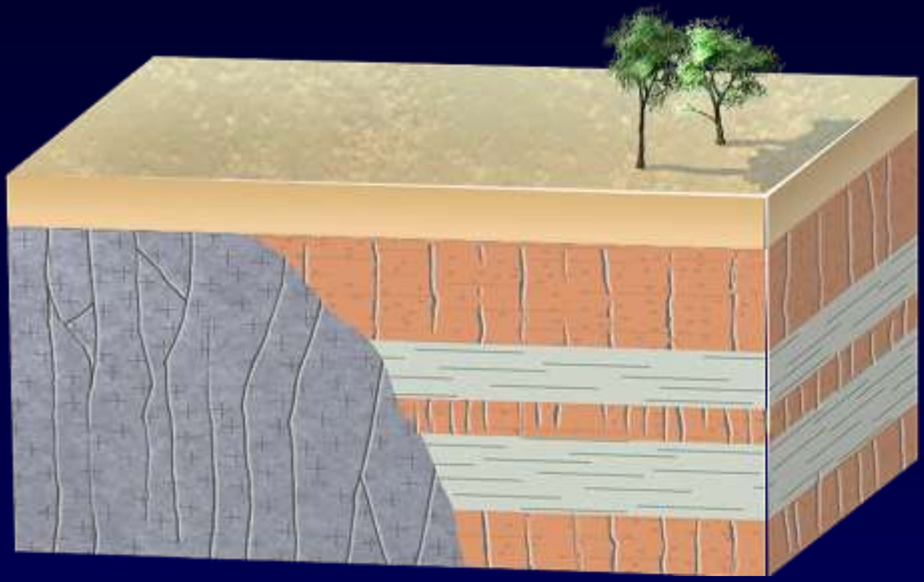
- Frost heaving – lifts rx and soil vertically. Ice first forms under large rock fragments in the soil. The expanding ice layers push boulders out of the ground.

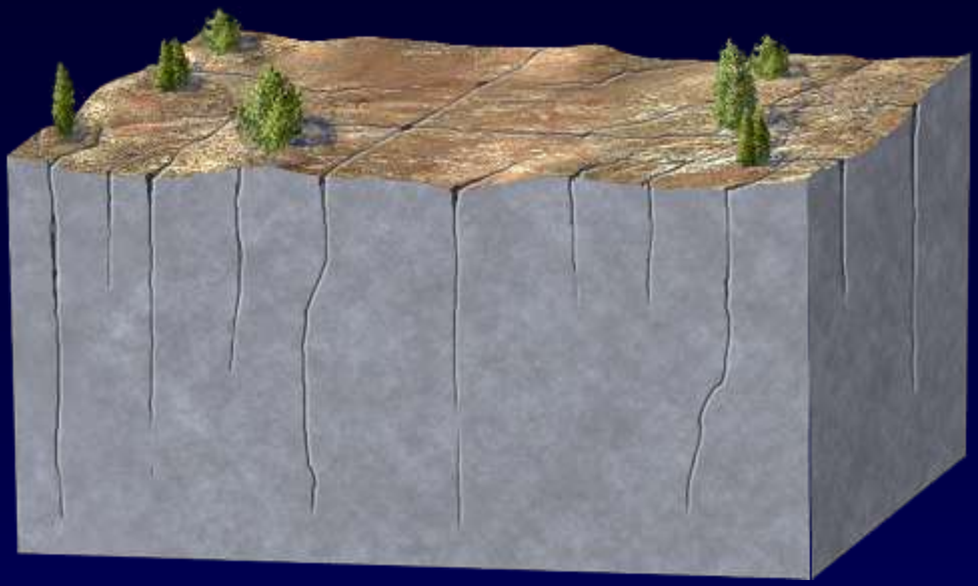
B

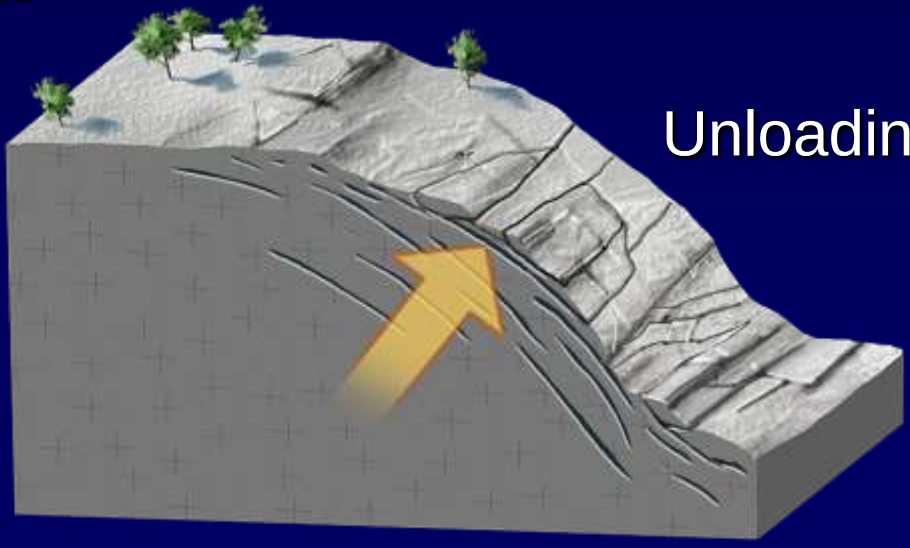
Pressure release

- Pressure release – removal of weight above batholith (unloading) allows granite to expand upward.
  - Sheet joints – cracks parallel to the outer surace of the rock
  - Exfoliation = Spalling off of rock in concentric slabs
  - Exfoliation domes = large rounded landforms developed in massive rocks (granite) by unloading

The Role of Joints in Weathering







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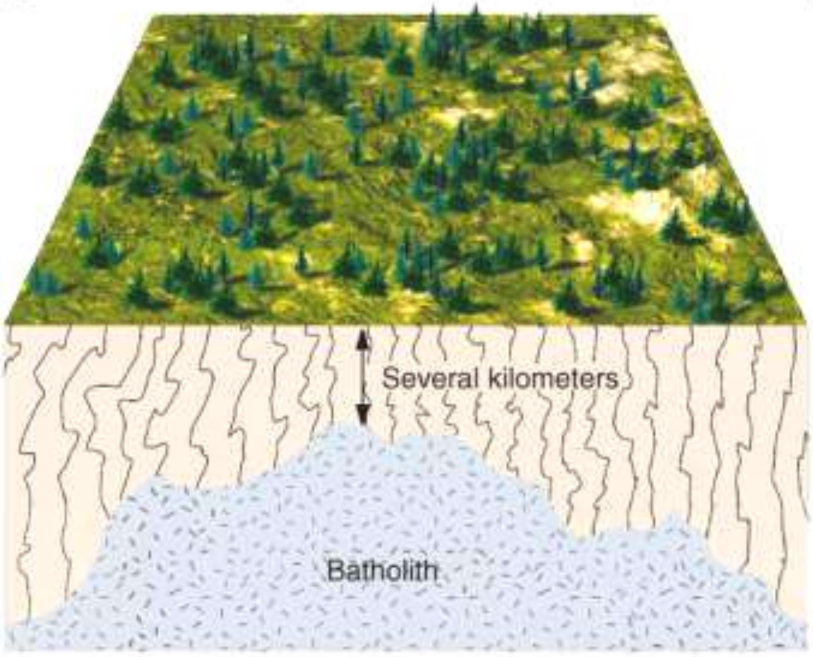
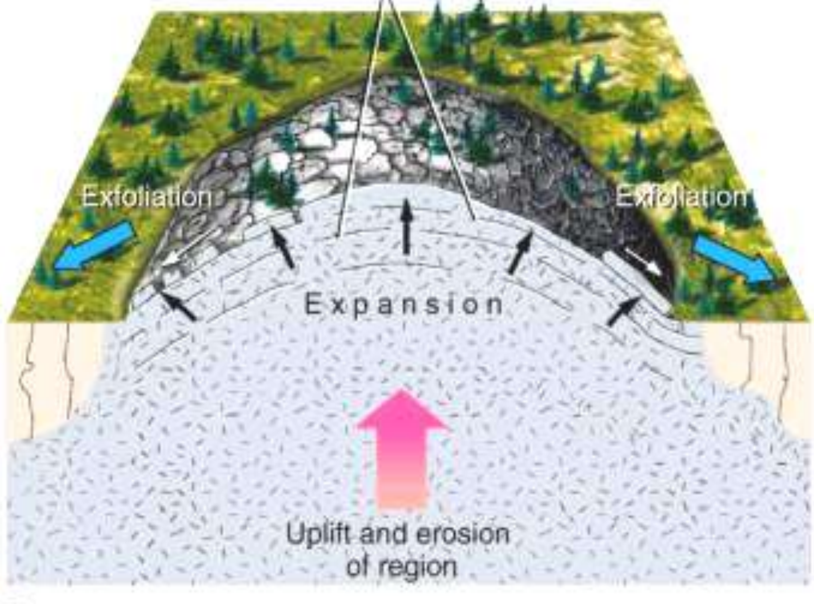

Several kilometers
Batholith

A


Sheet joints
Exfoliation
Exfoliation
Expansion
Uplift and erosion of region

B

Fig. 05.07

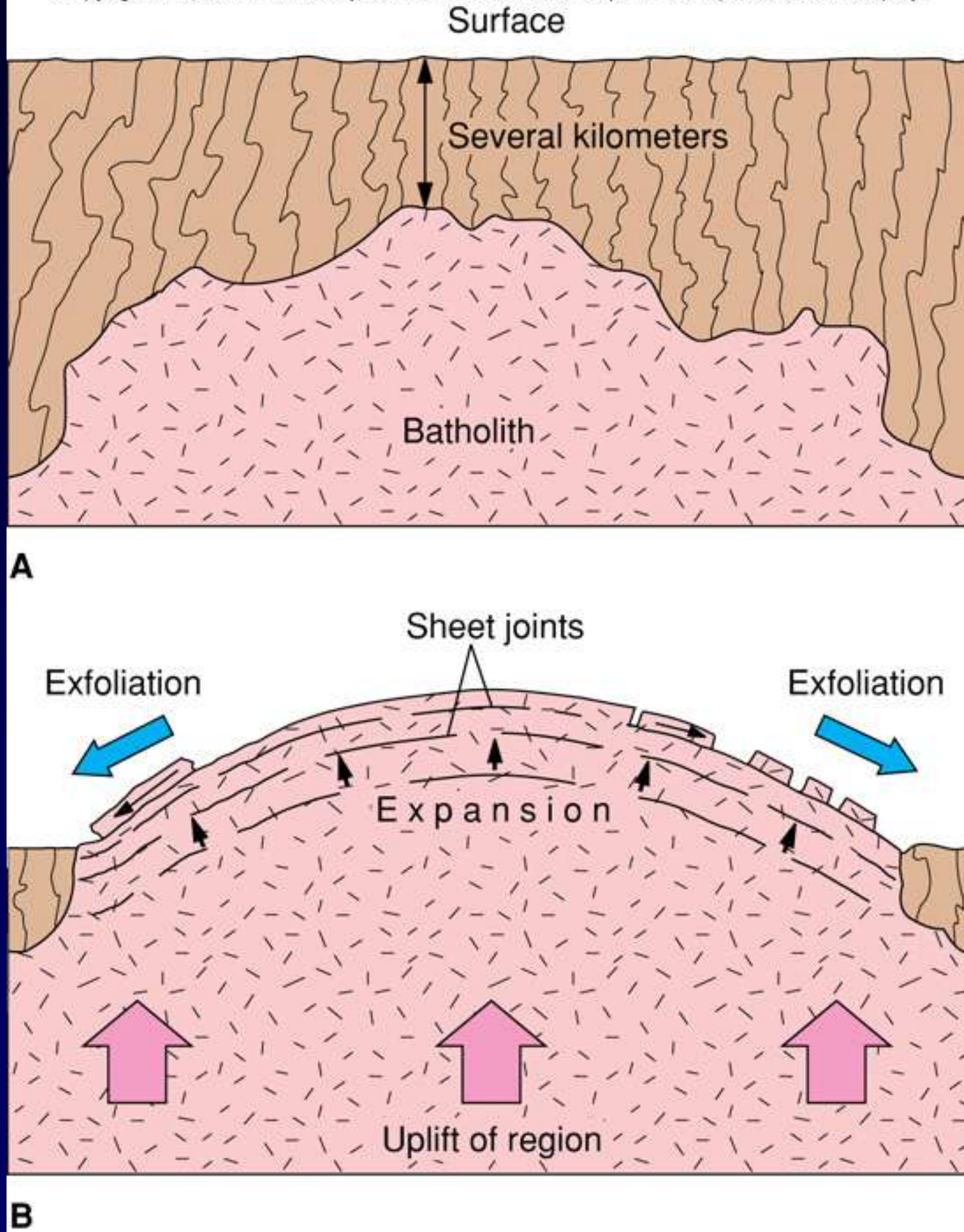
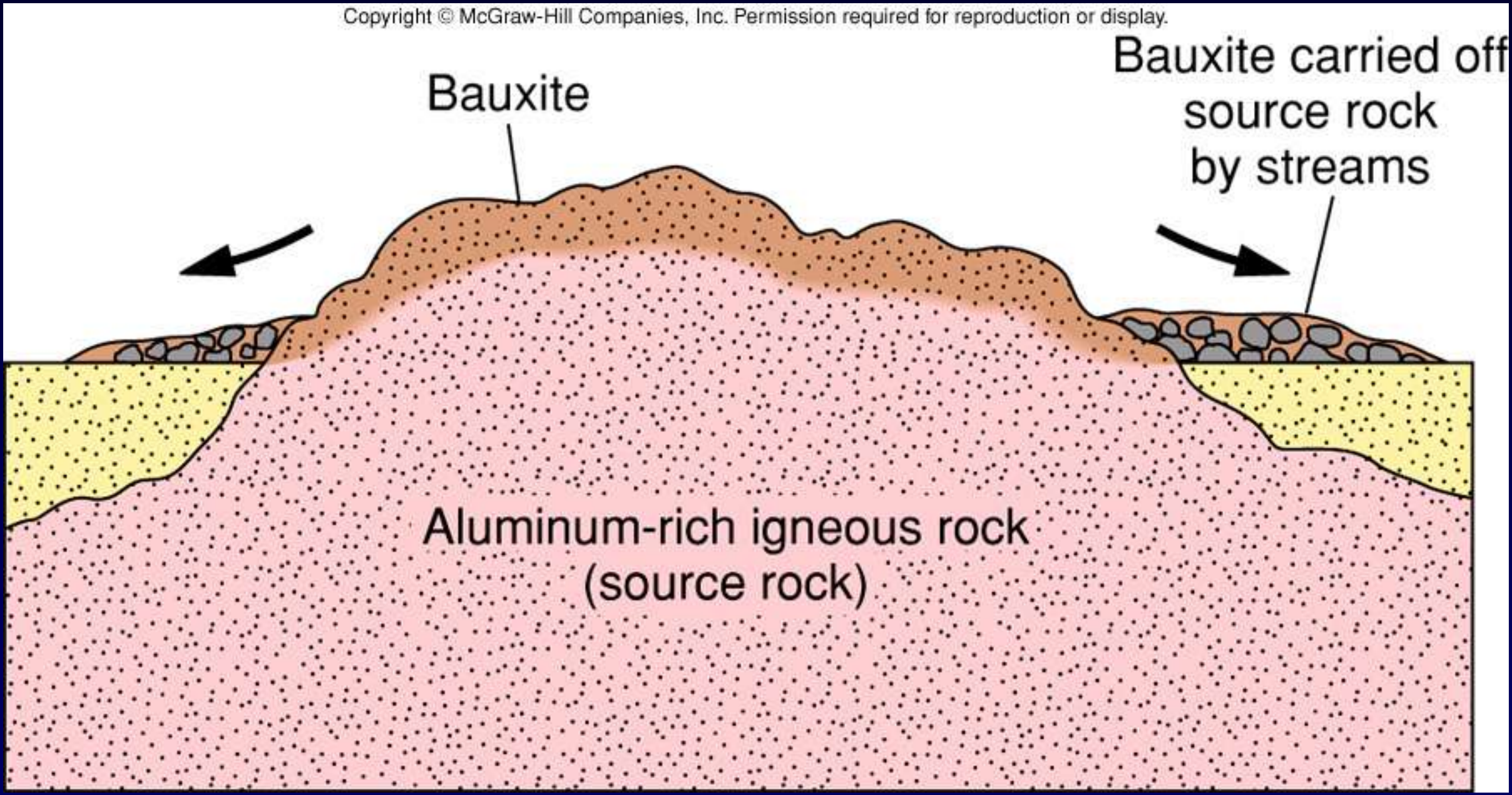

Surface
Several kilometers
Batholith
A
Sheet joints
Exfoliation
Exfoliation
Expansion
Uplift of region
B

Fig. 05.24



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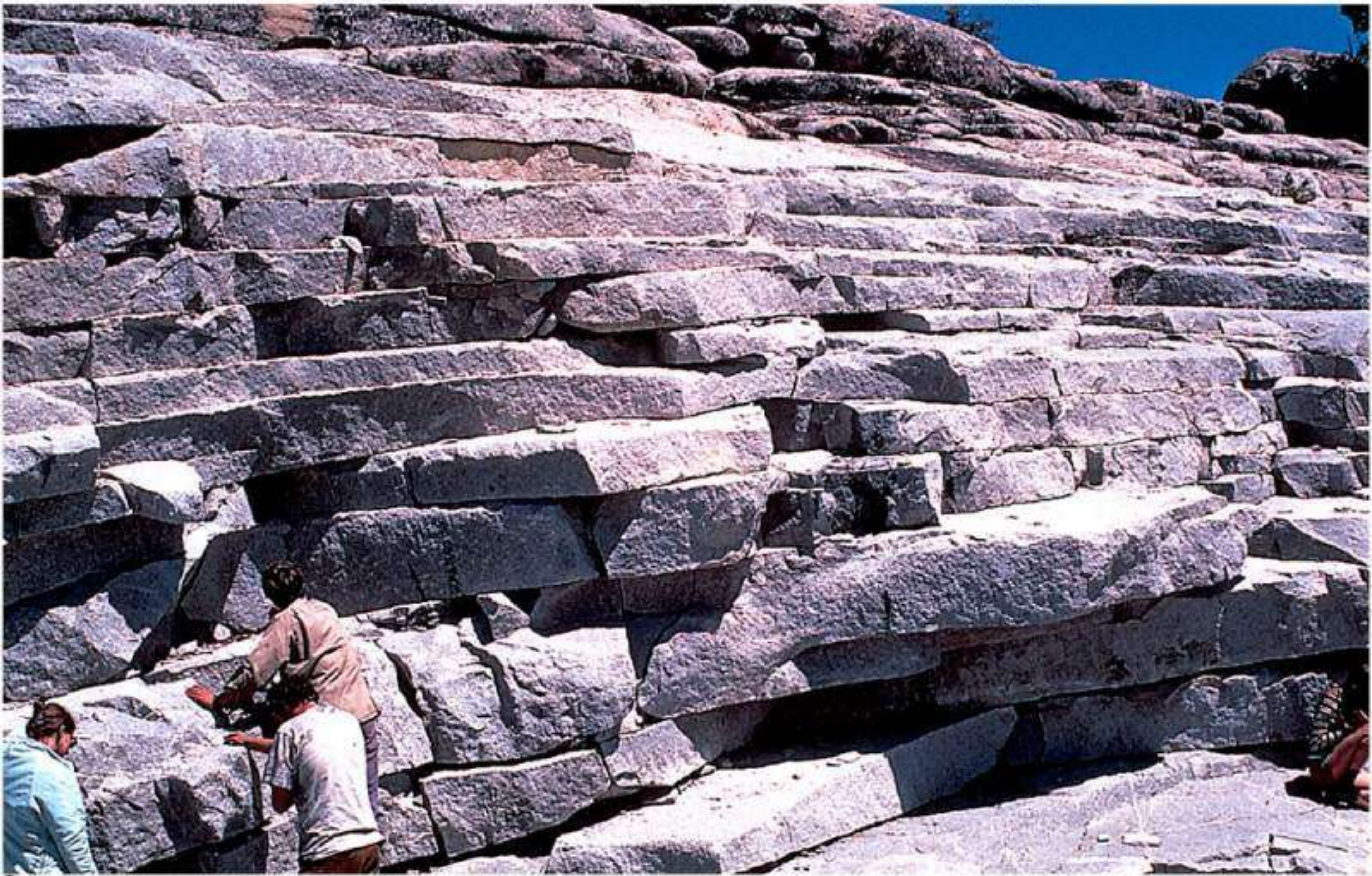
Bauxite
Bauxite carried off source rock by streams
Aluminum-rich igneous rock (source rock)



c

Observe how joints are expressed in the landscape


dome

Other mechanical weathering

- Plant growth
- Burrowing animals
- Pressure of salt crystal growth
- Extreme changes in temperature - fire

A

Salt crystals Death Valley

B

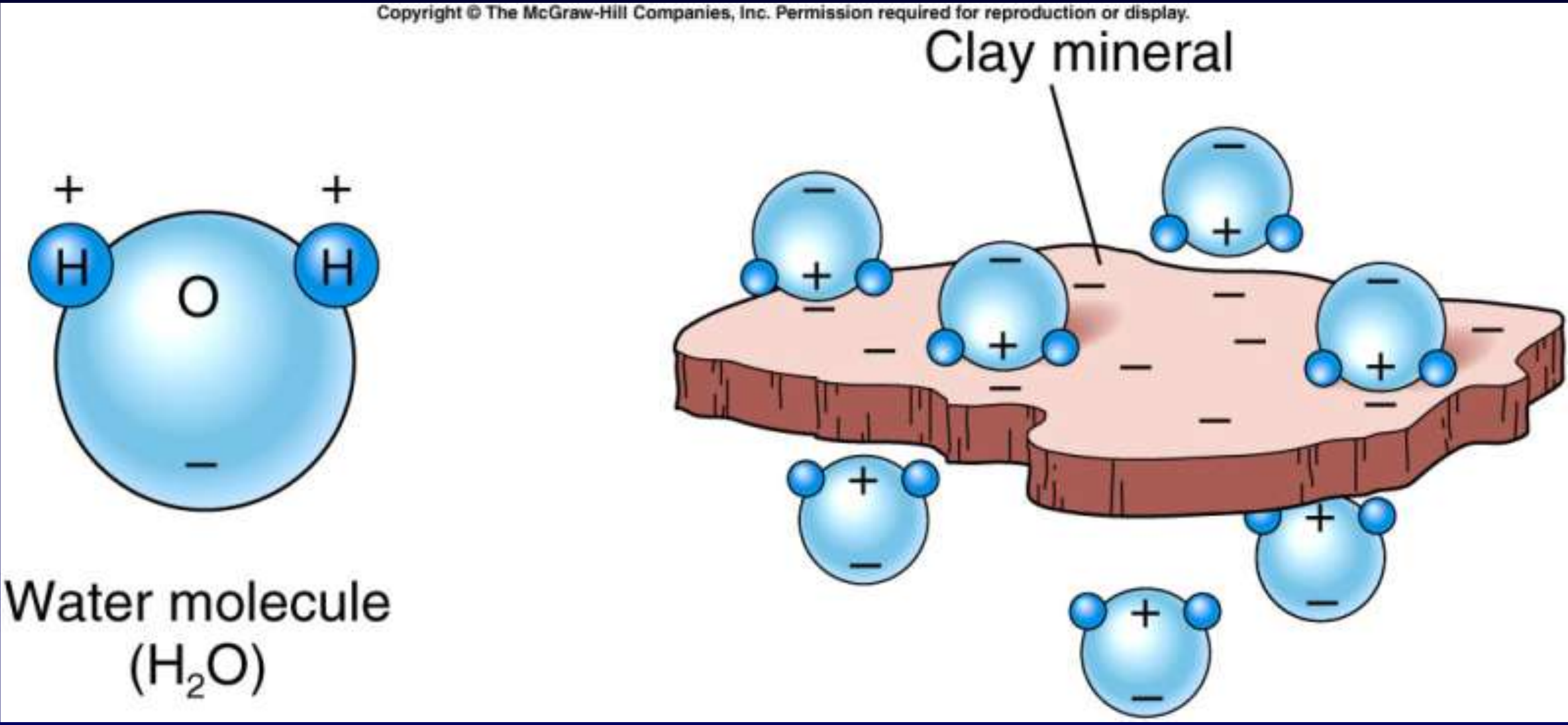
Mechanical Weathering

- Whatever processes of mechanical wx are at work, as rocks disintegrate into smaller fragments the total surface area increases, allowing more extensive chemical wx by water and air.

Chemical Weathering

The processes of chemical weathering transform rocks and minerals exposed to water and air into new chemical products. The minerals change gradually at the surface until they come into equilibrium, or balance, with the surrounding conditions. These new minerals are weathering products.

Clays & water



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Clay mineral
+
+
H
H
O
–
Water molecule
(H_2O)

Chemical Weathering

- Role of Oxygen
- Role of Acid
- Solution Weathering
- Chemical Weathering of Feldspar
- Chemical Weathering of Other Minerals
- Weathering and Climate
- Weathering Products

Chemical Weathering

- Role of oxygen

  - Abundant, chemically active -> easily combines with mineral exposed at earth's surface.

  - Oxygen from atmosphere combines with iron to form iron oxide

  - Brown, yellow, or red color of soil and many kinds of sedimentary rock is commonly the result of small amounts of hematite and limonite released by the weathering of iron-containing minerals.

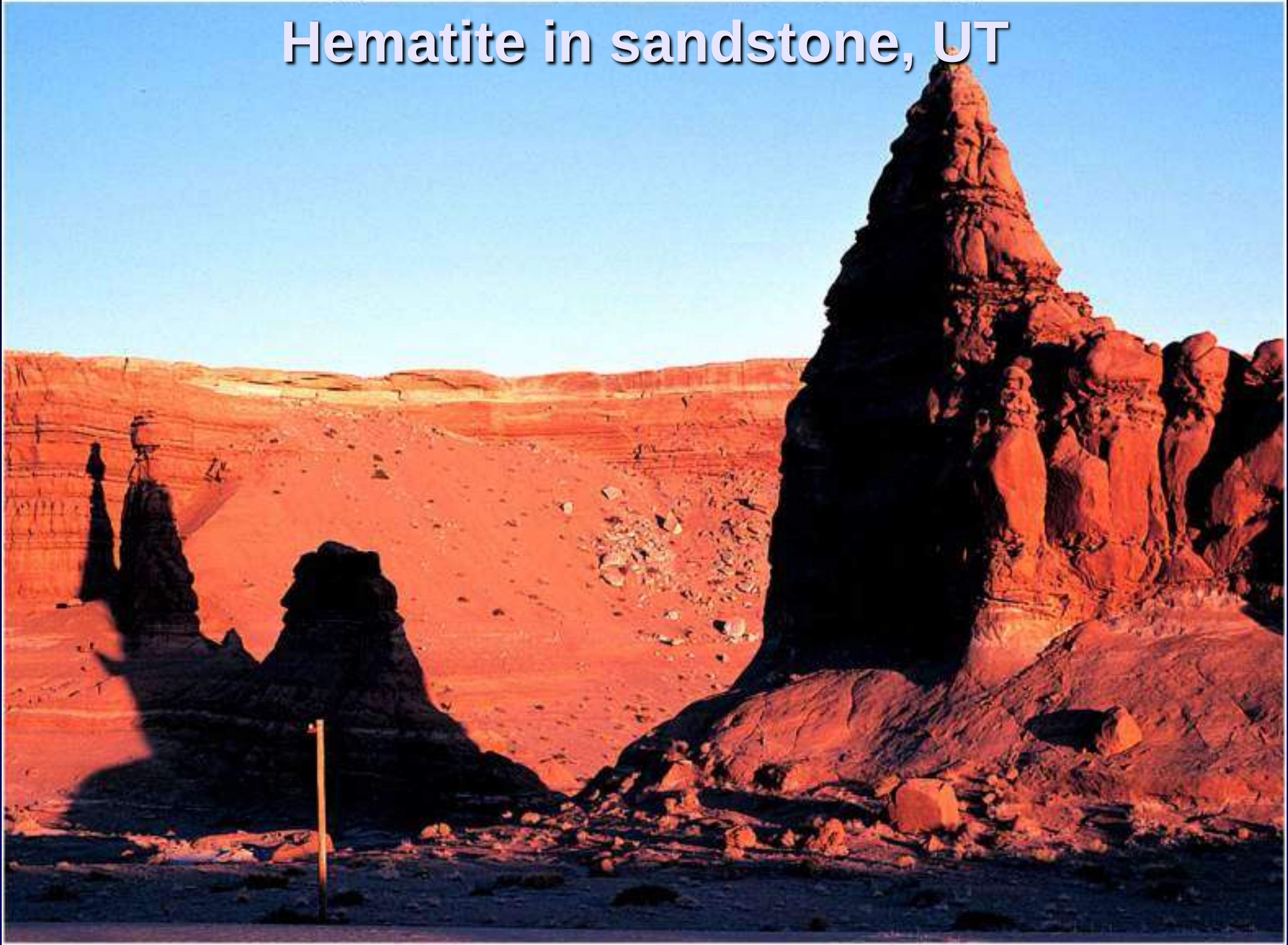
Chem weathering

Chemical Weathering

- *Oxidation*
  - Chemically active oxygen from atmosphere
  - Iron oxides are common result

    Soil and sedimentary rocks often stained with iron oxides

Hematite in sandstone, UT



Chem weathering

- *Acid dissolution*
  - Hydrogen cations replace others in minerals
  - Carbonic acid from atmospheric CO_2 dissolved in water
  - Sulfuric, hydrofluoric acids emitted by volcanic eruptions
  - Some minerals, such as calcite, may be totally dissolved

Chemical Weathering

- *Feldspars*
  - Most common minerals in crust
  - Slightly acidic rain water attacks feldspar
  - *Clay minerals* produced
    - K^+, Na^+, Ca^{++} ions released into water
- *Other minerals*
  - Ferromagnesian minerals
    - Clays, iron oxides, Mg^{++} ions produced
  - More complex silicate bonds lead to lower weathering susceptibility
    - Olivine most susceptible, quartz least
- *Warm, wet climatic conditions maximize weathering*

Chemical Weathering

- Chemical Weathering of Feldspar – an example of alteration of an original material to an entirely different type of mineral

  - feldspar is a framework silicate vs. a clay mineral is a hydrous aluminum silicate w/ a sheet-silicate structure

  - rainwater percolates into soil, picks up CO_2 from atmosphere and upper soil; the now slightly more acidic H_2O contacts feldspar in lower soil; acidic H_2O reacts w/ feldspar and alters it to clay.

Chemical weathering of feldspar to forma clay mineral

$2KAlSi_3O_8$ + [$2H^+$ + $2HCO_3^-$] + H_2O ->

K feldspar + (from CO_2 & H_2O)

$Al_2Si_2O_5(OH)_4$ + [$2K^+$ + $2HCO_3^-$] + $4SiO_2$

Clay mineral + (soluble ions) + silica in solution or as fine solid particles

The hydrogen ion attacks the feldspar structure, becomes incorporated into the clay mineral; when the hydrogen moves in, the potassium moves out and is carried away in solution as a dissolved ion… and silica?

Soil

- Feldspar gives off Ca^{++} and K^{+}, this accumulates loosely on surface of clay minerals, where a plant root is able to release H^{+} from organic acids and exchange is for the Ca^{++} or K^{+} the plant needs to grow.

Chem equations

Table 5.1

Chemical Equations Important to Weathering

A. Solution of Carbon Dioxide in Water to Form Acid

CO_2	+	H_2O	$\rightleftharpoons$	H_2CO_3	$\rightleftharpoons$	H^+	+	HCO_3^-
carbon dioxide		water		carbonic acid		hydrogen ion		bicarbonate ion

B. Solution of Calcite

$CaCO_3$	+	CO_2	+	H_2O	$\rightleftharpoons$	Ca^{++}	+	$2HCO_3^-$
calcite		carbon dioxide		water		calcium ion		bicarbonate ion

C. Solution of Calcite

$CaCO_3$	+	H^+	+	HCO_3^-	$\rightleftharpoons$	Ca^{++}	+	$2HCO_3^-$

D. Chemical Weathering of Feldspar to Form a Clay Mineral

$2KAlSi_3O_8$	+	$2H^+ + 2HCO_3^-$	+	H_2O	$\rightarrow$	$Al_2Si_2O_5(OH)_4$	+	$2K^+ + 2HCO_3^-$	+	$4\ SiO_2$
potassium feldspar		(from CO_2 and H_2O)				clay mineral		(soluble ions)		silica in solution or as fine solid particles

Wx products

Table 5.2

Weathering Products of Common Rock-Forming Minerals

Original Mineral	Under Influence of CO_2 and H_2O	Main Solid Product		Other Products (Mostly Soluble)
Feldspar	→	Clay mineral	+	Ions (Na^{+}, Ca^{++}, K^{+}), SiO_2
Ferromagnesian minerals (including biotite mica)	→	Clay mineral	+	Ions (Na^{+}, Ca^{++}, K^{+}, Mg^{++}), SiO_2, Fe oxides
Muscovite mica	→	Clay mineral	+	Ions (K^{+}), SiO_2
Quartz	→	Quartz grains (sand)		
Calcite	→	—		ons (Ca^{++}, HCO_3^{-})

Soil

- Clay minerals and quartz usually remain after complete wx of rx; both aid in development of soil and plant growth.
- Quartz -> sand grains -> good porosity
- Clay minerals -> hold H_2O and plant nutrients in soil. Clay plates have negative electrical charge on surface, allowing attraction of H_2O and nutrient ions to surface of clay.

Chemical Weathering

- Role of acid

  - Carbonic acid is the single most effective agent of chemical weathering at the earth's surface.

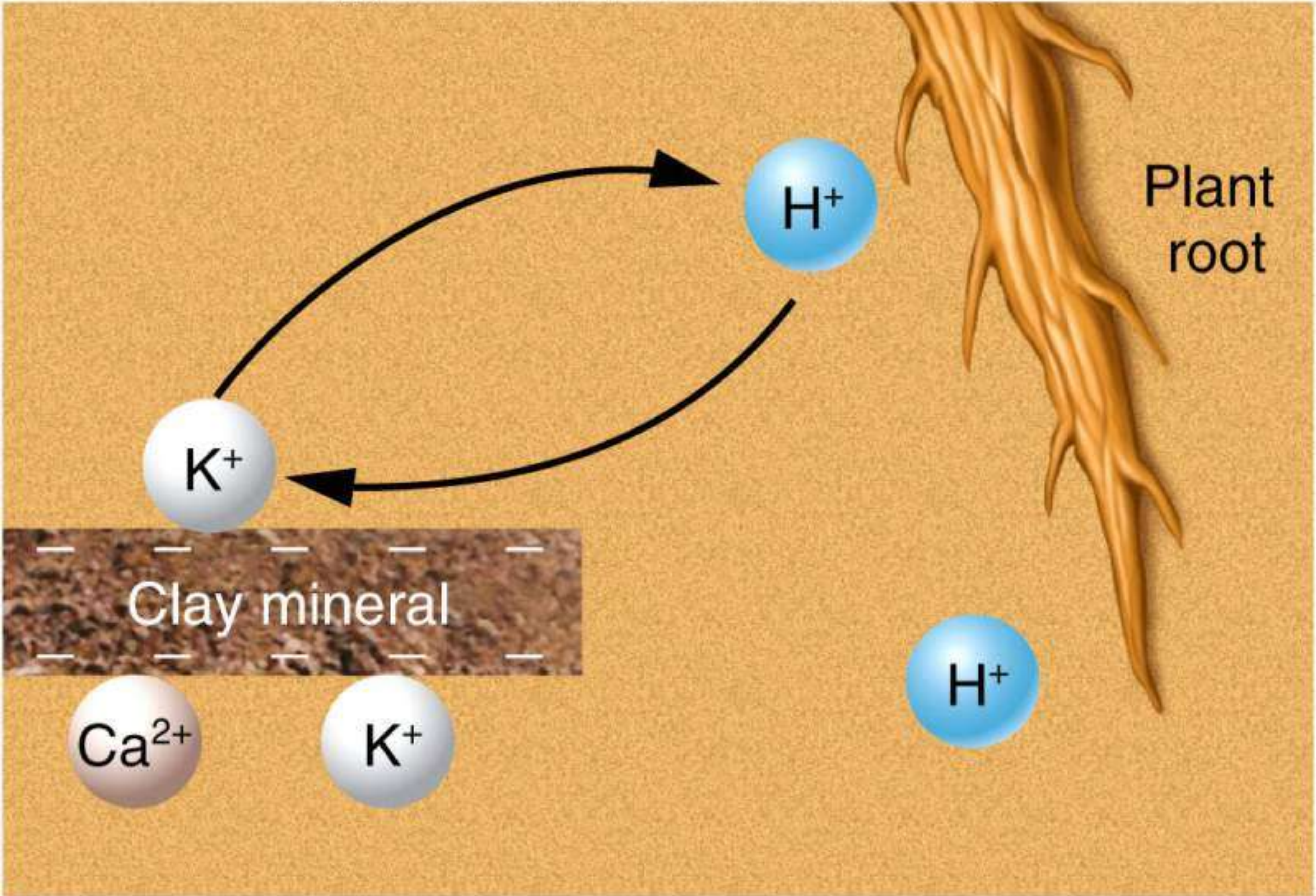
  - Acid rain and soil…

Chemical Weathering

- Role of acid – acid is the most effective agent of chemical weathering.

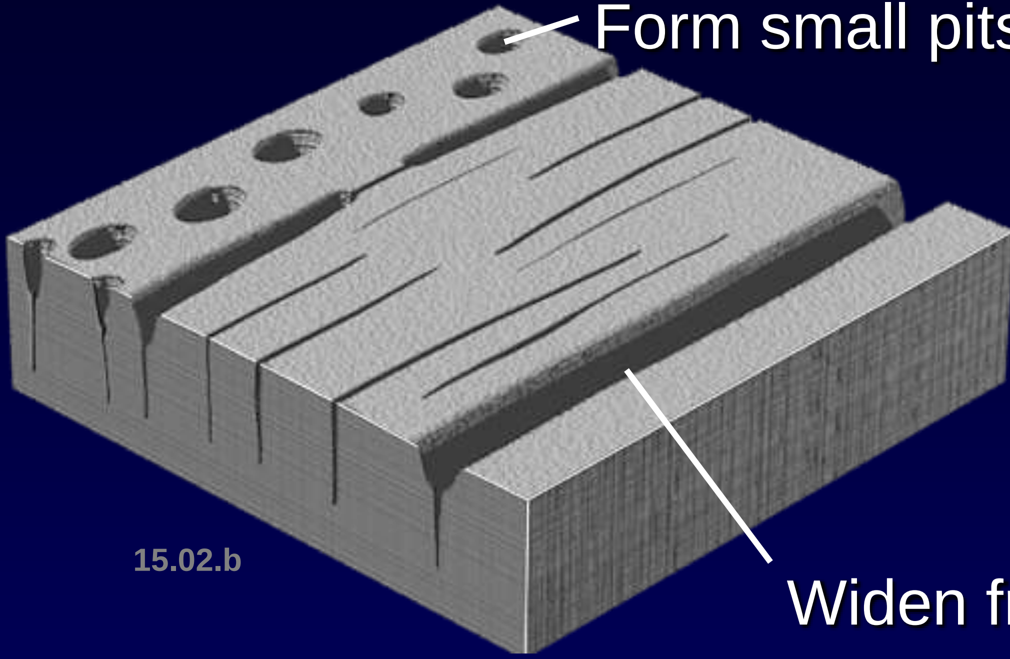
  - An acid is a compound that gives off hydrogen ions (H^+) when they break down in water (strong vs. Weak).

  - The hydrogen ion can substitute for other positive ions within minerals (ca^{++}, Na^+, or K^+) because it has a positive electrical charge and a very small size.



Plant root
H^+
K^+
Clay mineral
Ca^{2+}
K^+
H^+

Observe what happens when rocks dissolve



Form small pits

Widen fractures

One way that calcite dissolves in water

$$CaCO_3 + H_2CO_3 \longrightarrow Ca^{2+} + 2(HCO_3)^-$$

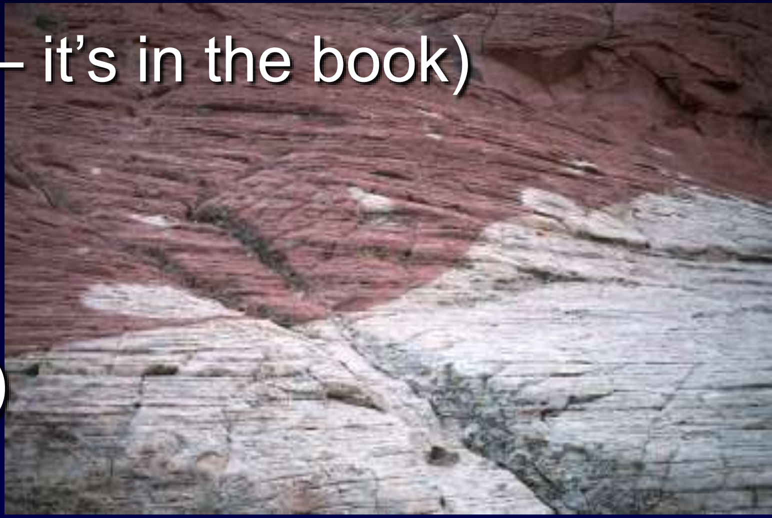
Calcite + Carbonic acid → Calcium ion + Bicarbonate ion in solution

How Rocks Oxidize Near Earth's Surface

(don't copy this formula down – it's in the book)

$$4FeSiO_3 + O_2 \longrightarrow 2Fe_2O_3 + 4SiO_2$$

pyroxene oxygen hematite silica (in water)



How the Process of Hydrolysis Operates

K-feldspar + water

↓

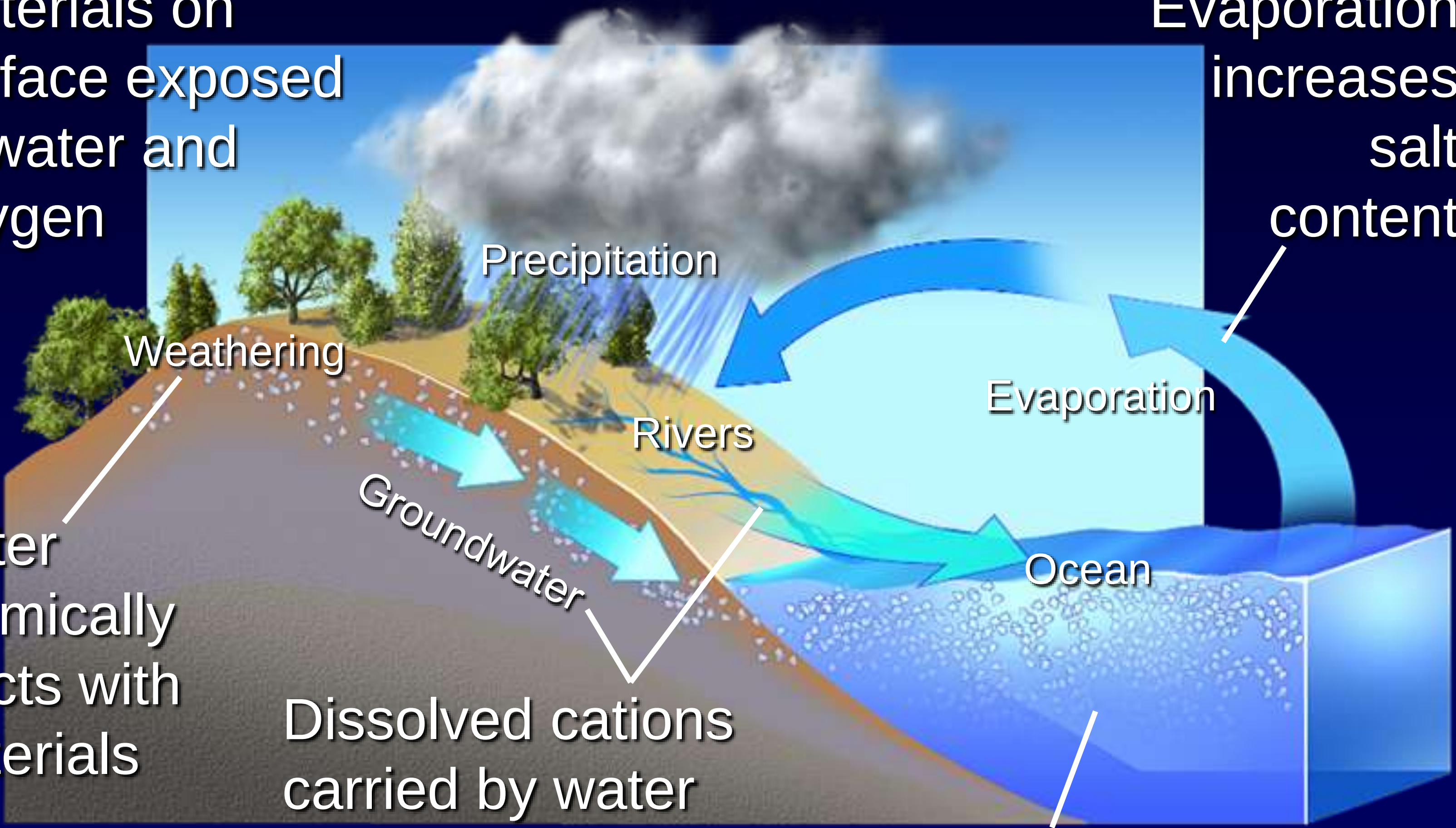
kaolinite (clay) + potassium (in water) + silica (in water)

15.02.c

How Weathering Makes the Oceans Salty

Materials on surface exposed to water and oxygen

Evaporation increases salt content



Water chemically reacts with materials

Dissolved cations carried by water to oceans

Salt concentrates in oceans

15.02.e1

How Different Rocks Respond to Weathering

15.03.a

Quartzite insoluble; weathers slowly

Limestone dissolves

Each mineral in granite weathers differently

Some rocks weather into angular blocks

Some rocks weather into small chips

15.01.d

Controls on How Minerals Weather

Chemical Bonding

Halite has ionic bonds (soluble)

15.03.d

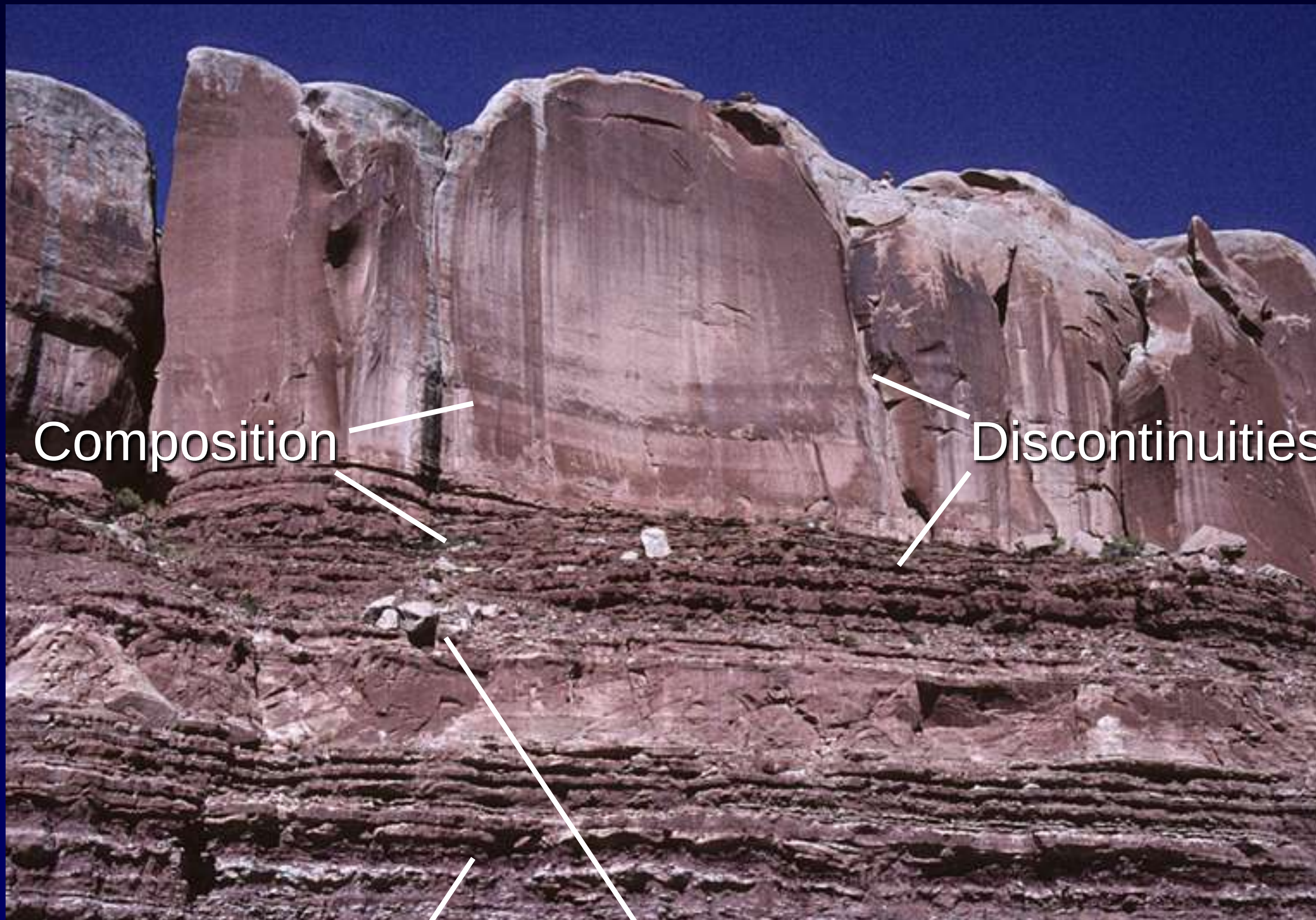
Quartz has covalent bonds (less soluble)

Reactivity

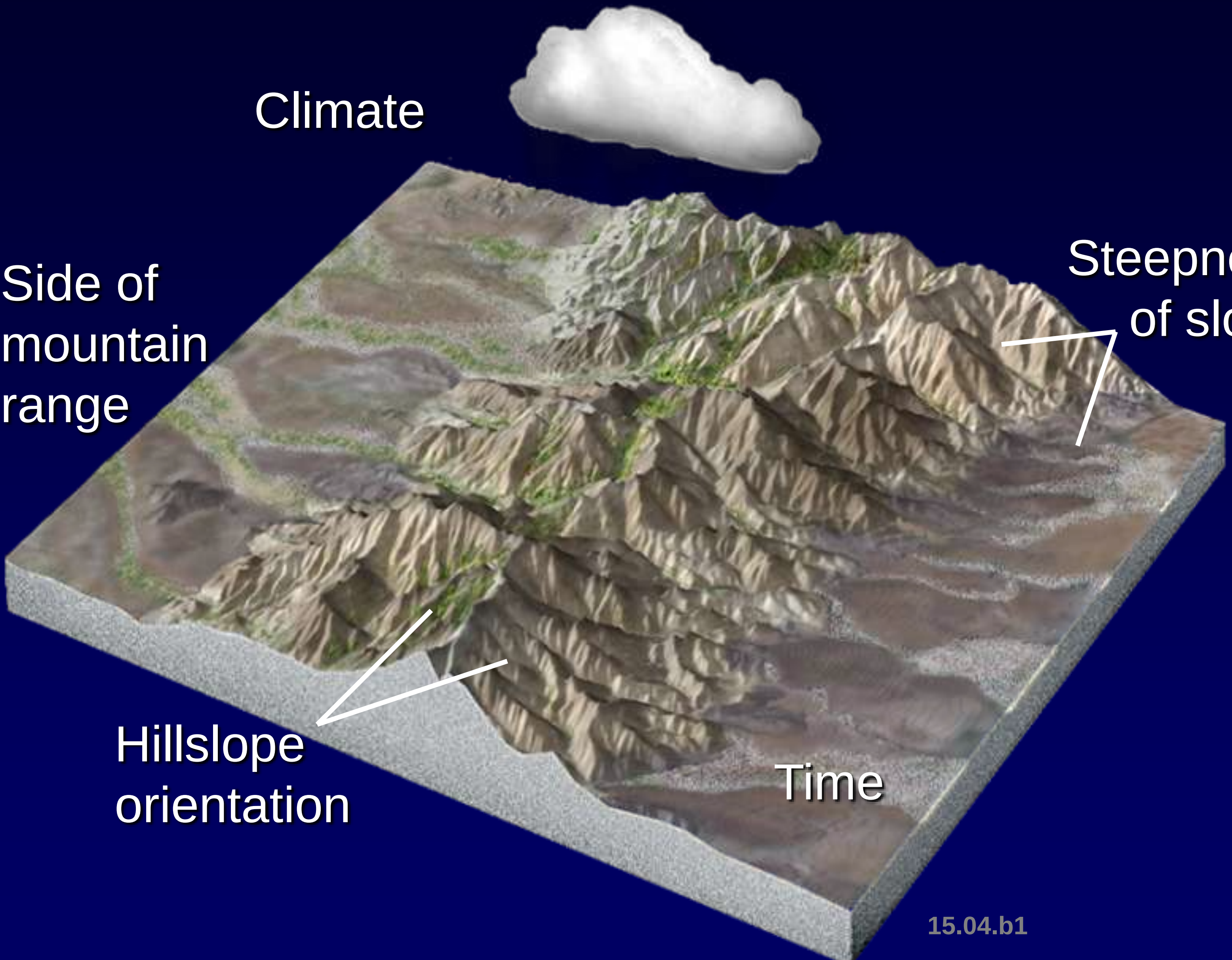
Limestone is calcite (soluble)

Most sandstone is quartz, (less soluble)

Factors that Influence Weathering

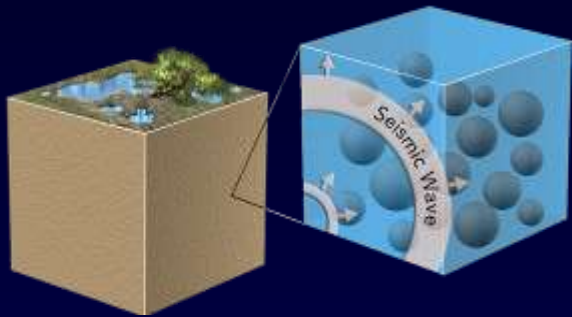


Other Factors that Influence Weathering

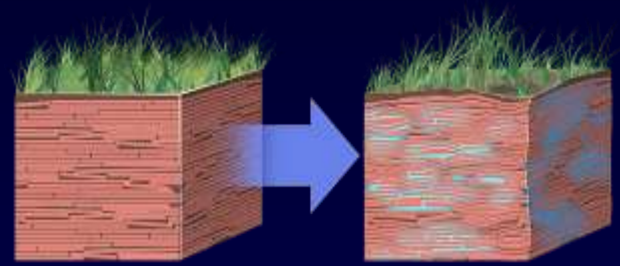


Activities that Threaten Soil

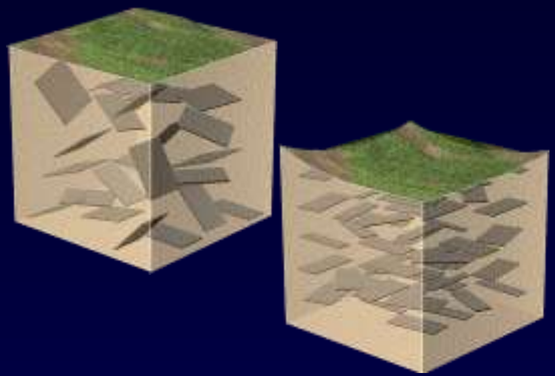
Observe some problems related to soil



Liquefaction



Swelling clays



Soil compaction

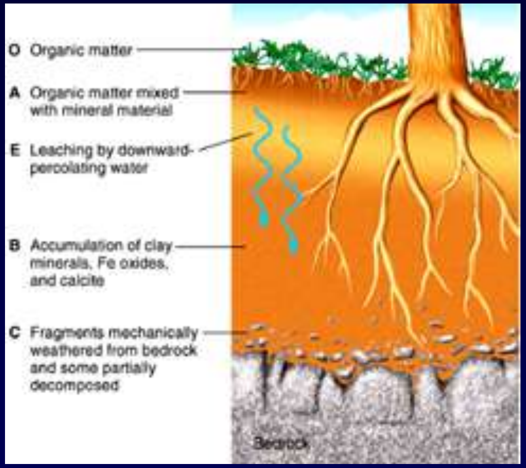
Liquefaction during an earthquake

Road destroyed by swelling clays

Cracks caused by compaction

Soil

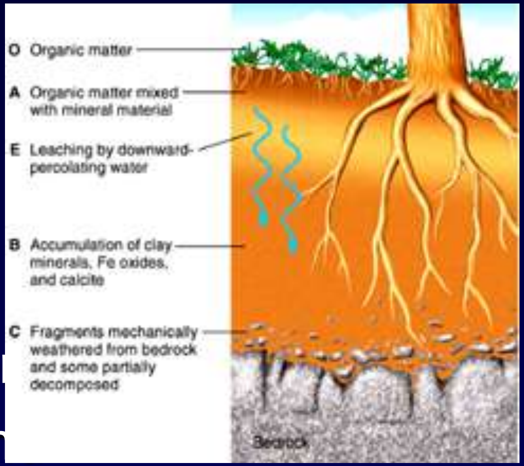
- *Soil* - a layer of weathered, unconsolidated material on top of bedrock
  - Common soil constituents:
    - *Clay minerals*
    - *Quartz*
    - *Water*
    - *Organic matter*

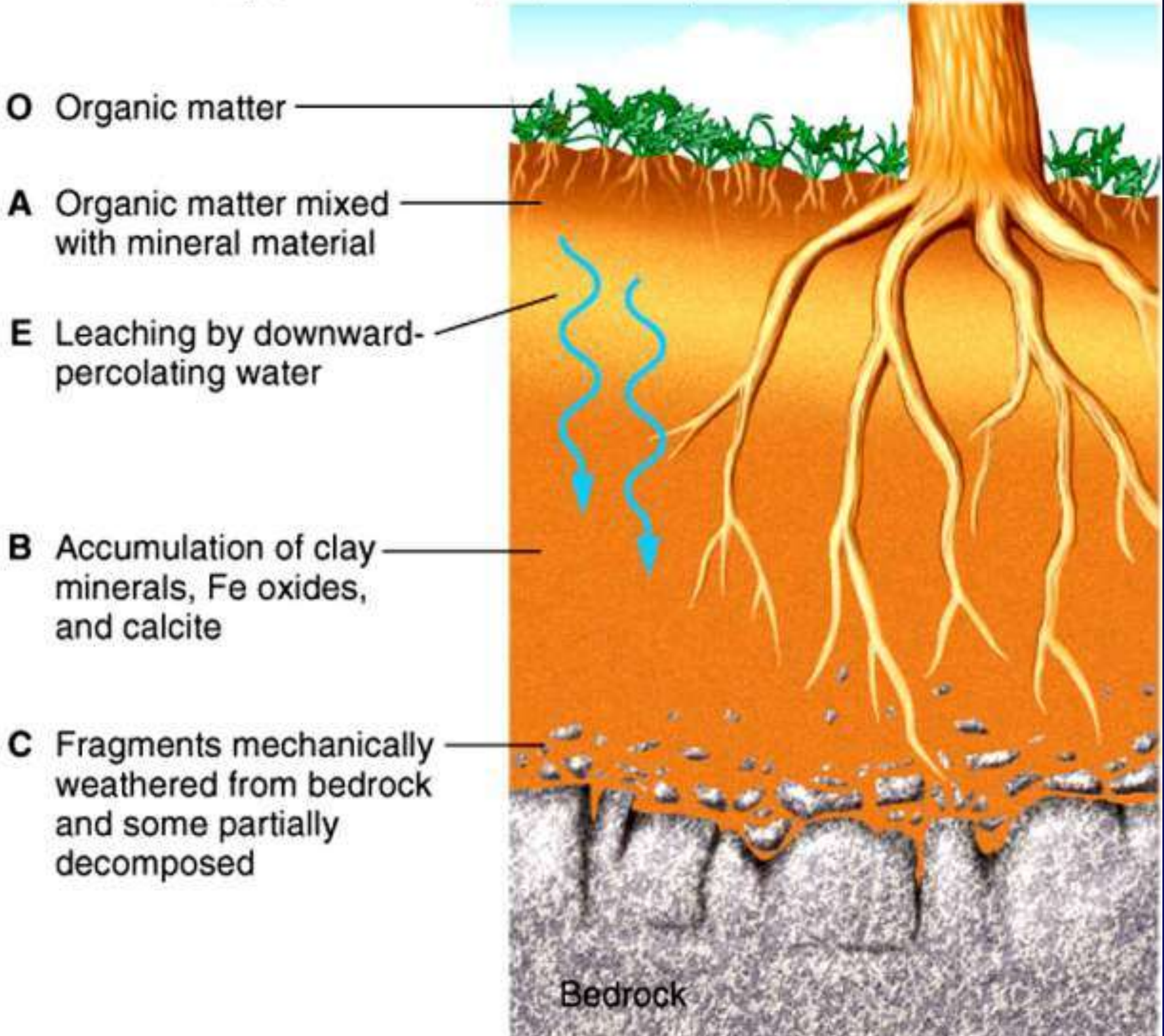


Soil horizons

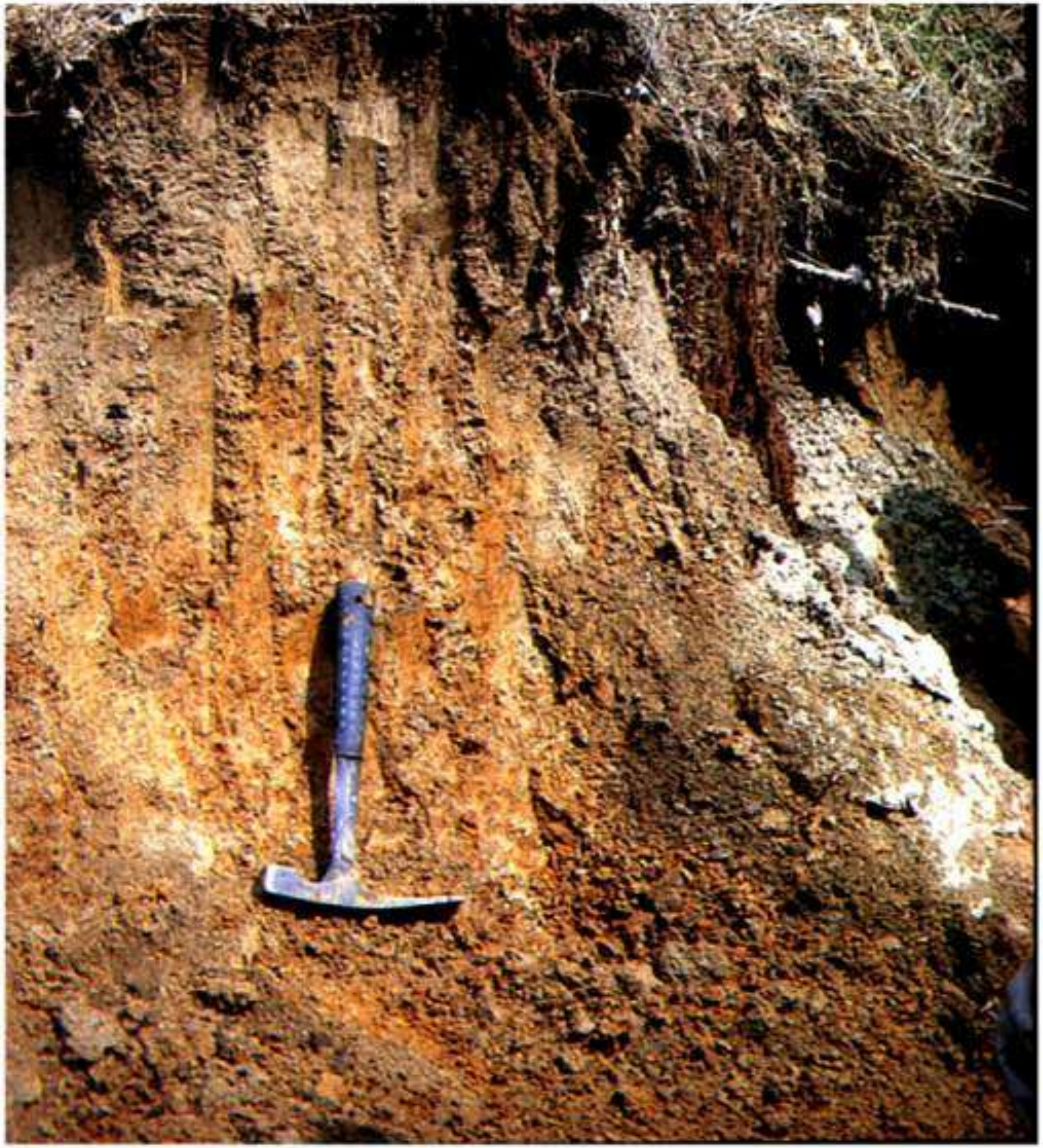
Soil horizons

- *O horizon* - uppermost layer; organic material
- *A horizon* - dark layer rich in *humus*, organic acids
- *E horizon* - zone of leaching; fine-grained components removed by percolating wate
- *B horizon* - zone of accumulation; clays an iron oxides leached down from above
- *A horizon* - partially weathered bedrock




O Organic matter
A Organic matter mixed with mineral material
E Leaching by downward-percolating water
B Accumulation of clay minerals, Fe oxides, and calcite
C Fragments mechanically weathered from bedrock and some partially decomposed
Bedrock

A



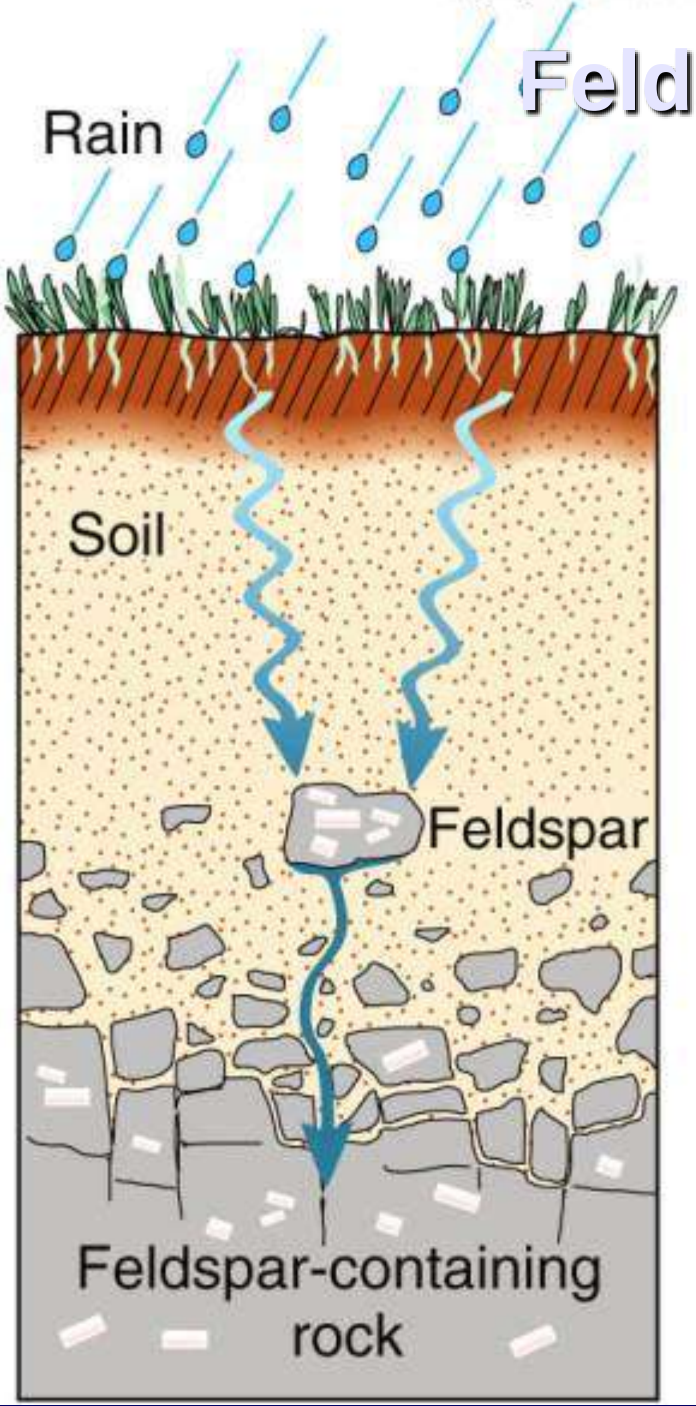
B

O = organic

E -leached

B = clay

Feldspar weathering



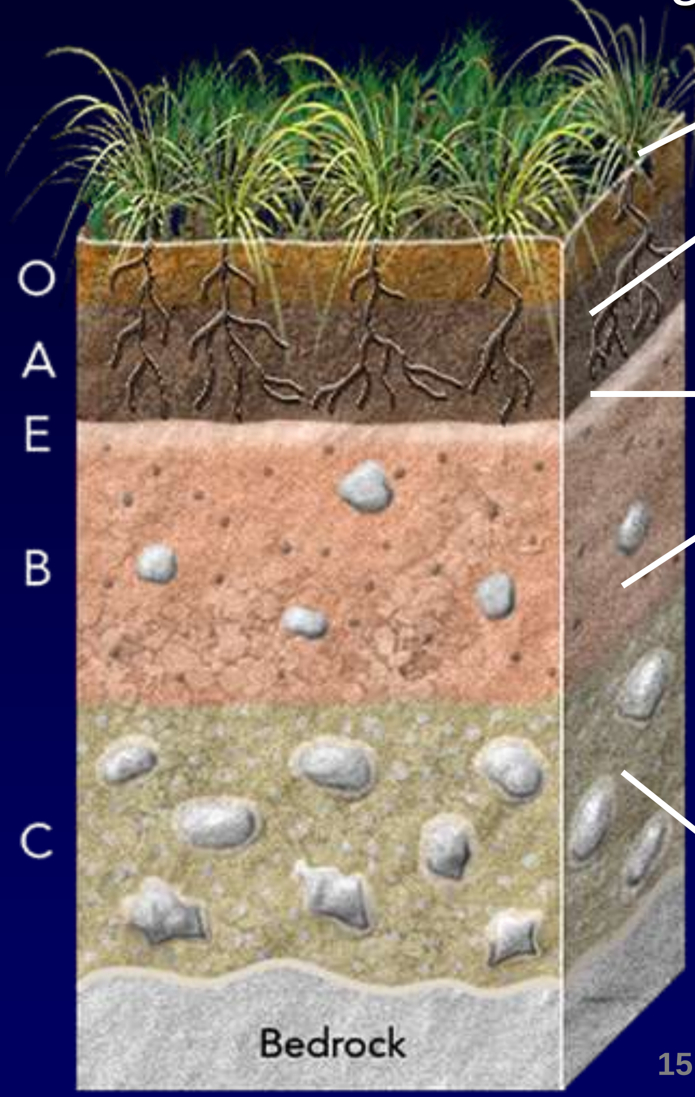
Rain picks up CO_2 from the atmosphere and becomes acidic

Water percolating through the ground picks up more CO_2 from the upper part of the soil, becoming more acidic

A rock particle containing a feldspar crystal, loosened from the rock below, slowly alters to a clay mineral as it reacts with the acidic water

The water carries away soluble ions and SiO_2 to the ground-water supply or to a stream

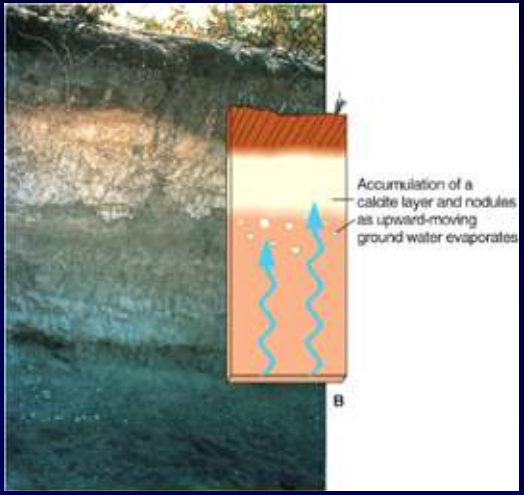
Observe this cut through soil



Soil layers are *horizons* and assigned letters

Soils and Climate

- Soil thickness and composition are greatly affected by climate
  - Wet climates:
    - More chemical weathering and thicker soils
    - Soils in moderately wet climates tend to have significant clay-rich layers, which may be solid enough to form a *hardpan*
  - Arid climates:
    - Less chemical weathering and thinner soils
    - Subsurface evaporation leads to build-up of salts
    - Calcite-rich accumulation zones may form, cementing soil together into a *hardpan*
  - Extremely wet climates (e.g., tropical rainforest)
    - Highly leached and unproductive soils (*laterites*)
    - Most nutrients come from thick O/A horizons



Processes of Soil Formation

Where Material Comes From

How Material Moves

Water, organic matter, and sediment from surface

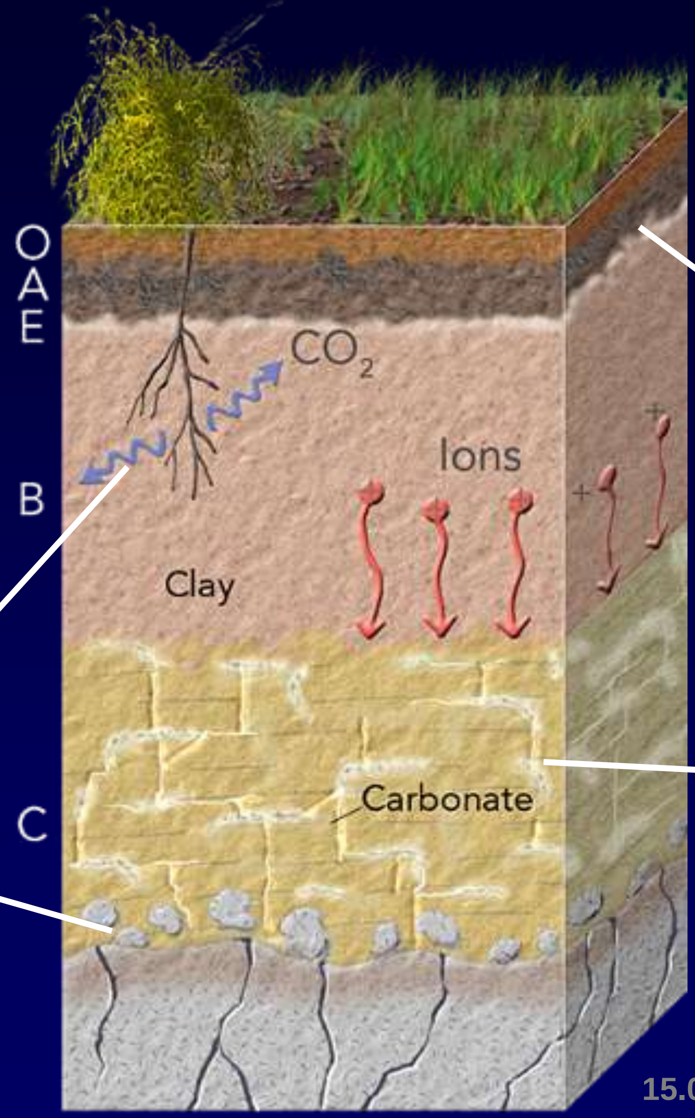
Gas from roots

Weathering weakens underlying bedrock

Ions leached from upper part

Clay and fine particles work downward

Calcite accumulates (in dry climates)



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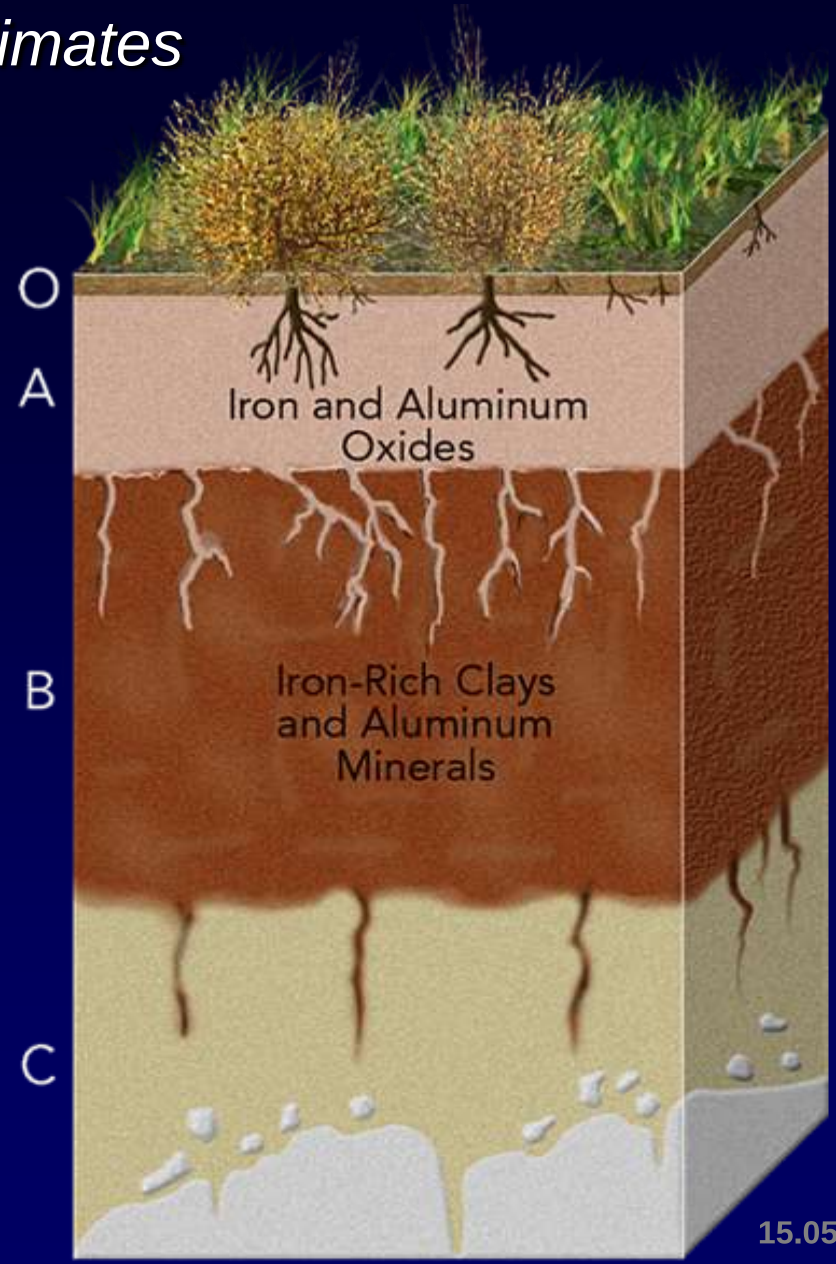
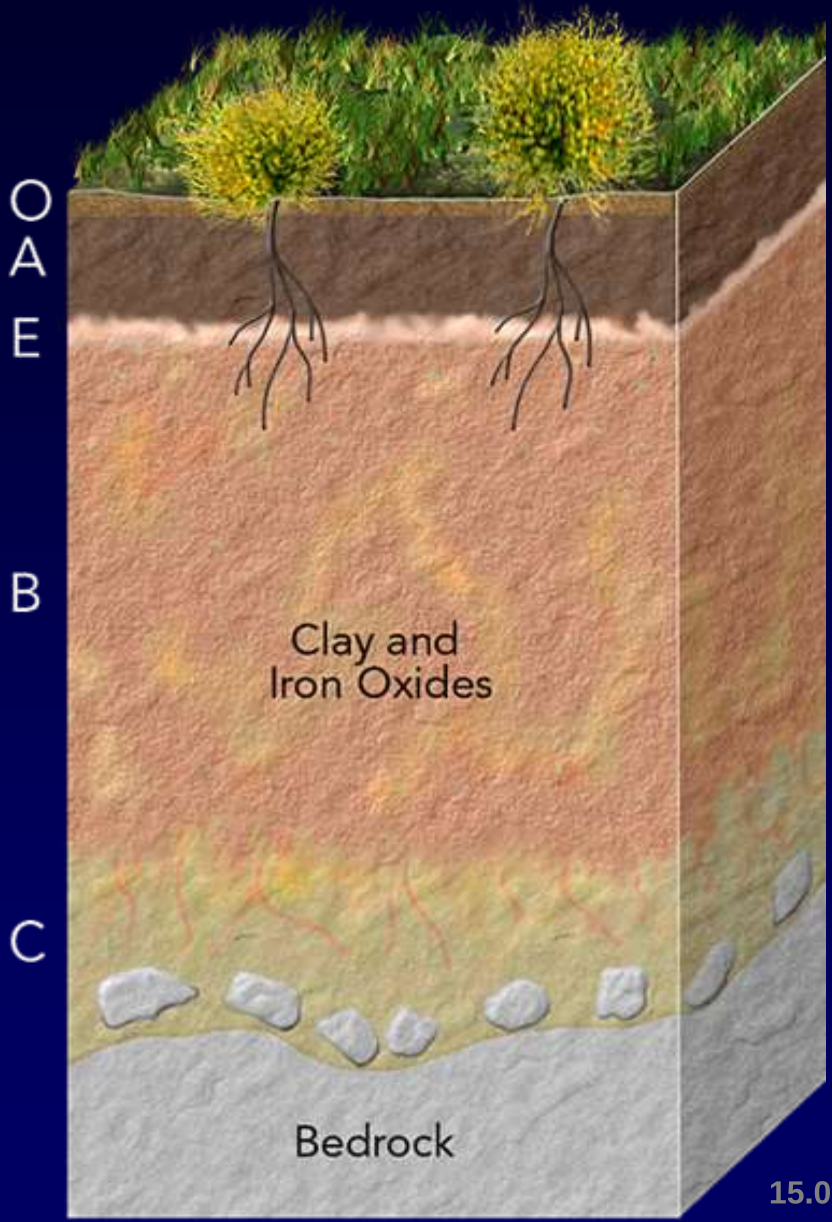
Observe soils in tropical climates

Extremely leached soil: *laterite*



Observe soils in temperate climates



15.05.c

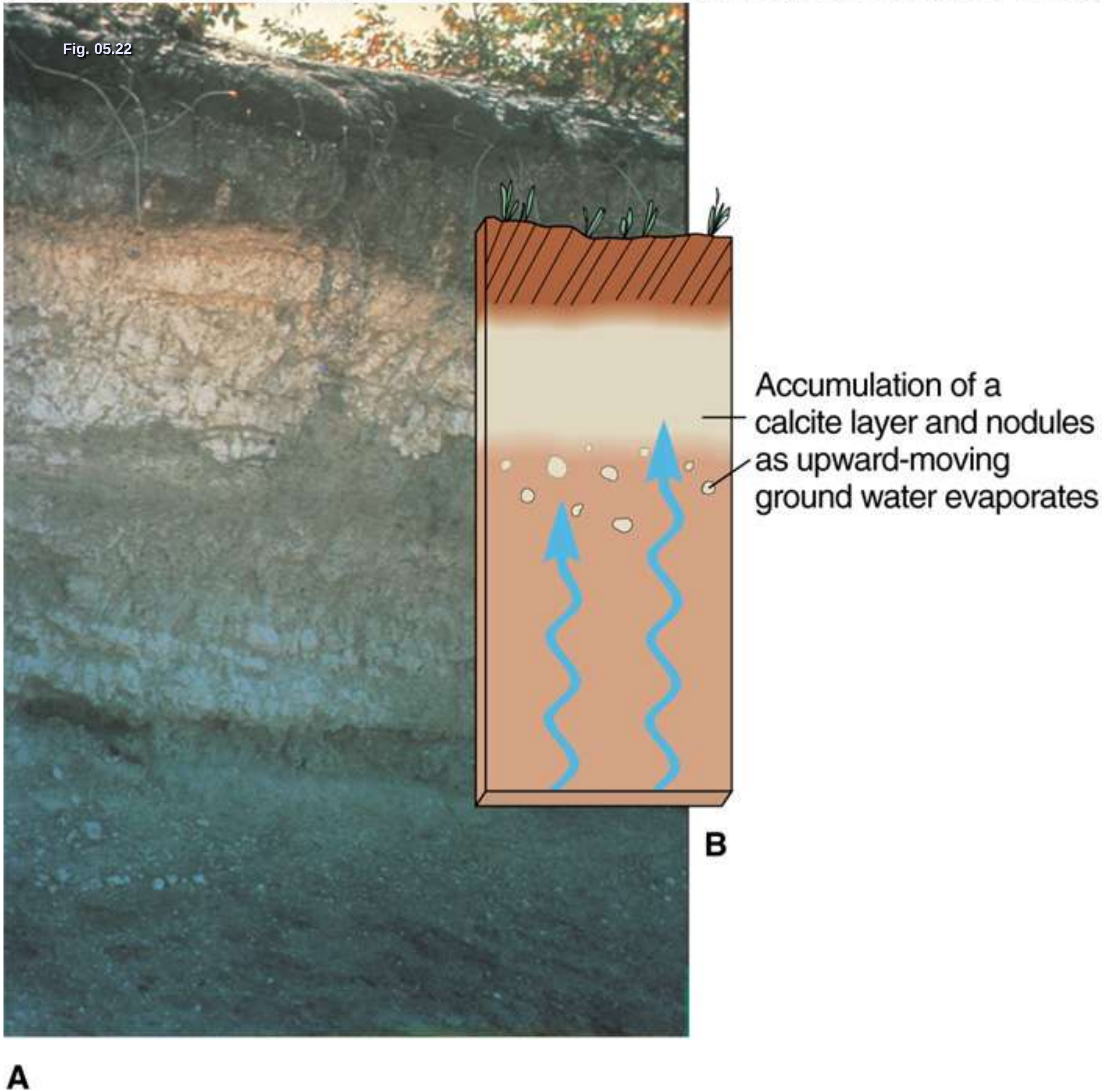
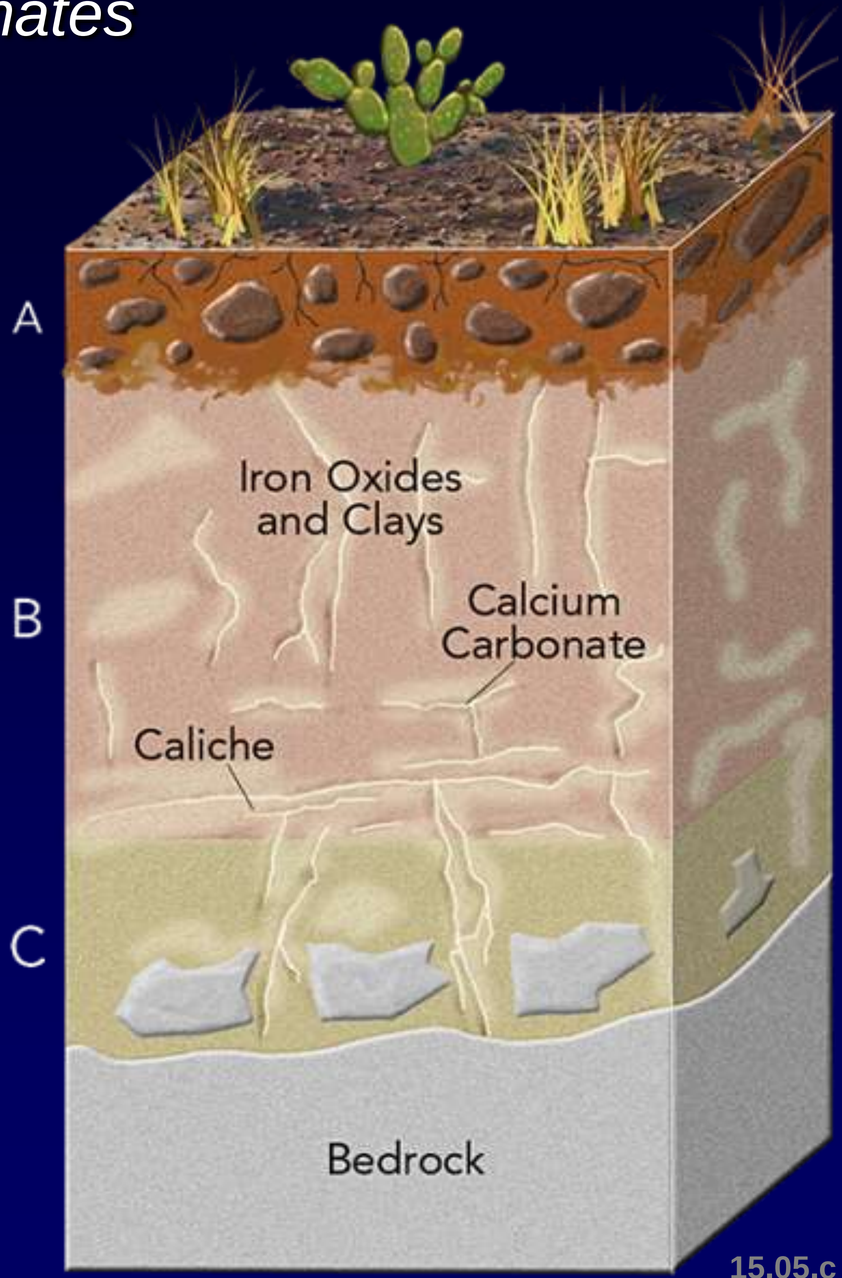


Photo by D. Yost, USDA-Soil Conservation Service

Observe soils in arid climates



15.05.c

Observe what happens when granite weathers

Feldspar weathers by hydrolysis to clay minerals

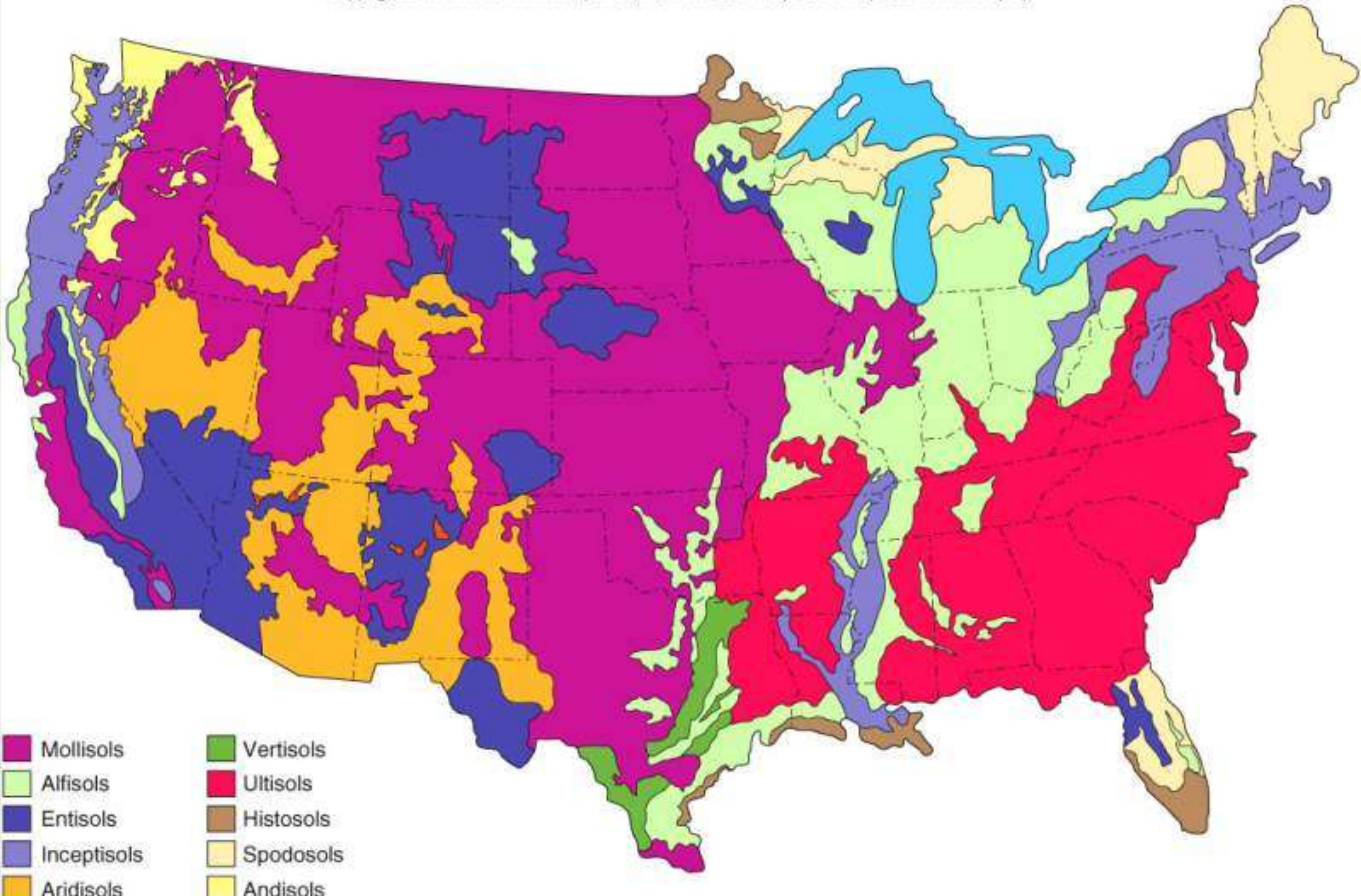
Clay minerals accumulate in soil or muddy environments

Mafic minerals form clay minerals or oxidize to hematite

Quartz is hard some weathers to quartz grains

Quartz grains become quartz sand

15.03.b


Mollisols
Alfisols
Entisols
Inceptisols
Aridisols
Vertisols
Ultisols
Histosols
Spodosols
Andisols

Soil types

Table 5.3

Soil Orders

Soil Orders (meaning of name)	Description
Gelisols (frozen soils)	Soils with permafrost within 2 meters of the surface
Histosols (organic soils)	Wet, organic soils such as peat in swamps and marshes
Spodosols (ashy soils)	Acid soils low in plant nutrient ions with subsurface accumulation of organic matter and compounds of aluminum and iron; cool, humid forests
Andisols (volcanic ash)	Soils formed in volcanic ash
Oxisols (oxide soils)	Heavily weathered soils low in plant nutrient ions and rich in aluminum and iron oxides; tropical, usually moist
Vertisols (inverted soils)	Clayey soils that swell when wet and shrink when dry, forming wide, deep cracks
Aridisols (arid soils)	Dry, desert soils low in organic matter and with carbonate horizons
Ultisols (ultimate soils)	Strongly weathered soils low in plant nutrient ions with clay accumulation in the subsurface; usually moist
Mollisols (soft soils)	Nearly black surface horizon rich in organic matter and plant nutrient ions; subhumid to subarid grasslands
Alfisols (pedalfers)	Gray to brown surface horizon, subsurface horizon of clay accumulation; medium to high in plant nutrient ions, usually moist, as in humid forests
Inceptisols (beginning soils)	Very young soils that have weak horizons; usually moist
Entisols (recent soils)	Soils that have no horizons

Soil thickness

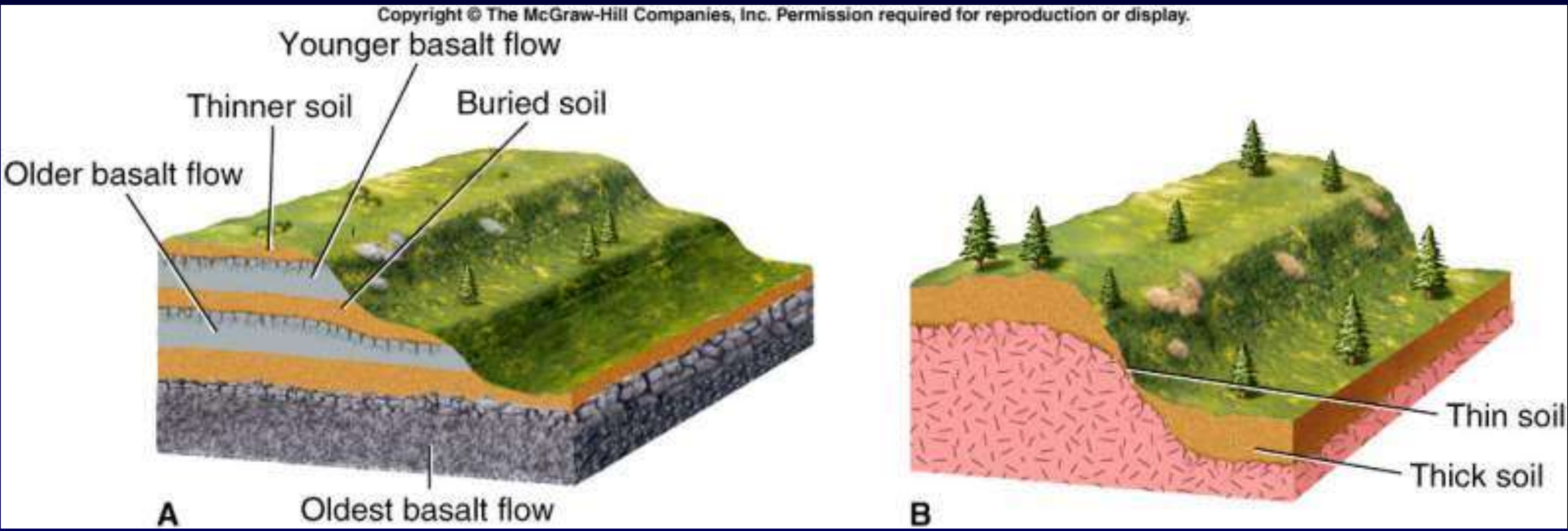
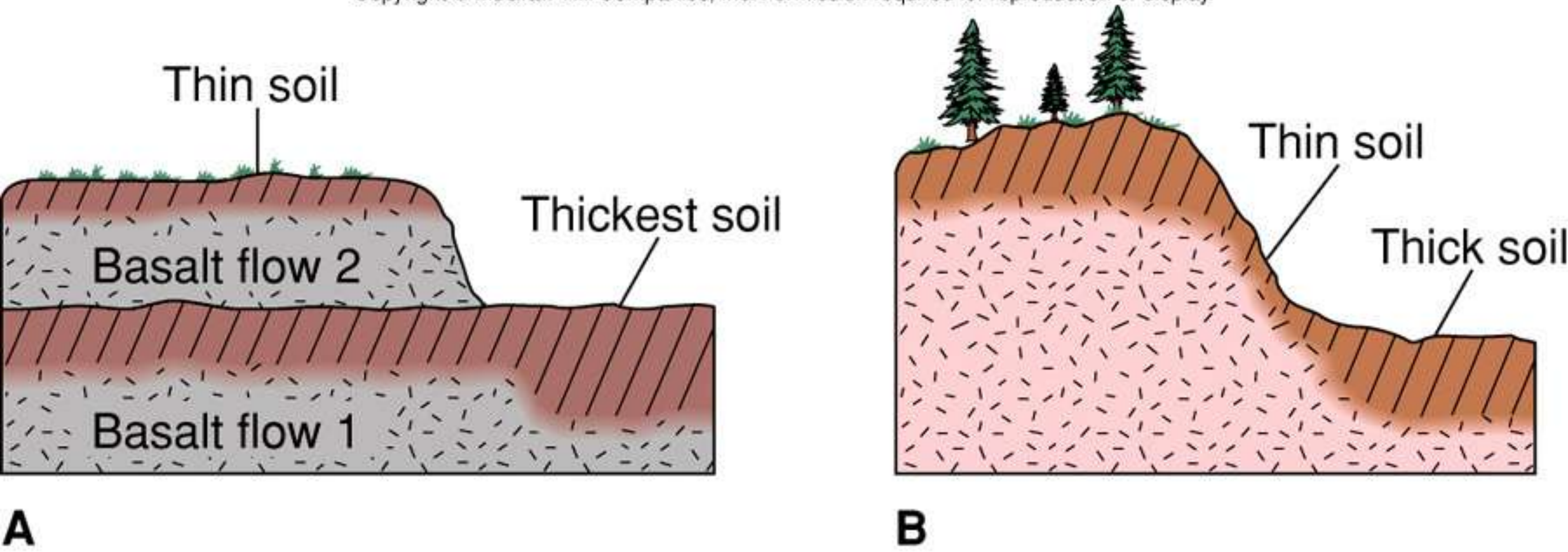


Fig. 05.21


Thin soil
Thickest soil
Basalt flow 2
Basalt flow 1
A
Thin soil
Thick soil
B

Chemical Weathering

- Weathering and climate

  - Chemical wx most intense where abundant H_2O is present; chemical wx is slow or absent in areas of scarce H_2O

  - Limestone in humid vs. arid climates

Soil

- Soils and climate

  - Climate affects soil thickness and character.

  - Wet climates produce soils that are usually thick and have downward movement of water through the earth materials.

  - Dry climates produce thin soils with little or no leaching and with upward movement of soil water (drawn up by subsurface evaporation and capillary action).

Soil

- Hardpans.

  - In humid areas are formed by clay minerals, silica, and iron compounds that have accumulated in the B horizon.

  - In arid climates, hardpans form by the cementing of soil by calcium carbonate and other salts that precipitate in the soil as water evaporates.

  - Both are layers of rock within loose soil.

Soil

- Soil Horizons and Classification

  - Rate of soil formation is controlled by rainfall, temp, slope, and bedrock; the higher the rainfall and temp the faster formation of soil; in general, fully developed soil that can support plant growth takes hundreds or thousands of years to form.

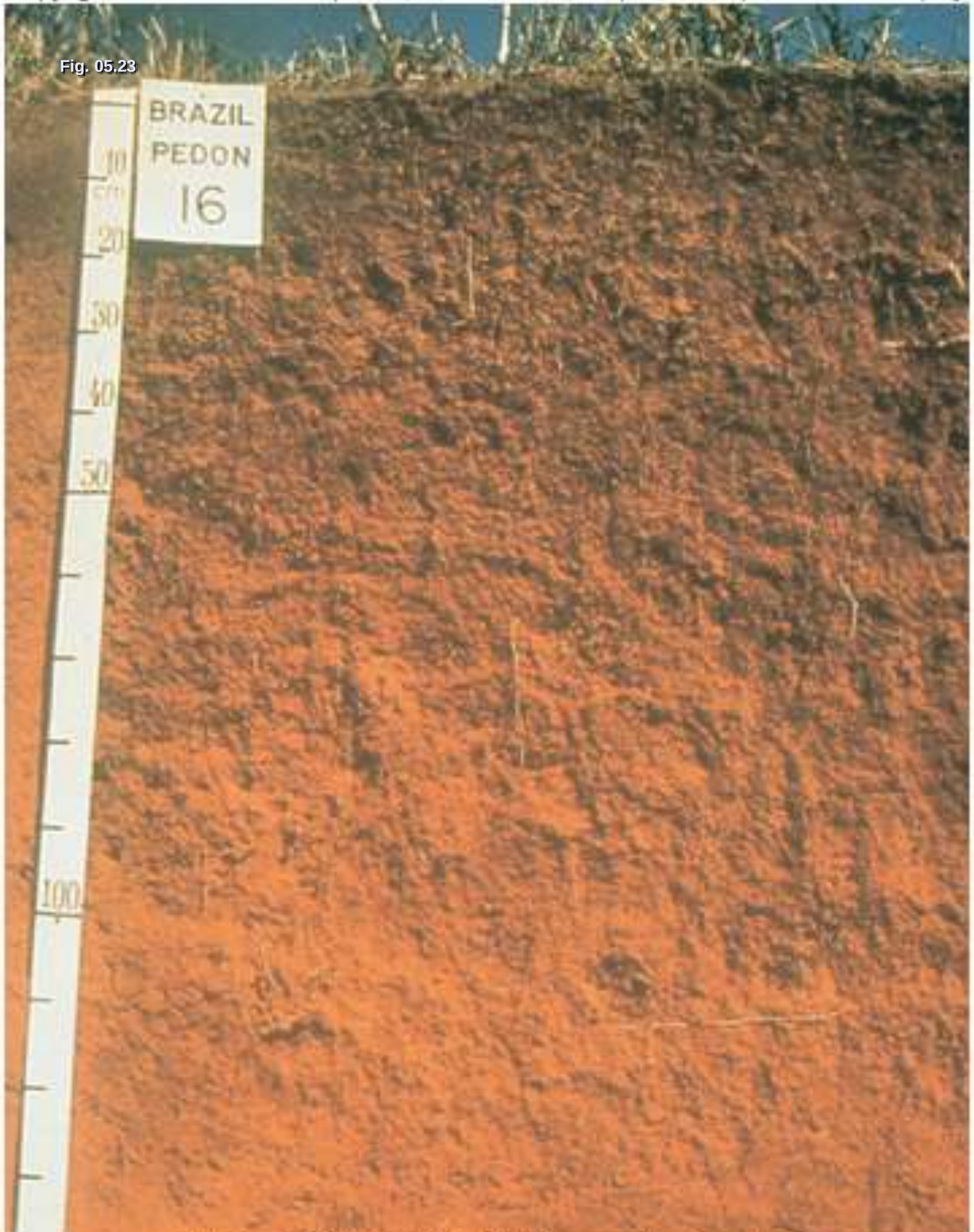
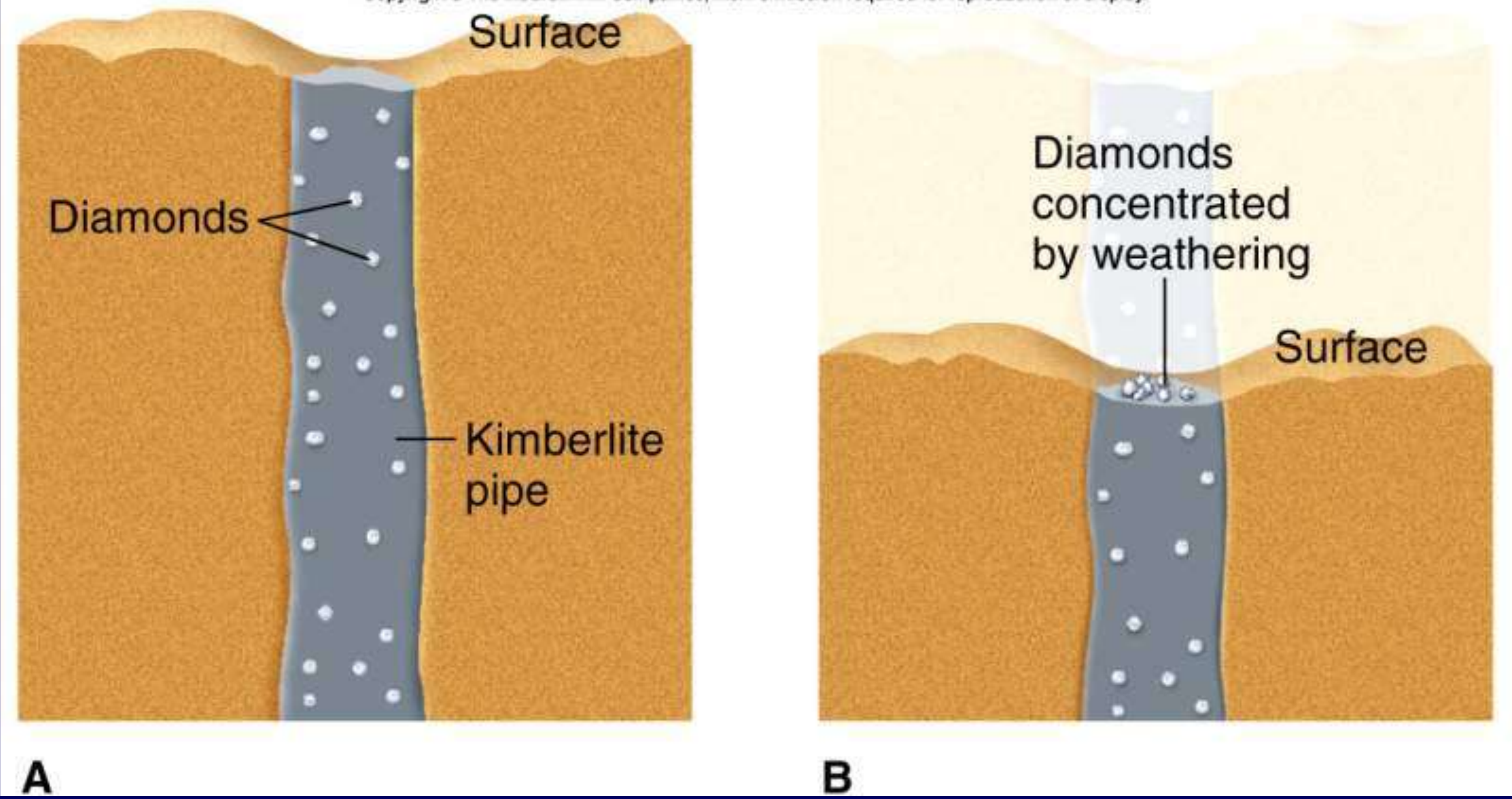


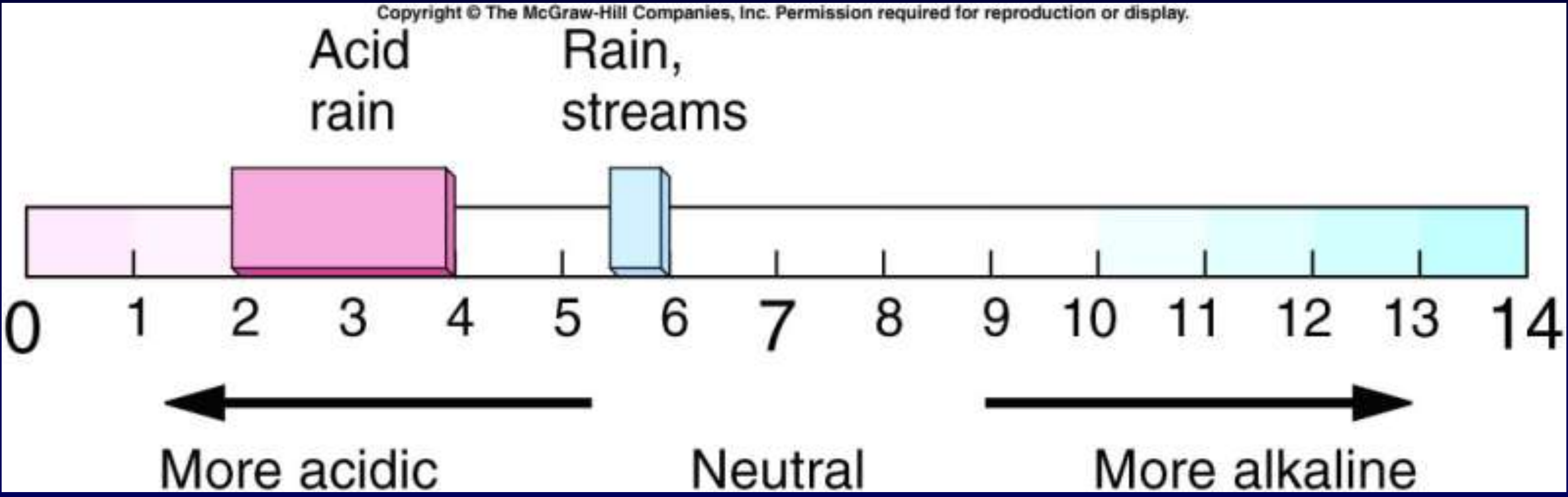
Photo by D. Yost, USDA-Soil Conservation Service

Residual concentration by weathering



Malaysia – clear cutting

pH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Acid rain
Rain, streams
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
More acidic
Neutral
More alkaline

Soil

- Residual and Transported Soils

  - residual soil is one that develops from wx of the rock directly beneath it.

  - transported soils did not form from the local rock but from regolith brought in from some other region.

Soil

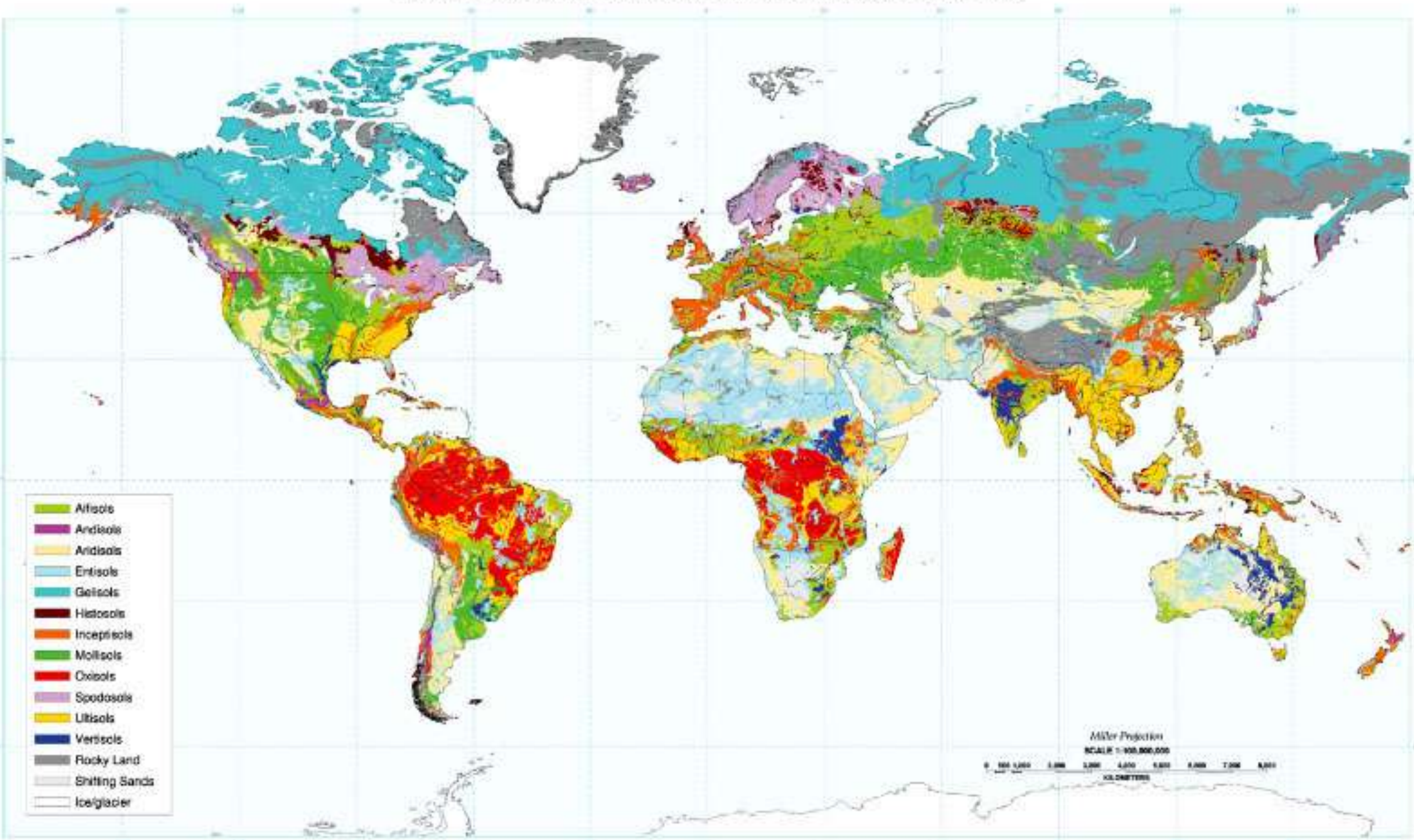
- Soils, parent material, time, and slope

  - The fertile agricultural soils of the Canadian plains and the northern US took more than 10,000 years to develop on glacial deposits after the thick continental ice sheets melted.

Chapter 11

Soil as a Resource

Figure 11.8


Alfisols
Andisols
Aridisols
Entisols
Gelisols
Histosols
Inceptisols
Mollisols
Oxisols
Spodosols
Ultisols
Vertisols
Rocky Land
Shifting Sands
Ice/glacier
Miller Projection
KILOMETERS

Soil Formation

- **Soil** – several ways to define
  - Unconsolidated material overlying bedrock
  - Material capable of supporting plant growth
  - **Regolith** encompasses all unconsolidated material at the surface, fertile or not
- Soil: is produced by weathering
  - Involves chemical, physical, biological processes to breakdown rocks
  - Climate, topography, source material composition, and time are factors

Soil-Forming Processes
Weathering

- Climate and water a major factor
- **Mechanical Weathering:** physical breakdown of minerals by mechanical action. No changes chemically.
  - Freezing water expansion
    Frost wedging
  - Break up of rocks and minerals without changing the rock's composition
  - Salt crystallization can wedge cracks
- **Chemical Weathering:** breakdown of minerals by chemical reaction

Figure 11.1

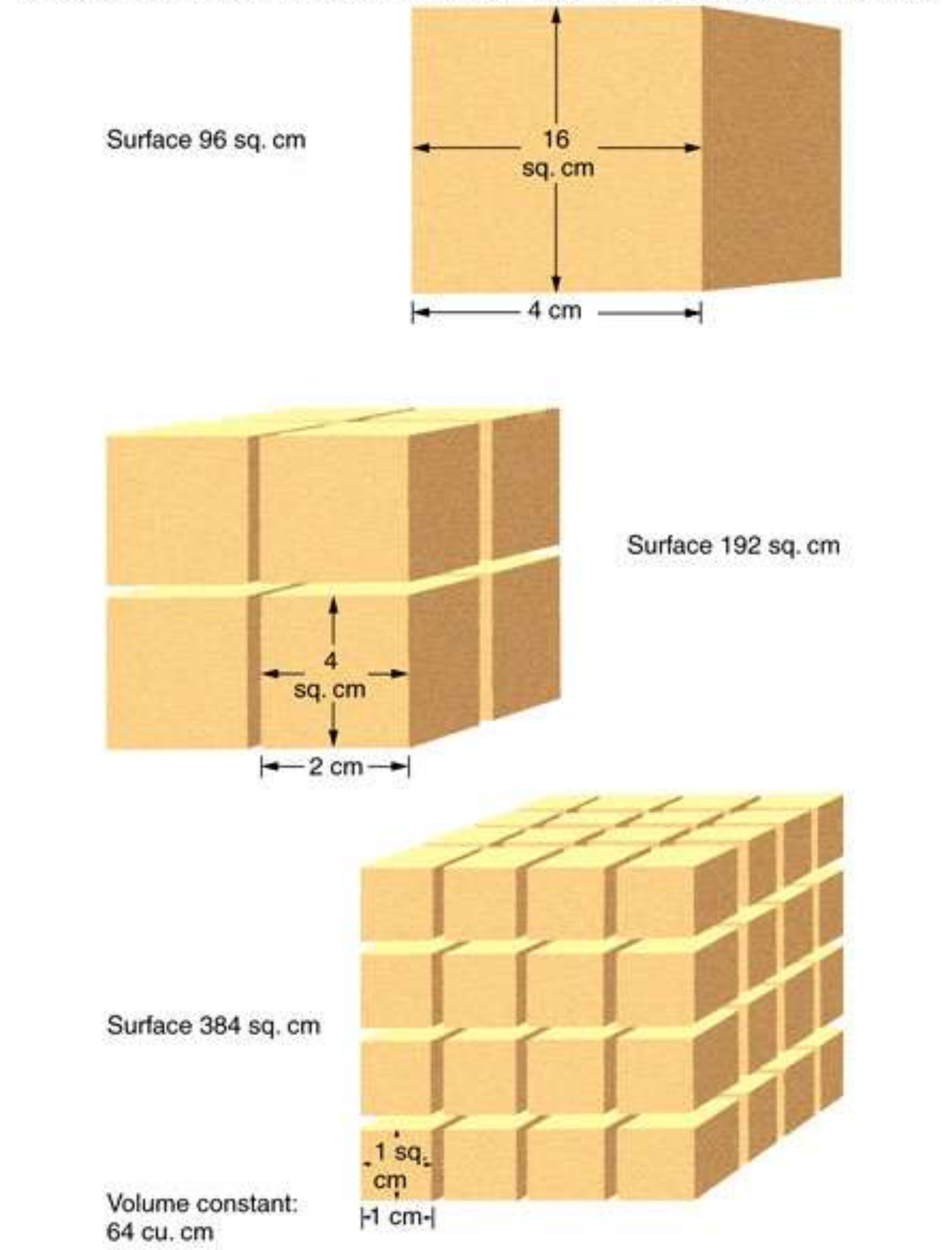

Surface 96 sq. cm
16
sq. cm
4 cm
4
sq. cm
2 cm
Surface 192 sq. cm
Surface 384 sq. cm
1 sq.
cm
1 cm
Volume constant:
64 cu. cm

TABLE 11.1

Some Chemical Weathering Reactions

Solution of calcite (no solid residue)

$CaCO_3 + 2\,H^+ = Ca^{2+} + H_2O + CO_2$ (gas)

Breakdown of ferromagnesians (possible mineral residues include iron compounds and clays)

$FeMgSiO_4$ (olivine) $+ 2\,H^+ = Mg^{2+} + Fe(OH)_2 + SiO_2$*

$2\,KMg_2FeAlSi_3O_{10}(OH)_2$ (biotite) $+ 10\,H^+ + \frac{1}{2}\,O_2$ (gas) $=$
$2\,Fe(OH)_3 + Al_2Si_2O_5(OH)_4$ (kaolinite, a clay) $+$
$4\,SiO_2$* $+ 2\,K^+ + 4\,Mg^{2+} + 2\,H_2O$

Breakdown of feldspar (clay is the common residue)

$2\,NaAlSi_3O_8$ (sodium feldspar) $+ 2\,H^+ + H_2O =$
$Al_2Si_2O_5(OH)_4 + 4\,SiO_2$* $+ 2\,Na^+$

Solution of pyrite (making dissolved sulfuric acid, H_2SO_4)

$2\,FeS_2 + 5\,H_2O + \frac{15}{2}\,O_2$ (gas) $= 4\,H_2SO_4 + Fe_2O_3 \cdot H_2O$

Notes: Hundreds of possible reactions could be written; the above are only examples of the kinds of processes involved.

All ions (charged species) are dissolved in solution; all other substances, except water, are solid unless specified otherwise.

Commonly, the source of the H^+ ions for solution of calcite and weathering of silicates is carbonic acid, H_2CO_3, formed by solution of atmospheric CO_2.

*Silica is commonly removed in solution.

Soil-Forming Processes
Chemical Weathering

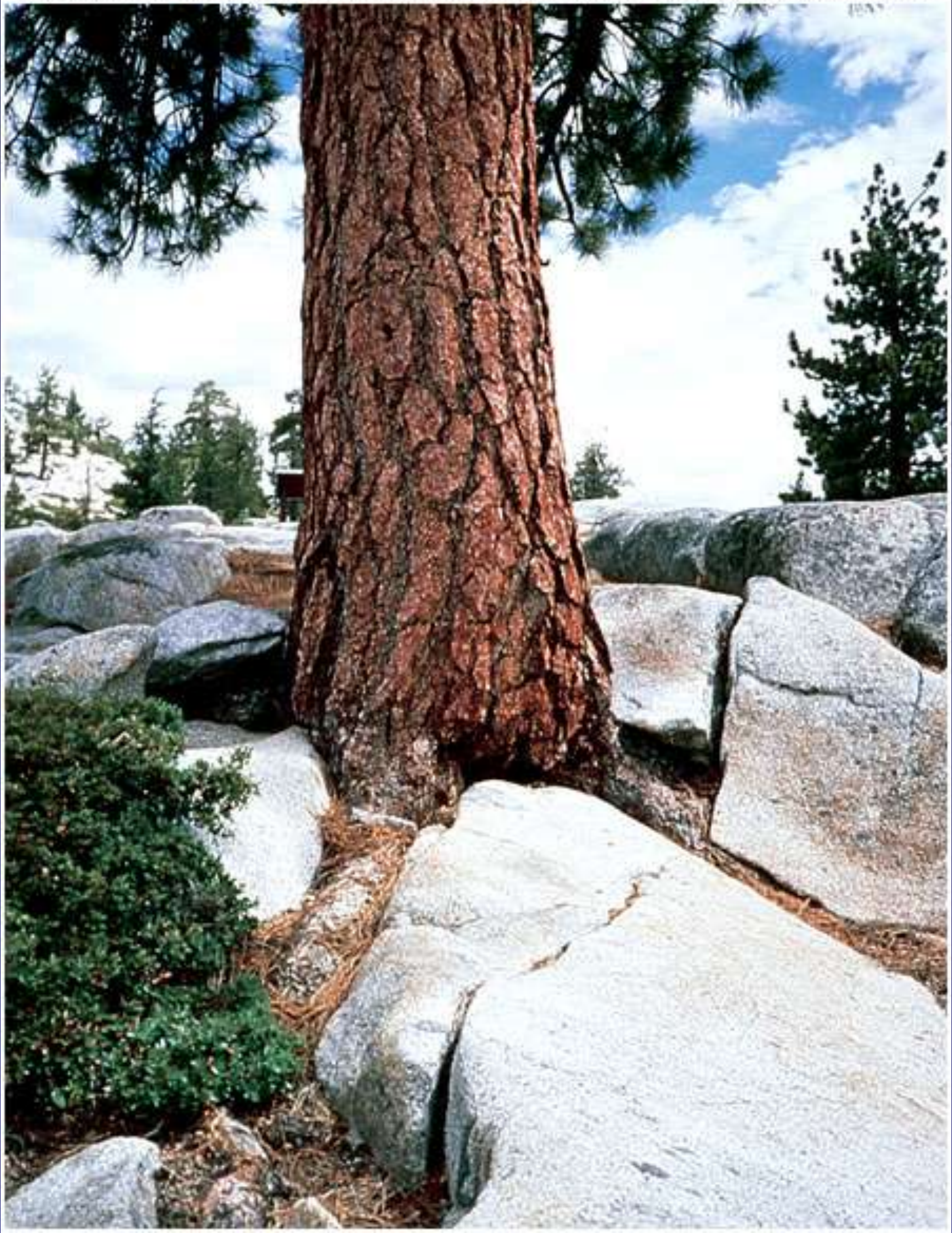
- Calcium Carbonate dissolves in water
- Some silicates dissolve – clays and oxides tend to form
- Organic acids breakdown minerals in rocks from the infiltrating water
- Biological activity or roots or burrowers aid chemical weathering
- Airborne chemicals such as acids or sulfate wash into soil

Figures 11.2 a and b

A

B

Figure 11.3



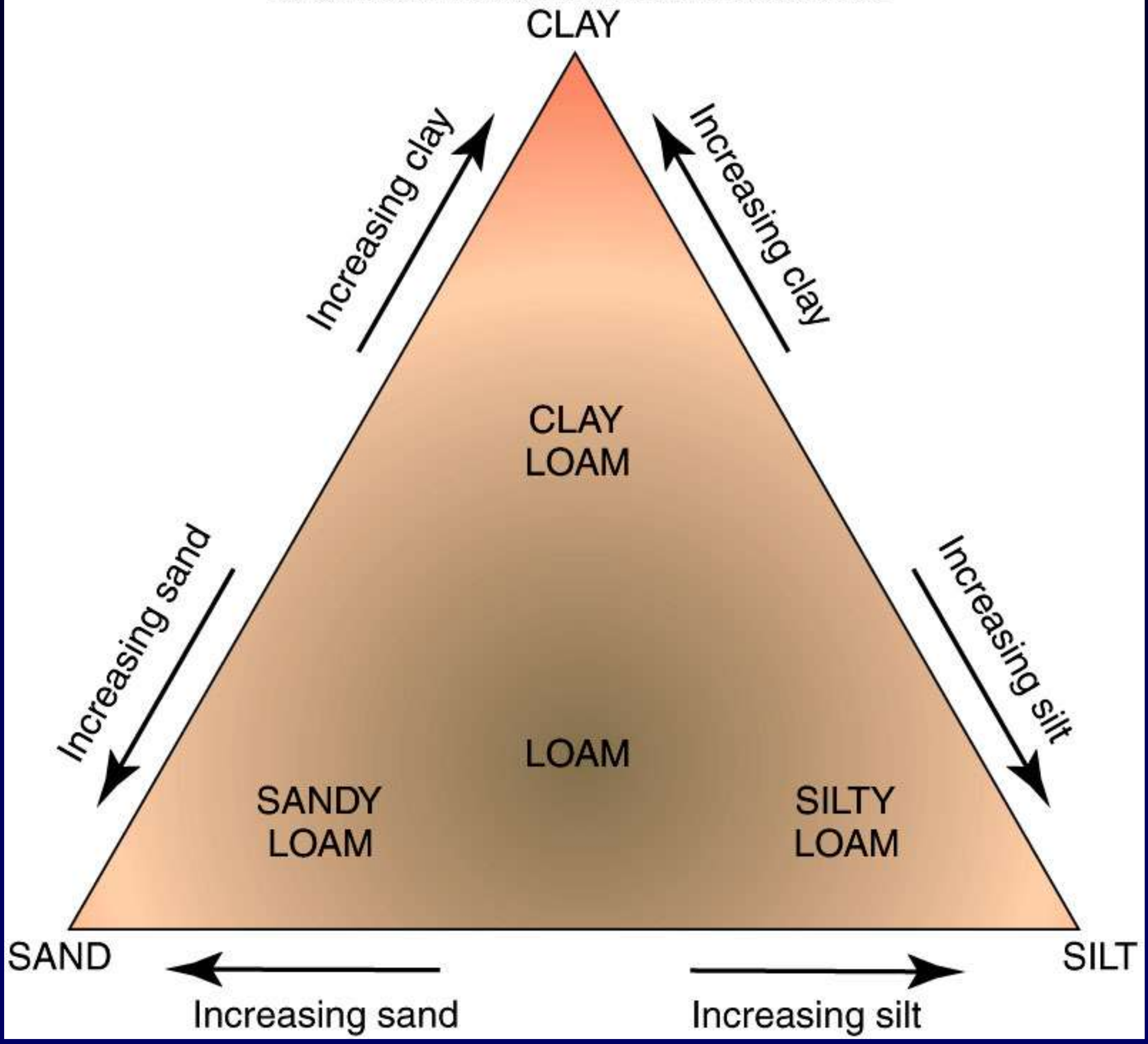
Soil Profiles and Horizons

- **A cross section of the soil blanket between bedrock and atmosphere usually reveals a series of zones of different colors, chemical compositions, and physical properties**
- **A Horizon**
  - Rock material is exposed to **heavy leaching**
- **B Horizon**
  - **Zone of accumulation (zone of deposition)**
  - **Zone of leaching**
- **C Horizon**
  - Very coarsely broken-up bedrock
  - Below this is R horizon: bedrock or parent rock material

Chemical and Physical Properties of Soils

- Color: dark or light
  - Dark soils tend to be rich in organic matter
  - Light soils generally lack organic matter
- Texture: size of fragments
  - Sand-sized (2-0.05 mm)
  - Silt-sized (0.05-0.002 mm)
  - Clay-sized (less than 0.002 mm)
- Structure: tendency to form peds
  - Ped forming soils resist erosion
  - Finer soils may become loess

Figure 11.6


CLAY
Increasing clay
Increasing clay
CLAY LOAM
Increasing sand
Increasing silt
LOAM
SANDY LOAM
SILTY LOAM
SAND
SILT
Increasing sand
Increasing silt

Soils and Human Activities

- **Laterite** soil
  - Extreme version of pedalfer
  - Forms in tropical climates
  - Contains few soluble nutrients
  - Forests in tropical areas hold the nutrients, not the soil
  - Slash and burn agriculture quickly depletes the nutrients over time
  - In areas where climates are monsoonal, soil may form '*brick*' hard surfaces
  - Lateritic soils are difficult to farm or work for people to grow food with

Wetland Soils

- Tend to be rich in accumulated organic matter, are reduced chemically because they accumulate organic matter easily which will decay and consumes oxygen
- Provide vital habitats for birds and other organisms
- Retain flood waters easily and often trap sediments
- Also serve as pollution traps
- Complex soils and land system

Soil Erosion

- Weathering is the breakdown of rock or mineral material
- Erosion is the physical removal of the material that has been weathered
- Rain strikes – breaks up and softens soil
- Surface run and wind off picks up soil particles
- Faster moving water or wind will carry off large size particles and a greater load
- Soil erosion is not beneficial to humans

Figure 11.11

Soil Erosion versus Soil Formation

- Soil losses in U.S. amount to billions of tons per year – about 0.04 cm per year
- Human activities, including farming, accelerate the loss of soil
- In general, soil formation is slower than soil erosion
- Important factors:
  - Climate and time
  - Nature of the source rock that weathering can work on

Figure 11.12 a

A

Figure 11.12 b

B

Figure 11.13 a

A

Figure 11.13 b

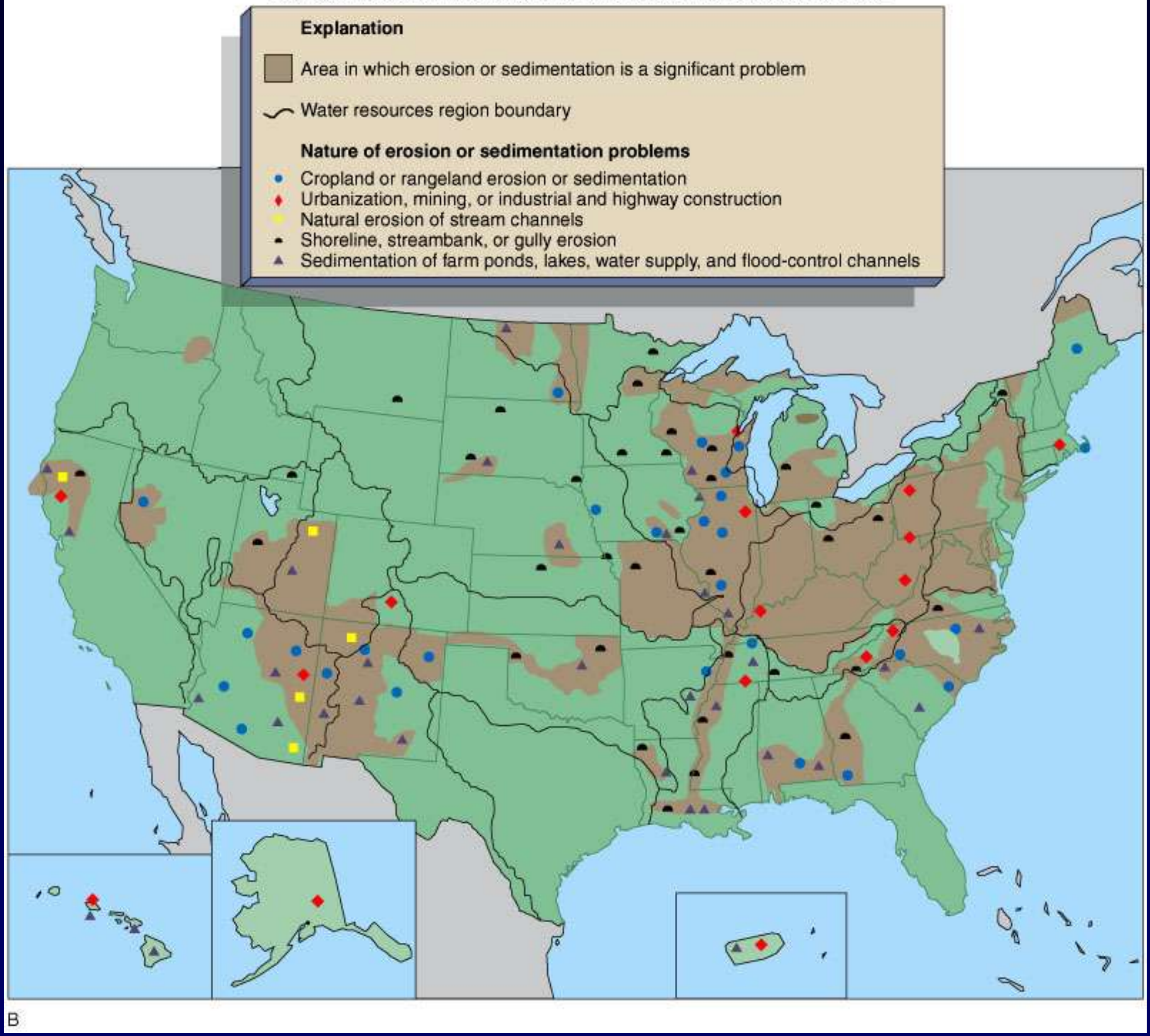
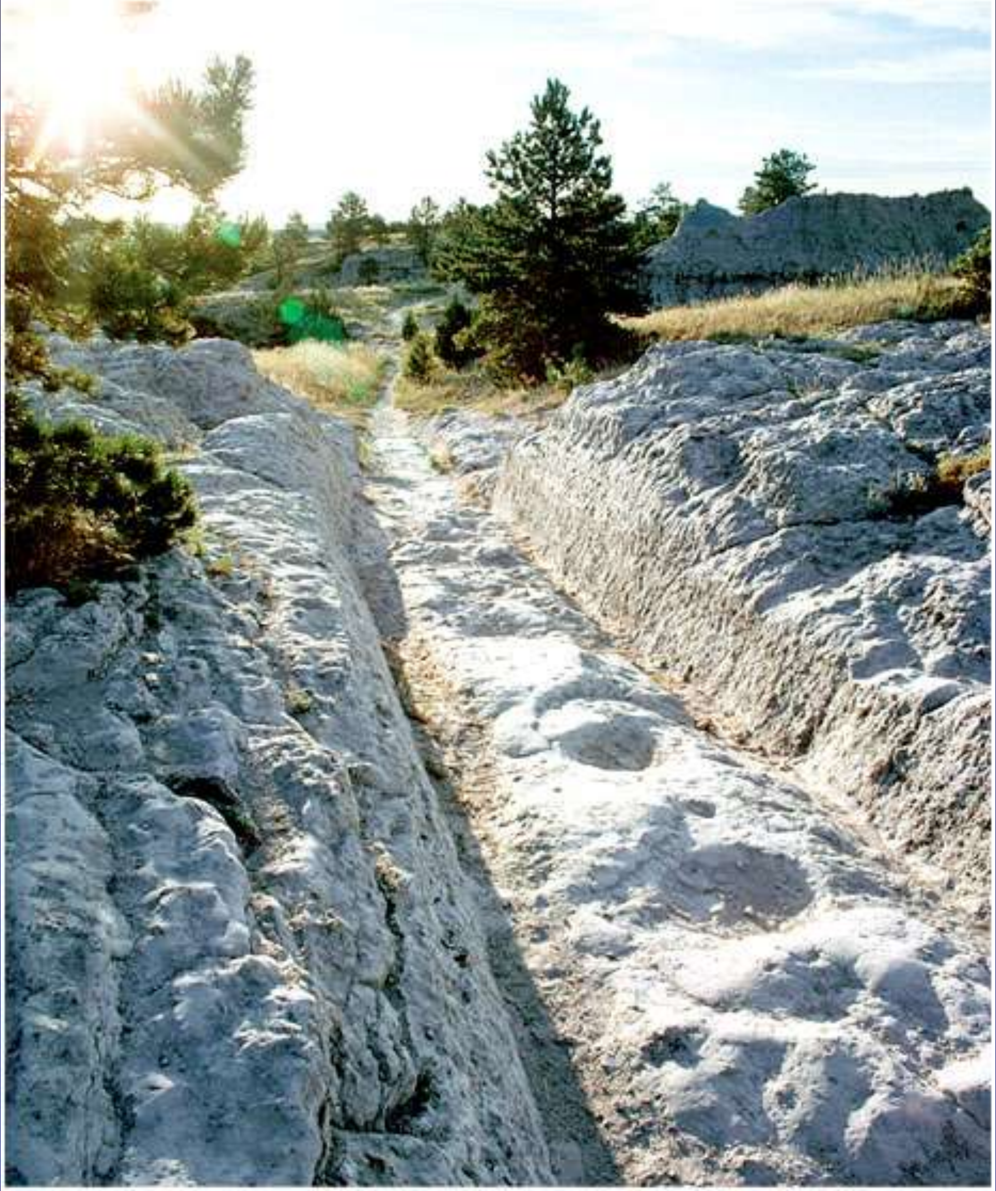


Figure 11.14 a

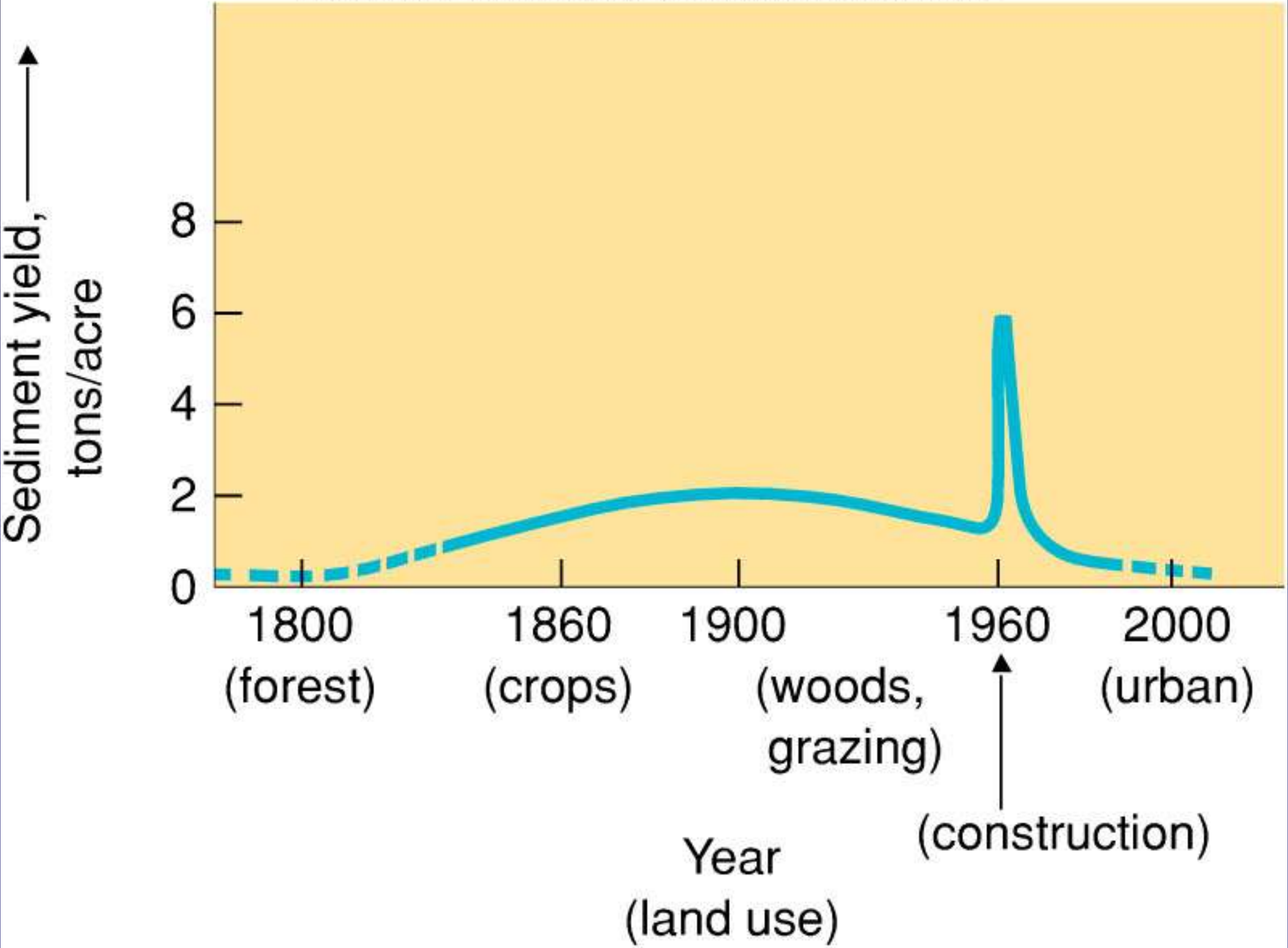
A

Figure 11.14 b



B

Figure 11.15


Sediment yield, tons/acre
8
6
4
2
0
1800
(forest)
1860
(crops)
1900
(woods, grazing)
1960
(construction)
2000
(urban)
Year
(land use)

Strategies for Reducing Erosion

- Protect the soil from fast moving wind
  - Plant wind breaks perpendicular to dominate wind direction
- Protect the soil from fast moving water
  - Reduce the slope so runoff is slowed
  - Plow fields parallel to contours
  - Terrace fields
- Encourage the growth of plants with extensive root systems to hold the soil in place

Figure 11.16 a

A

Figure 11.16 b

B

Figure 11.17

Figure 11.18 a

A

Figure 11.18 b

B

Figure 11.19 a

A

Figure 11.19 b

B

Figure 11.19 c

C

Figure 11.20 a

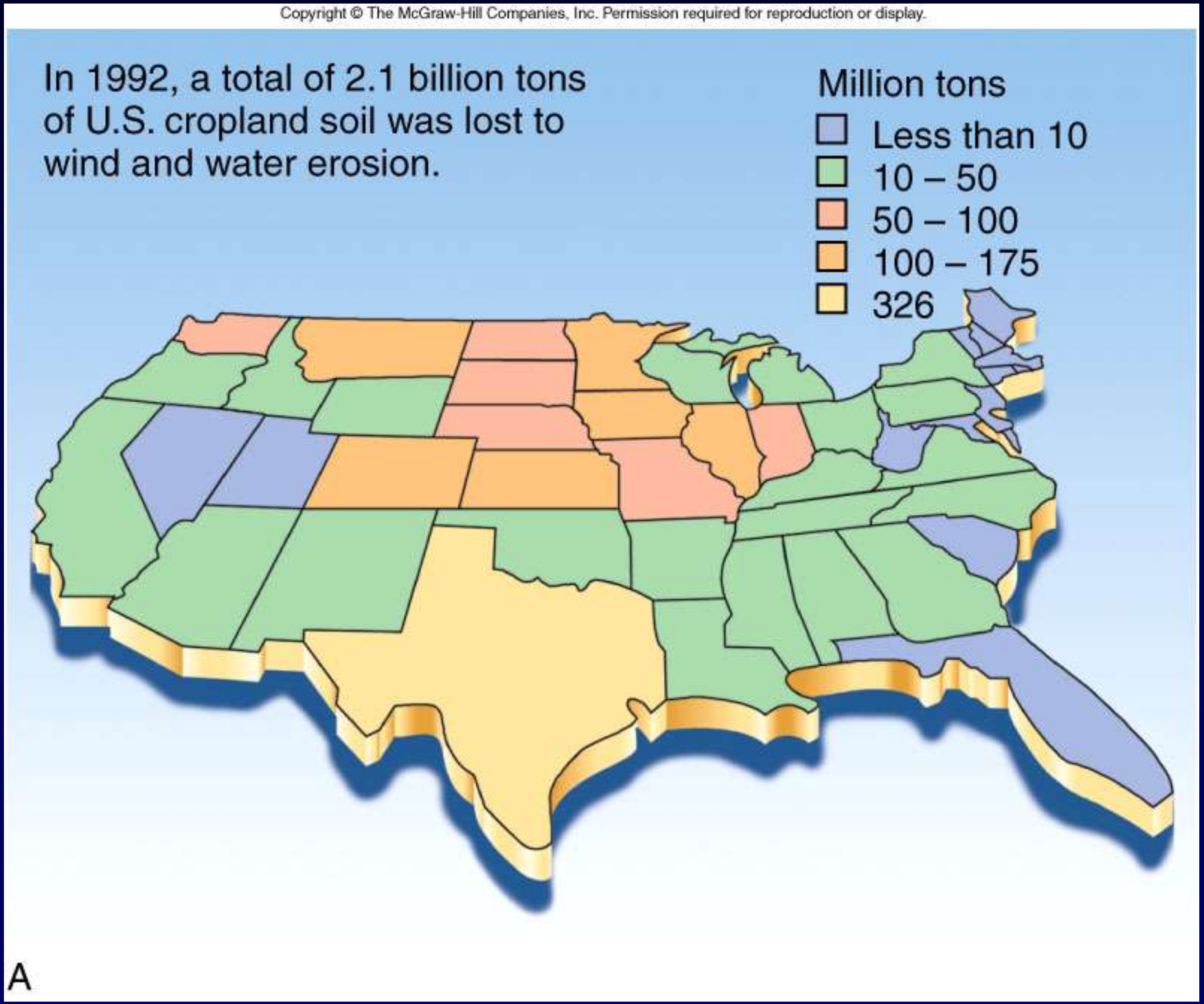
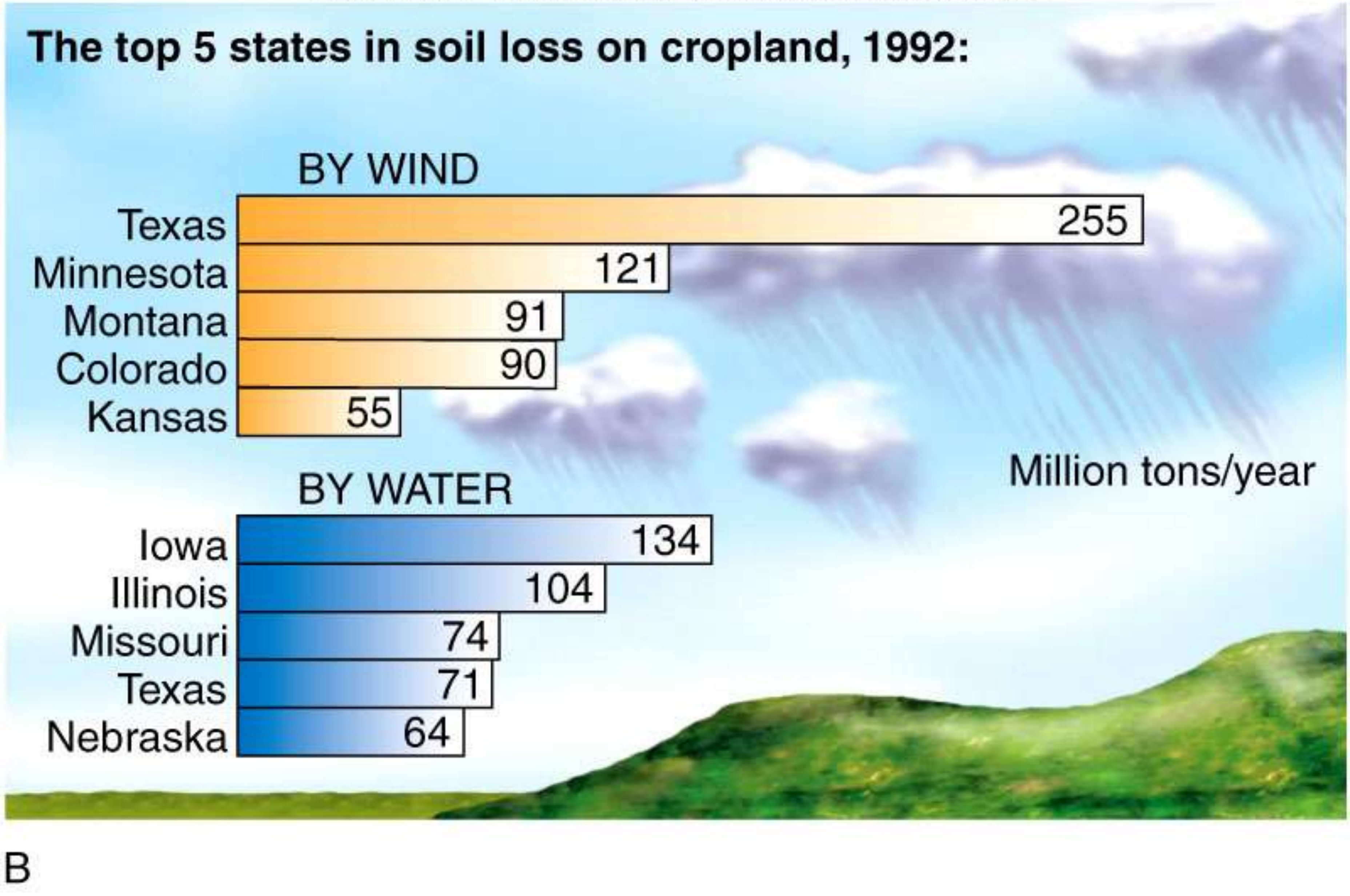


Figure 11.20 b



Irrigation and Soil Chemistry

- Leaching modifies soil chemistry
- Application of fertilizers, herbicides and pesticides alters soil chemistry
- Human activity modifies soil chemistry
- Runoff water from irrigated fields carries off toxic chemicals
  - These chemical can collect in lowland areas or wetlands

The Soil Resource

The Global View

- Soil degradation is a global issue
- Destructive processes exist such as:
  - Desertification
  - Erosion
  - Deterioration of lateritic soil
  - Contamination from pollution
  - Chemical modification to soil by humans
- These processes combine to the loss of soil, loss of soil quality, and degraded acreage left to grow enough food for a hungry world. Land area is finite.

Figure 11.23 a

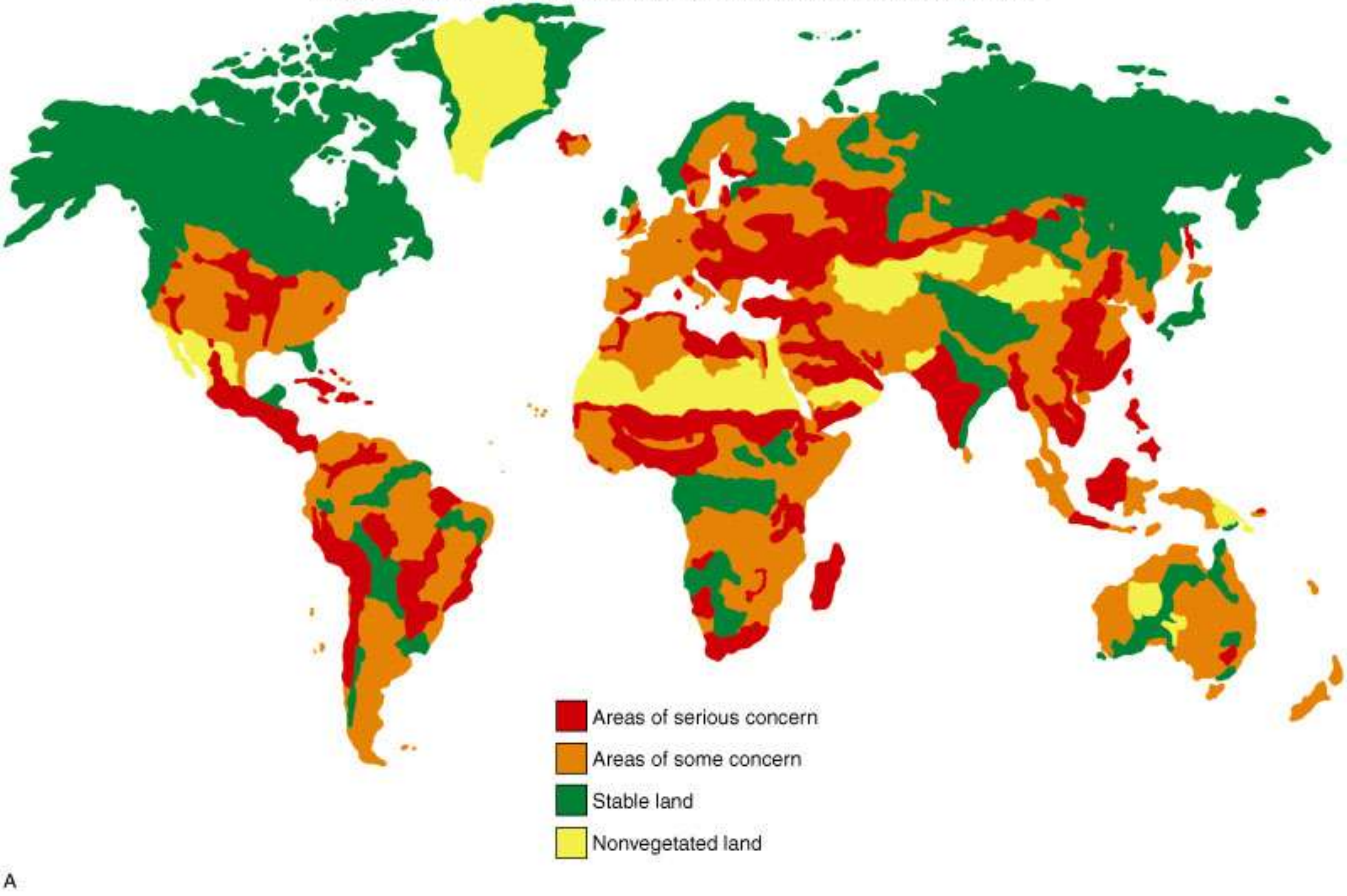


Figure 11.23 b