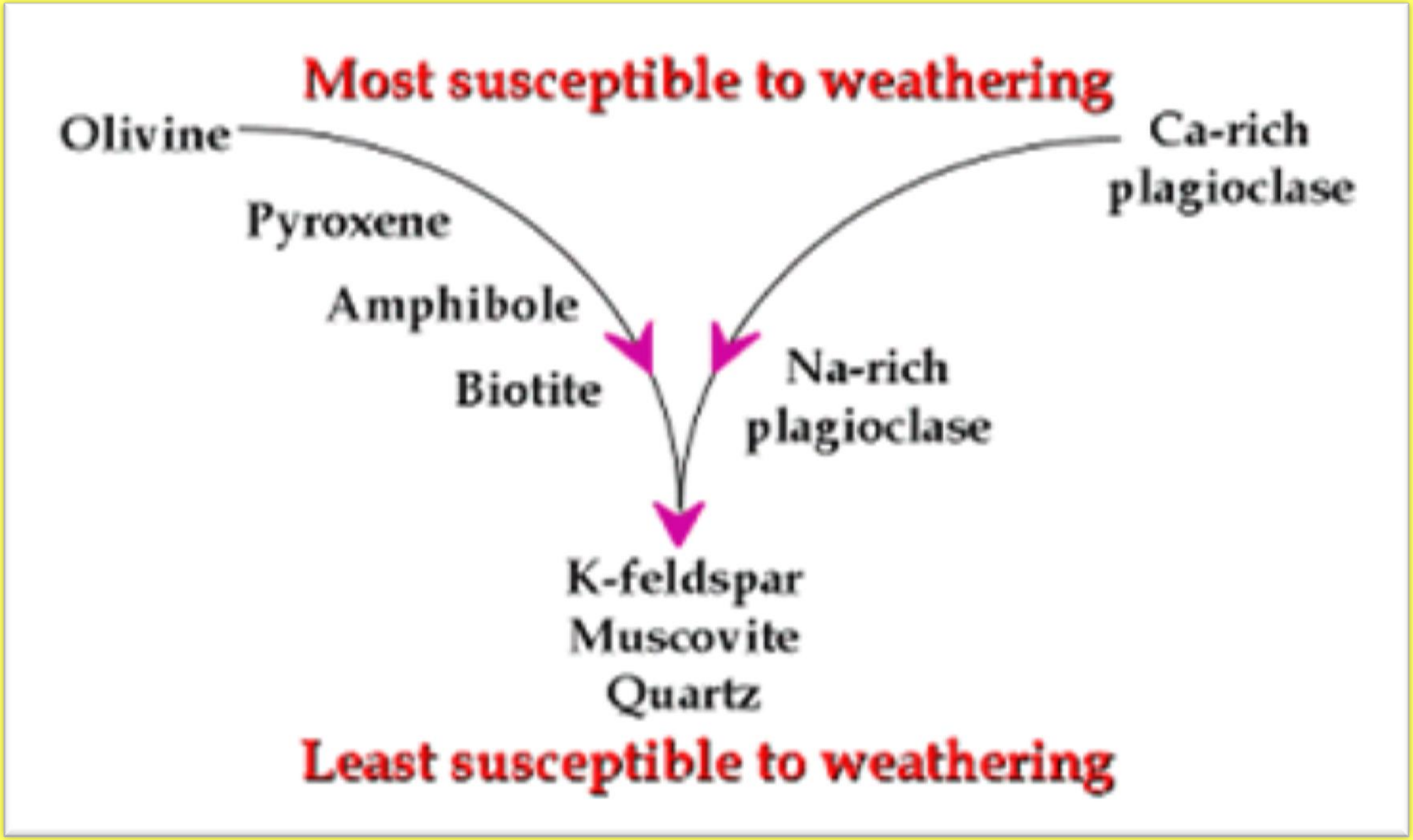
Weathering and Soils ☺

(look familiar…)



Mechanical and Chemical Weathering

A. WEATHERING

1. The group of ___*destructive*______ processes that change the physical and chemical character of rock at or near Earth's surface.

- ❑ Weathering breaks rocks into smaller particles that are easily moved over Earth's surface.

2. **Rocks exposed at Earth's Surface are constantly being altered by:**

   water, air, changing temperature, living organisms, and other environmental factors.

3. Weathering breaks down rocks that are either **stationary or moving**

B. ___Erosion___

1. This is the ___picking up or physical removal___ or rock particles by an *agent* of erosion.
   Agents of erosion include:
   - Gravity
   - Wind
   - Running Water (streams and glaciers)
   - Wave action
2. Most eroded rock paraticles are at least partially ___weathered___.
3. Rock can be eroded before it has weathered at all.

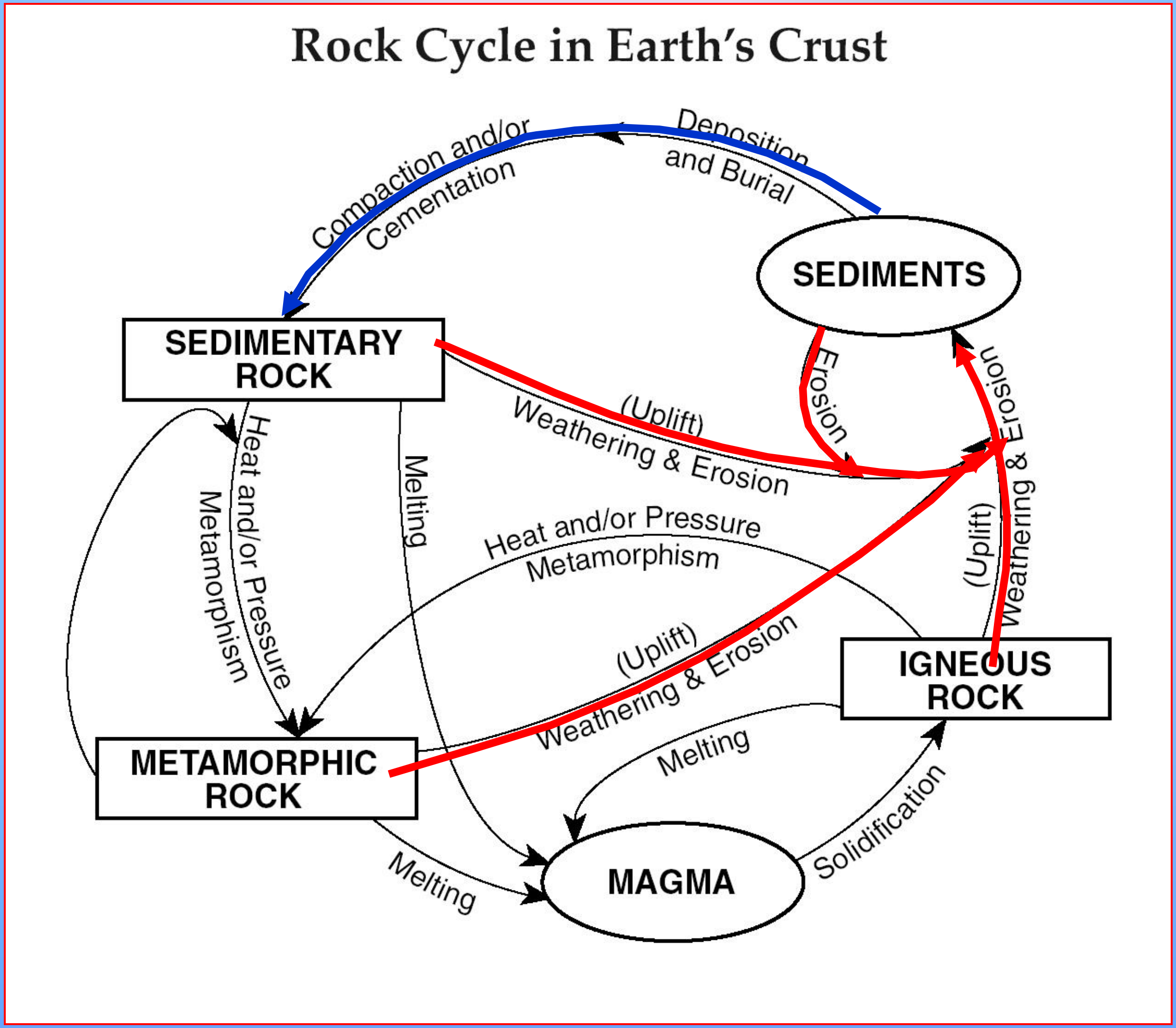
C. __TRANSPORTATION__

1. After a rock fragment is picked up (**eroded**), it is transported.

2. The same *agents* that erode rocks transport rocks.

3. **Weathering** processes continue during **transportation.**

Weathering and Erosion are Important Parts of the Rock Cycle



II. Mechanical Weathering

A. Also called ***physical disintegration***

B. **Includes several processes that break rock into smaller pieces**

C. **There is little or no *chemical* weathering.**

D. Types of Mechanical Weathering

1. ___**Frost Action**___: This is the mechanical effect of freezing water on rocks.

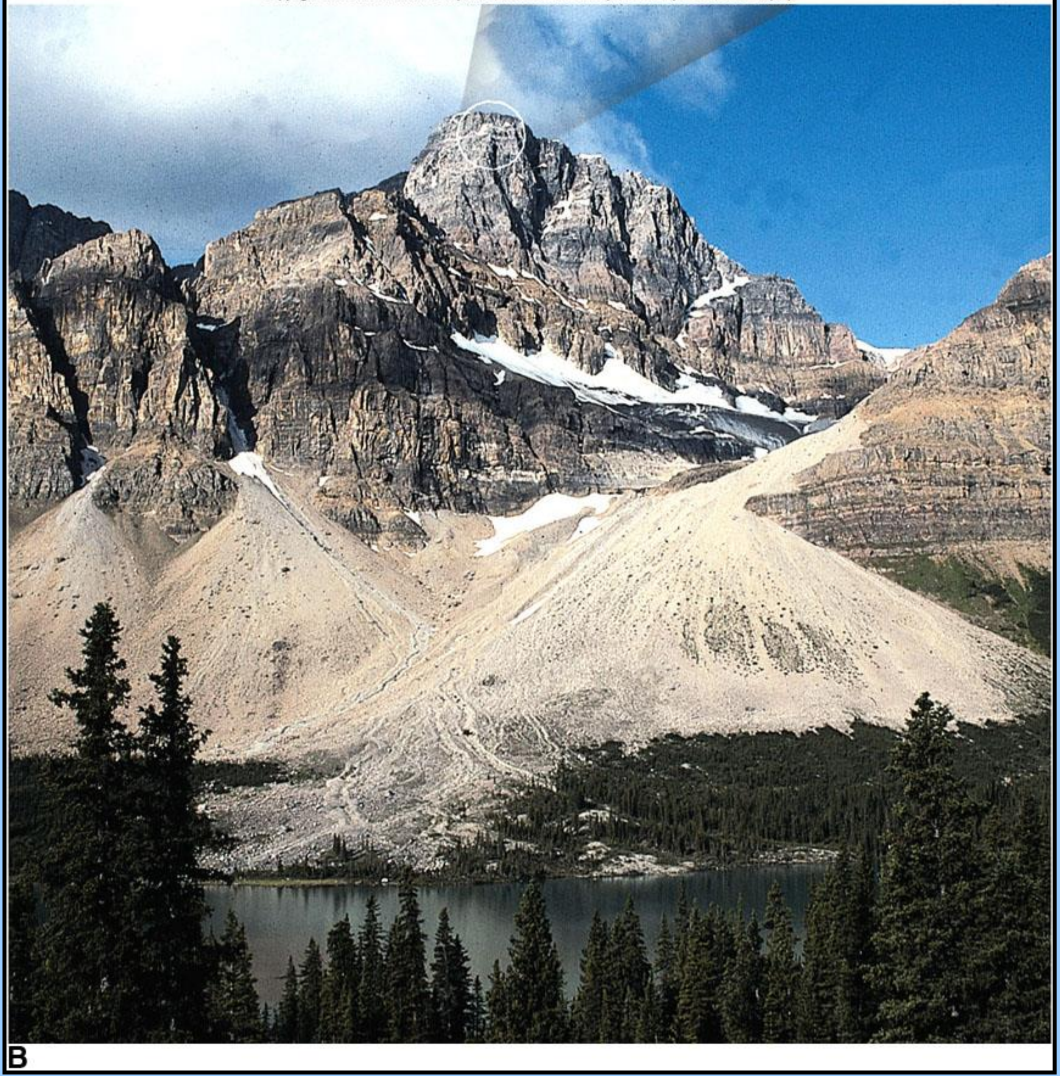
Frost Action

a)_Frost Wedging_________

- Expansion of freezing water in cracks forces rock apart

b) ____**Frost Heaving**________

- Lifts rock and soil vertically. Ice forms under buried rock fragments in soil because being a better conductor of heat, the rocks are colder than the soil. The expanding ice pushes cobbles and boulders out of the ground



- **Crawford Mt. In Banff –Alberta, Canada**
- ***Talus* (cone-shaped piles of debris) is seen at the base of the mountains**

2. Plant Action

- Plant growth, particularly by roots
- Grow in pores and cracks and break rocks apart
- At right:
  - Tree roots in joints (Tulumne Meadows, CA)

3. Temperature Action

- Also called *thermal cycling*
- Large temperature changes result in differential expansion and contraction of mineral constituents of rocks

- Granular disintegration of granite
- Joshua Tree National Park, CA

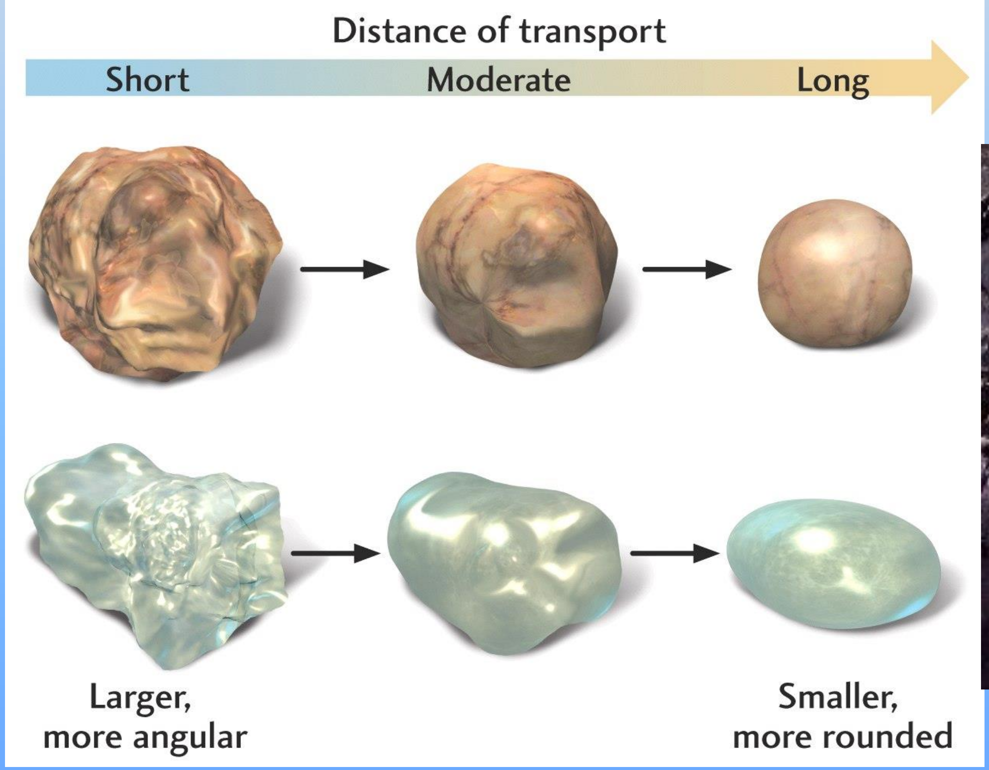
Temperature Action

- Extreme temperature variation in the Mojave Desert.
- The rock is being split into layers which increases its surface area.

- **Extreme changes, as in a forest fire, can cause rocks to expand until they break**

4. Abrasion

- The grinding away of rock by friction and impact during transportation



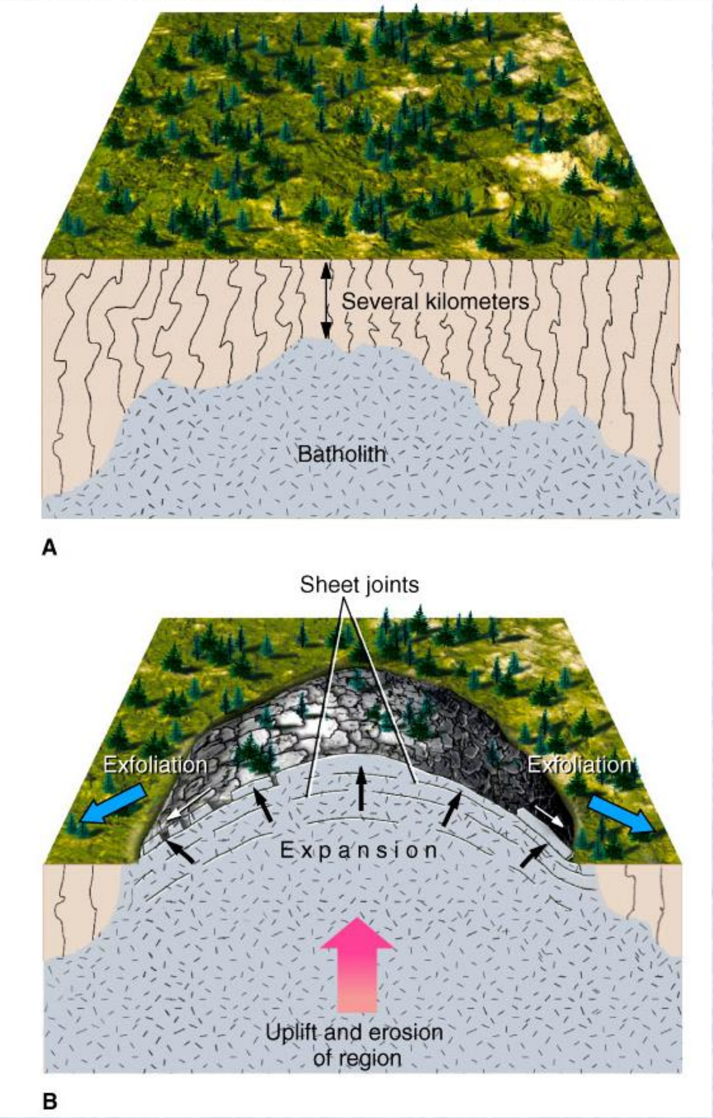
Polished Rock

5. Pressure Release

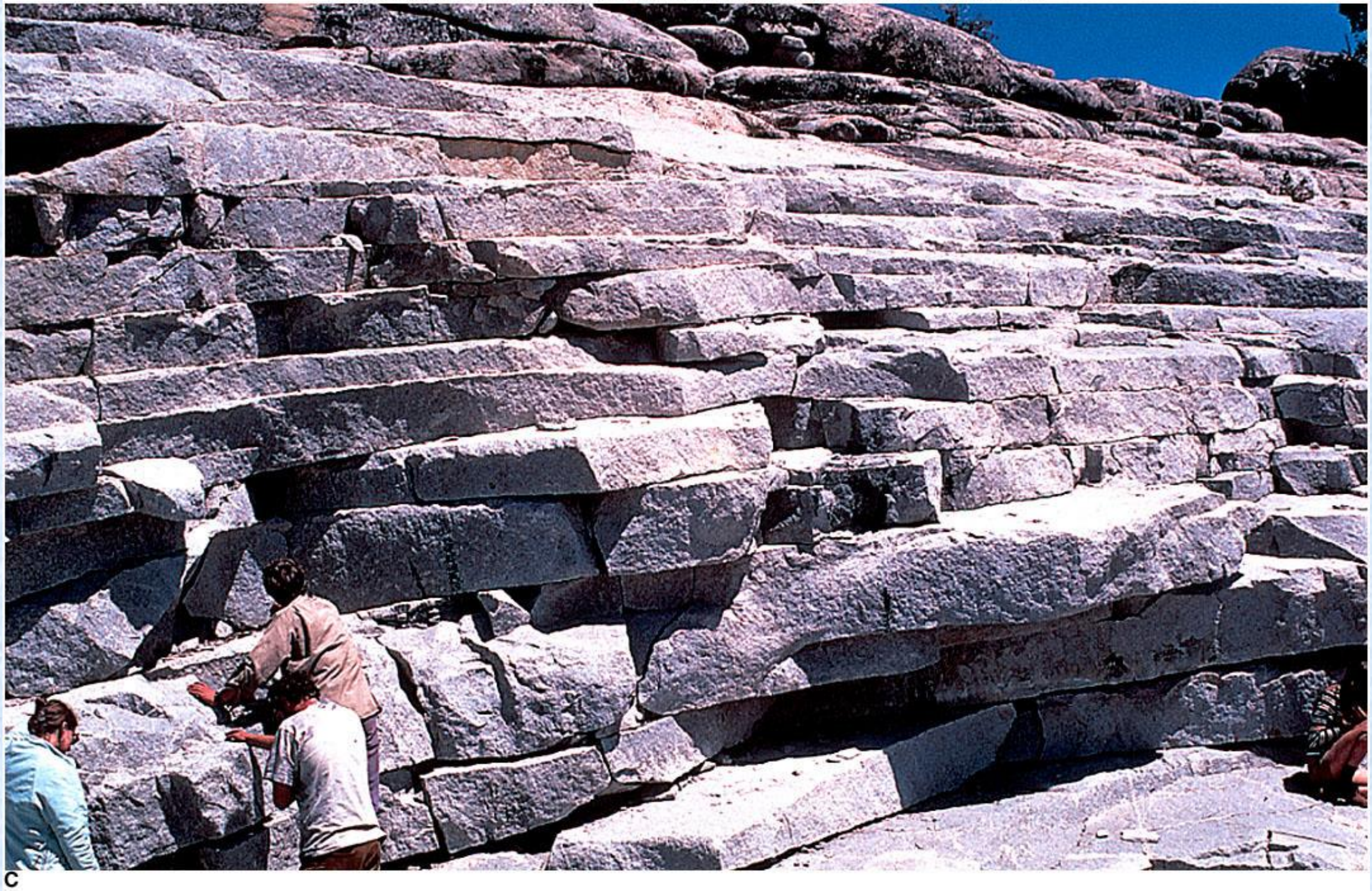
a) The removal of a great mass of rock above a batholith (**unloading**) allows the granite to expand upward.

b) **Sheet Joints**:

- Cracks that develop parallel to the outer surface of the rock.
- Gravity may loosen the rock between joints in concentric slabs.
  - **Exfoliation** is the name of this process.
  - Exfoliation domes are
    - Large, rounded landforms
    - Developed in massive rock, such as granite by exfoliation



Sheet Joints in Granite



Sierra Nevada, CA

Exfoliation Dome
Yosemite National Park, CA

Exfoliation in Yosemite

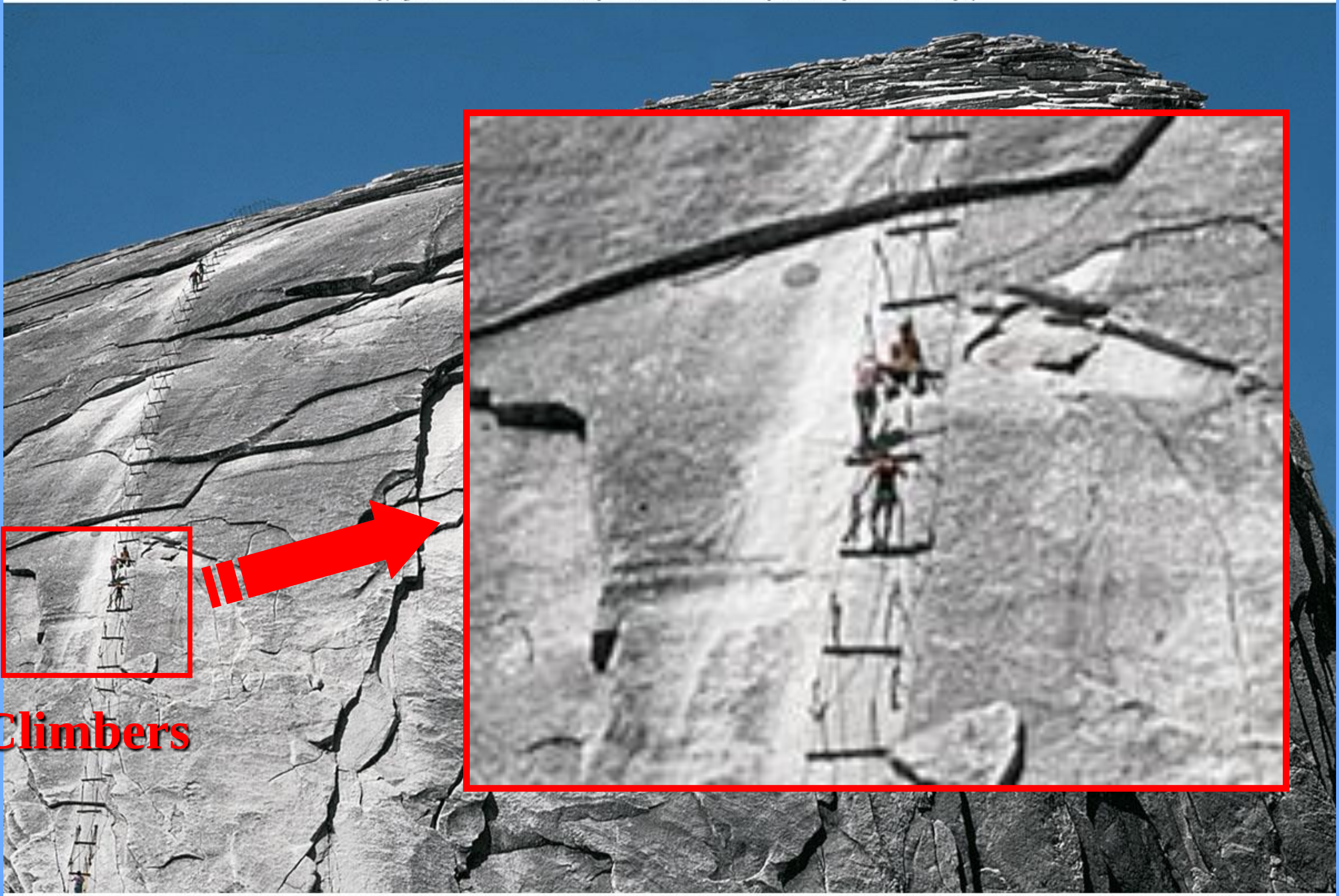


Photo © by Dean Conger/CORBIS

Exfoliation
Stone Mountain, GA

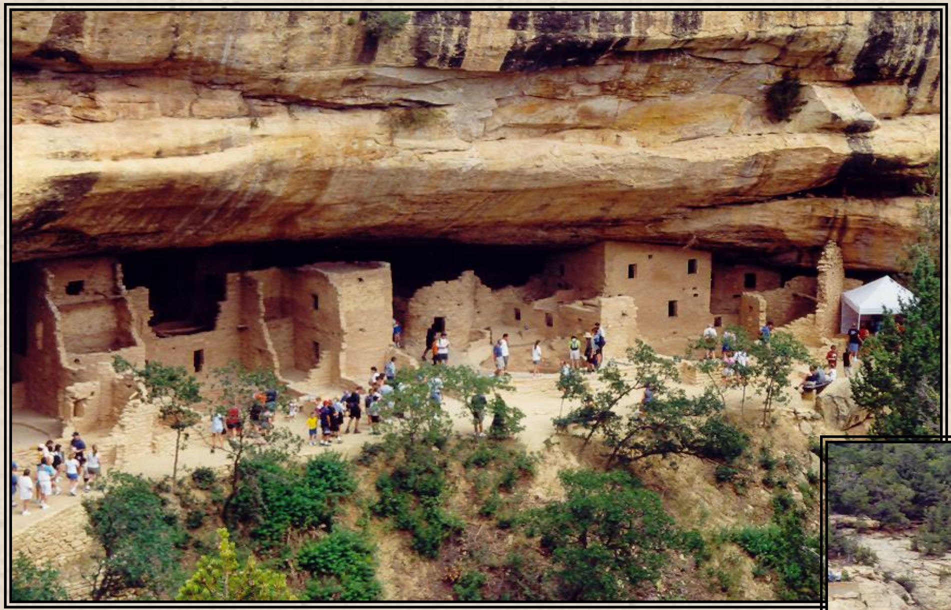
6. Burrowing Animals

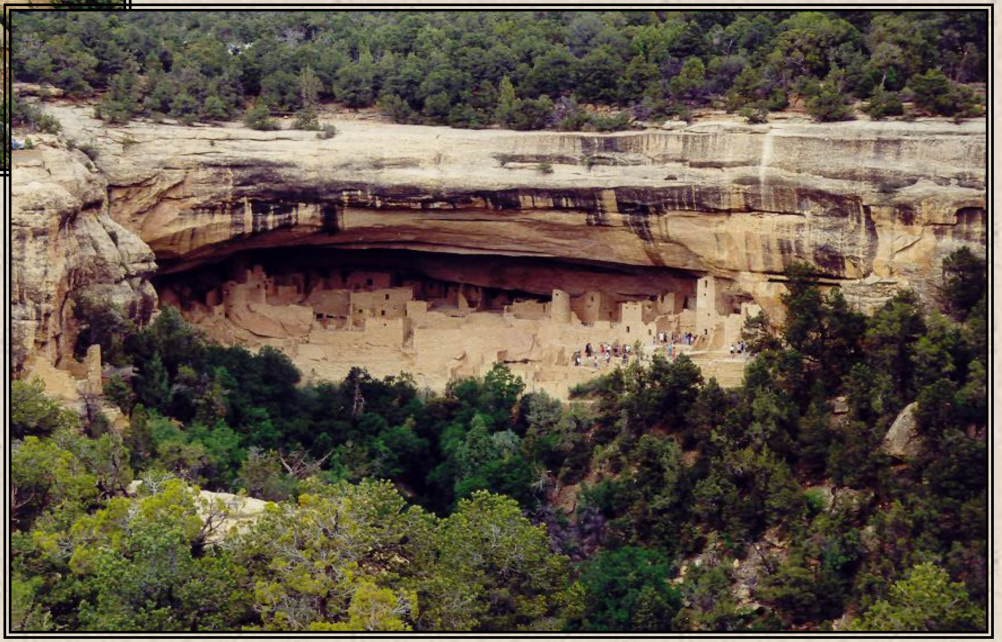
Earthworms

7. Pressure of Salt Crystals

- Water in cracks and pore spaces evaporates
- Salt precipitates
- As crystals grow they help disintegrate rocks
- Occurs in *desert* regions

Anaszi Cliff Dwellings
Mesa Verde, CO





II. Chemical Weathering

- Transforms rocks and minerals exposed to water and air into new chemical products

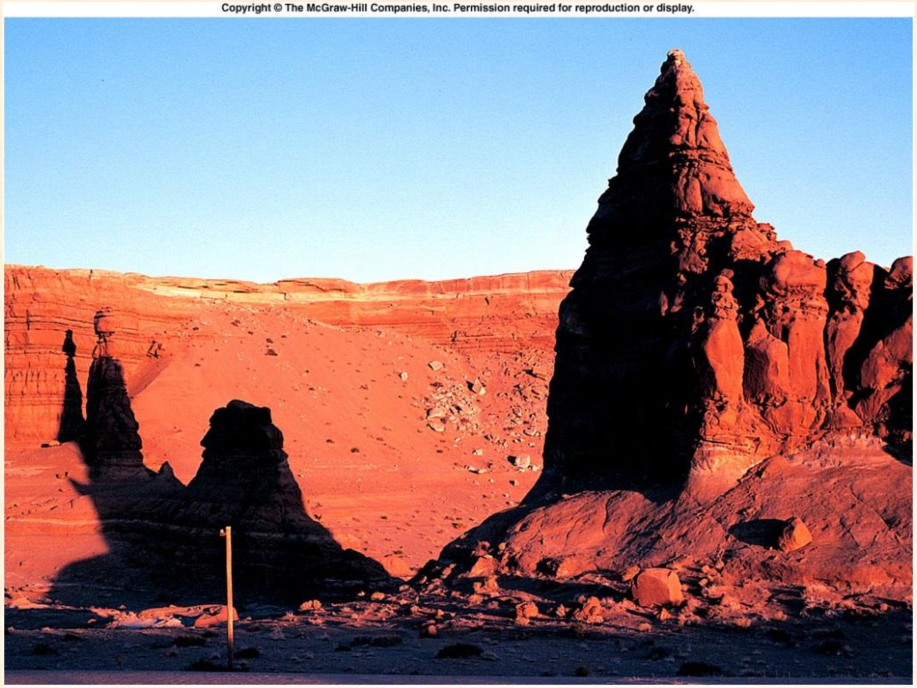
- Minerals change gradually at Earth’s surface until they reach an equilibrium with the surrounding conditions.

A. The Role of Oxygen

1. Oxidation

a) The chemical combination of oxygen in the atmosphere or dissolved in water

- with one mineral to form a completely different mineral.
- Soil and rocks often stained a red to reddish brown color.



b) __Iron Oxide__

- Forms in the rusting of an iron nail. Iron oxide formed this way is a weathering product of numerous minerals containing iron (__**ferromagnesian minerals**__) such as olivine, pyroxene, amphibole and biotite mica, hornblende.

Oxidation Examples

- **Formation of iron oxide:**

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$

- **Oxidation of Olivine:**

$$\underset{\text{olivine}}{2Fe_2SiO_4} + \underset{\text{water}}{4H_2O} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{hematite}}{2Fe_2O_3} + \underset{\text{silcic acid}}{2H_4SiO_4}$$

2. ___Hydration___________

a. The chemical union of water with a mineral.
b. The mineral absorbs water and the new product is a new mineral.
c. A good example is the conversion of hematite to limonite

Hematite

Limonite

$$2Fe_2O_3 + 3H_20 \longrightarrow 2Fe_2O_3 \cdot 3H_20$$

- Notice that the new mineral is the same composition as the original.
- This is why some geologists consider this a type of mechanical weathering

Hematite

Limonite

$$2Fe_2O_3 + 3H_20 \longrightarrow 2Fe_2O_3 \cdot 3H_20$$

B. The Role of Acids

1. **Chemical Weathering of Feldspar**

a. The process is referred to a **hydrolysis** .

b. An exchange reaction involving minerals and water.

c. Free hydrogen (H+) and hydroxide (OH-) ions in water

- Are able to replace mineral ions and drive them into solution
- As a result the mineral's atomic structure is changed into a new form.

d. It is a process whereby silicate minerals like potassium feldspar are weathered and a clay mineral is formed

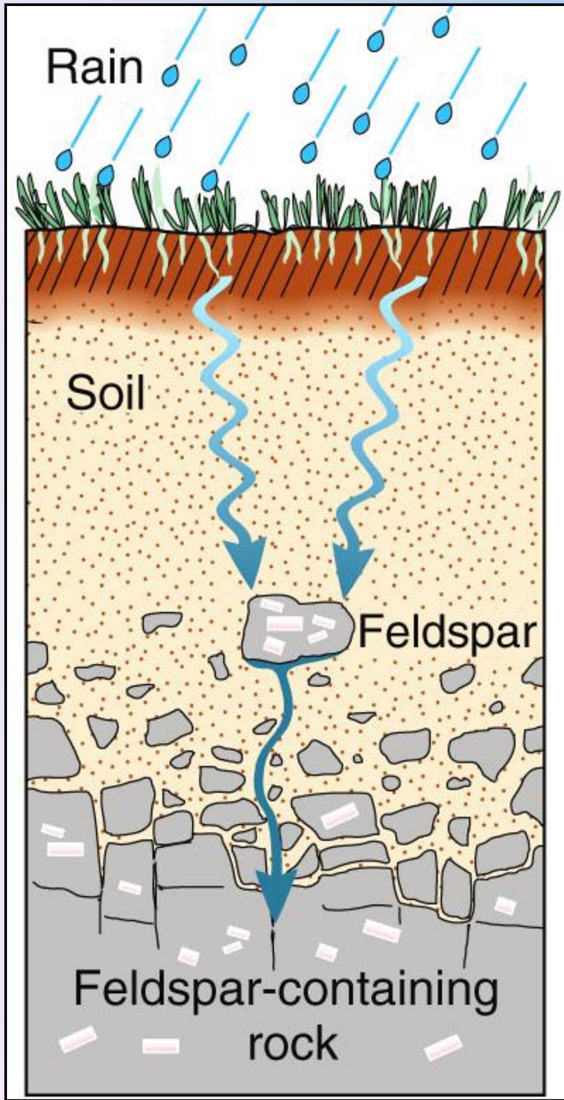
Orthoclase Feldspar (K-Feldspar)

Becomes

Kaolinite

d. Feldspar is a common mineral in many igneous, sedimentary, and metamorphic rocks.

Chemical Weathering of Orthoclase Feldspar



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

f. The following reaction occurs when the most common feldspar, a sodium plagioclase, reacts with *carbonic acid* (formed by carbon dioxide dissolving in rain water and groundwater).

$$2NaAl_3Si_3O_8 + 2H_2CO_3 + 9H_20 \longrightarrow$$

Na-Feldspar Carbonic Acid Water

$$Al_2Si_2O_5(OH)_4 + 2Na + 2HCO_3 + 4H_4SiO_4$$

Clay mineral **(Soluable ions)**

- **Sodium eventually accumulates in the oceans as dissolved**

Salts______________.

2. Carbonation

a. Carbonic acid dissolves calcite which is the main mineral in the rocks limestone and marble.

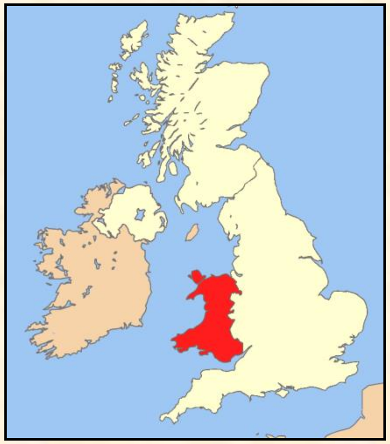
b. **$CaCO_3$ + H_2CO_3 → Ca + $2HCO_3$**

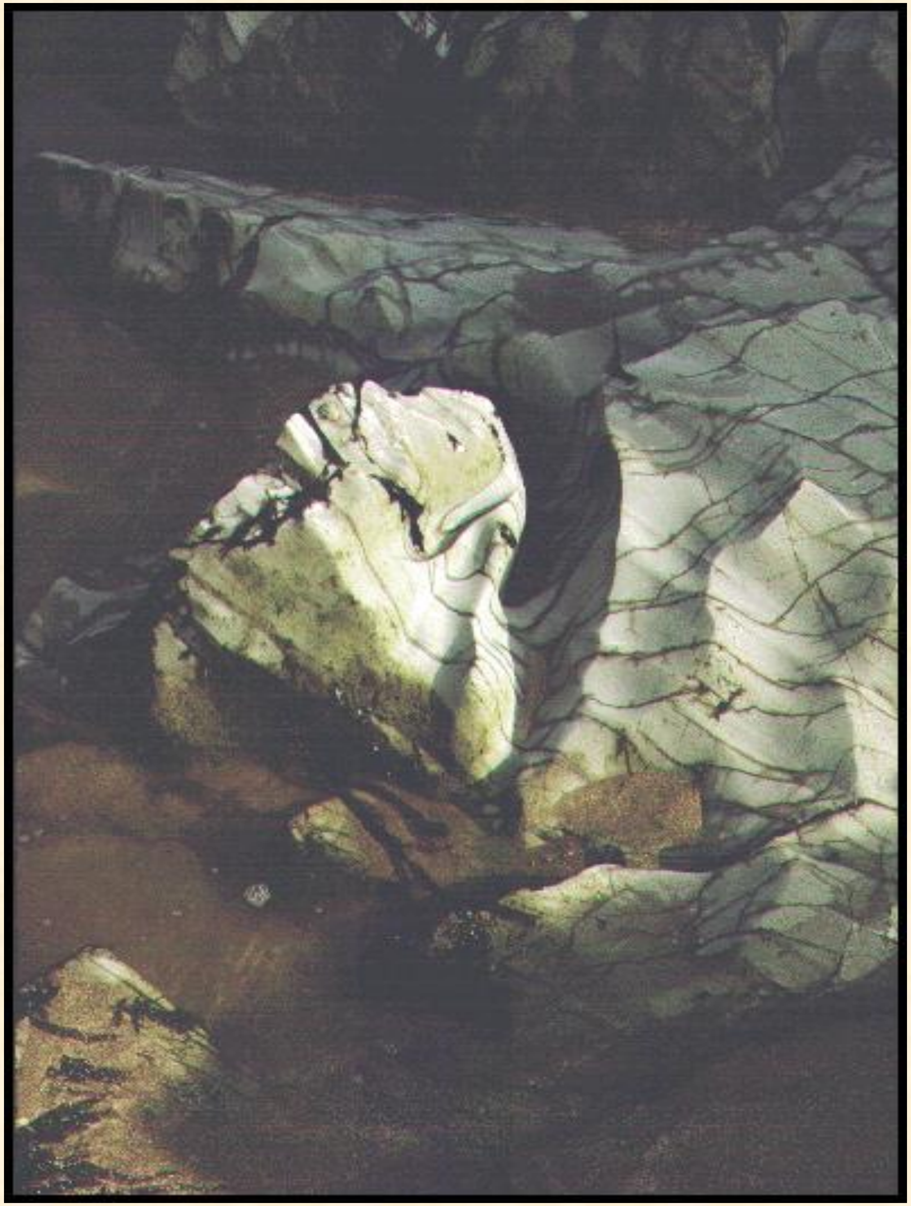
calcite **carbonic acid** **calcium bicarbonate**

c. A type of solution weathering

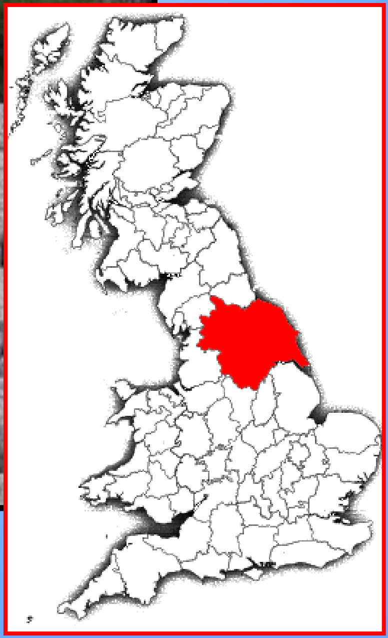
Chemical Weathering of Calcite

- Calcite ($CaCO_3$) dissolves when CO_2 & water combine to form carbonic acid.
- No solid products result.
- Limestone and marble most affected
- At right - Solution weathering in Wales, UK

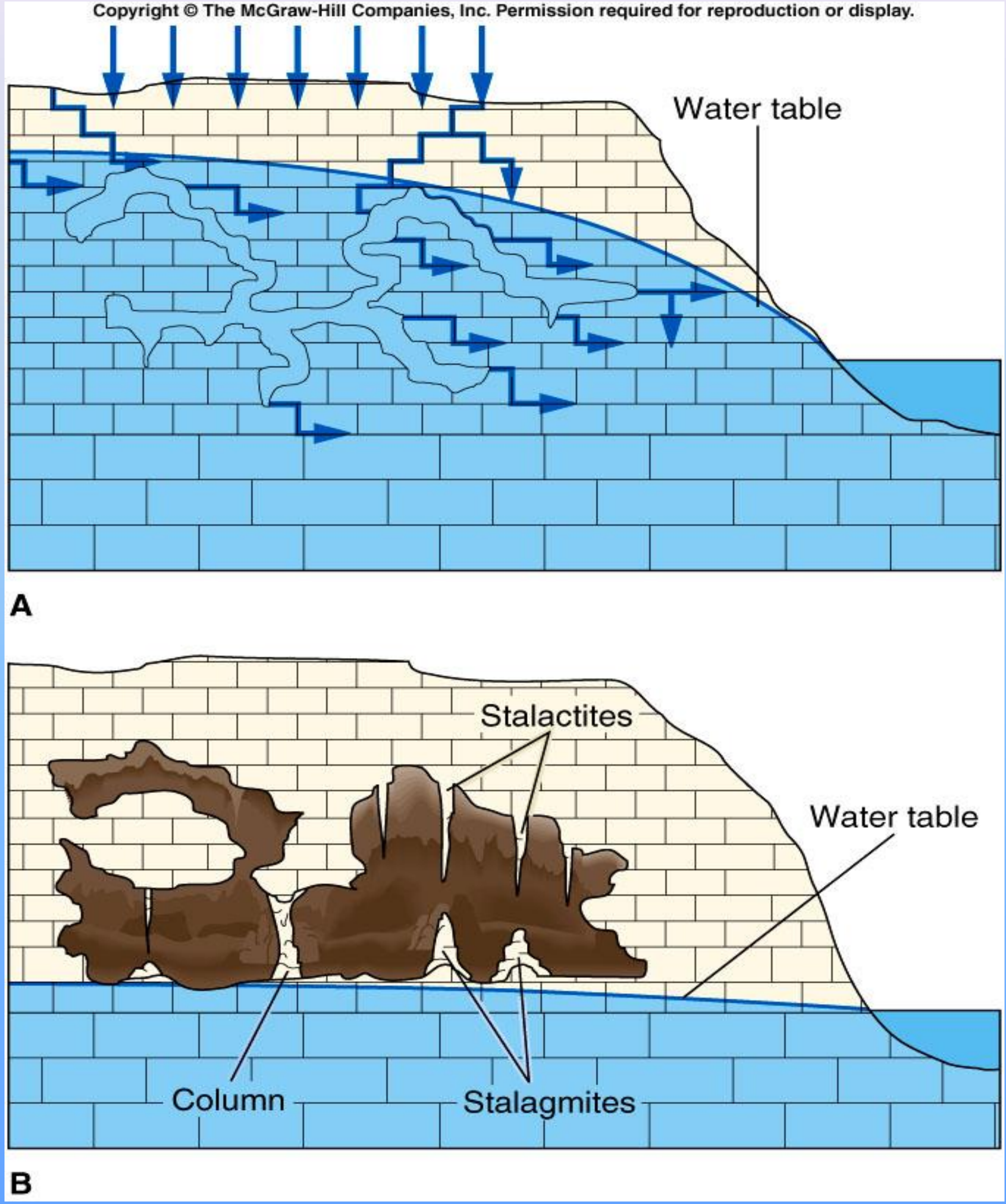




Solution Weathering in Yorkshire, UK

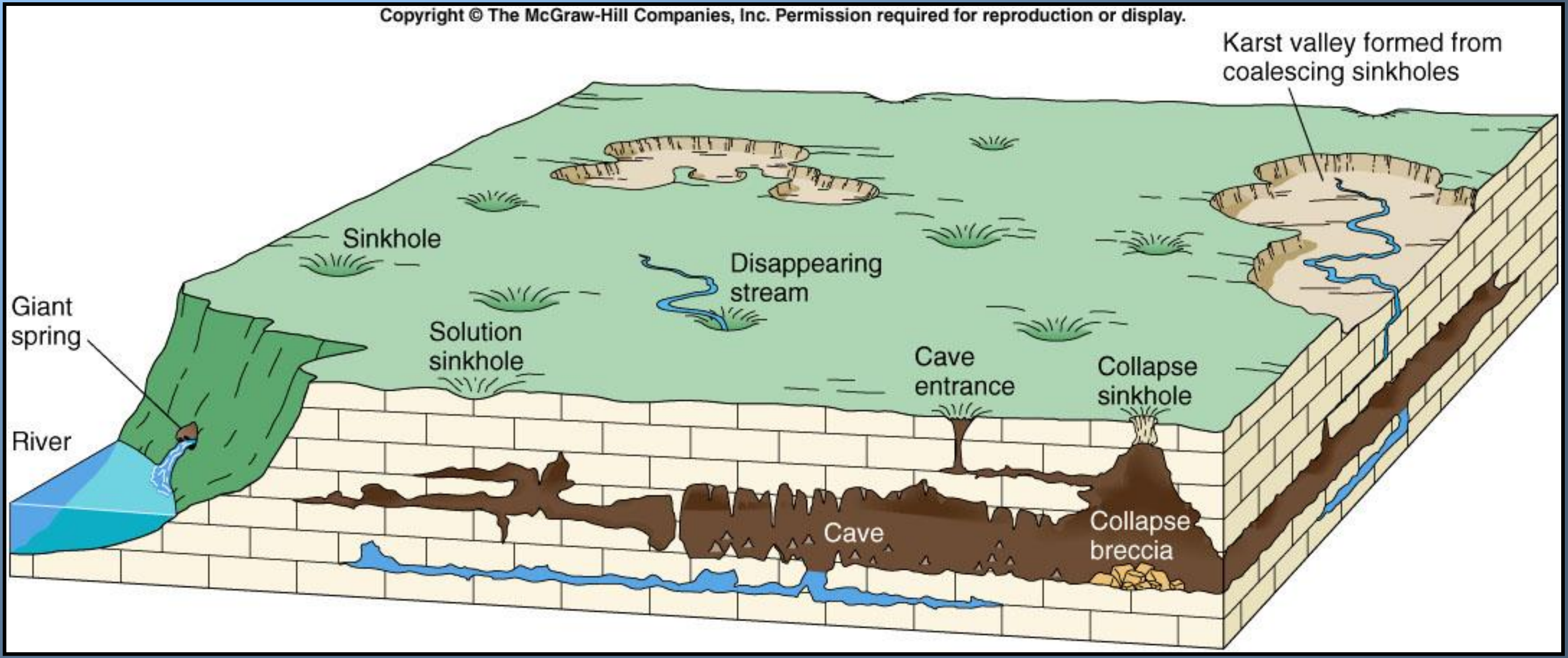


Solution of Limestone Forming Caves



Limestone Caves

Karst Topography

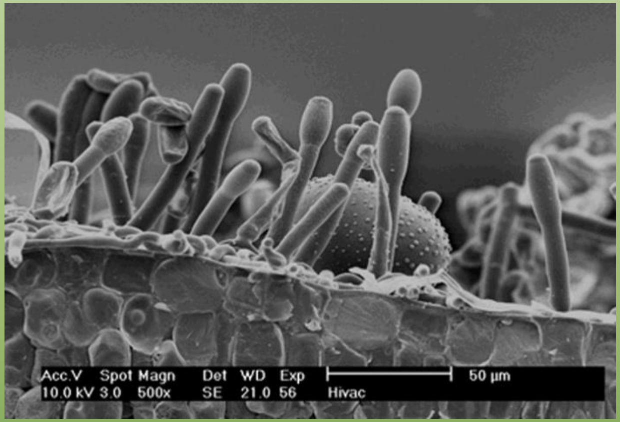


Sinkholes

- Left: Sinkholes near Timaru, New Zealand
- Right: Winter Park, FL sinkhole collapse in 1981

3. Chemical Weathering by Living Organisms

a) **Lichens**



- Fungus and Algae in a symbiotic relationship
- Algae provides sugar (from photosynthesis) for the fungus
- The fungus provides protection to the algae.

- Lichens secrete acids which decompose the minerals in the underlying bedrock.
- Produces a habitat for mosses and eventually higher plants

4. Strong Acids on Earth's Surface

Acids from Mines

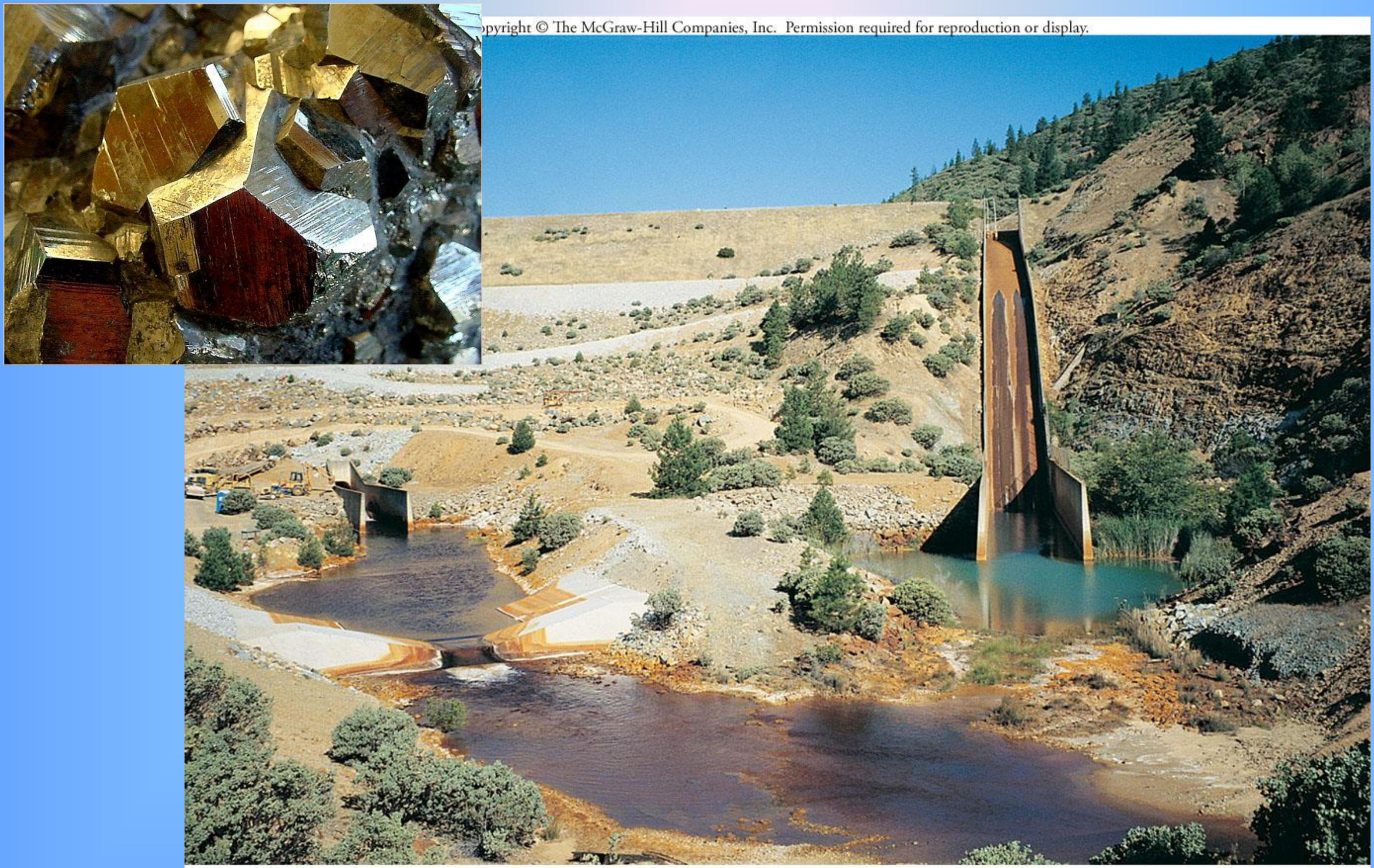


Photo by Charles Alpers, U.S. Geological Survey

- Mines with sulfur-containing minerals (e.g., pyrite)
- Minerals oxidize and form acids on the surface.

Sudbury, Ontario

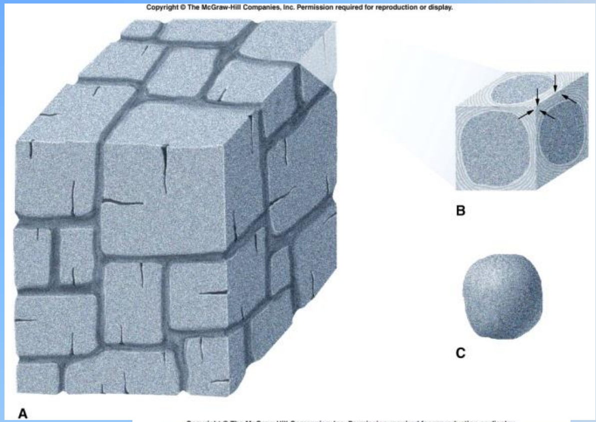
Effects of Chemical Weathering

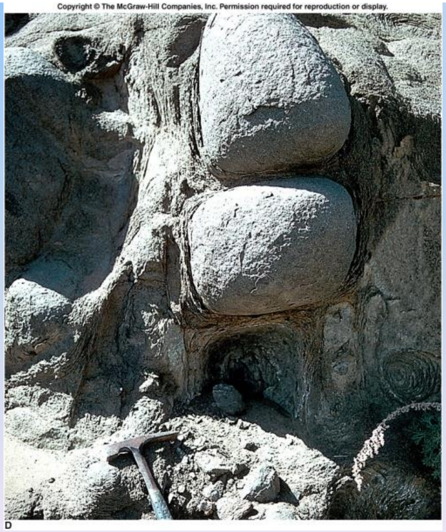
A

B

Effects of Chemical Weathering: Spheroidal Weathering

- **Top: Water penetrates along cracks resulting in rounded shapes.**
  - **Chemical weathering is more rapid on corners and edges.**
- **Bottom: Salt River Canyon, AZ**





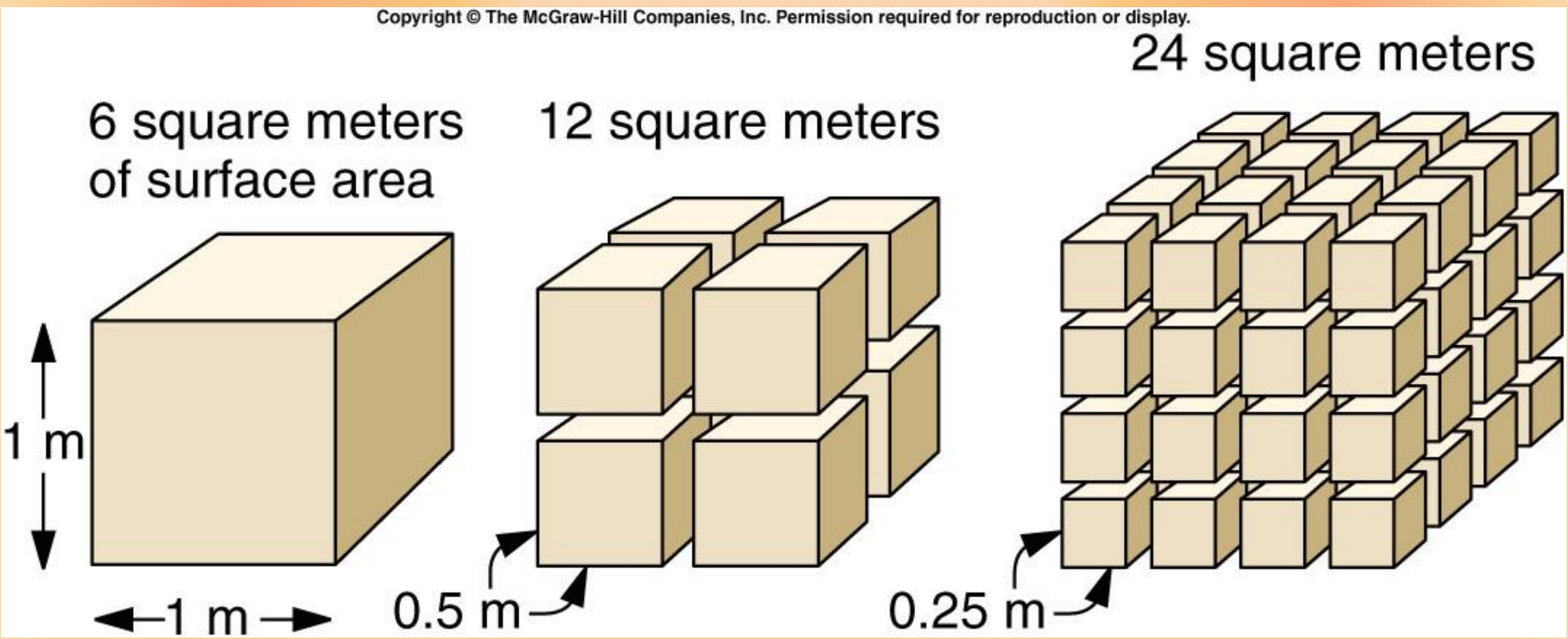
Happy Friday 4-4-14

- Grab Do Now and Begin
- Take out Alka-Seltzer Lab
- Finish Lab and Hand in
- Lab 3-1 Abrasion Monday!!

III. Factors Affecting the Rate of Weathering

A. Particle Size (Surface Area)

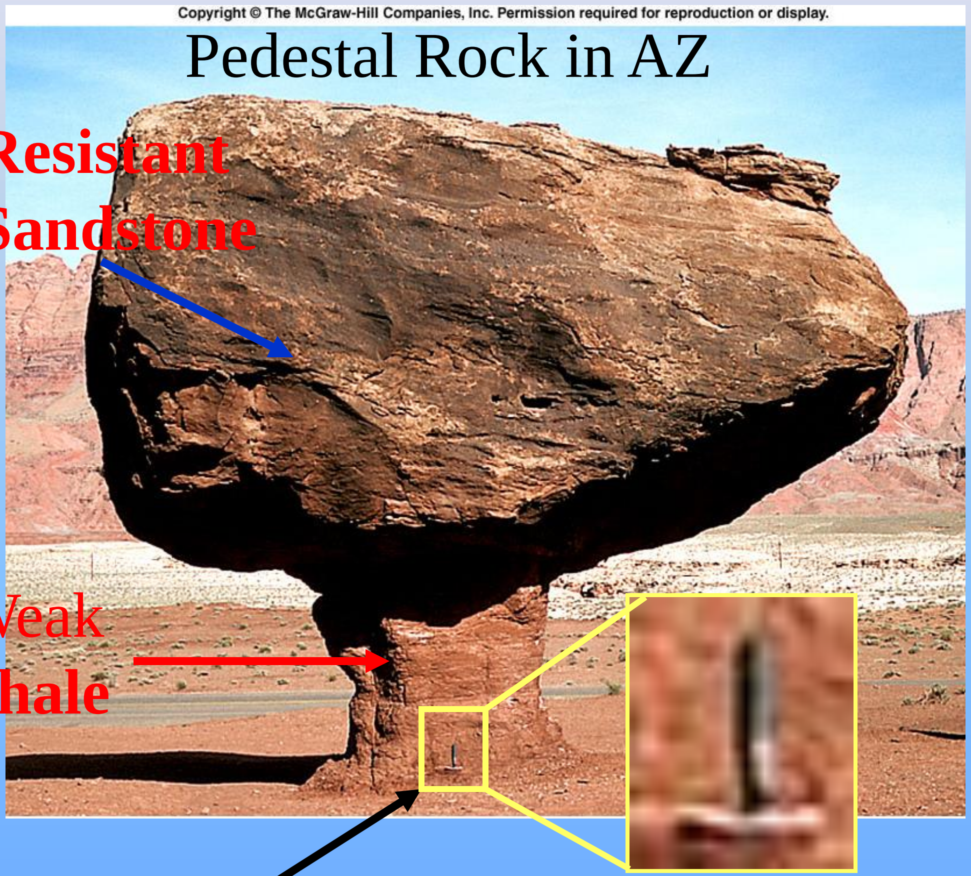
Mechanical Weathering Can Accelerate Chemical Weathering

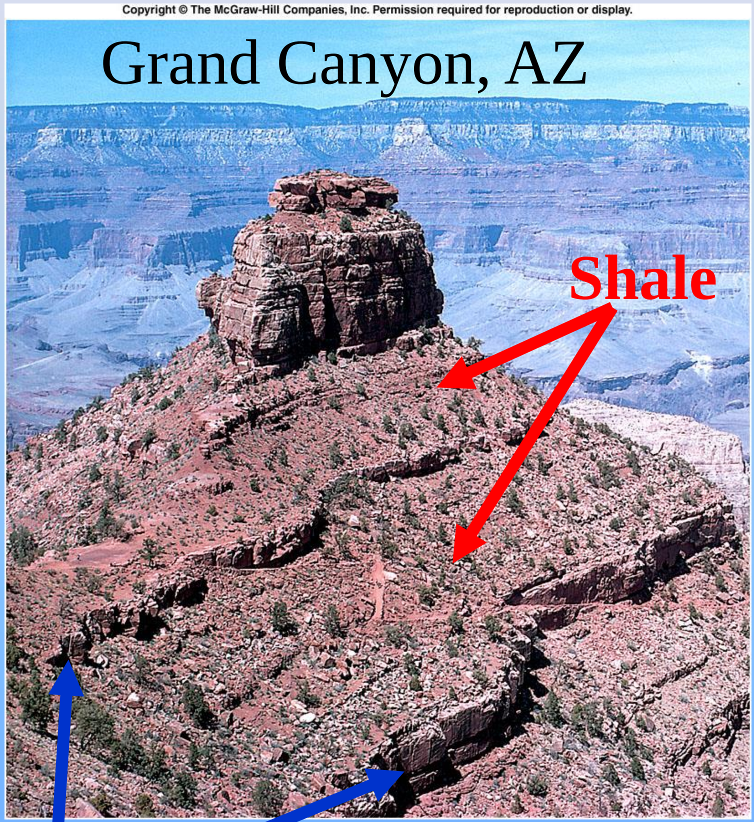


B. Rock Type (Lithology)

1. **Differential** weathering is the term for varying rates of weathering in an area where some rocks are more resistant to weathering than others.

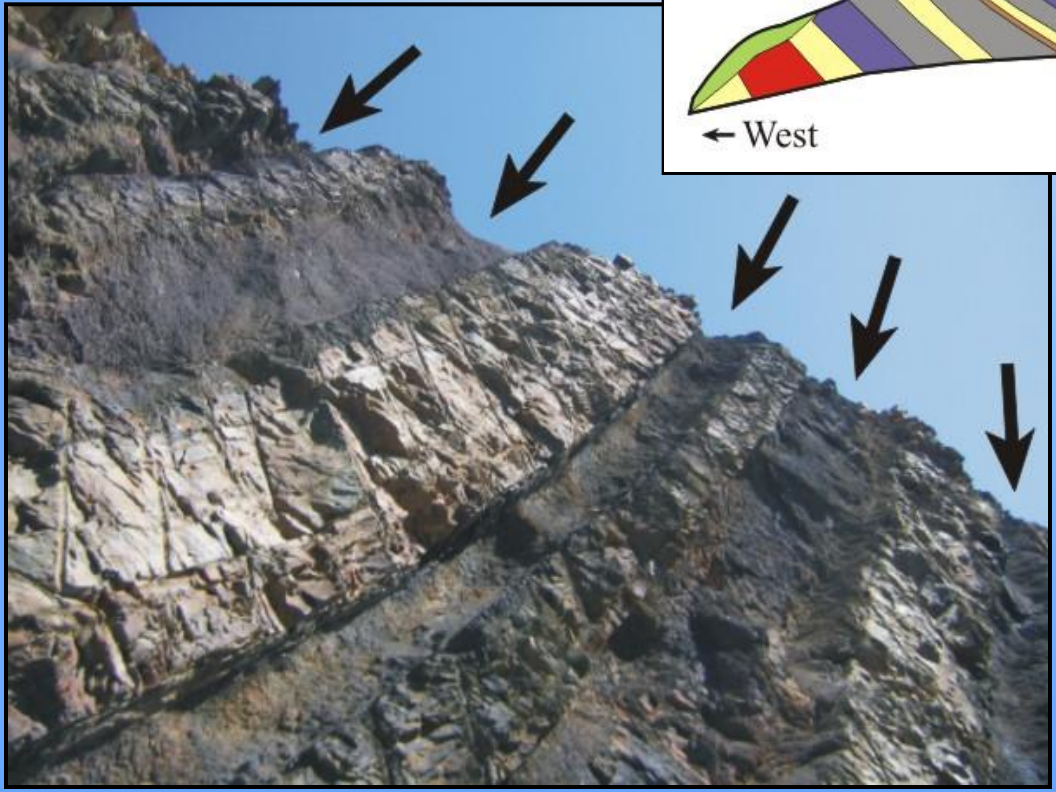
Differential Weathering

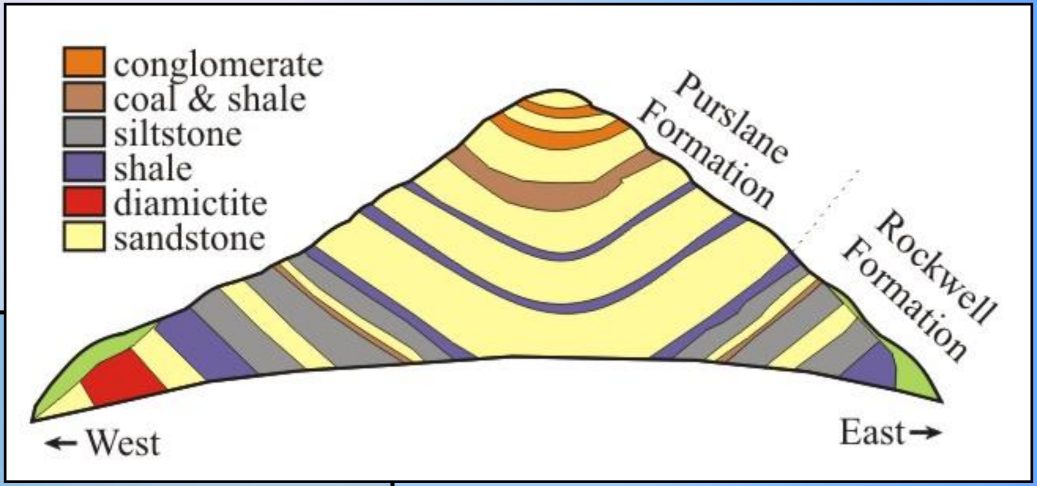




Sideling Hill Roadcut Near Hancock, MD

Sideling Hill Roadcut Near Hancock, MD





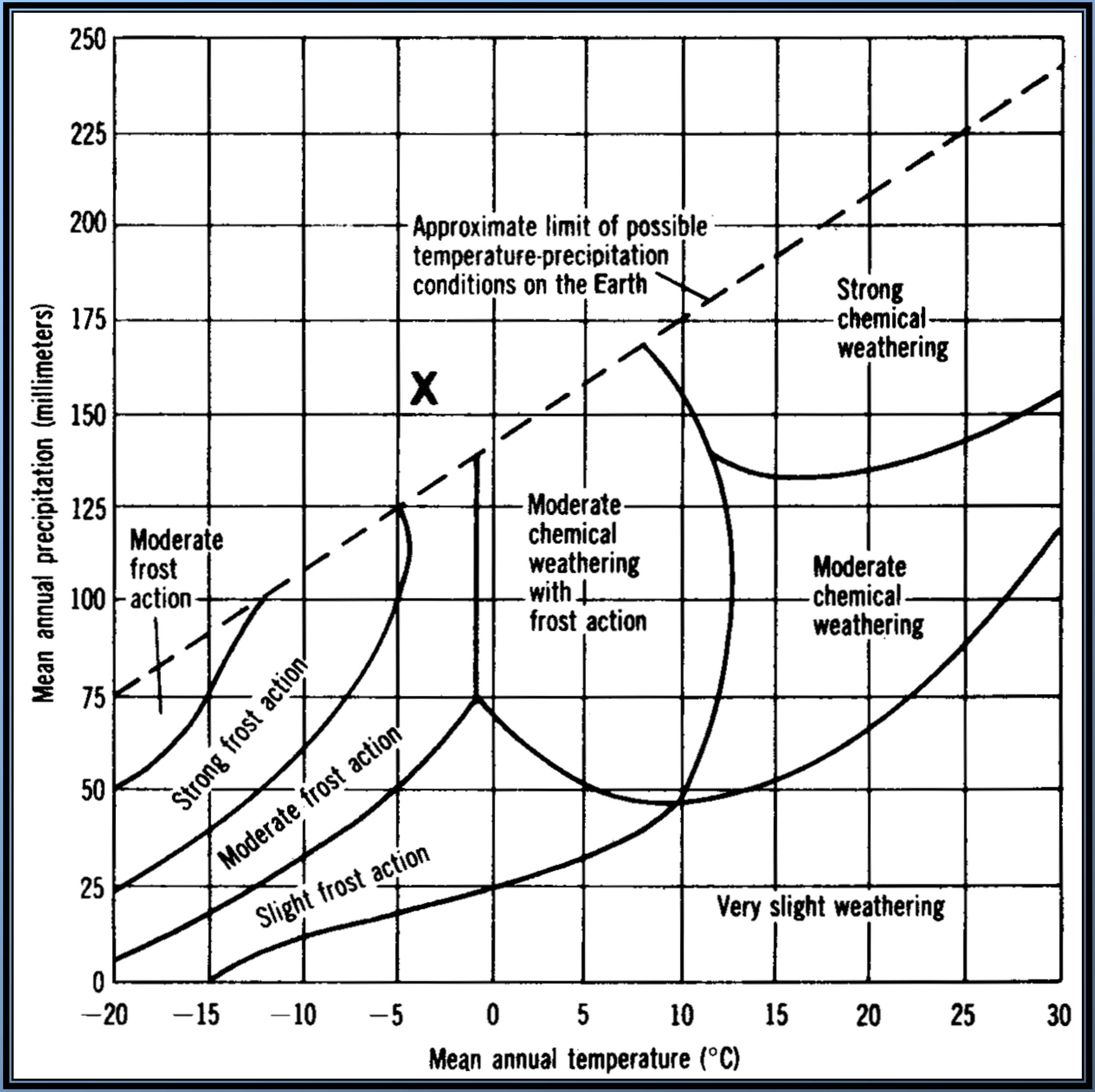
2. Generally, igneous and metamorphic rocks are more resistant than sedimentary rocks

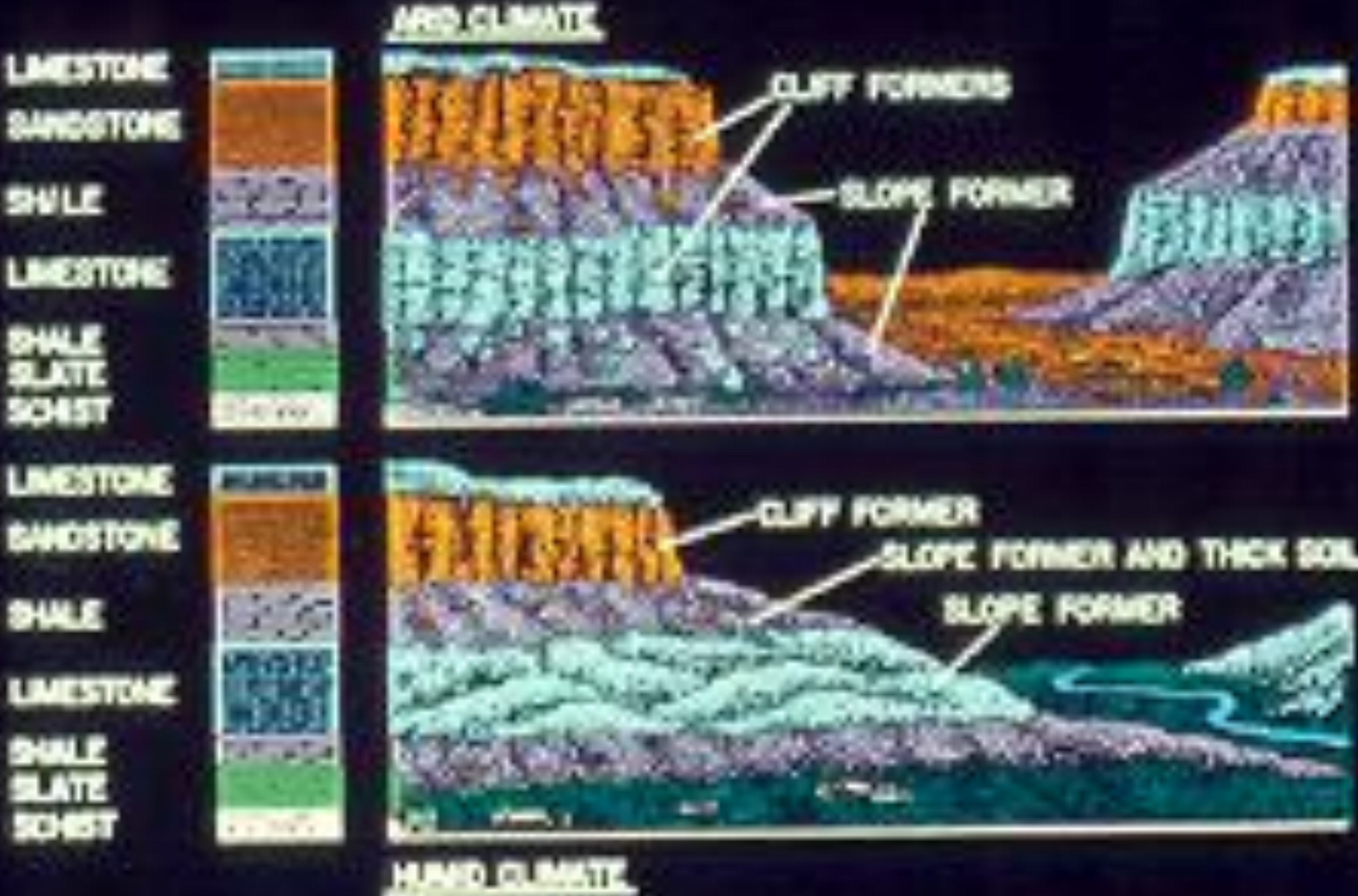
- This vein of igneous rock is more resistant to erosion than the limestone it transects and stands out like a small, vertical wall.

C. ___**Climate**_________________

1. Chemical weathering is most intense where there is abundant liquid ___**water**________.
2. In moist cold climates _**frost action**__________ is dominant.

Effect of Climate on Weathering





ARID CLIMATE
LIMESTONE
SANDSTONE
SHALE
LIMESTONE
SHALE
SLATE
SCHIST
CLIFF FORMERS
SLOPE FORMER
LIMESTONE
SANDSTONE
SHALE
LIMESTONE
SHALE
SLATE
SCHIST
CLIFF FORMER
SLOPE FORMER AND THICK SOIL
SLOPE FORMER
HUMID CLIMATE

Weathering Products

A. **Minerals**
   - Quartz and clay minerals commonly are left after complete chemical weathering of a rock.

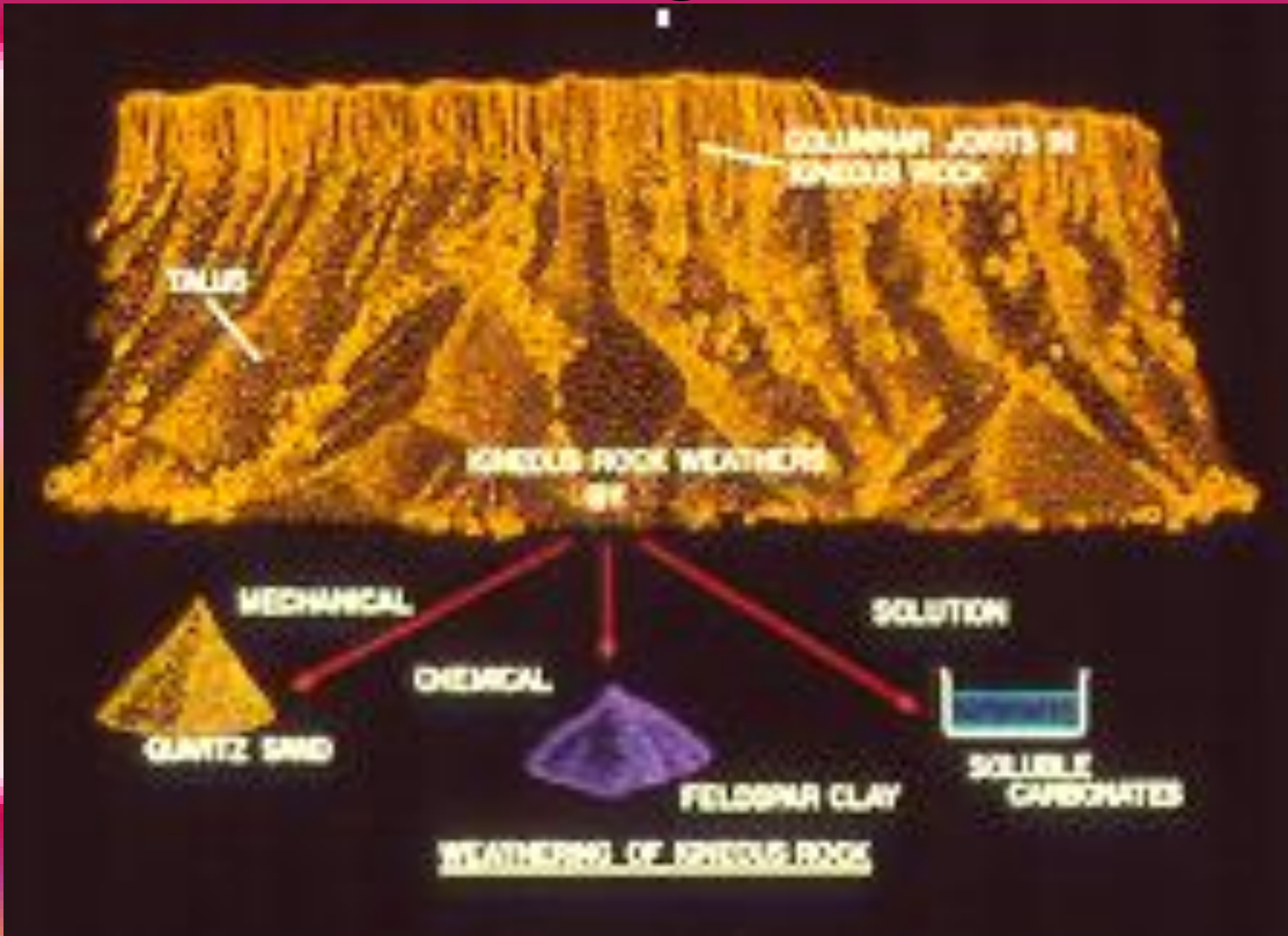
B. **Soluable Ions and Silica**
   - Remain in solution an may eventually find their way into a stream and then into the ocean.

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^-)

Weathering Products



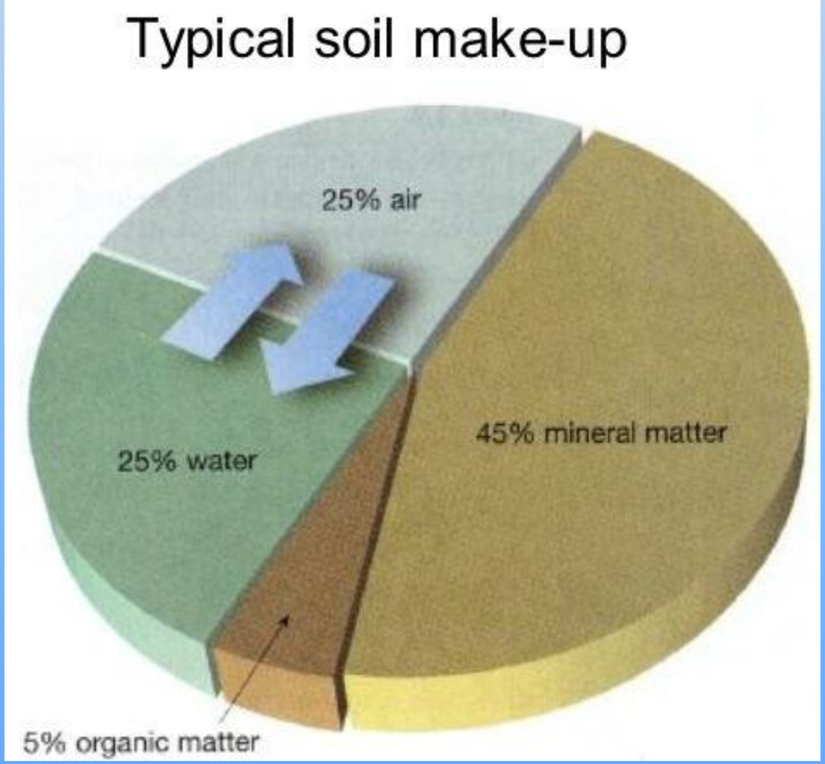
Good Morning ☺

- **Please find Alka Seltzer and hand in**
- **Begin Do Now**
- **Take out Weathering Notes Soils**
- **Go over HW from last night**
- **Questions on Abrasion Lab discuss tomorrow**
- **HW is in your UPCO RB**

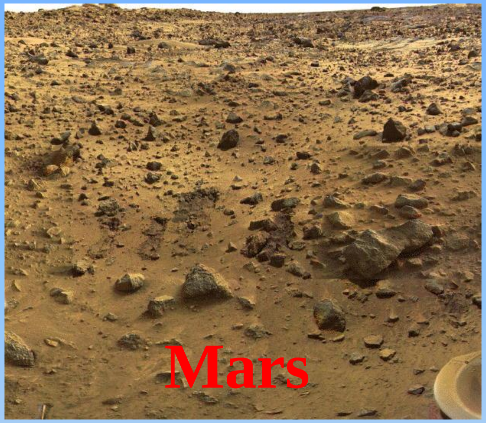
C. **Soil**

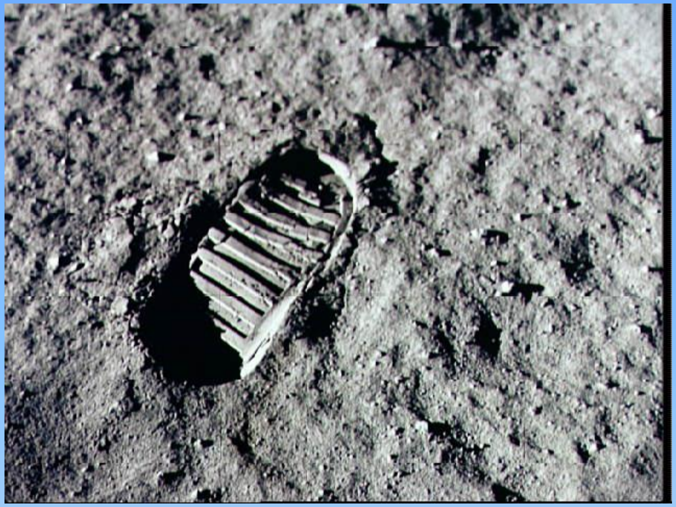
1. This is the layer of weathered, unconsolidated material on top of bedrock. A true soil contains:

- ❑ Minerals
- ❑ Water
- ❑ Air
- ❑ Organic Matter

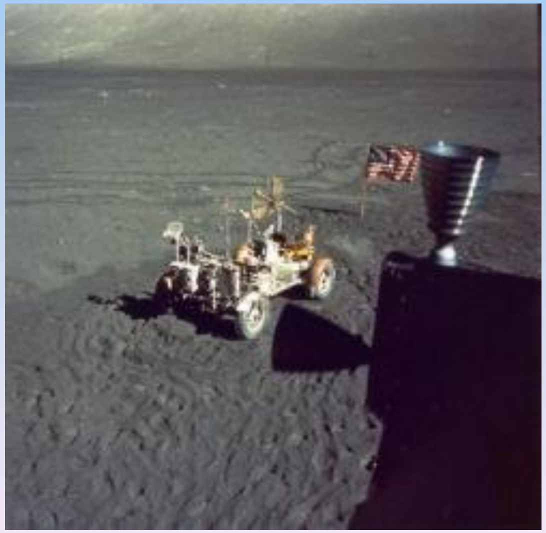


2. ___**Regolith**___: This is the loose surface sediment and soil is the upper part





The Moon



3. **Loam**: A soil of approximately equal amounts of *sand*, *silt*, and *clay*

Ternary Diagram

- Loamy soils are often well-drained and are often very fertile.
- **Soil Texture Diagram**
  - Sample A
    - 65% sand
    - 20% silt
    - 15% clay
  - Sample B
    - 33% of each size
  - Sample C
    - 40% sand
    - 42% silt
    - 18% clay

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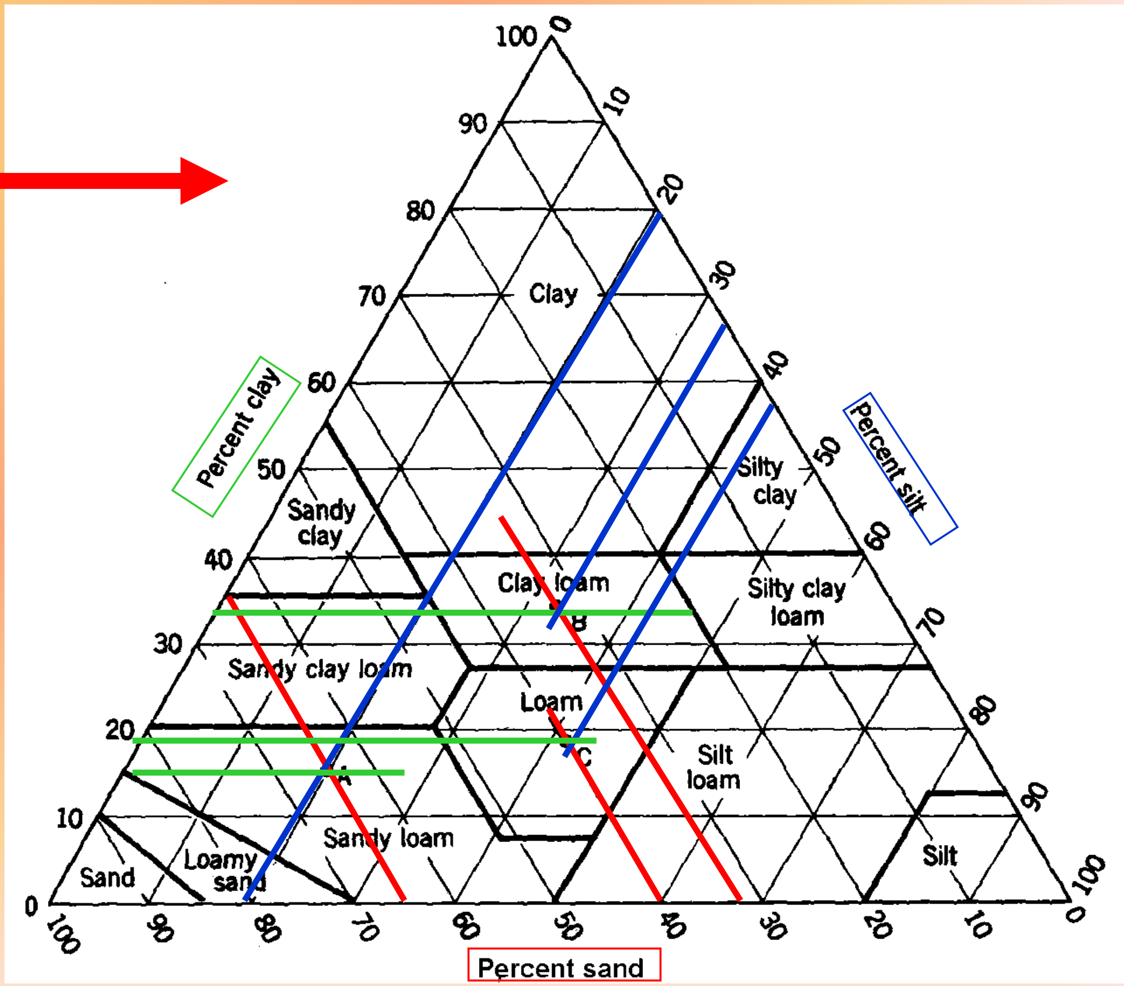
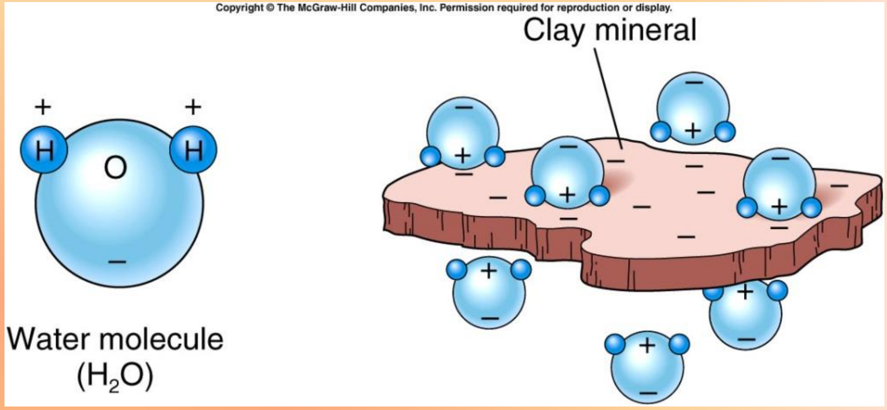
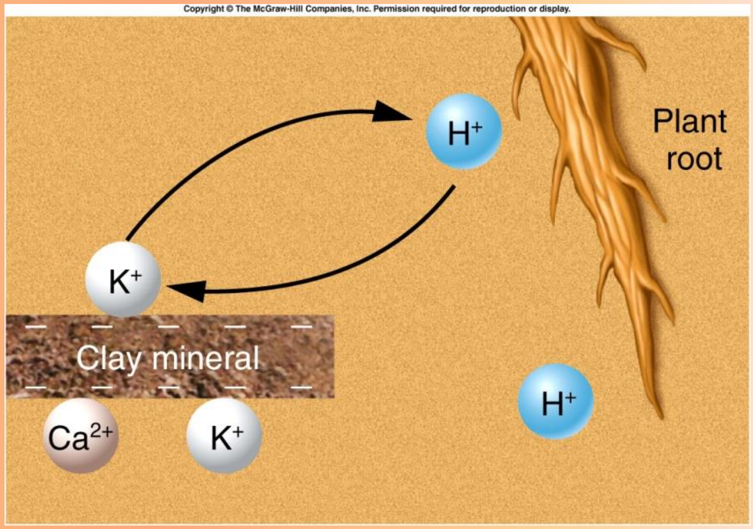


Loam

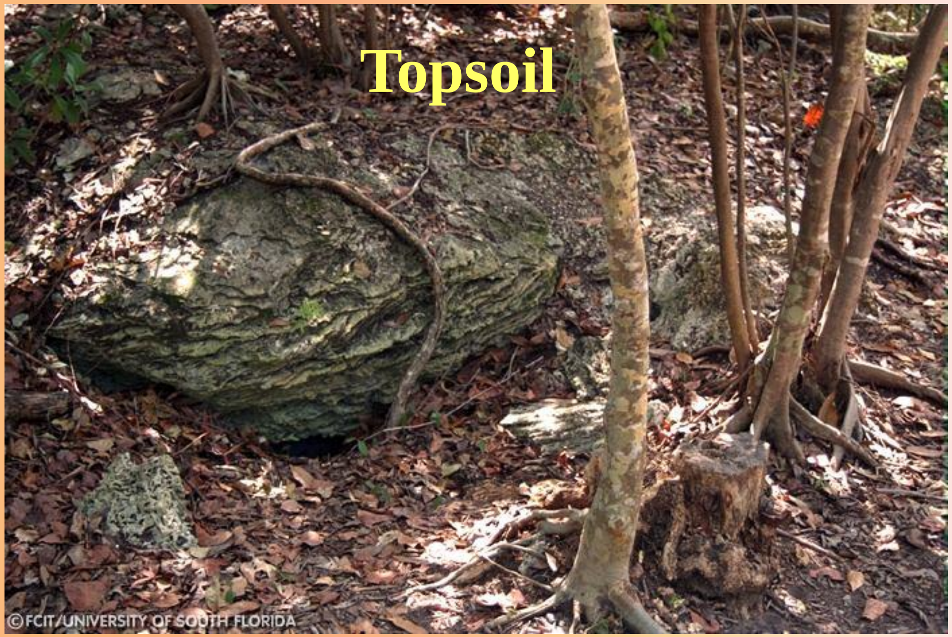
b. The **clay**-sized particles usually consist of clay minerals.
   i Help hold water and plant nutrients in a soil.
   ii. Holds water loosely enough so that most of it is available for uptake by plant roots.
   iii. Plant nutrients (Ca+ + and K +) often from weathering of feldspar also are held loosely on surfaces of clay minerals.

c. **Quartz sand grains** help keep soil loose and aerated, permitting good water drainage.





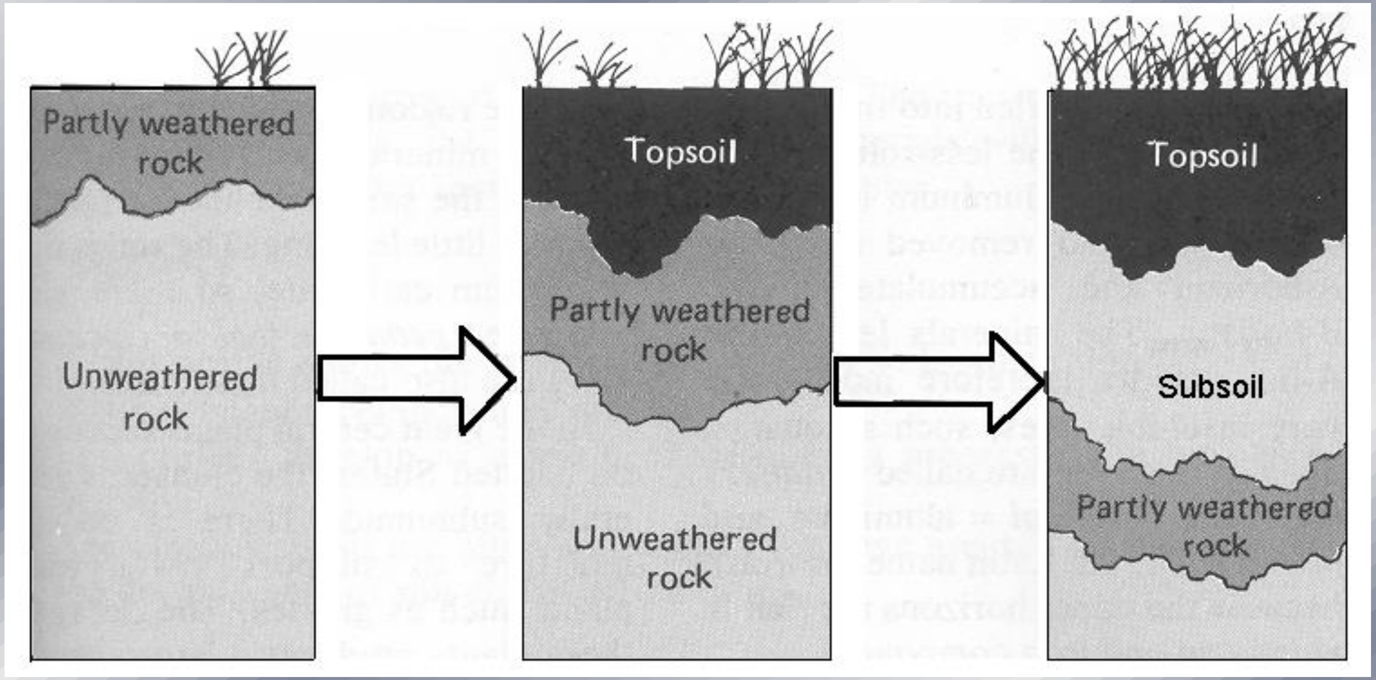
4. ___Topsoil___



- Basically the same as loam
- It is more fertile than the underlying ***subsoil***.

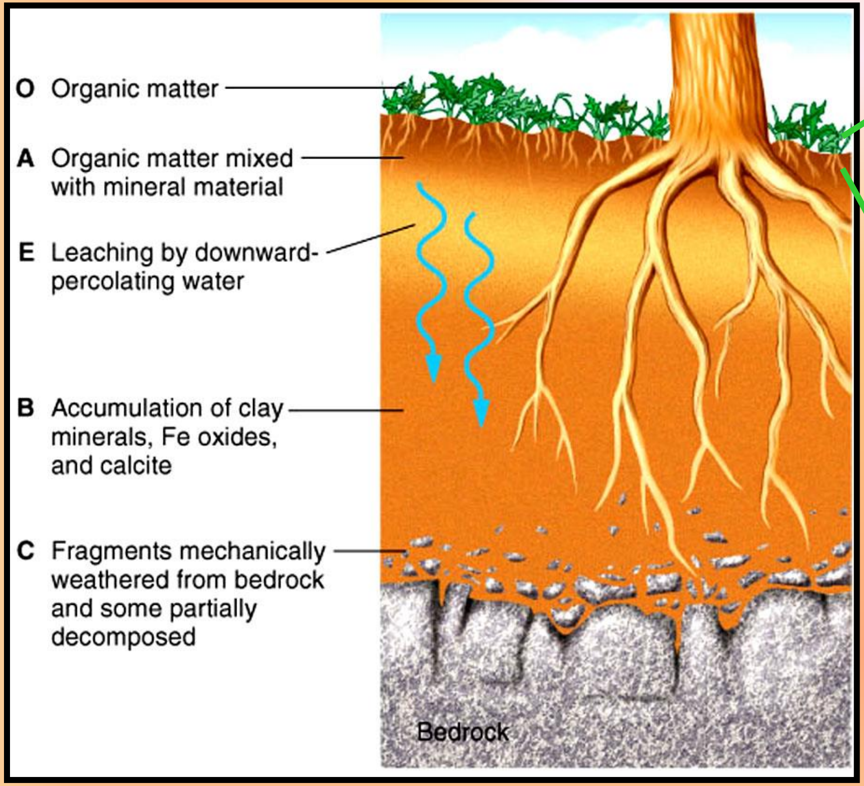
5. Soil **Horizons**

- As soils mature, distinct layers appear in them. These layers are called **soil horizons**. The rate of soil formation is controlled by ***rainfall, temperature*, and the *type of bedrock***.
- Most soils take a **long time** to form.



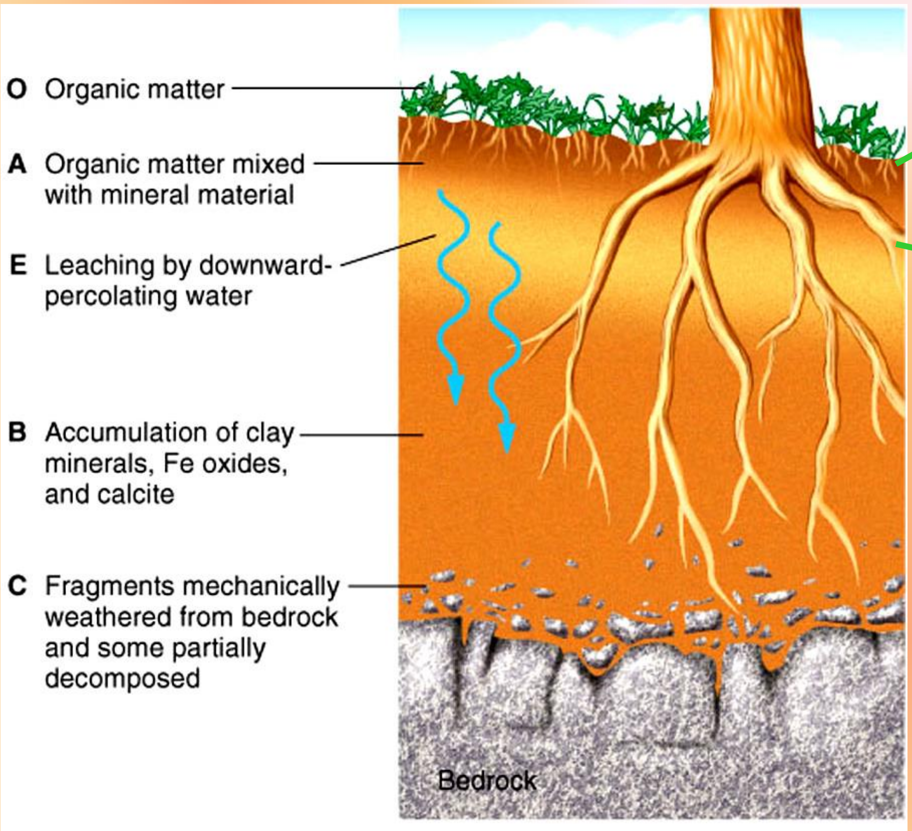
Immature | Immature | Mature

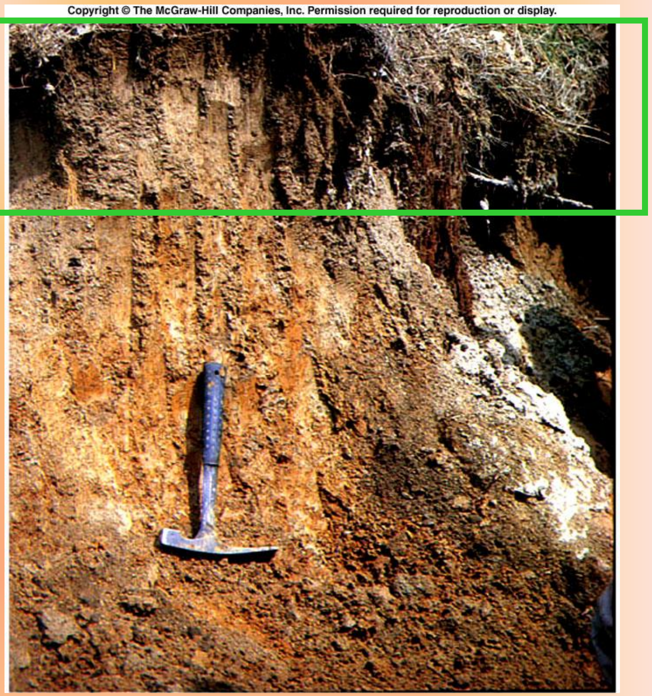
a) ___O___ Horizon



- Uppermost layer
- Entirely consists of undecomposed and highly decomposed organic material such as fallen leaves and needs along with ground vegetation

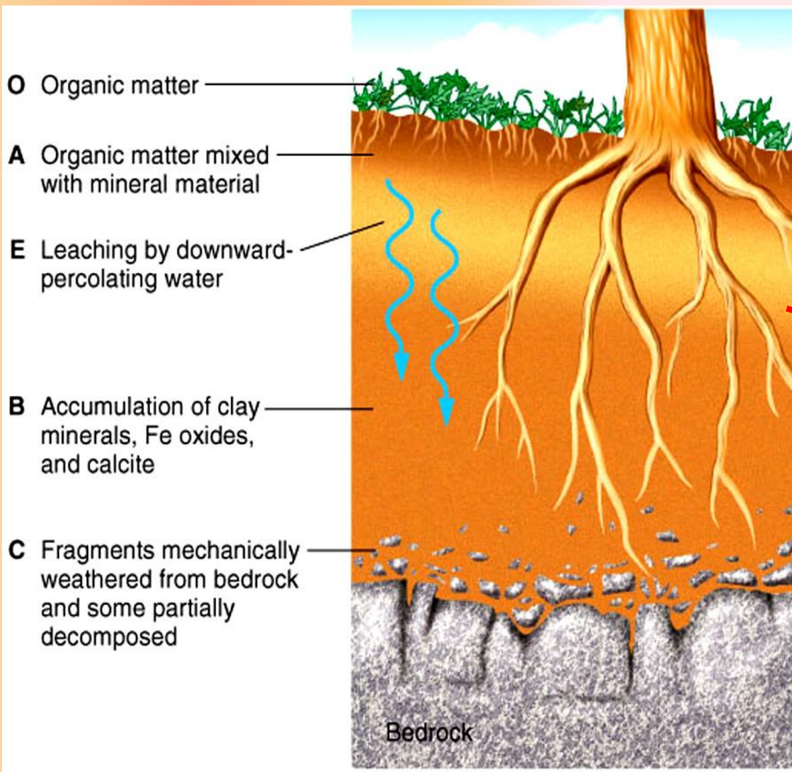
b) ___A___ Horizon

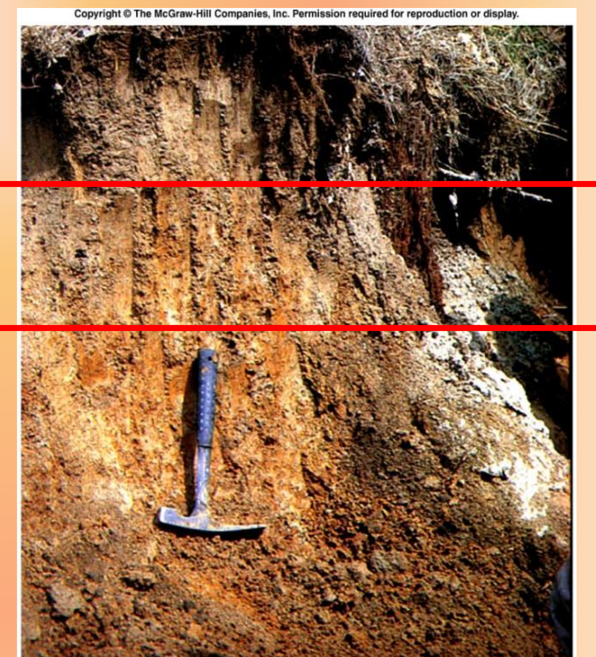




- Dark-colored soil layer
- Contains humus (topsoil) and usually dark in color from accumulated organic matter.

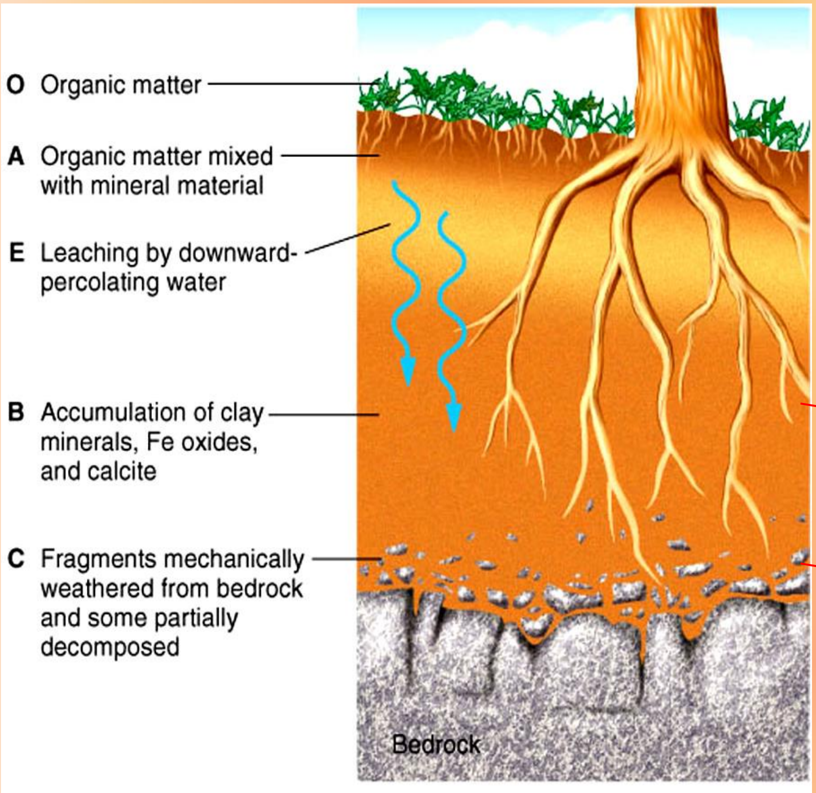
c) E Horizon or Zone of Leaching

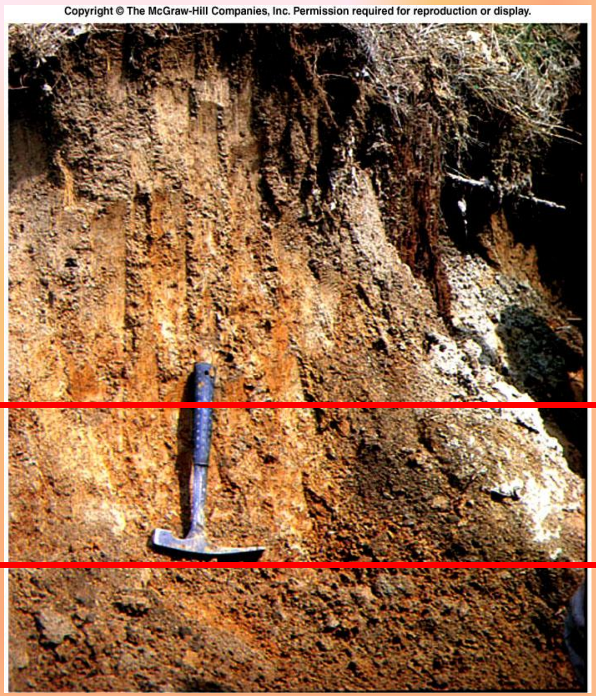




- Characterized by the *downward* movement of water
- Elluviation: Removal of fine-grained soil components (clay) by downward movement of water.
- Dissolved chemicals are carried to lower portions of the soil profile
- In a humid climate iron oxides and dissolved calcite are leached downward along with clays.
- This horizon may appear pale and sandy.

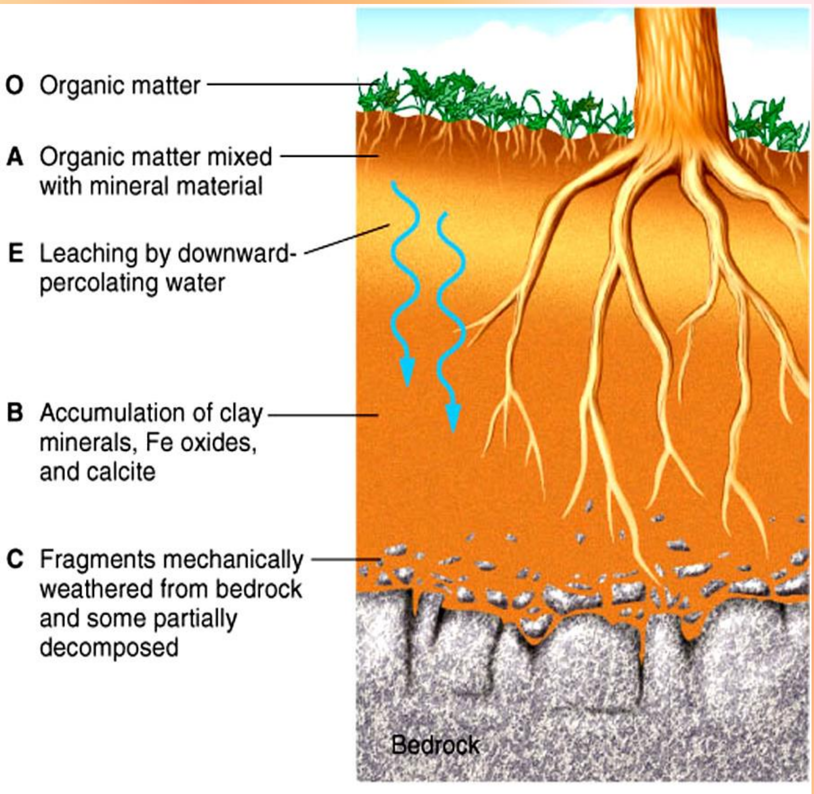
d) __B__ Horizon or Zone of __Accumulation__

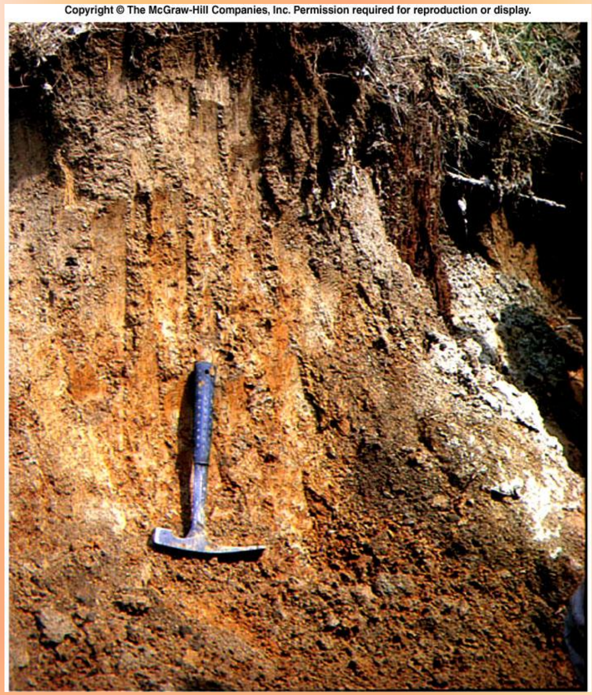




- Zone of accumulation of material leached from the A horizon.
- Is often clayey and stained from iron oxides.
- Calcite may also build up in this horizon.

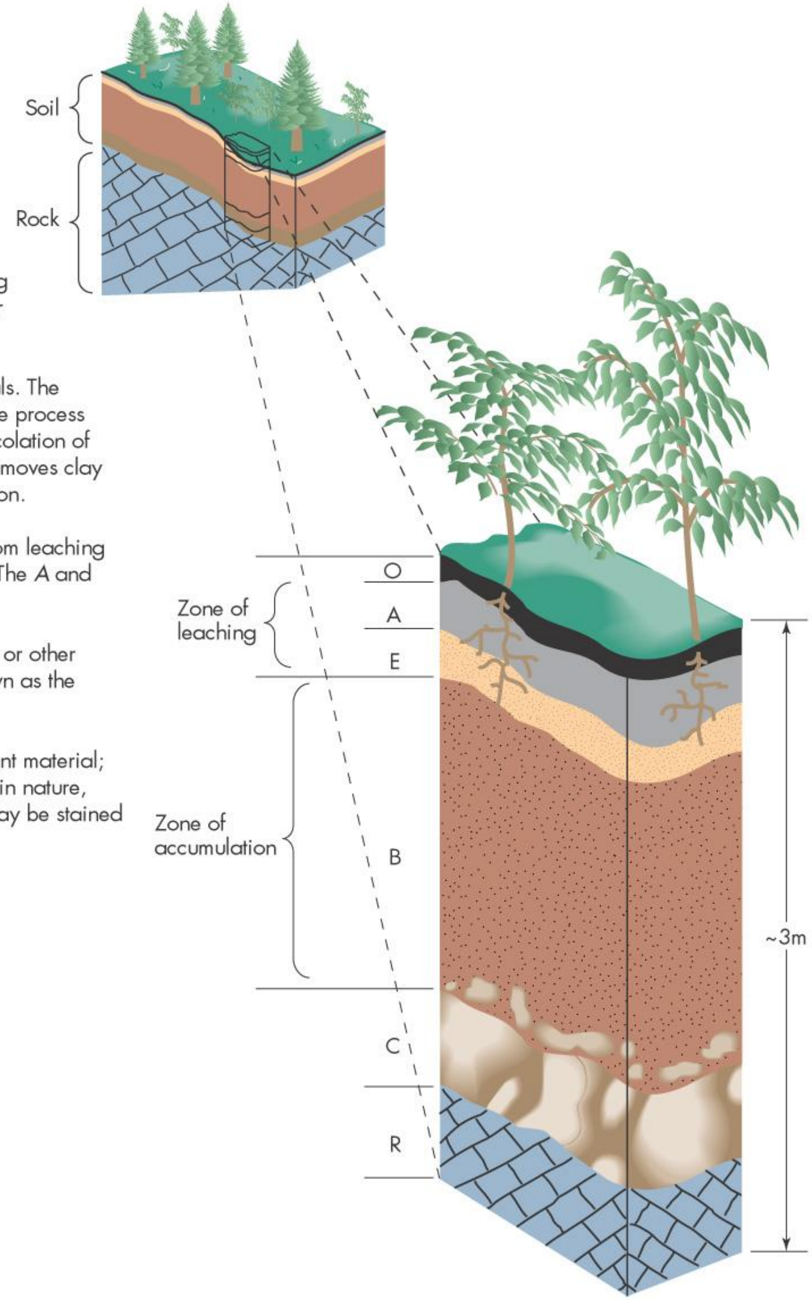
e) ____C____ Horizon





- Incompletely weathered parent material below the B horizon
- Contains fragments of weathered bedrock
- Transitional between unweathered bedrock and the developing soil above.

(a)



O. Horizon is composed mostly of organic materials including decomposed or decomposing leaves, twigs, etc. The color of the horizon is often dark brown or black.

A. Horizon is composed of both mineral and organic materials. The color is often light black to brown. Leaching, defined as the process of dissolving, washing, or draining Earth materials by percolation of groundwater or other liquids, occurs in the *A* horizon and moves clay and other material such as iron and calcium to the *B* horizon.

E. Horizon is composed of light-colored materials resulting from leaching of clay, calcium, magnesium, and iron to lower horizons. The *A* and *E* horizons together constitute the zone of leaching.

B. Horizon is enriched in clay, iron oxides, silica, carbonate, or other material leached from overlying horizons. Horizon is known as the zone of accumulation.

C. Horizon is composed of partially altered (weathered) parent material; rock as shown here but the material could also be alluvial in nature, such as river gravels in other environments. The horizon may be stained red with iron oxides.

R. Unweathered (unaltered) parent material.

Soil Classification

6. Residual and Transported Soils

a) Residual Soil


Soil from Basalt

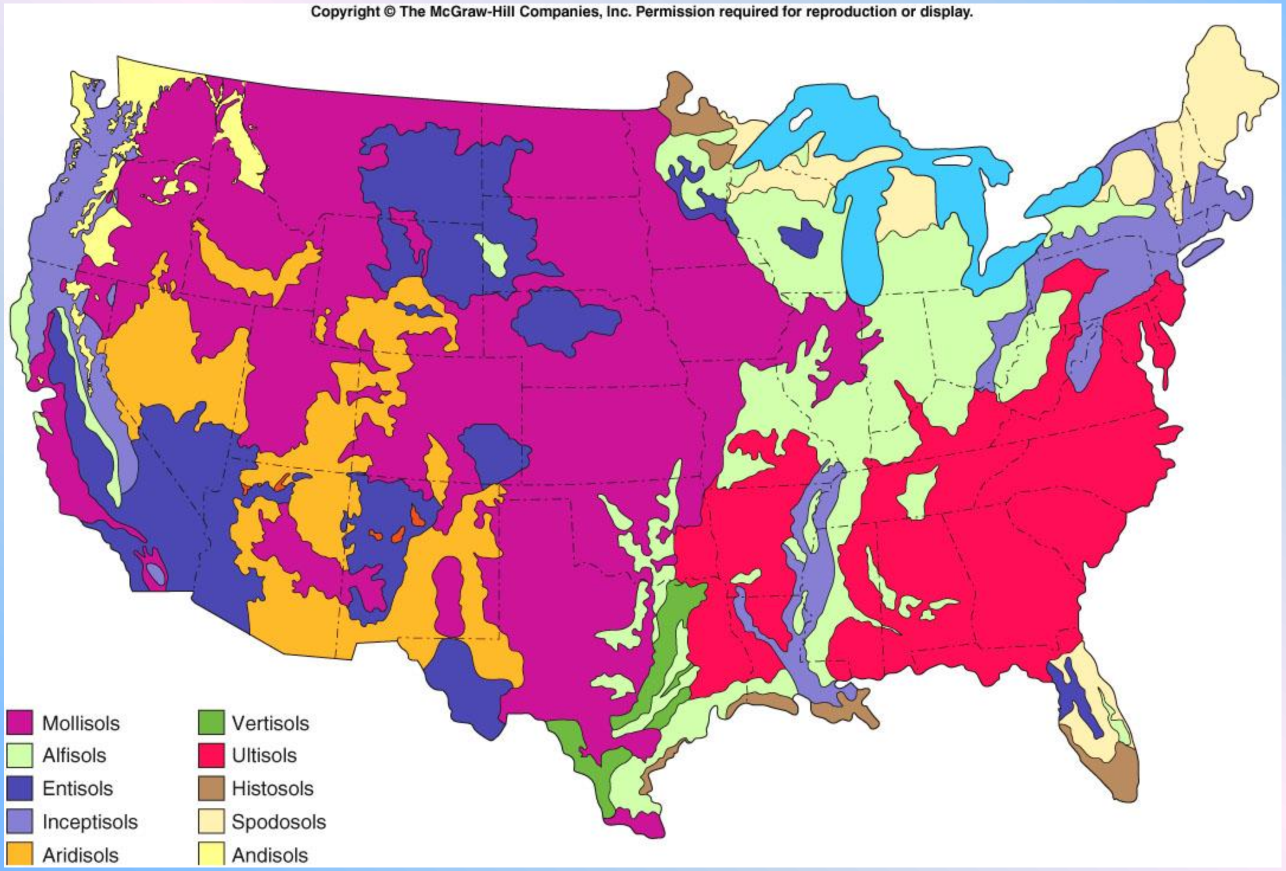

Soil from Limestone

- A soil that develops from weathering of the rock directly beneath it.
- The soil will have a similar appearance as the bedrock in terms of mineral content and color.

b) Transported Soil

- A soil which did not form from the rock.
- It was brought in from another region, usually as sediment deposited by running water, wind (***loess***), or glacial ice.

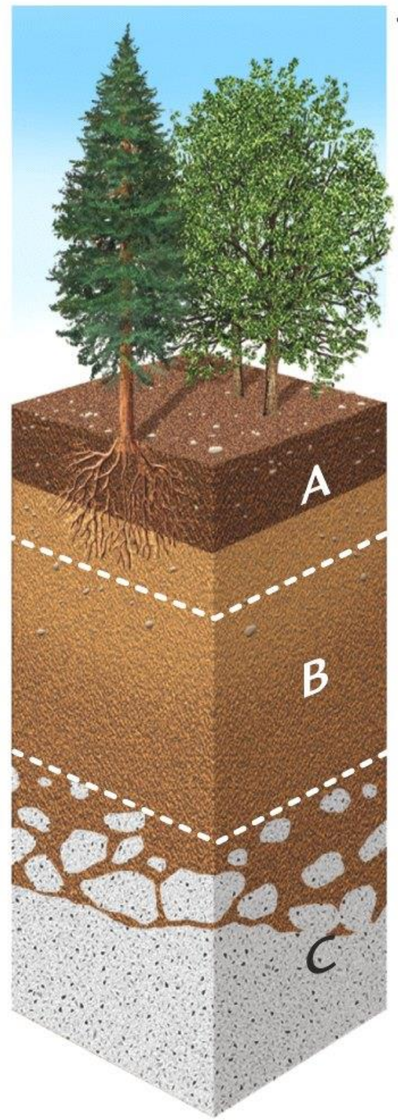
U.S. Dept. of Agriculture Soil Orders



7. Soils and Climate

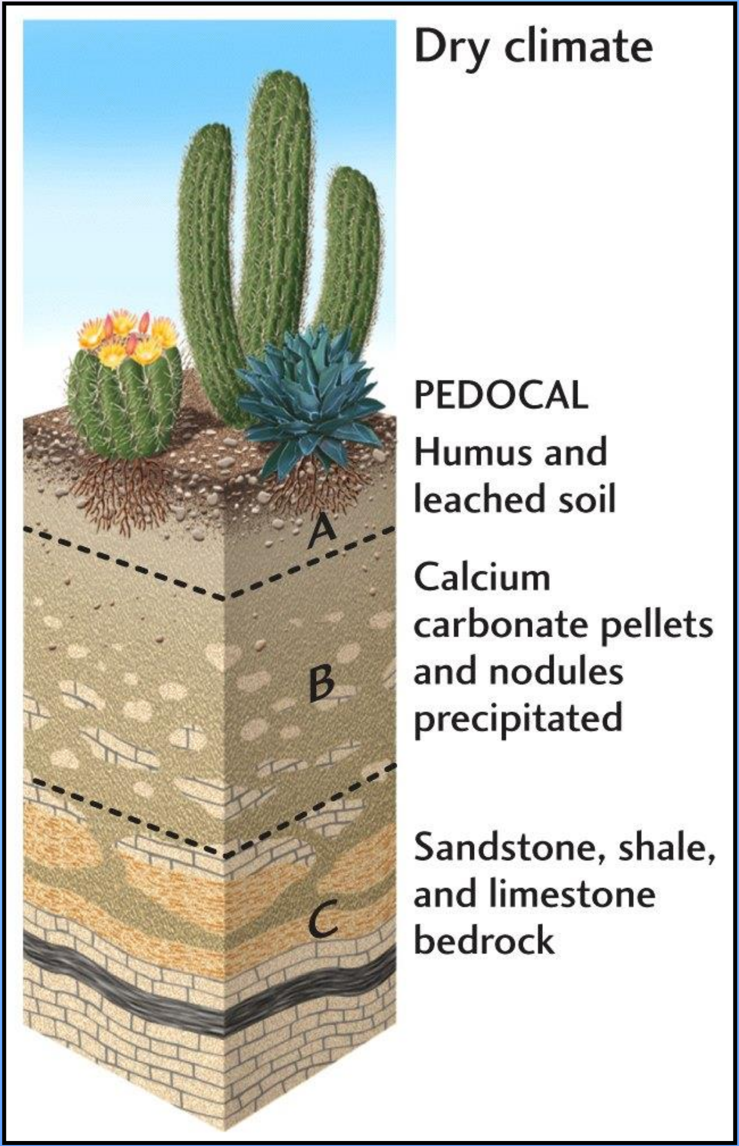
a) Pedalfer Soils

- Soils formed in wet climates, as in the eastern United States.
- High content in aluminum and iron oxides (Al and Fe)
- Also called *forest soils*

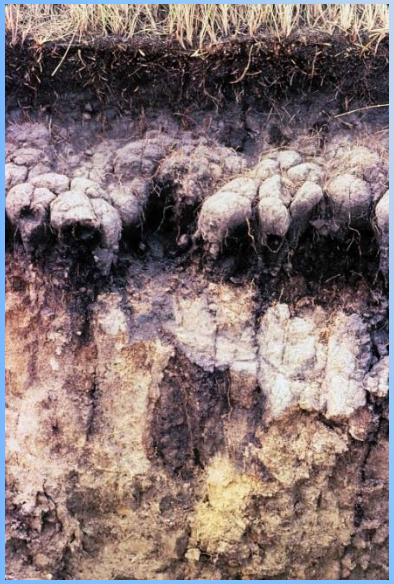


b) Pedocal Soils

- Arid climates
- Western U.S.
- Thin with little leaching and upward movement of soil water (caused by evaporation and capillary action.
- Salts (usually calcium salts such a calcite) are deposited inhibiting plant growth.

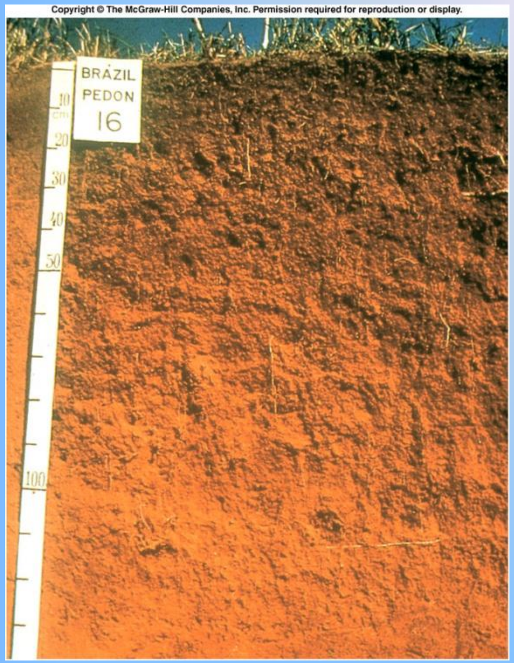


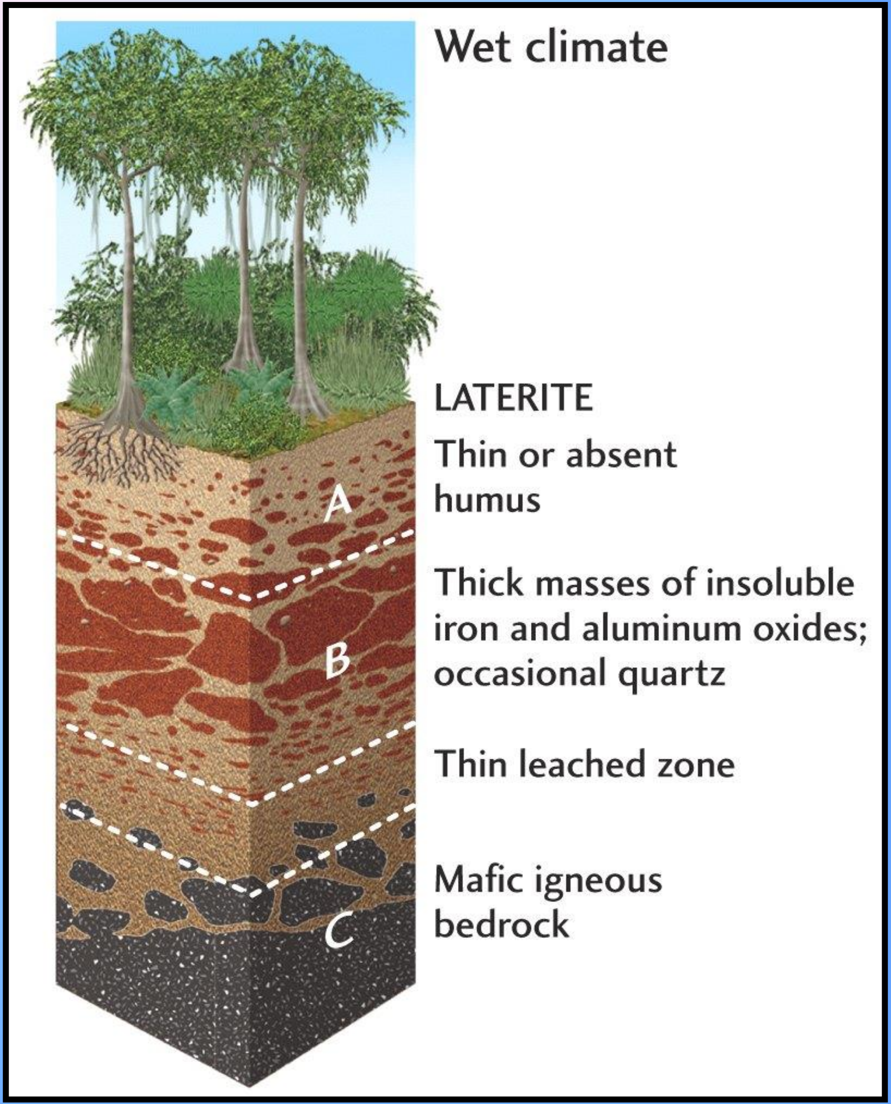
c) ___Hardpan___



- Hard layer of Earth material that is difficult to dig or drill.
- In wet climates it forms from clay minerals, silica, and iron compounds accumulating in the B horizon (Zone of Accumulation).
- In arid climates hardpan called ***caliche*** forms from the cementing of soil by calcium carbonate and other salts precipitated by evaporating water.

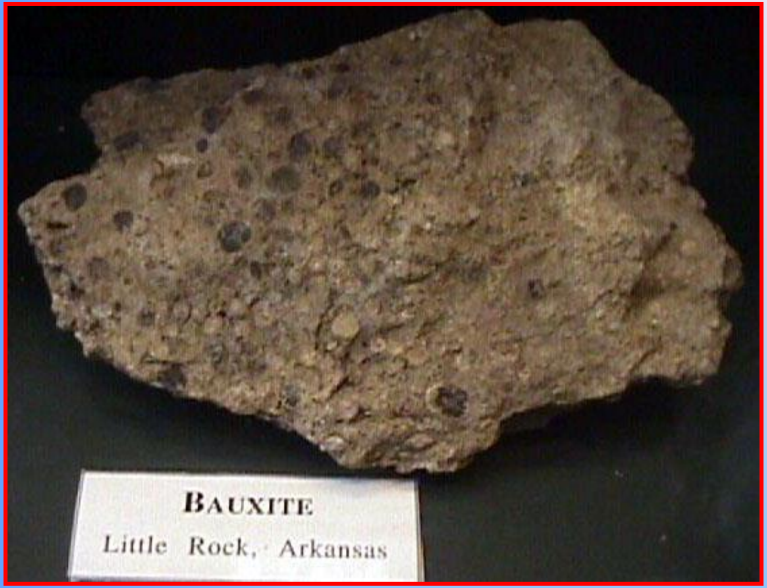
d) ___Laterites___



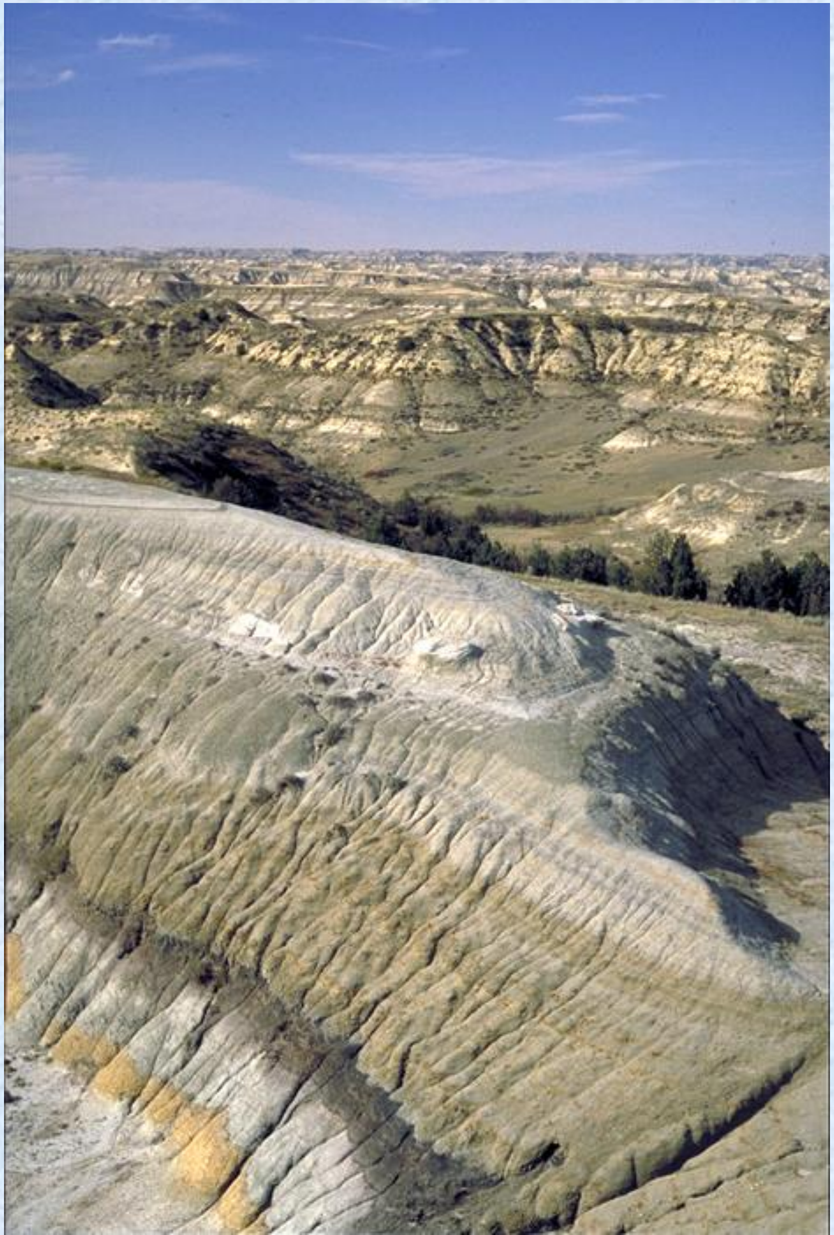


- Tropical soils that are highly leached (high rainfall and temperatures).
- Usually red (iron and aluminum oxides).
- The mineral *bauxite*, a principle ore of aluminum
  forms from weathering of al-rich igneous rocks.
- **<u>Laterites are unproductive soils</u>**, even in a lush tropical jungle

Bauxite



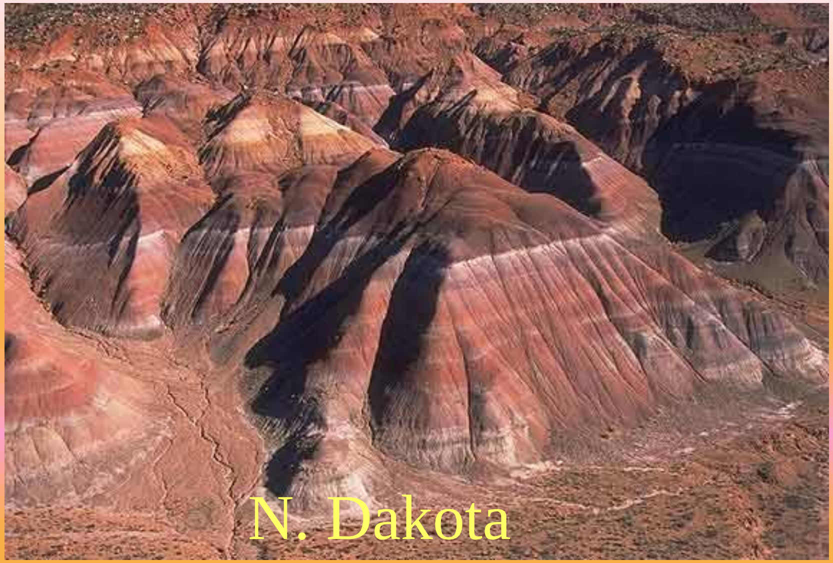
Badlands Topography



What are Badlands?

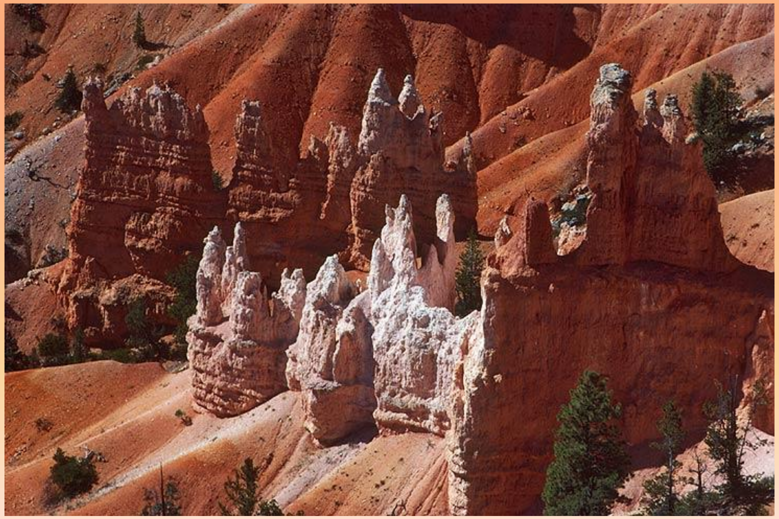
- Badlands are semiarid regions with sparse vegetation that experience high rates of erosion.
- Water and wind, instead of carving gentle hills and broad valleys, sculpt soft sedimentary rock into intricate mazes of narrow ravines, v-shaped gullies, knife-sharp ridges, buttes, and colorful pinnacles.
- Badlands are found throughout the world; however, a special set of geological conditions must be present for the formation of badlands *topography*.

How Are Badlands Formed?



- For badlands to form, the land must be composed of alternating layers of hard and soft rocks and soil.
- When easily eroded material, such as clay or mud stone, is topped by more resistant material, such as sandstone, the harder horizontal layers offer some protection to the beds of soft deposits below.
- Uncovered layers of softer rocks or soil wash away quickly, while protected deposits form nearly vertical walls beneath the harder material.

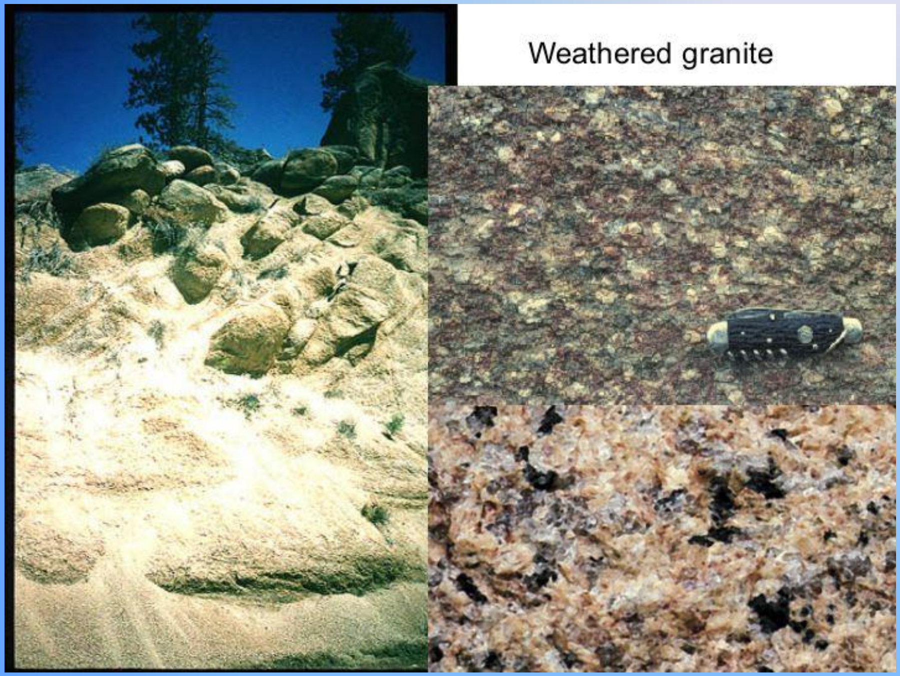
Brice Canyon, UT



8. Summary of Factors Affecting Soil Formation

a) Parent Rock

- Source of the weathered mineral matter that makes up most of a soil.

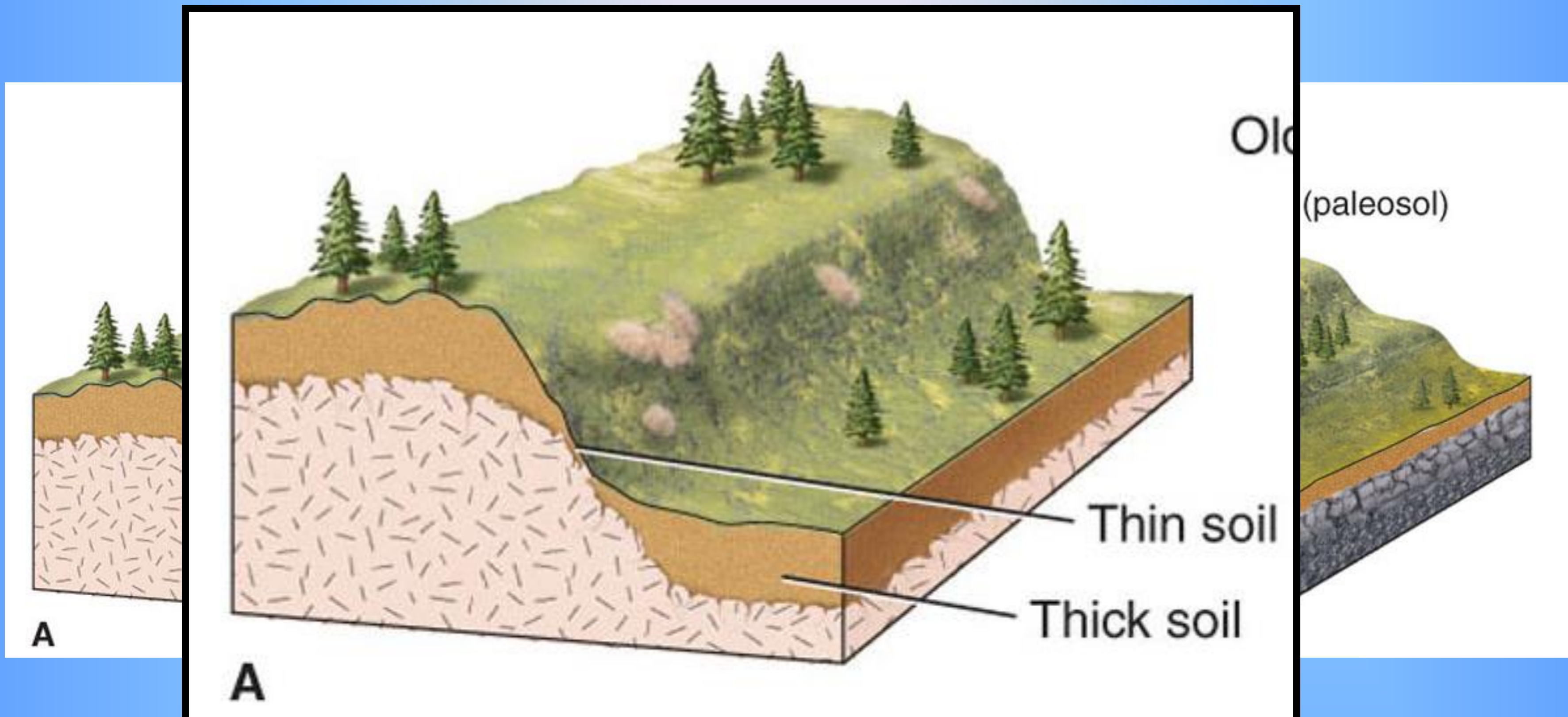


- Granite Parent Rock:
  - Results in a sandy soil containing quartz and feldspar which may weather to clay.
  - The variety of grain sizes results in a soil with good drainage and water-retention properties.

Parent Rock

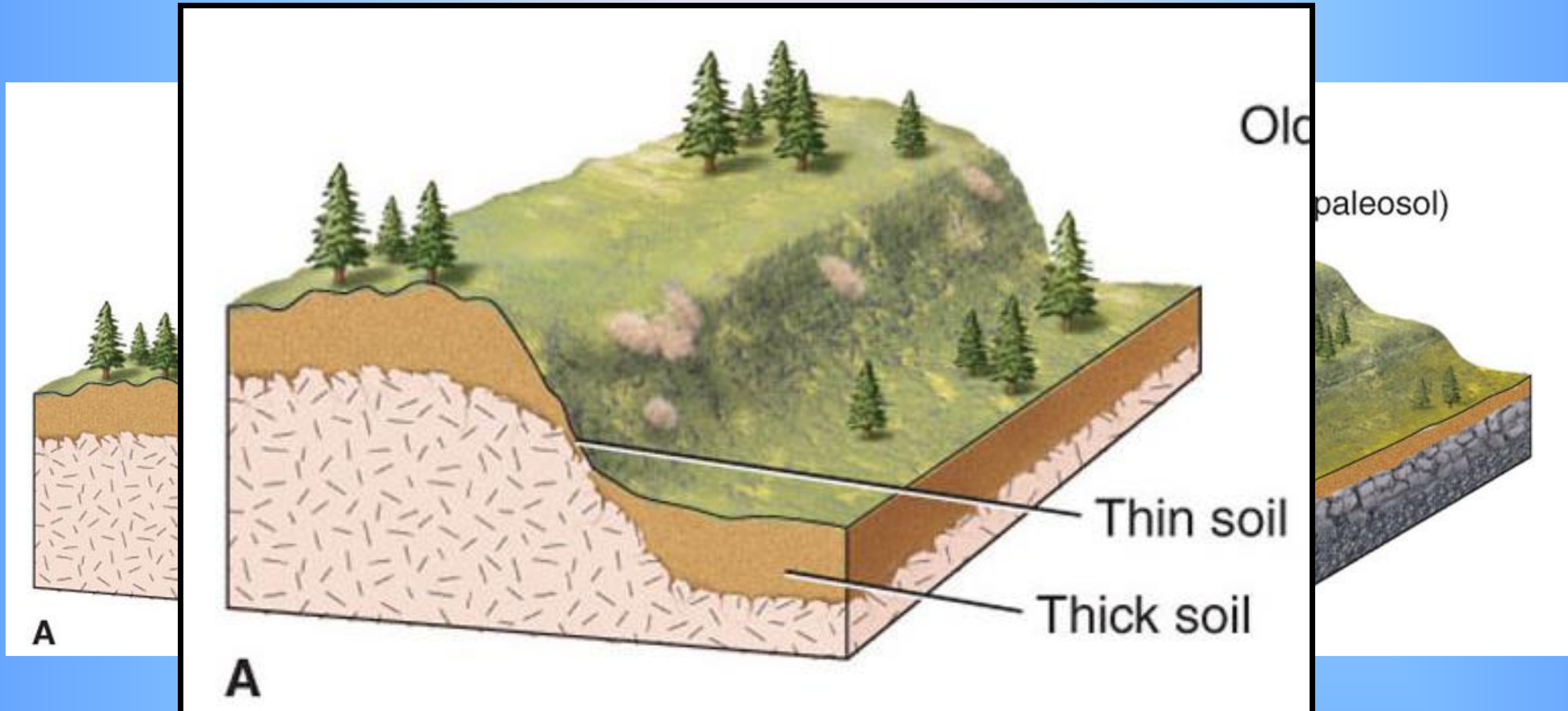
- Basalt Parent Rock:
  - Fine grained feldspars may weather directly to clay minerals.
  - No coarse grained minerals and no quartz so it may never be sandy.
  - Will not drain well.
  - May be quite fertile.

b) Slope



- Steep slopes:
  - Soil thin or not present
  - Because there is sparse vegetation roots are not present to hold weathering rock in place.

b) Slope



- Gentle Slopes: Optimal topography for soil formation
  - Good drainage
  - Minimal erosion
  - Healthy vegetation cover

Factors Affecting Soil Formation

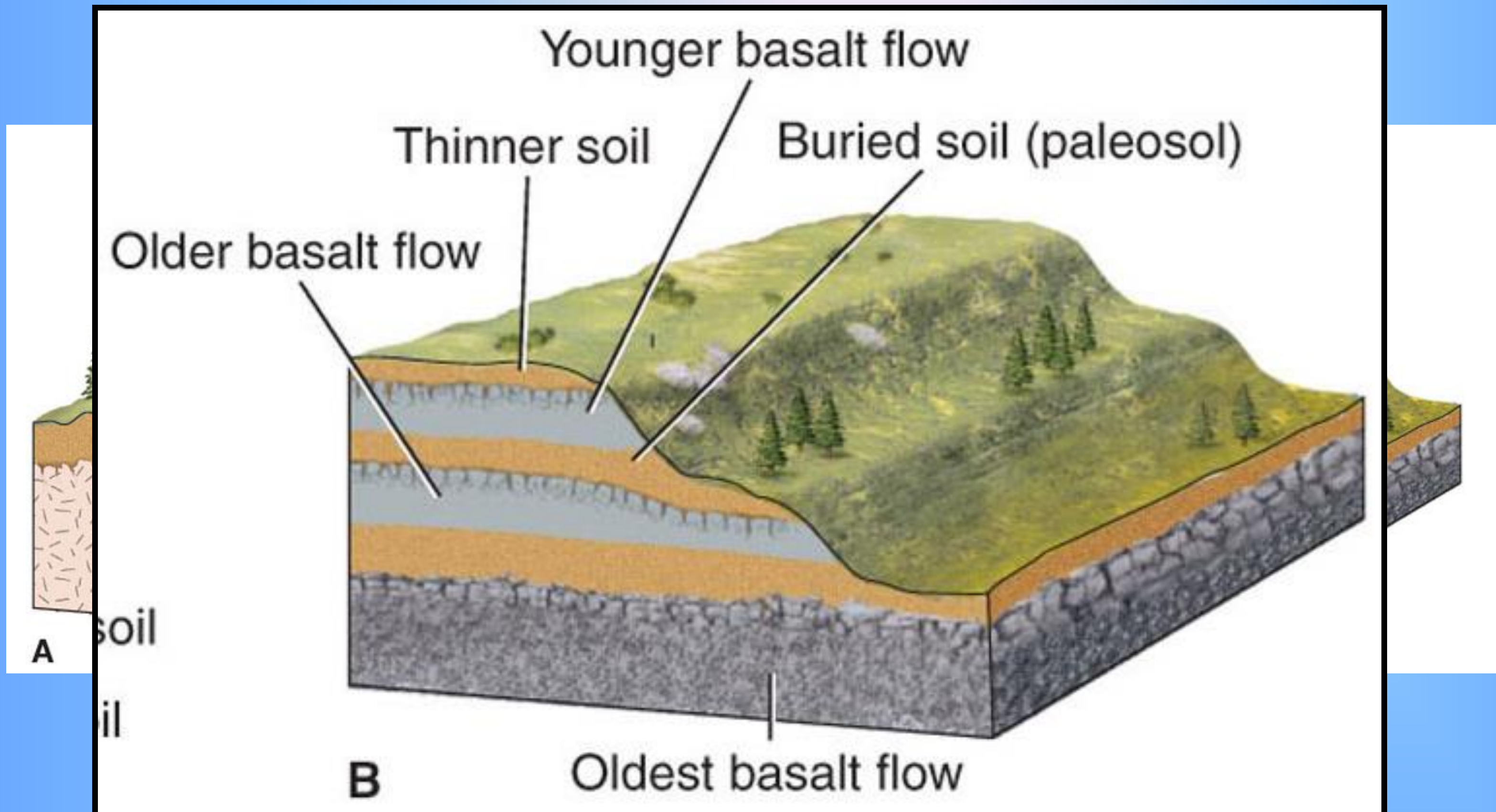
c) ___Living Organisms___:

- Contribute to the formation of humus
- Burrowing animals bring soil to the surface and mix the organic and mineral components of the soil

d) ___Climate___

- The most influential factor affecting soil thickness and character.

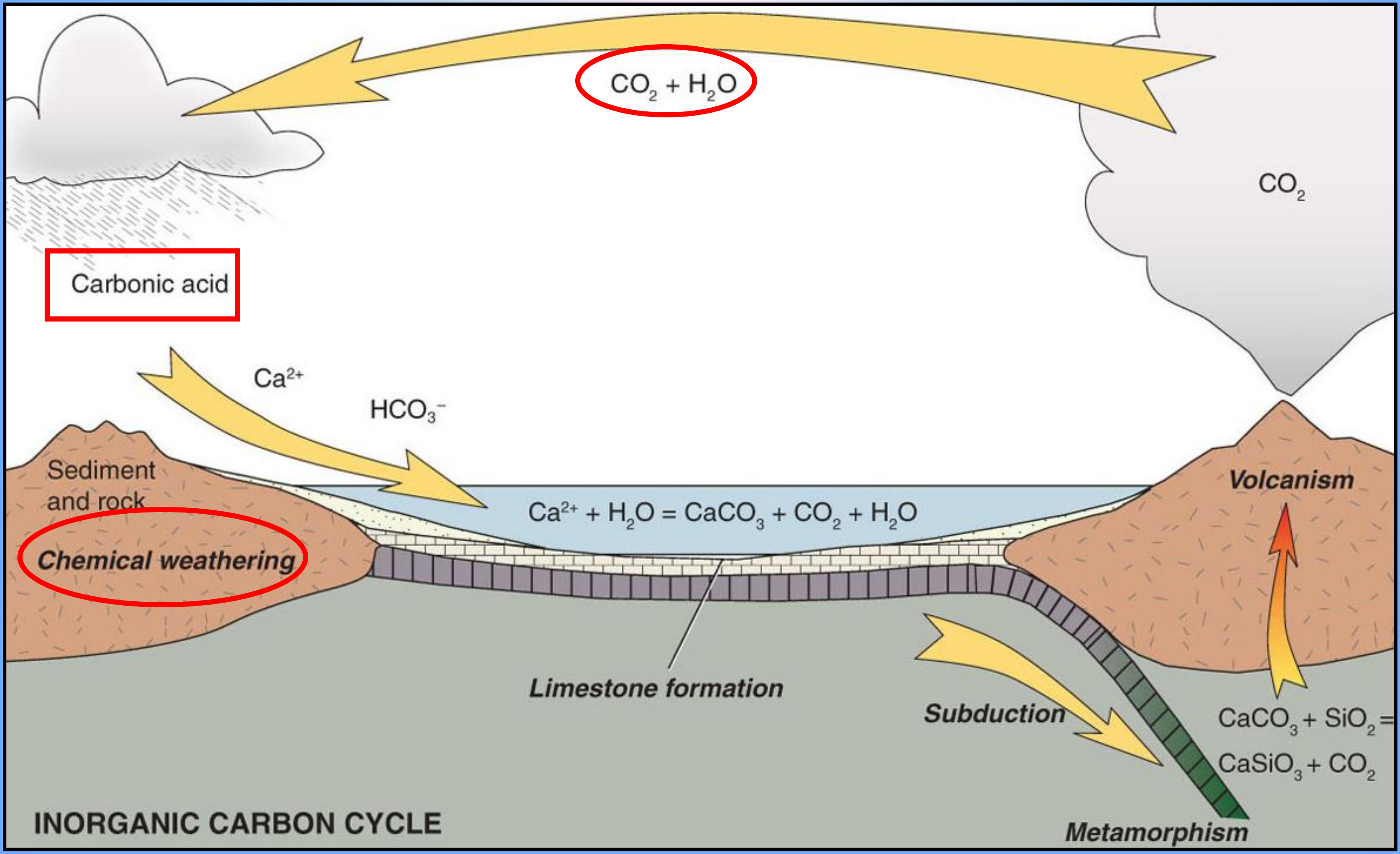
e) __Time______



- Affects thickness and character of the soil.
- Young residual soils will retain the character of the parent rock.

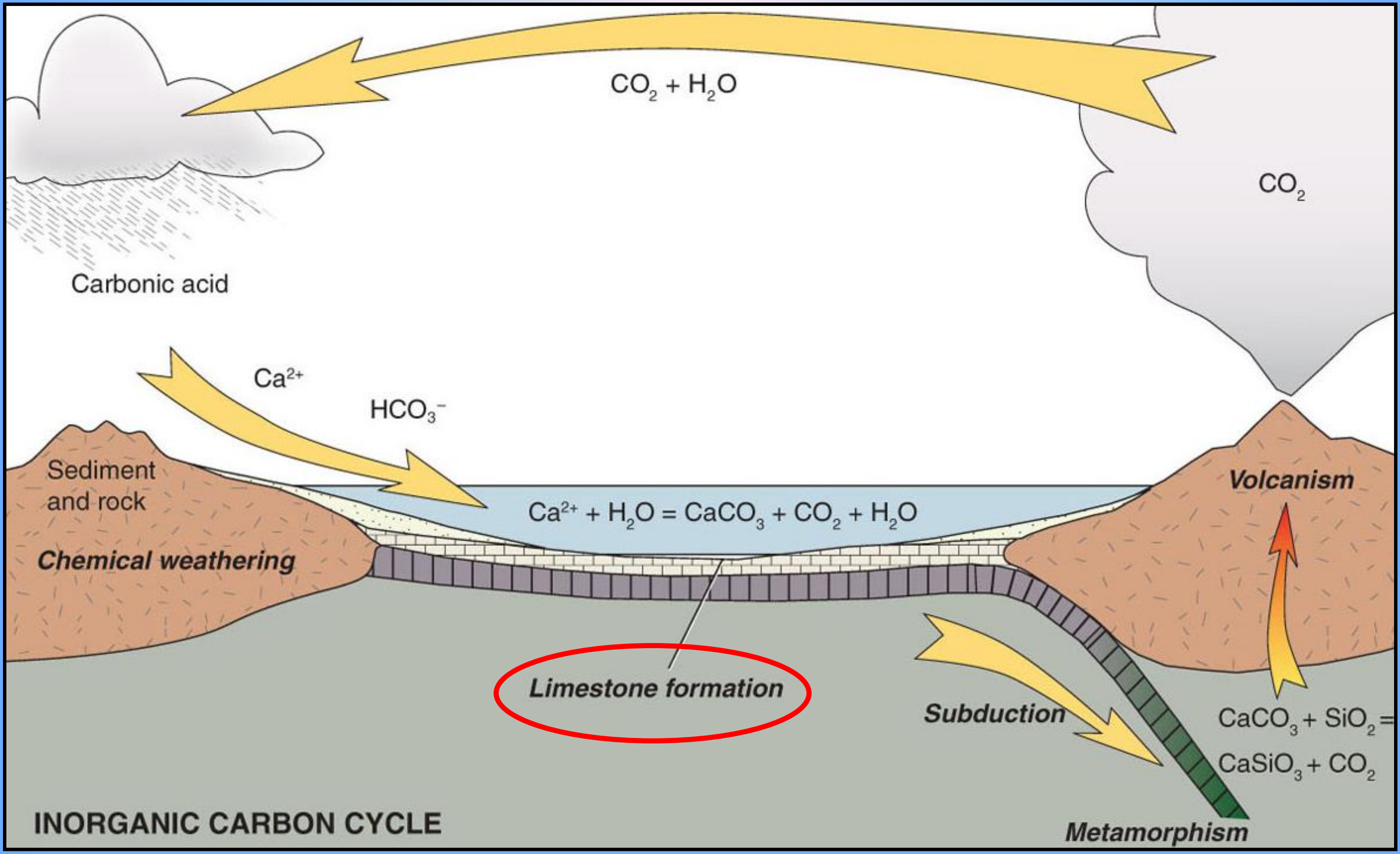
V. Weathering, the Carbon Cycle, and Global Climate

A. The Carbon Cycle



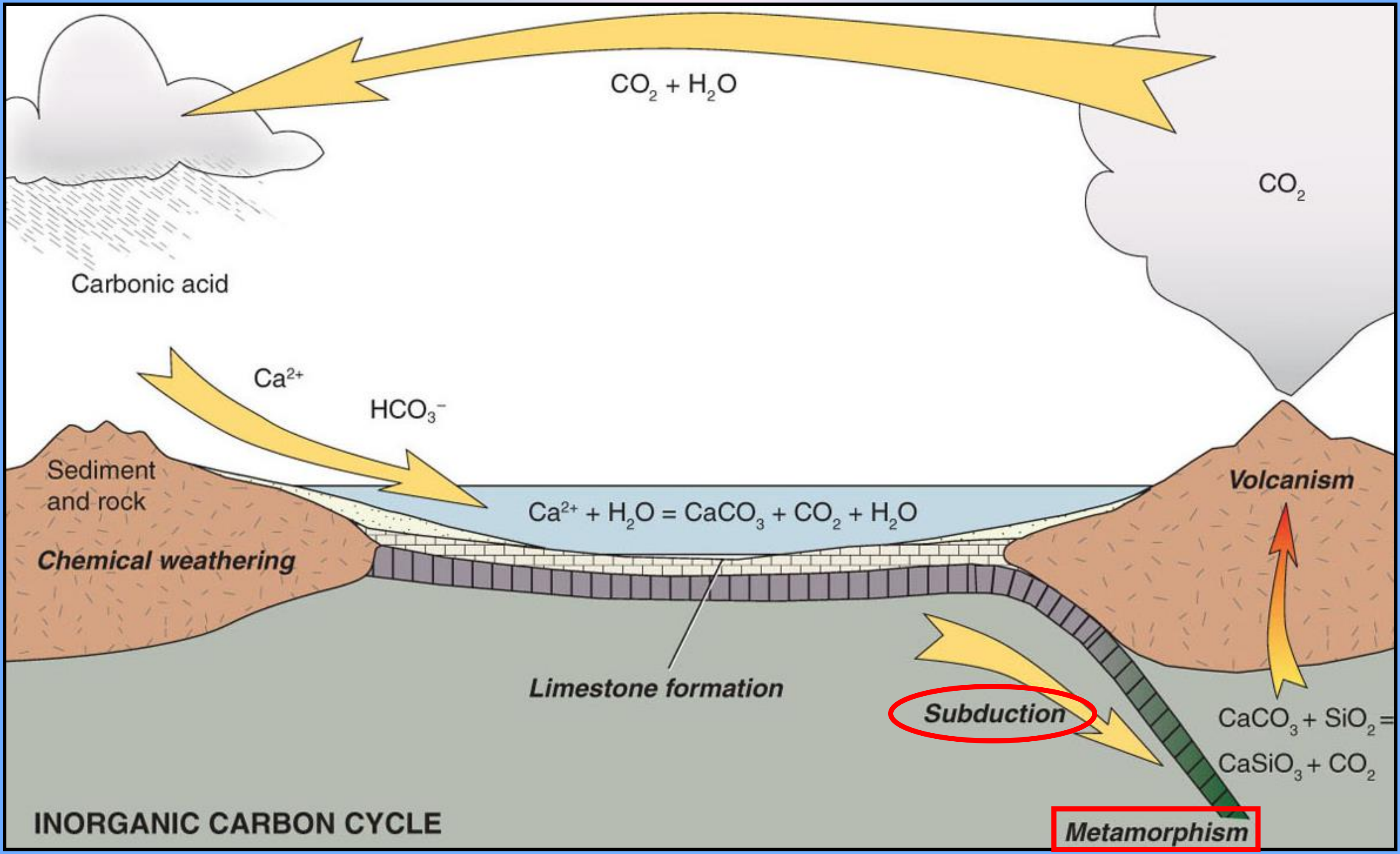
- Carbon dioxides dissolves in water to form carbonic acid in the atmosphere.
- Carbonic acid reacts with sediment and rocks during chemical weathering
  - Calcium ions and bicarbonate ions (HCO_3-) are released.
  - These ions are carried by rivers into the sea.

Inorganic Carbon Cycle



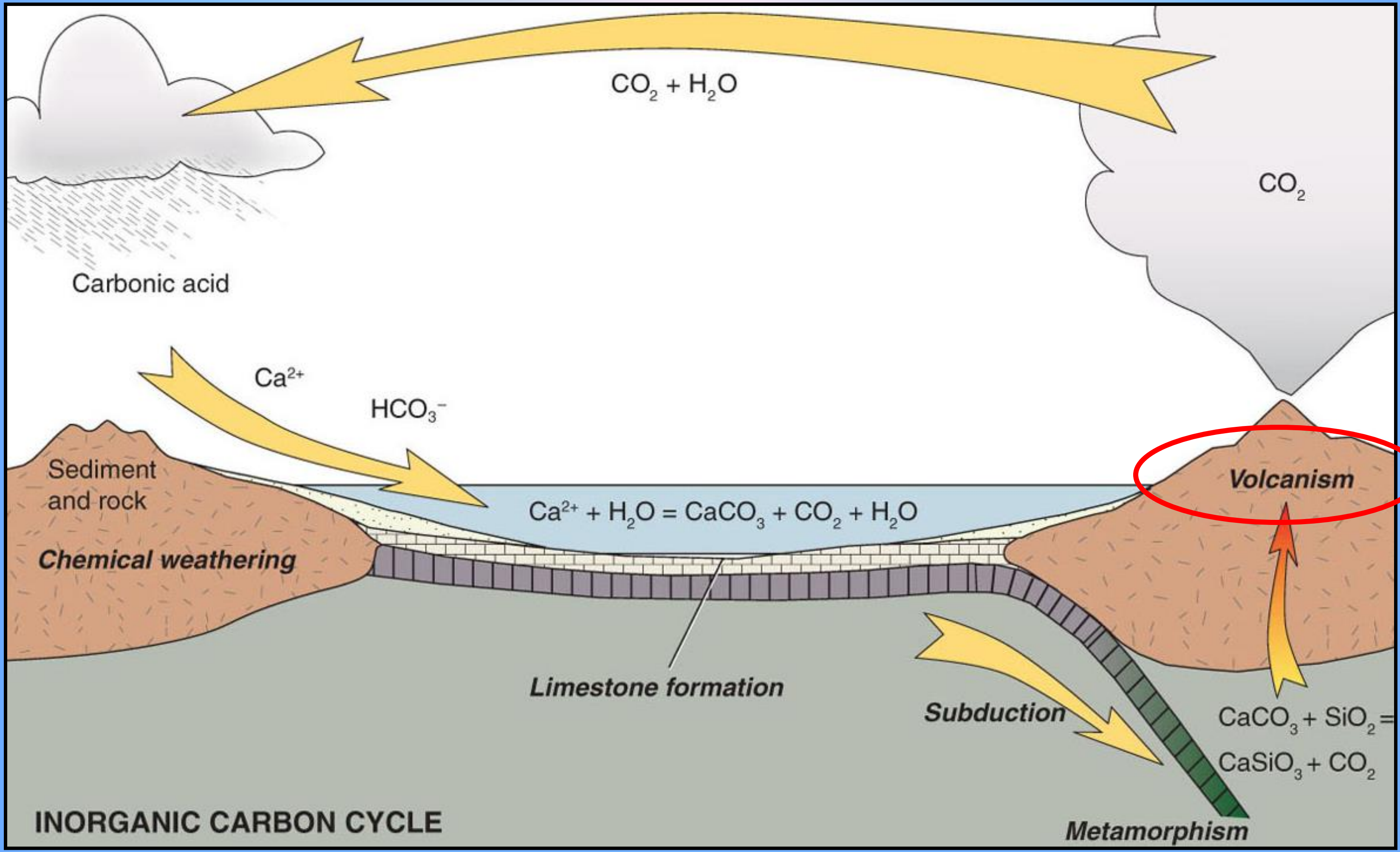
- The precipitation of $CaCO_3$ (calcite) mineral in the oceans forms layers of limestone

Inorganic Carbon Cycle



- Deep burial of limestone leads to metamorphism.
  - Reacts with silica and calcite
  - **<u>Forms calcium silicate minerals and carbon dioxide (gas).</u>**

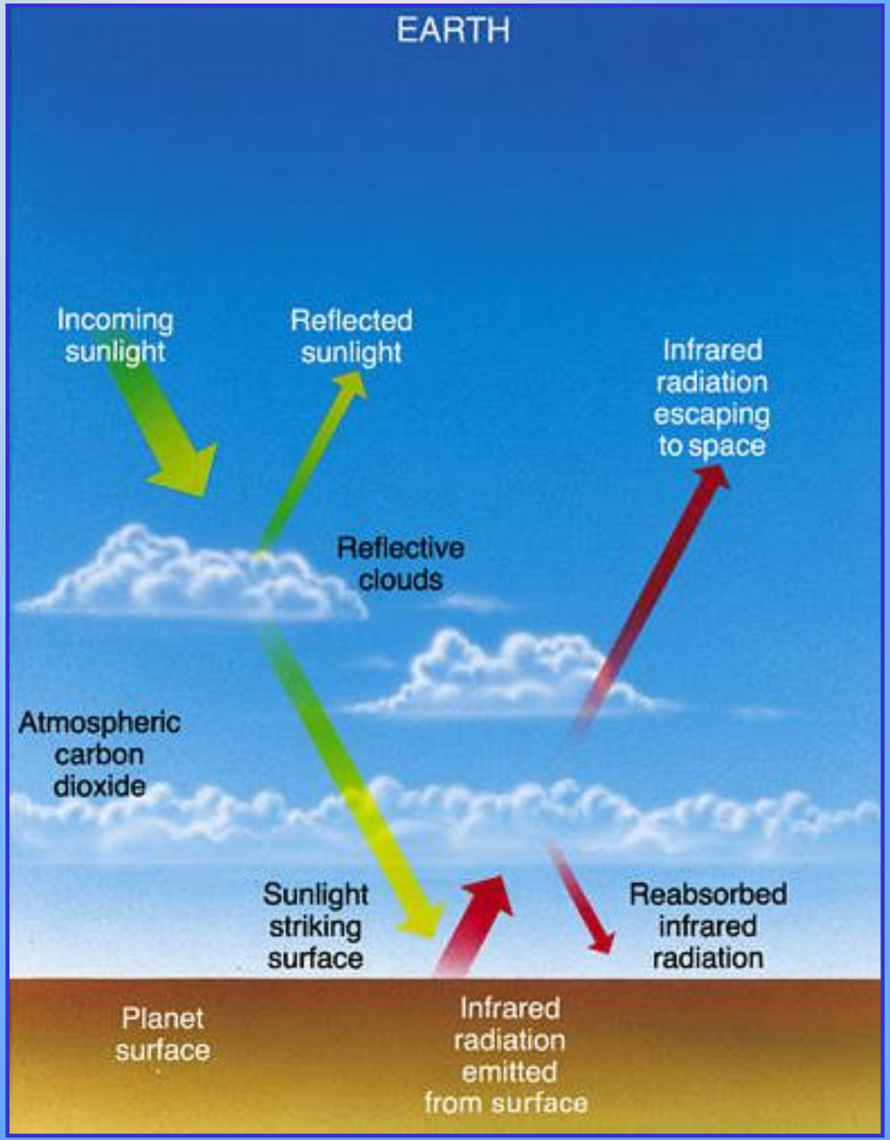
Inorganic Carbon Cycle



- CO_2 remains trapped in Earth's interior until it is released during volcanic eruptions.

B. The Greenhouse Effect of the Atmosphere

1. The atmosphere is relatively transparent to short-wave incoming solar radiation.
2. Earth's surface is heated and radiates long-wave infrared radiation.
3. CO_2, water vapor, and methane in the atmosphere absorb some of the terrestrial long-wave radiation.



CO_2 Comparisons

BOX 5.1 ■ TABLE 1

Carbon Dioxide in the Atmospheres of Earth, Mars, and Venus

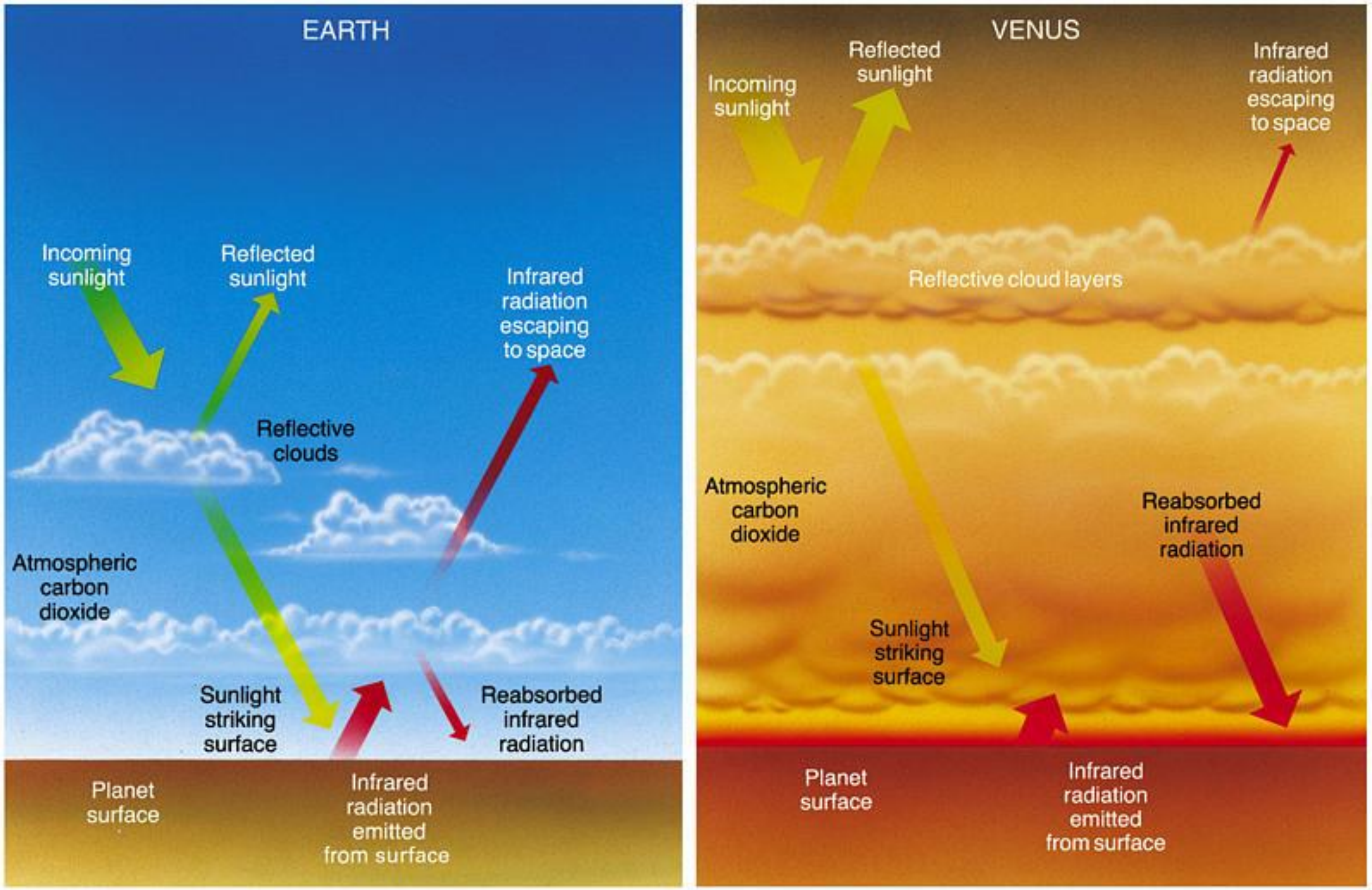
	Earth	Mars	Venus
CO_2%	0.33	95.3	96.5
Total surface pressure, bars	1.0[a]	.006	92

[a]Approximately 50 bars of CO_2 is buried in the crust of the Earth as limestone and organic carbon.

a. While there is relatively little CO_2 in Earth's atmosphere, it's enough to keep most of the surface above freezing, but not too hot to support life.

(1) The Early Earth probably had much more CO_2 and was probably much more like Venus is today.

Venus has a "Runaway" Greenhouse Effect

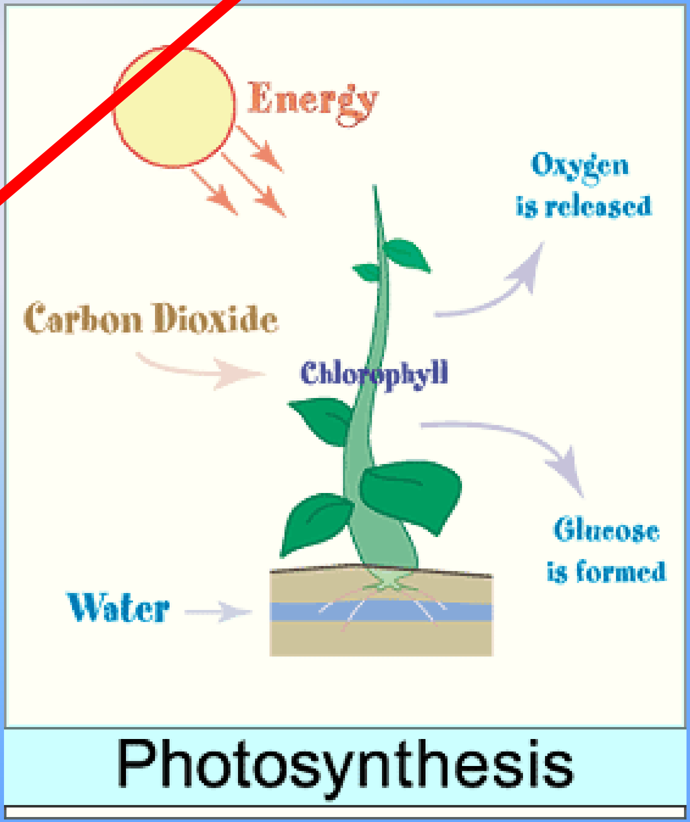


- The dense atmosphere of Venus is mostly CO_2.
- So much solar heat is trapped that the surface temperature is 480^{o}C (900^o F)

The Greenhouse Effect of the Atmosphere

(2) It's estimated that a quantity of CO_2 is about 65,000 times the mass of CO_2 in the modern atmosphere is buried in Earth's crust and upper mantle.

- Some was used to make organic molecules during photosynthesis and is now trapped as buried organic matter and fossil fuels in sedimentary rocks.



The Greenhouse Effect of the Atmosphere

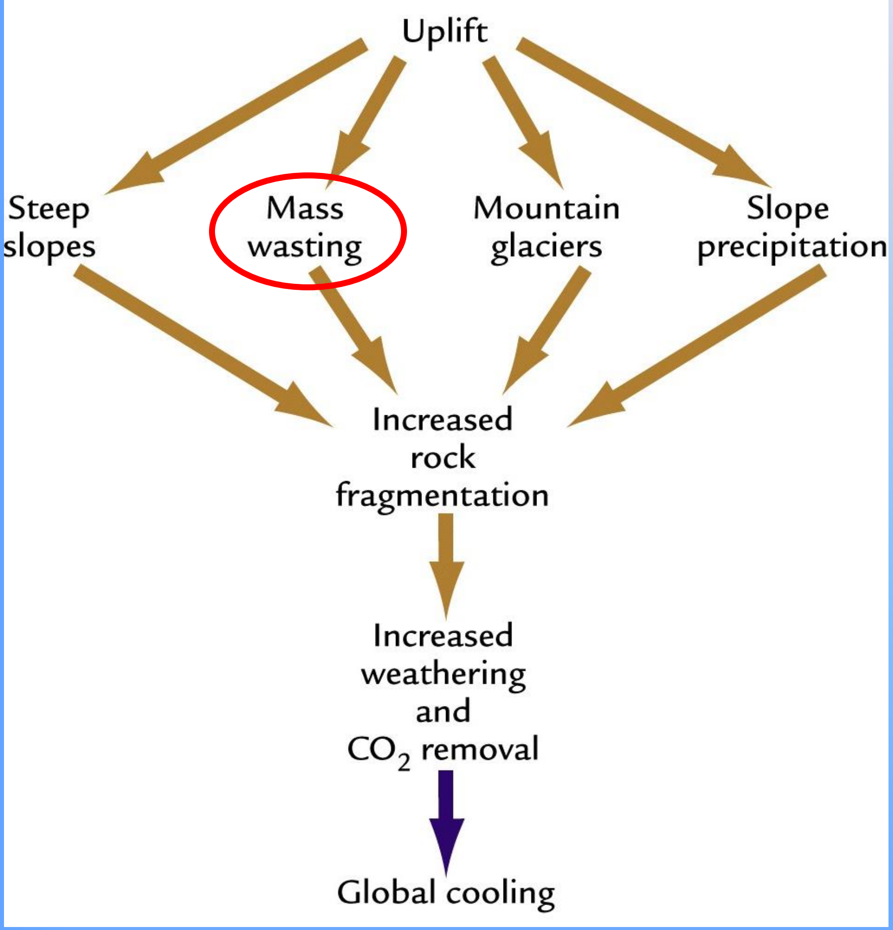
- A majority was converted to bicarbonate during chemical weathering that was incorporated into carbonate minerals in layers of limestone.

b. Variations in atmospheric CO_2 are believed to have affected Earth's temperature over time

Uplift and Weathering

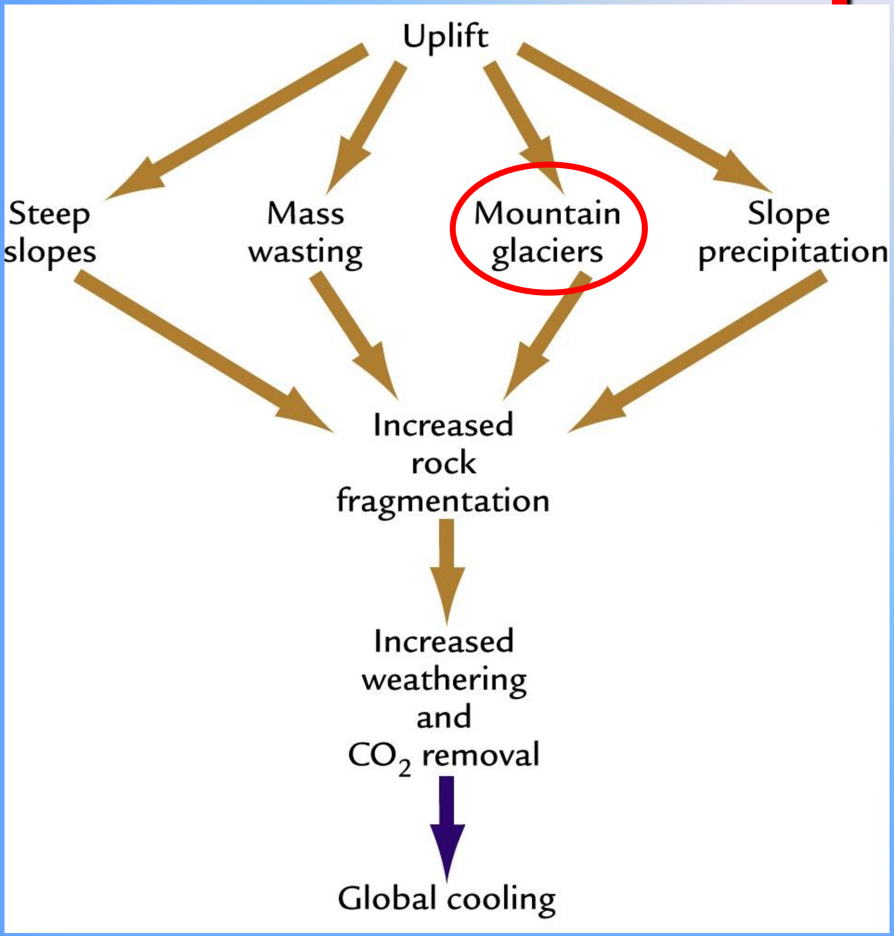
- Tectonics results in the uplifting of Earth's crust and the formation of mountains at many plate boundaries.
- In regions of uplift exposure of freshly fragmented rock is enhanced.

Factors Increasing Weathering Rates in Uplifting Areas



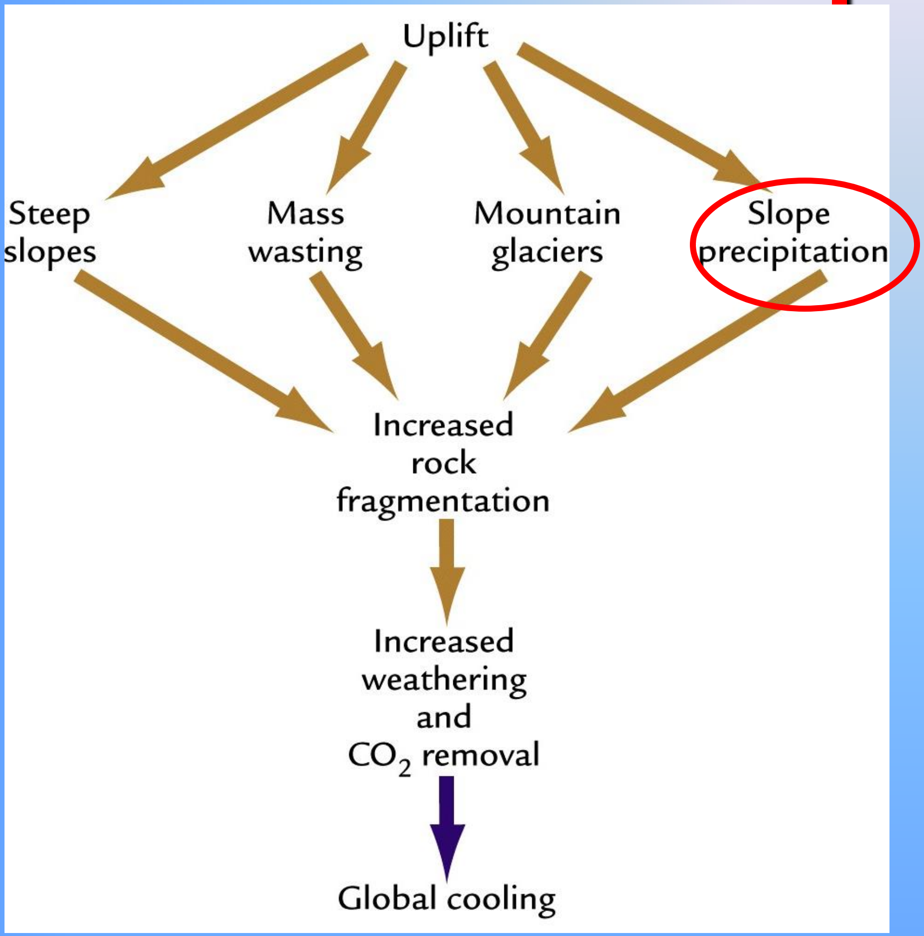
- Steep Slopes
  - Erosional processes called Mass Wasting are unusually active
    - Rock slides and falls
    - Landslides
    - Flows of water saturated debris
  - Removal of overlying debris exposes fresh bedrock

Factors Increasing Weathering Rates in Uplifting Areas



- Steep Slopes
  - Mountain Glaciation
    - Pulverizes underlying bedrock
    - Carries sediment to lower elevations
    - Increases regional rates of chemical weathering

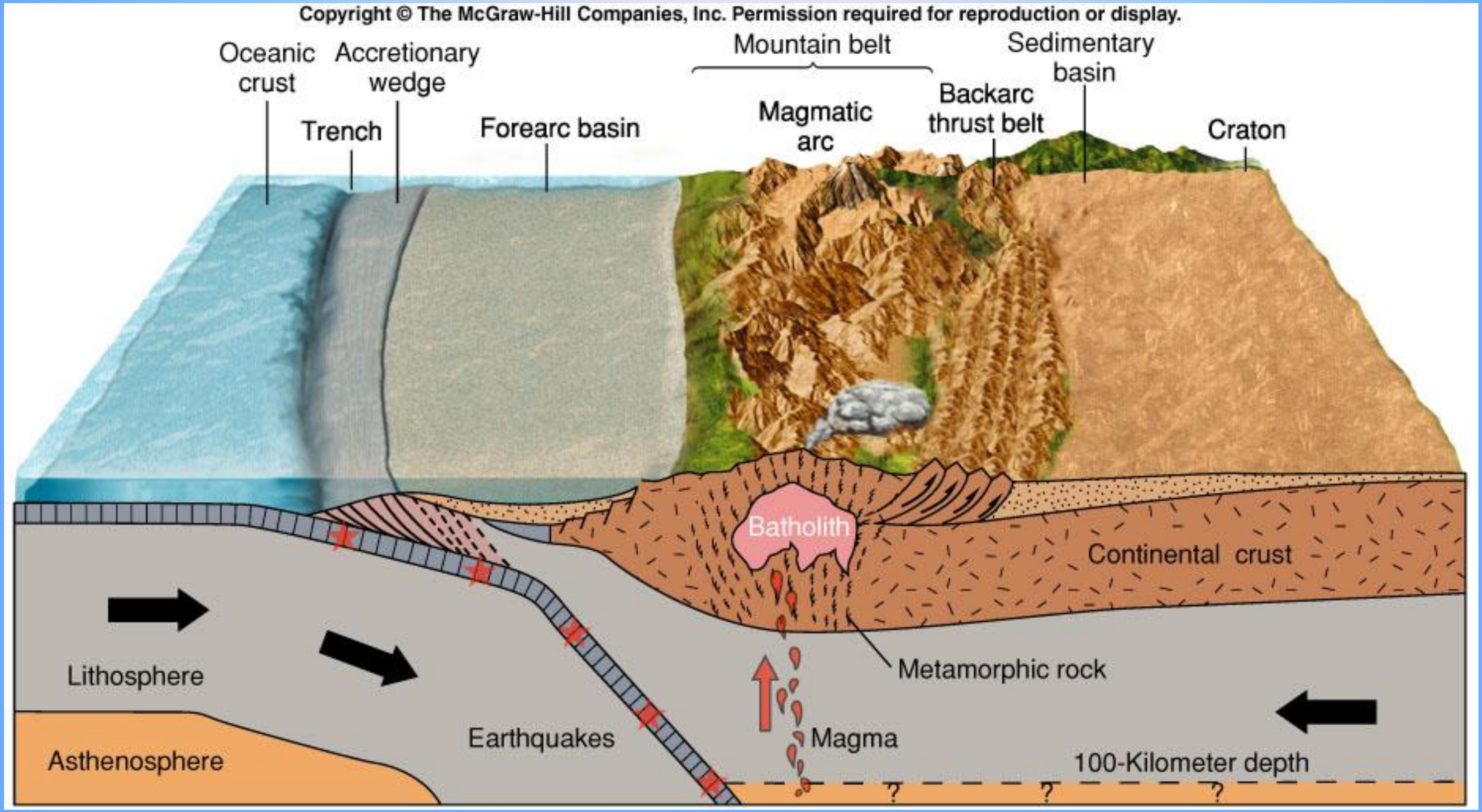
Factors Increasing Weathering Rates in Uplifting Areas



- Steep Slopes
  - Heavy precipitation generated on
    - High but narrow mountain belts
      - Intercept moisture carried by tropical easterlies and mid-latitude westerlies
    - Large plateaus create their only monsoonal circulation (e.g., Tibetan Plateau) by pulling moisture from adjacent oceans

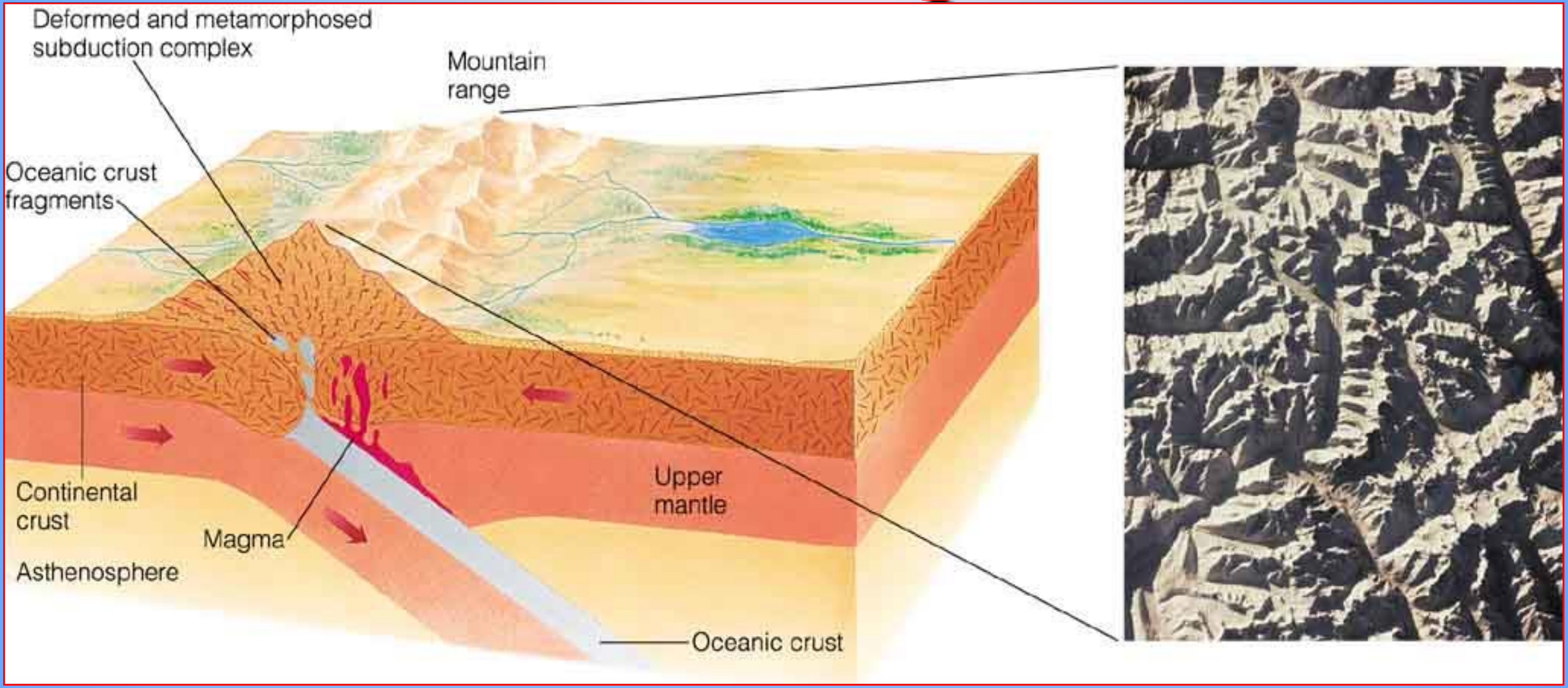
Tectonic Uplift

Ocean-continent convergence



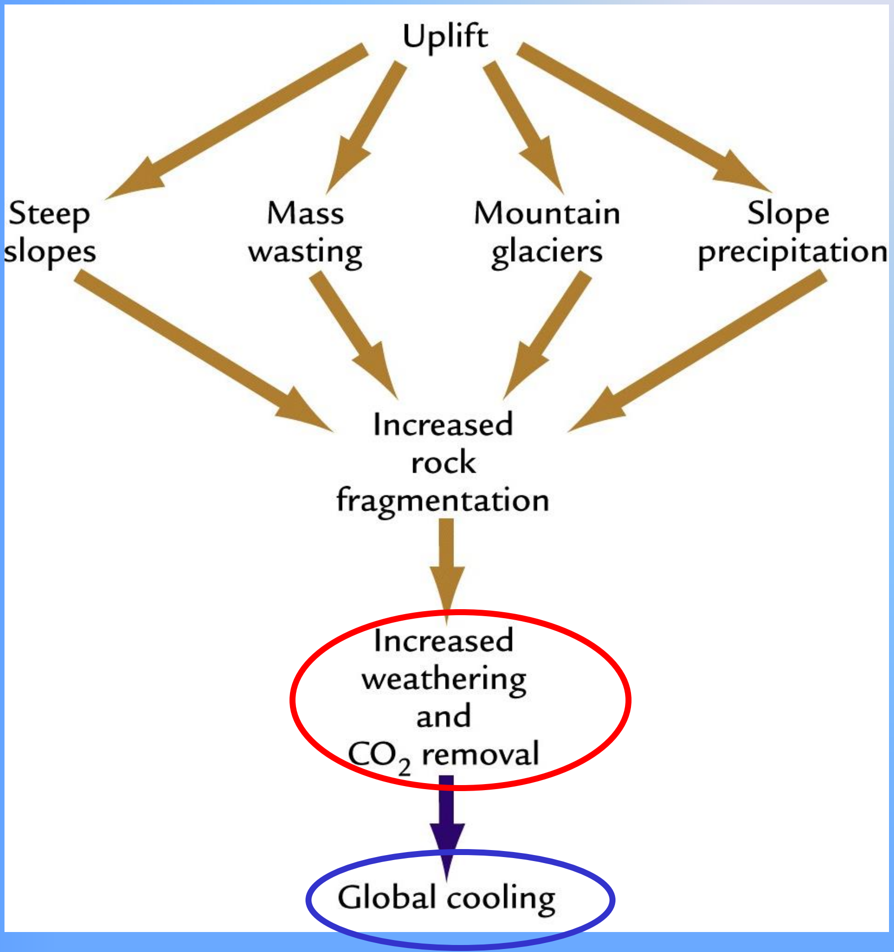
- Subduction occurs relatively steadily over time
- Total amount of high mountain terrain on Earth remains constant through time
  - Locations and heights of individual ranges may vary

Tectonic Uplift



Continent-continent collision – the Himalayas and Tibetan Plateau

Active Tectonic Uplift Cools Climate



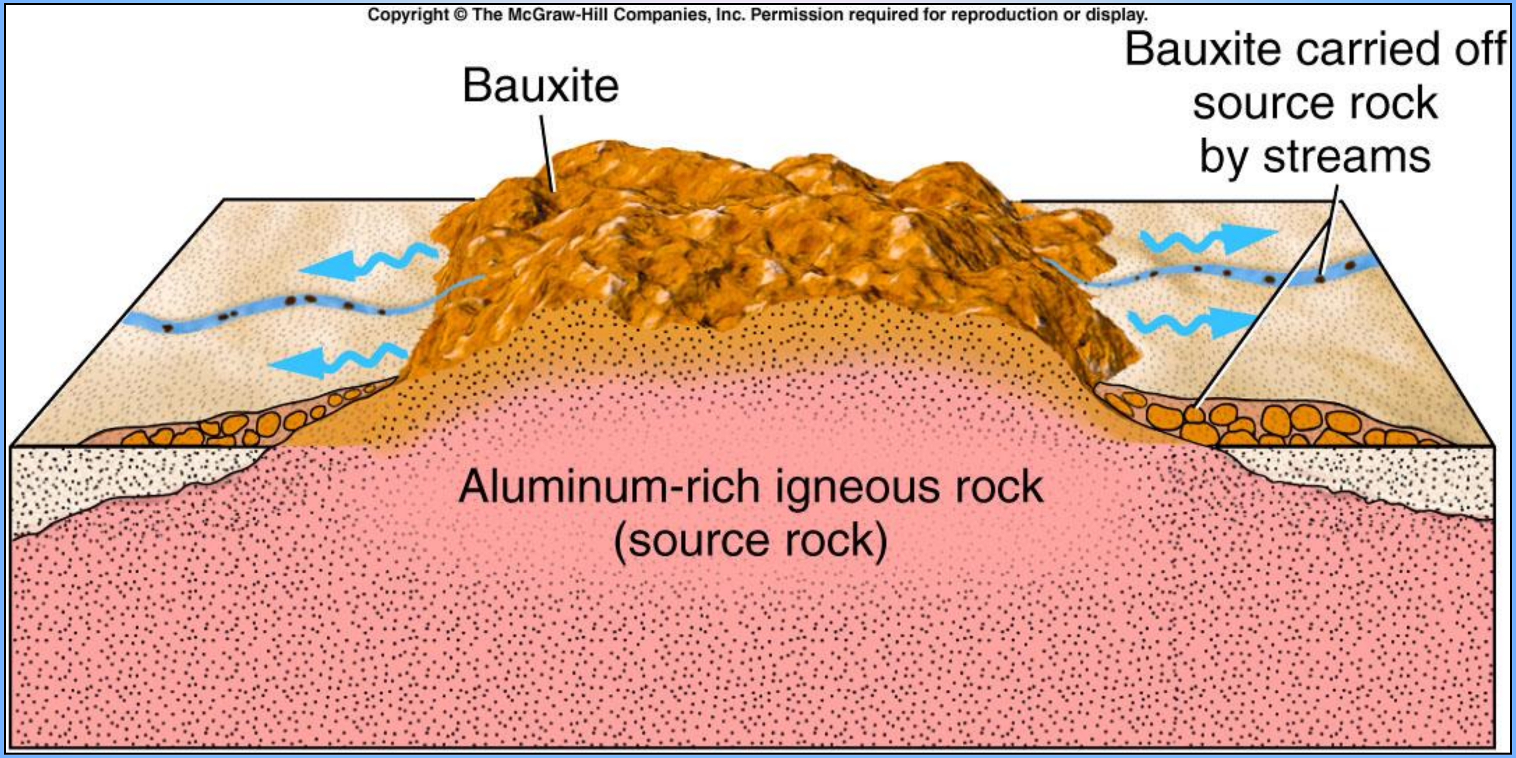
- Uplift accelerates chemical weathering
- Draws CO_2 out of the atmosphere
  - Cools climate
- Greenhouse Conditions
  - Slower uplift
  - Less chemical weathering
    - More CO_2 in atmosphere

End!! ☺

Bauxite

- Bauxite is a rock composed mainly of aluminum oxide and aluminum hydroxide minerals.
  - These might include: gibbsite, boehmite and diaspore.
  - The rock usually includes other materials such as iron hydroxides, clay, silt and free silica.
  - It most often occurs as a residual soil material in tropical and subtropical areas.
  - It is the primary source of aluminum

Formation of Bauxite



- **Tropical conditions of high rainfall and high temperature**
- **Aluminum-rich volcanic tuffs (compacted ash) chemically weather leaving least soluable Al oxide.**