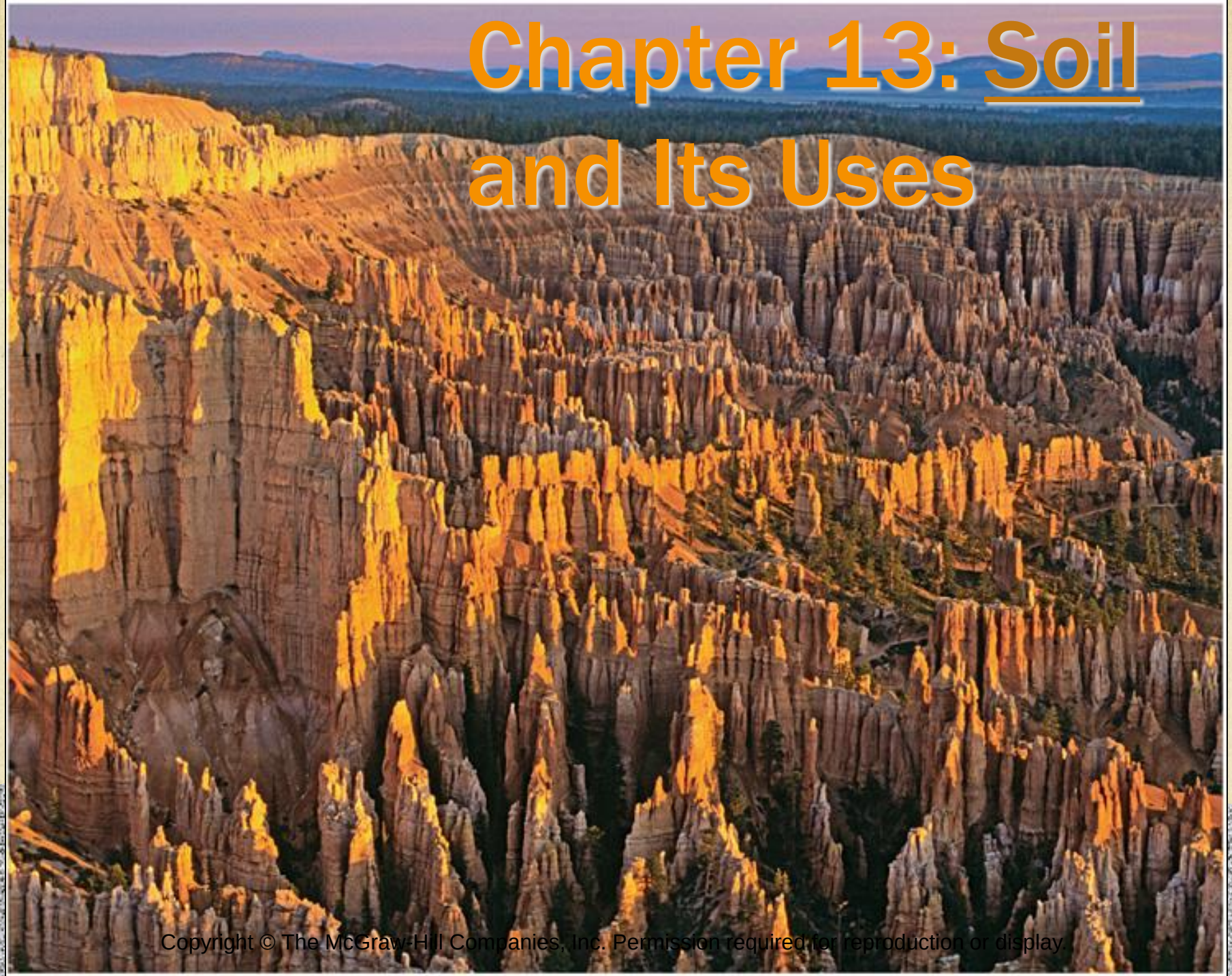
Chapter 13: Soil and Its Uses



Soil Science

- Soil formation
- Classification and mapping
- Physical
- Chemical
- Biological
- Fertility Properties
- Use and Management
- Impact of soils on civilization

Layers of the earth

PASS ☑
FAIL ☐

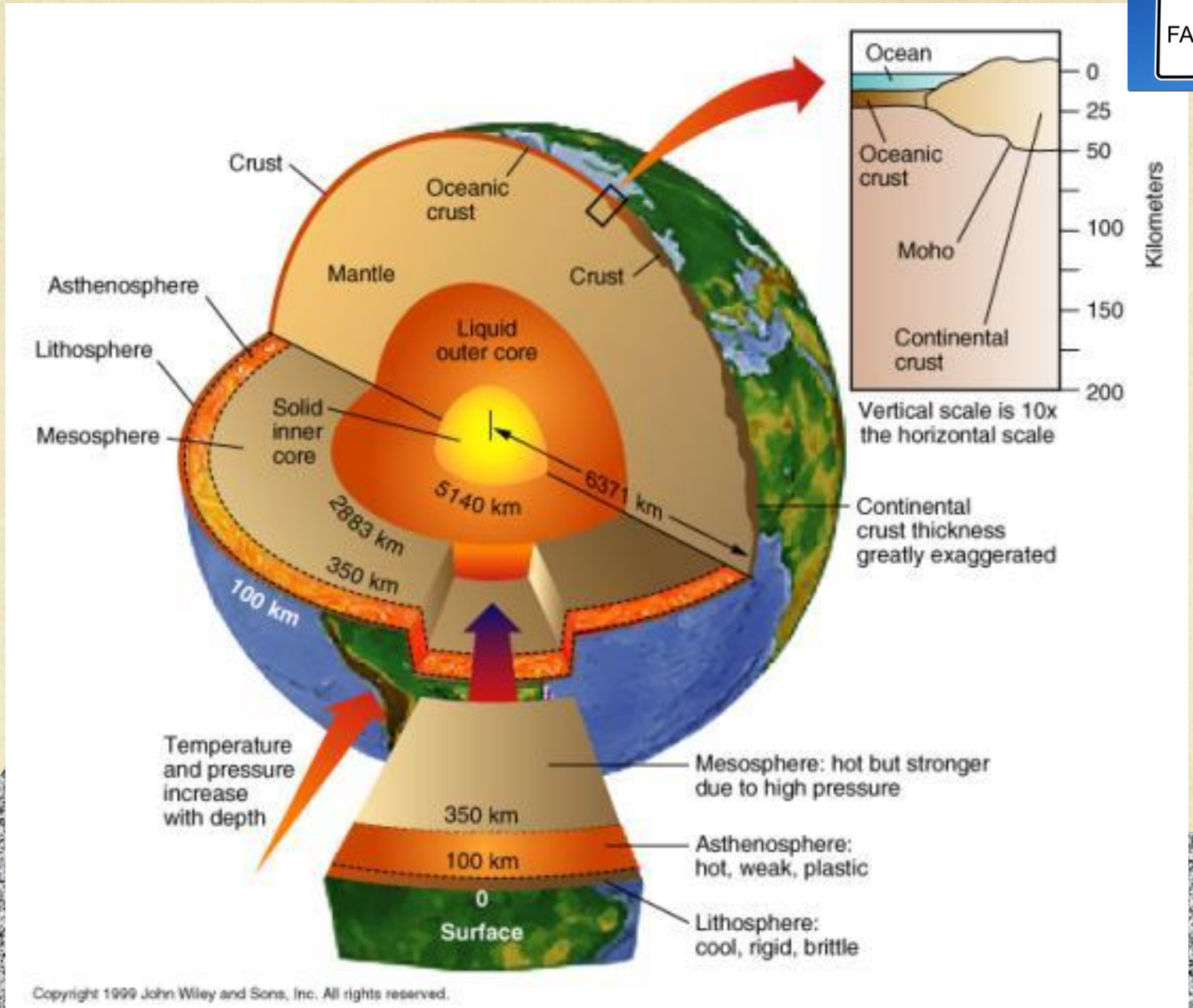
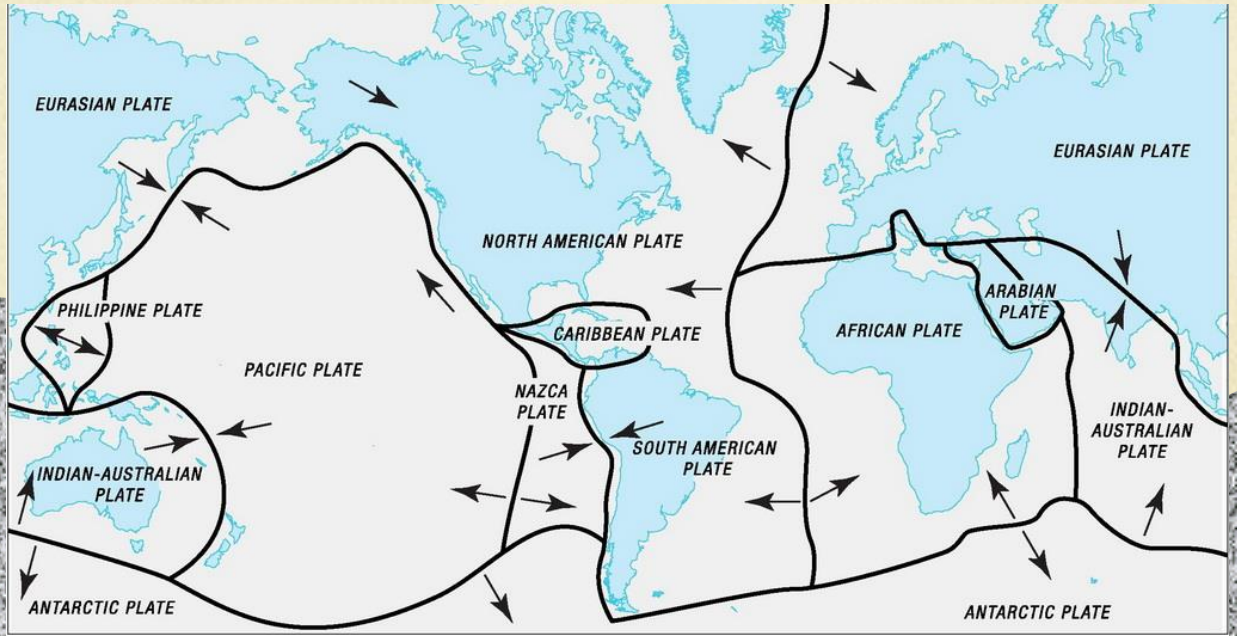
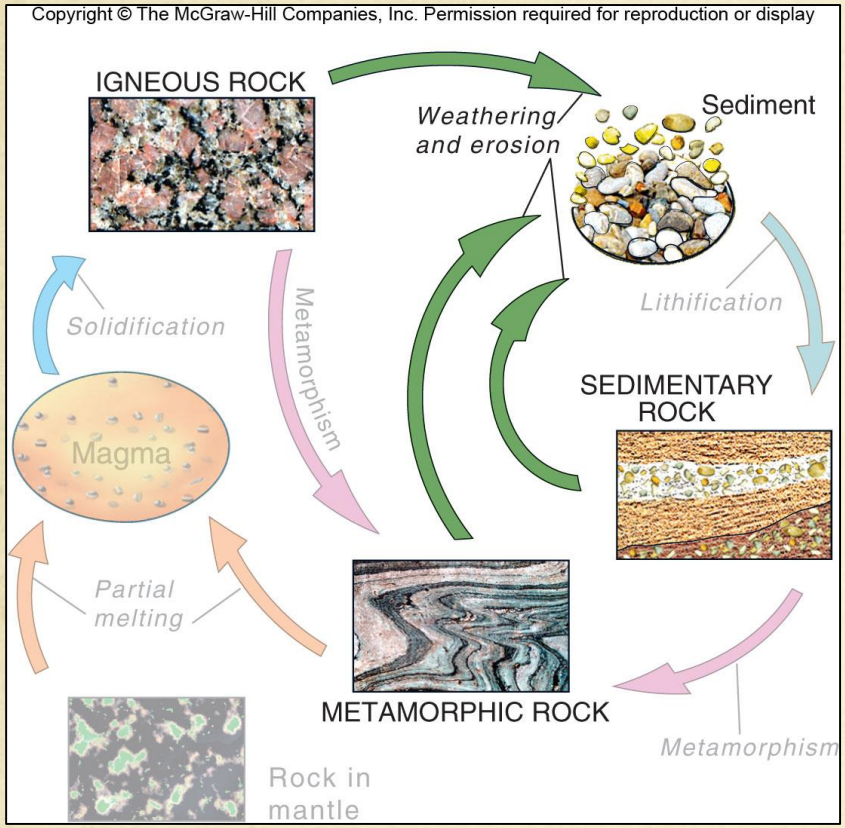


Plate Tectonics

- The movement of Earth's lithosphere (crust and upper mantle) is composed of seven or eight major plates and many minor plates.
- Where the plates meet and their relative motions determine the type of boundary: convergent, divergent or transform.
- Earthquakes, volcanic activity, mountain-building, and oceanic trench formation occur along these boundaries.



Weathering, Erosion & 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 & Earth Systems

A

B

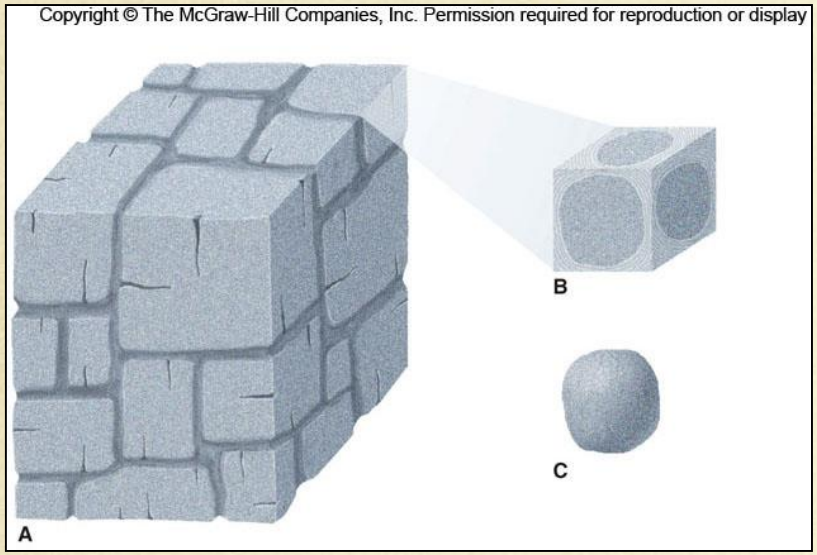
a: Photo by C.C. Plummer;
b: Photo by David McGeary

Atmosphere

- Oxygen and carbon dioxide critical to **chemical weathering**
- Water cycled through atmosphere is critical to chemical and **mechanical weathering** processes
- Chemical weathering also removes carbon dioxide from the atmosphere, helping keep global temperatures from soaring

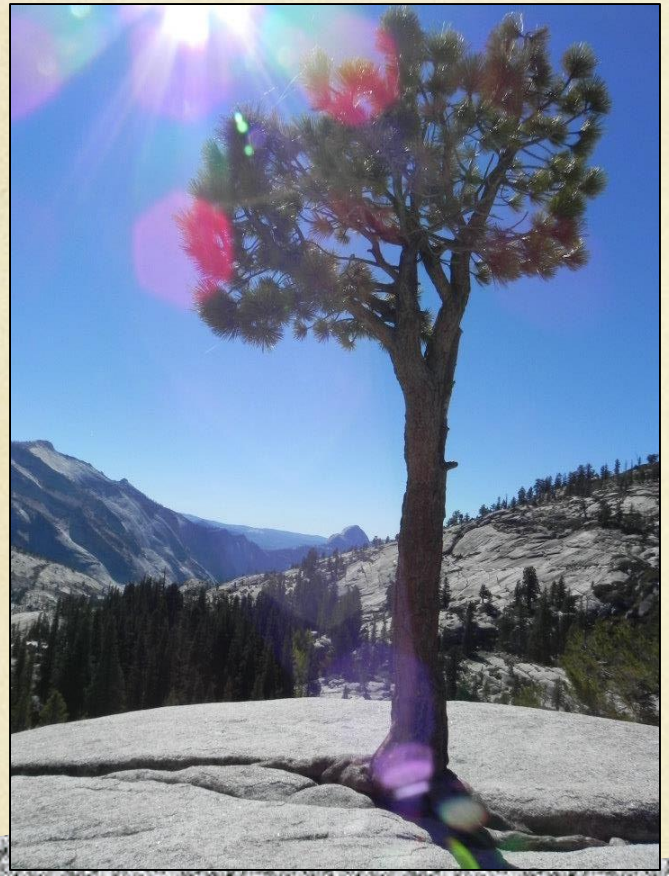
Weathering & Earth Systems

Hydrosphere



- Water is necessary for **chemical weathering**
- Oxygen dissolved in water **oxidizes iron** in rocks
- Carbon dioxide dissolved in water creates **carbonic acid**
- Running water loosens and abrades particles
- Glacial ice removes and abrades particles
- Freeze/thaw cycling mechanically weathers

Weathering & Earth Systems



Biosphere

Plant root growth widens cracks

Animal movement and human activity mechanically weather

Decaying organic matter in soils produces acidic soil moisture

Types of Weathering

Spheroidal weathering

1. Mechanical weathering

- Physical disintegration
- Frost action, pressure-release fracturing, plant growth, burrowing animals, salt wedging, thermal cycling

2. 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

Mechanical Weathering

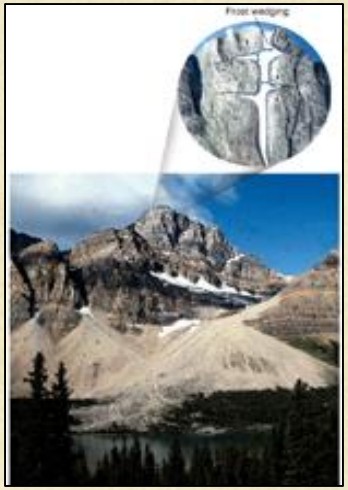
Frost action – mechanic effect of freezing (and expanding) water on rocks

Pressure release – removal of overlying rock allows expansion and fracturing

Plant growth – growing roots widen fractures

Burrowing animals

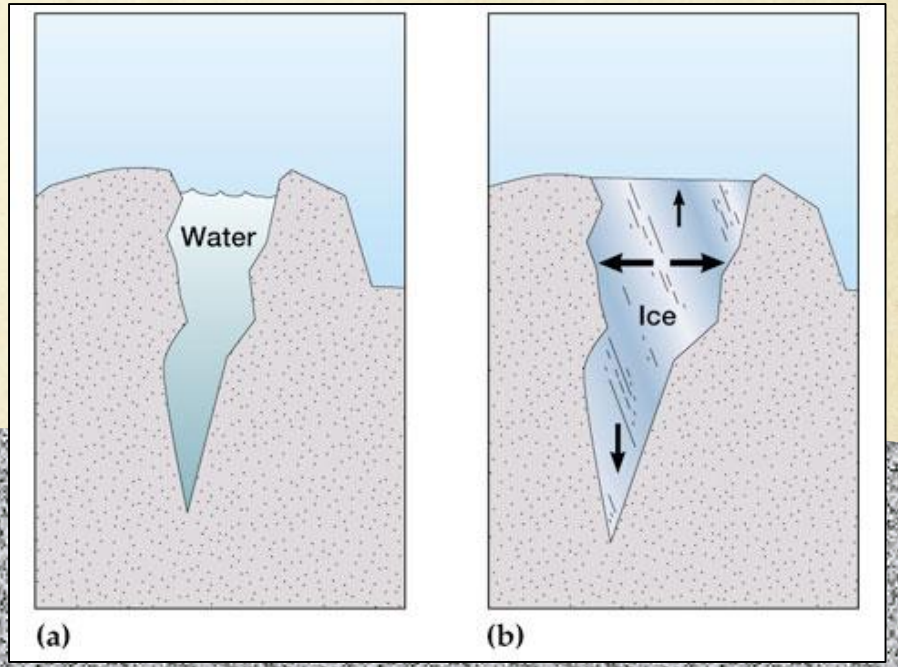
Thermal cycling – large temperature changes fracture rocks by repeated expansion and contraction



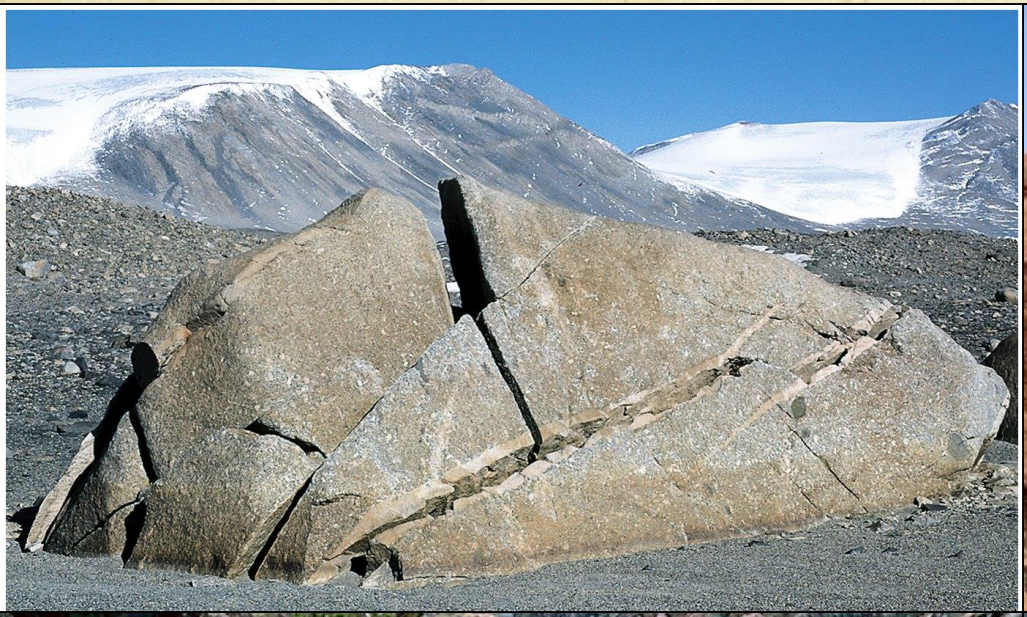
Frost Action

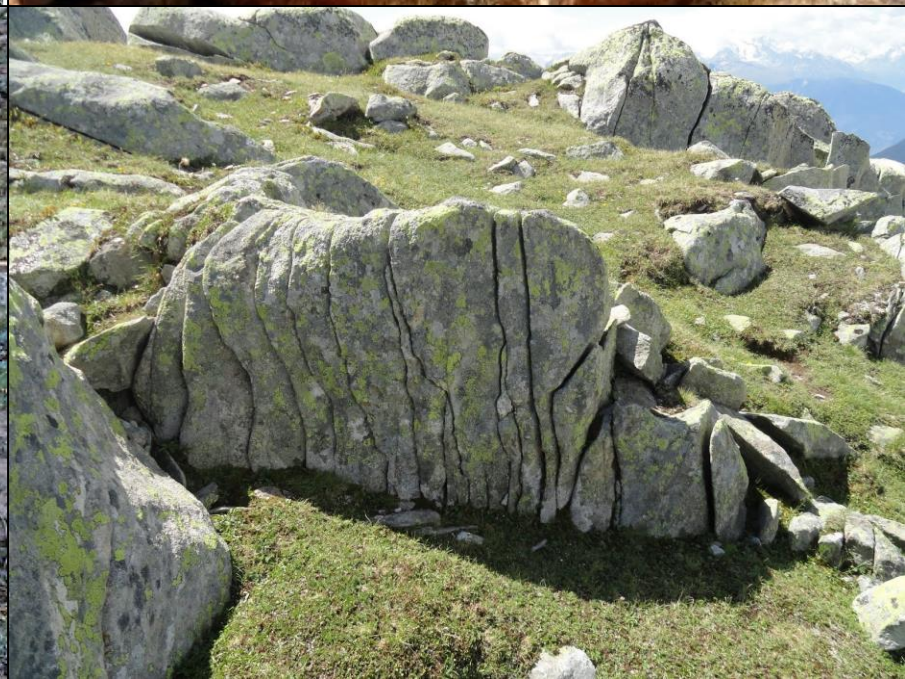
Frost Wedging

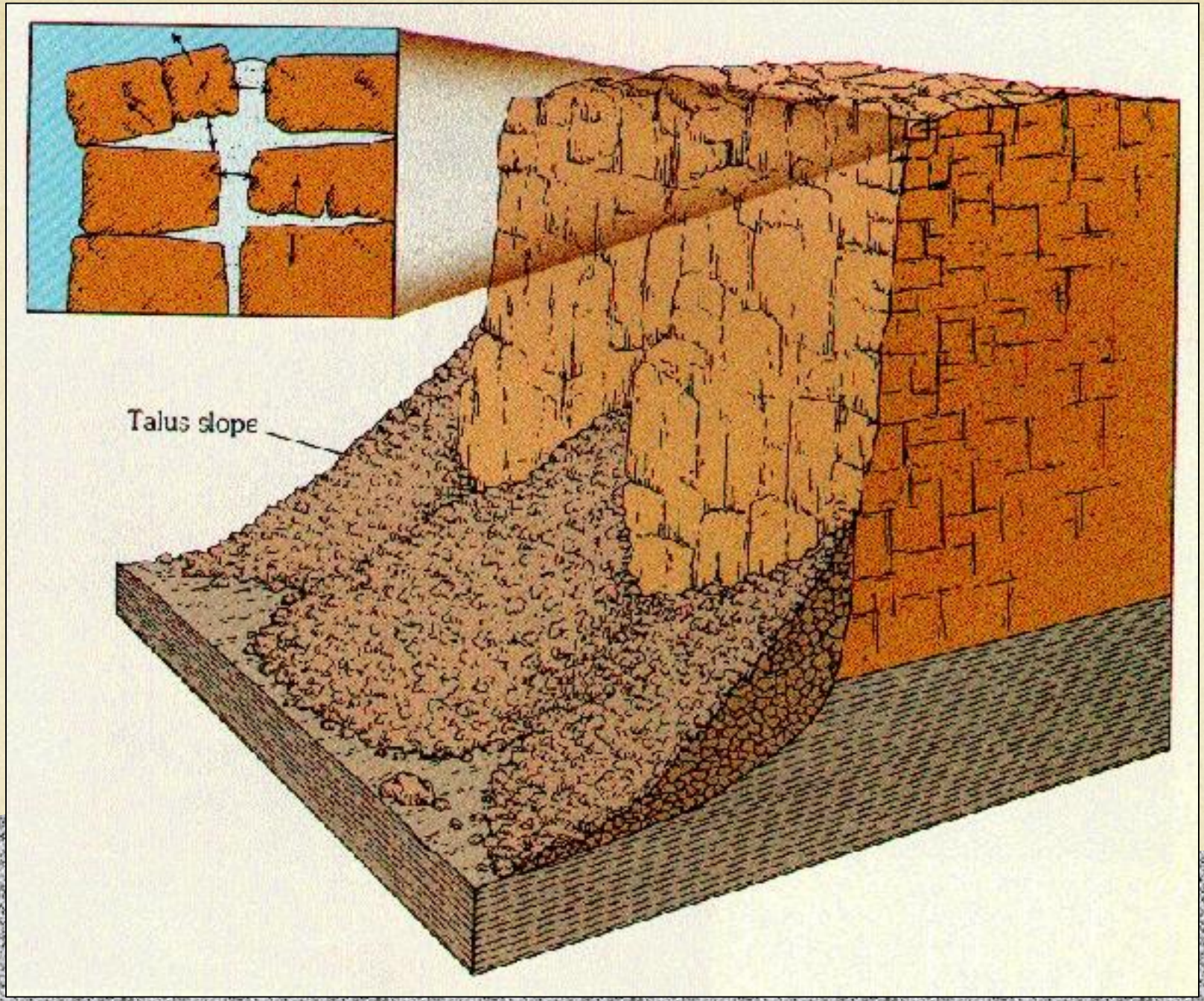
- Expansion of freezing water pries the rock apart
- Most rock contains cracks (*joints*) caused by the slow flexing of brittle rock by Earth's forces



Frost Wedging



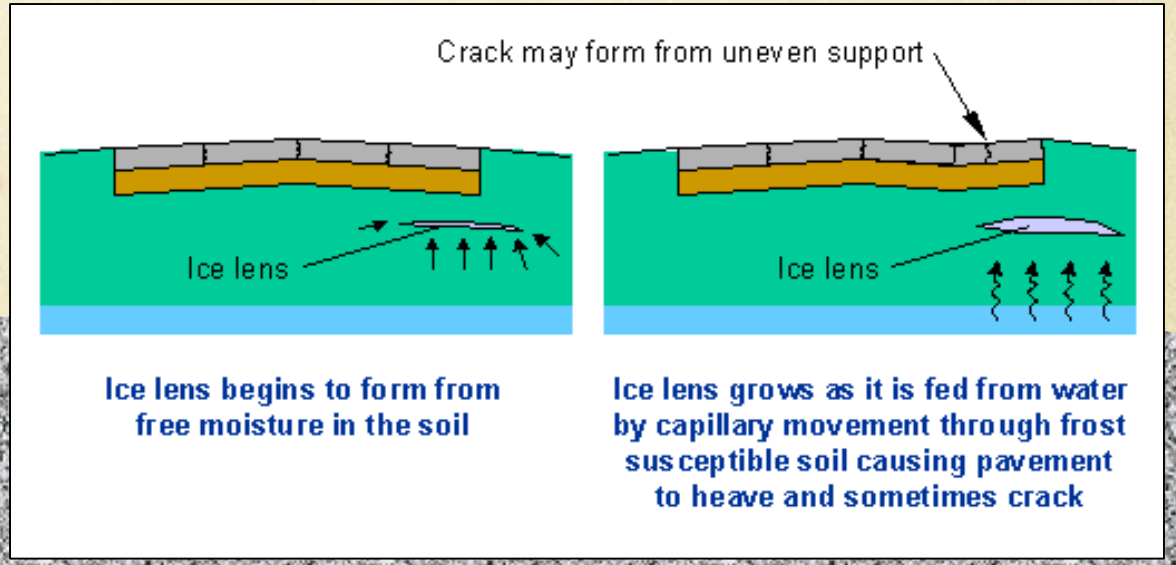



Talus slope

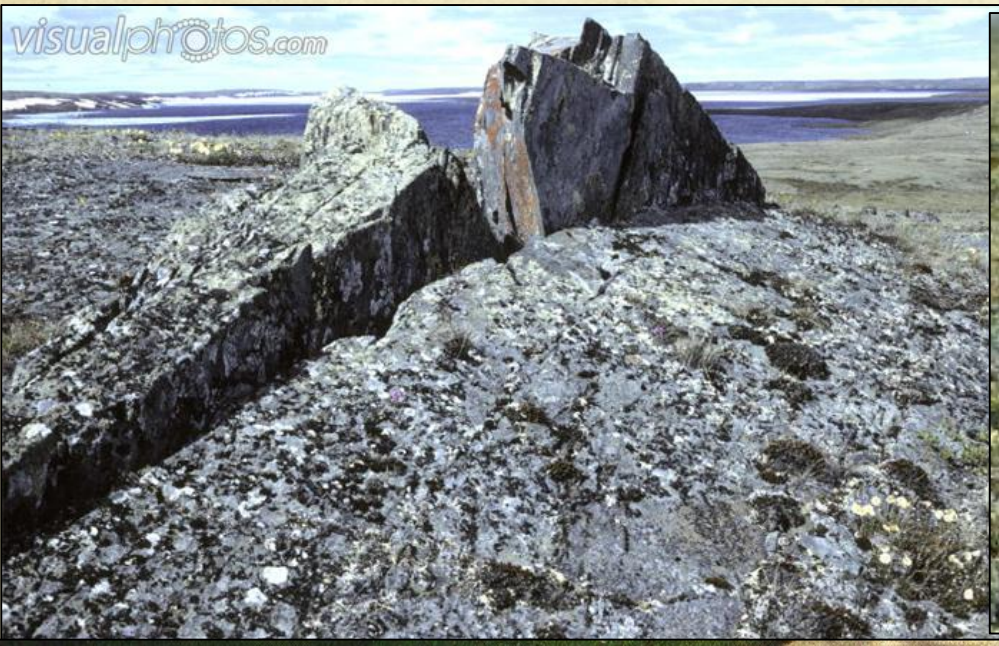
Frost Action

Frost Heaving

- Solid rock conducts heat faster than soil
- Bottom of a partially buried rock will be much colder than surrounding soil
- As ground freezes, ice forms under large rock fragments in soil
- Ice expands and rocks are pushed out of the ground vertically



Frost Heaving



Thermal Cycling

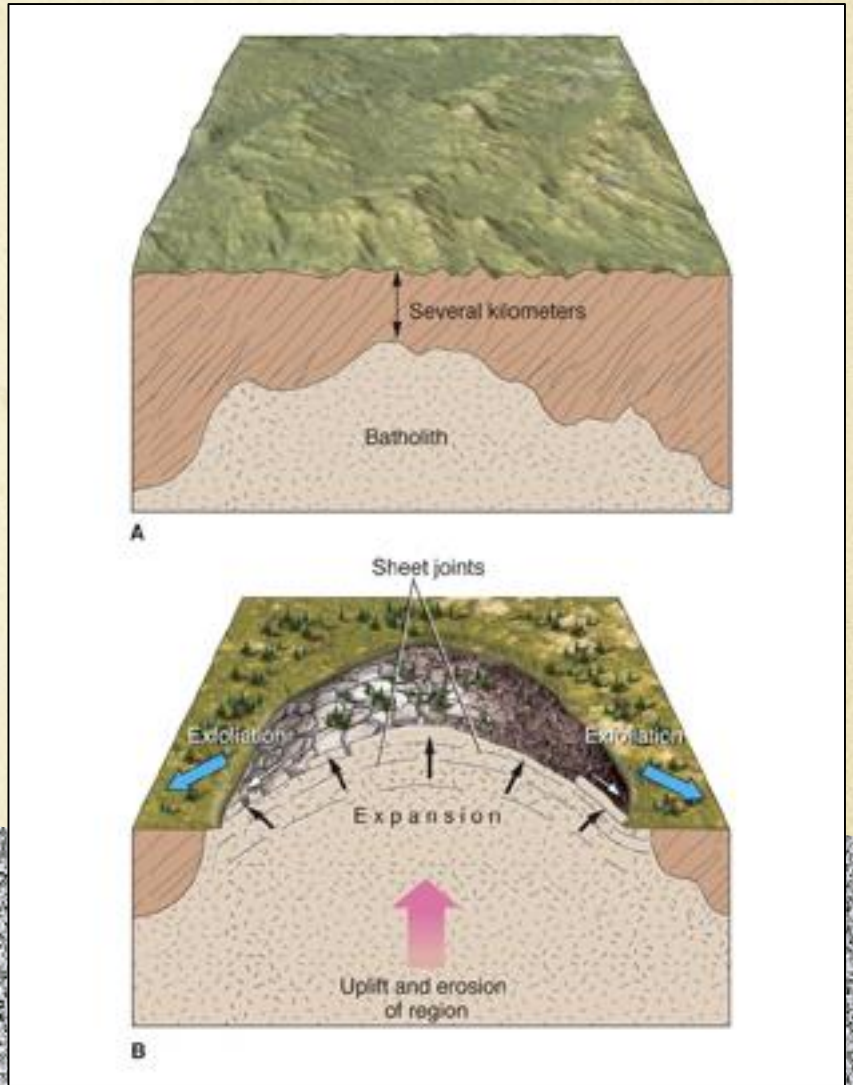
- Driven by extreme changes in temperature
- Ex. Forest fires
- Thermal expansion and contraction – repeated heating and cooling of materials cause rigid substances to crack and separate

Photo by Crystal Hootman and Diane Carlson

Pressure Release

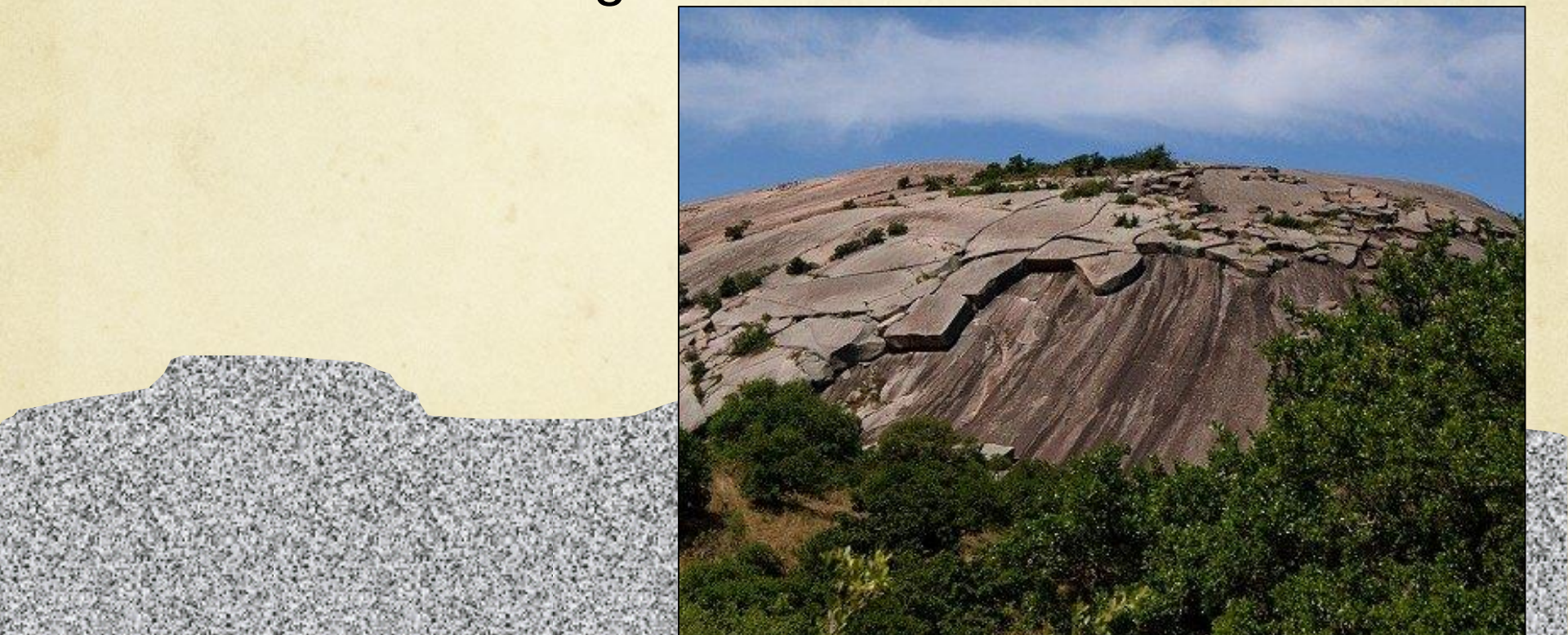
- Release of pressure causes a rock to expand and crack (*sheet joints*)
- How is pressure released?

  - Tectonic uplift



Pressure Release - Exfoliation

- Exfoliation
  - Slabs of rock falling off in areas with slopes
  - Common in granite

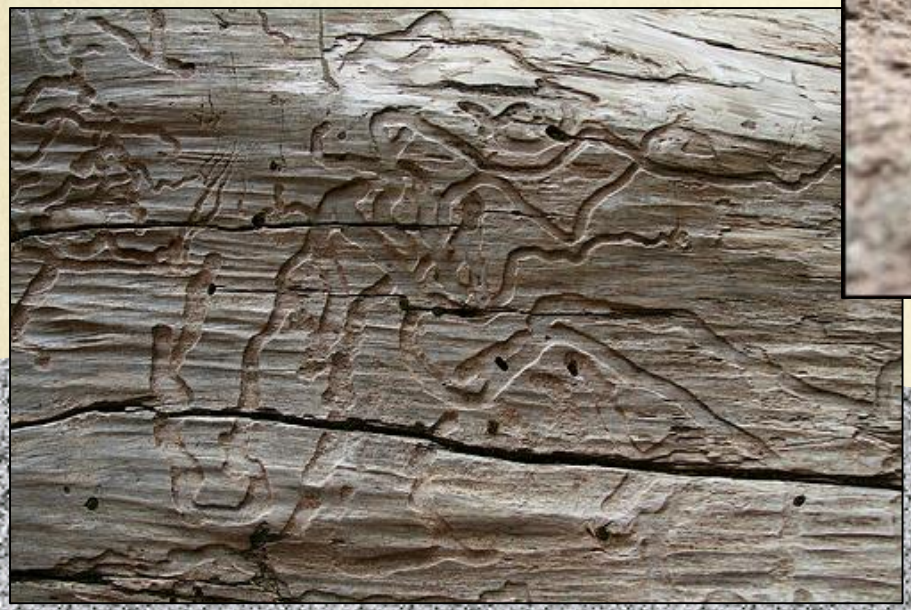


Plant Growth

- i.e. plant wedging
- Plant roots can grow through cracks in the rocks
- Similar to frost wedging

Burrowing Animals

- Burrowing animals can disrupt the rocks and soil
- Causing pockets of open space
- Speeds up weathering
- “Biological Weathering”



Abrasion

- Moving sediments or rock sections can break off pieces from an exposed rock surface that they strike
- The sediments can be moved by wind or water and the large rock sections by gravity
- This causes friction, and wears away the rock that it is acting upon like sandpaper on wood

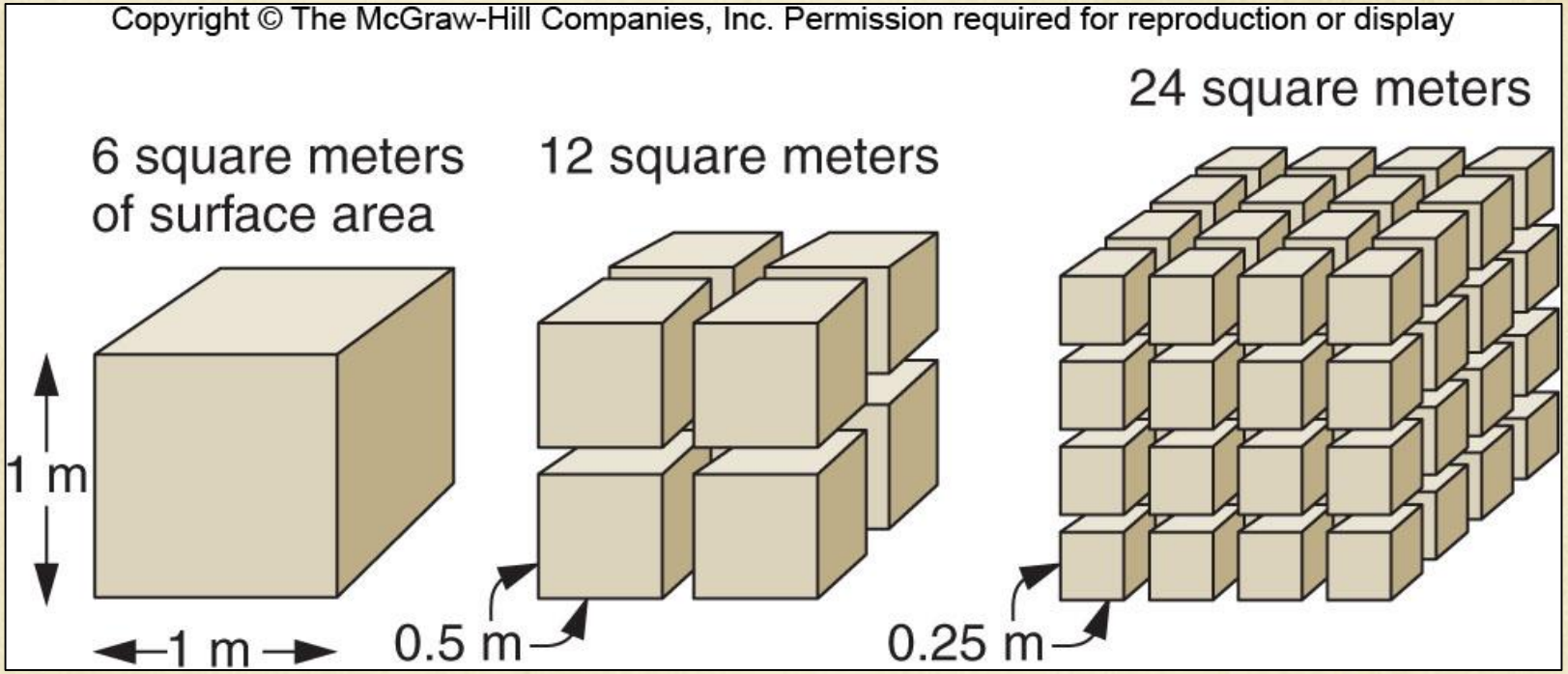
Glacial

- Glacier – large mass of ice, formed on land by compaction and recrystallization of snow
- Located at the North and South Pole and at high elevations
- Glaciers move/flow under the pressure of their own weight and thanks to gravity
- Pick up and erode material as they move
- Fine-grained material scours and polishes underlying rock (like sand paper)

Humans and Mechanical Weathering

What actions do you think humans do that can speed up weathering?

Chemical Weathering and Surface Areas

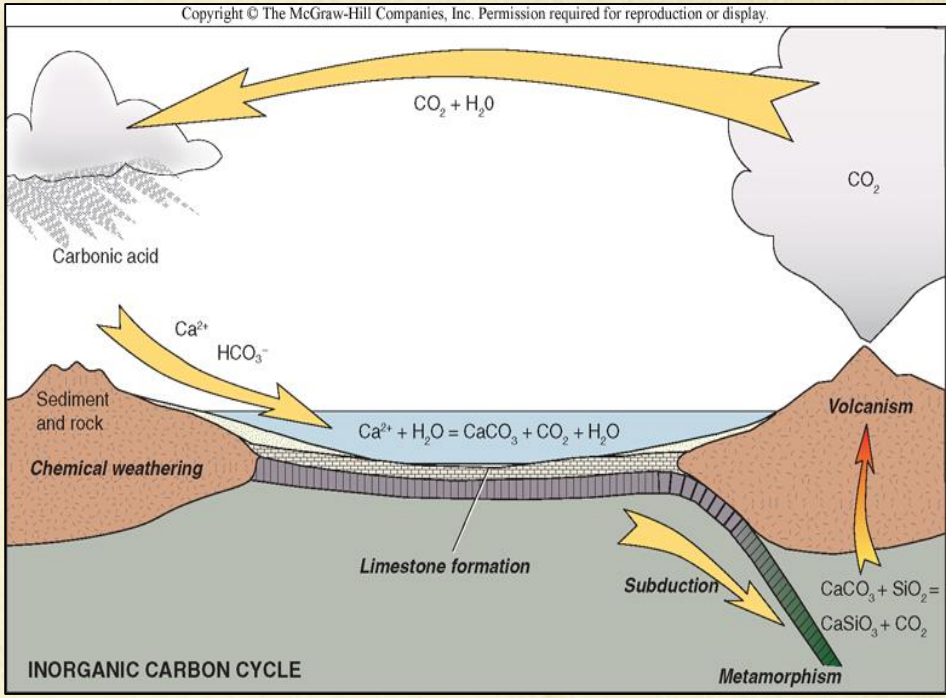


Greater surface areas mean more surfaces for chemical weathering to take place.

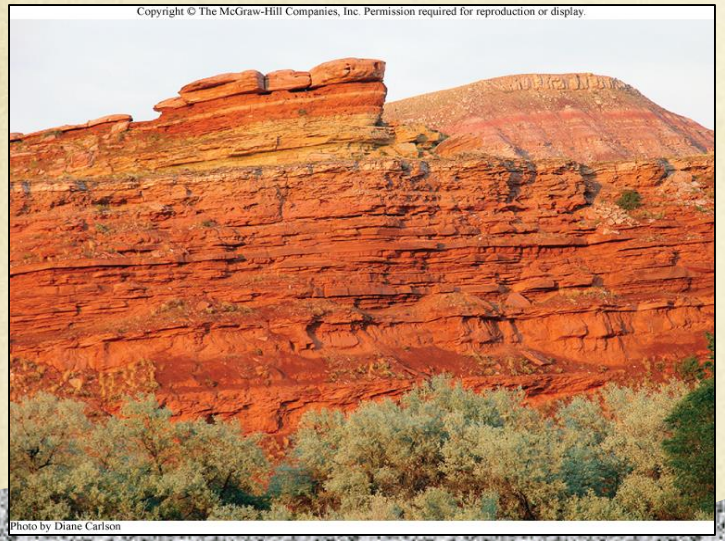
Inorganic Carbon Cycle

Follow the carbon: Present as trace gas carbon dioxide in atmosphere

- Combines with water to form carbonic acid
- Weathers rocks and leads to limestone formation in bodies of water
- Returned to mantle by tectonic plate movement
- Released back to atmosphere by volcanic eruptions



Chemical Weathering



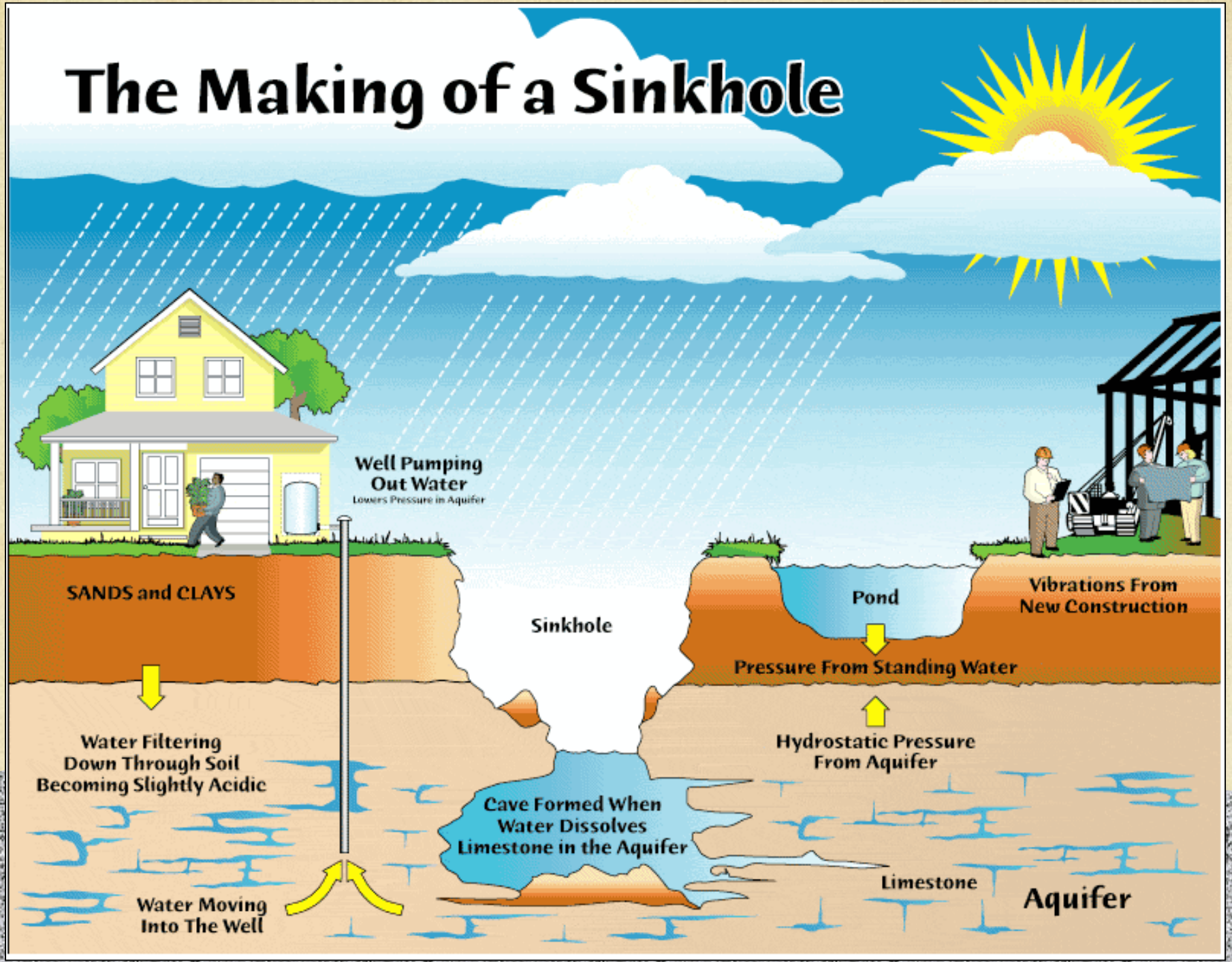
Oxidation – chemically active oxygen from atmosphere

- Iron oxide stains are common result

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
- Human activity, such as mining and burning of fossil fuels, produces acids

Acid mine drainage; Iron Mines Superfund Site, Northern California


The Making of a Sinkhole
Well Pumping Out Water
Lowers Pressure in Aquifer
SANDS and CLAYS
Sinkhole
Pond
Vibrations From New Construction
Pressure From Standing Water
Water Filtering Down Through Soil Becoming Slightly Acidic
Hydrostatic Pressure From Aquifer
Cave Formed When Water Dissolves Limestone in the Aquifer
Limestone
Aquifer
Water Moving Into The Well

Where sinkholes lurk

In some geological formations, surface layers may collapse into caverns below

- Formations in which sinkholes may occur
- ○ Areas with extensive subsidence and sinkholes
- ★ Florida's fatal sinkhole incident, 28 February 2013

Photo courtesy of Doug Gouzie, 2006

Humans and Chemical Weathering

- We can speed up the process of weathering
- Pollution (burning coal, natural gas, & oil) releases Nitrogen Oxide (NO) and Sulfur Dioxide (SO_2) into the air where it can fall back as *acid rain*
- Acid rain weathers objects made of marble and limestone

Differential Weathering

- Different rock types weather at different rates
- Results in uniquely shaped landforms

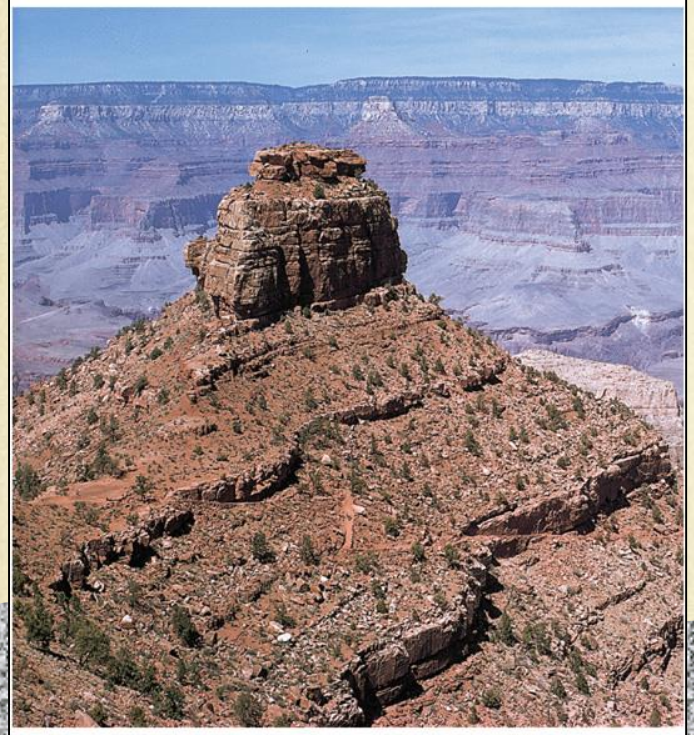


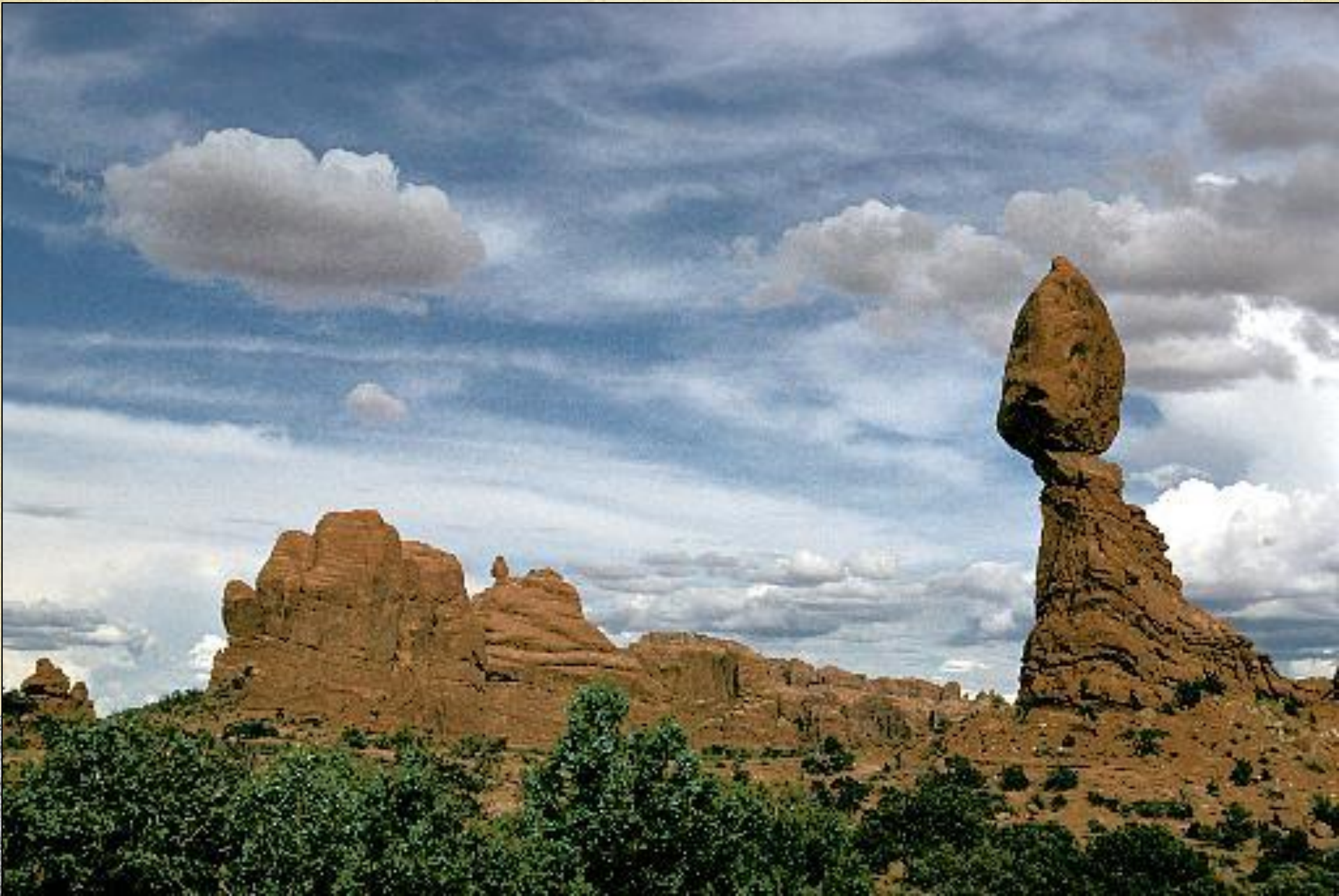
Photo by David McGeary

Photo by David McGeary

Differential Weathering

Differential Weathering

Differential Weathering



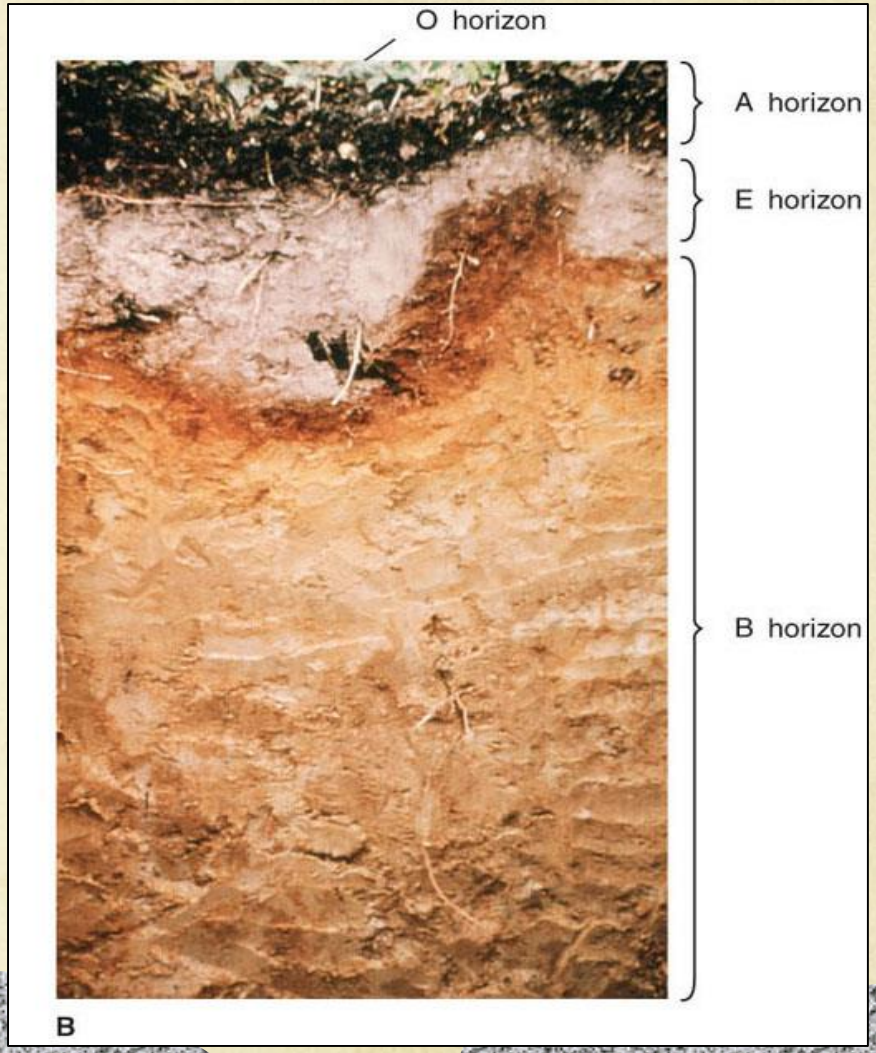
Differential Weathering

Soil	Land
Thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air and water	Part of the world not covered by oceans

Soil

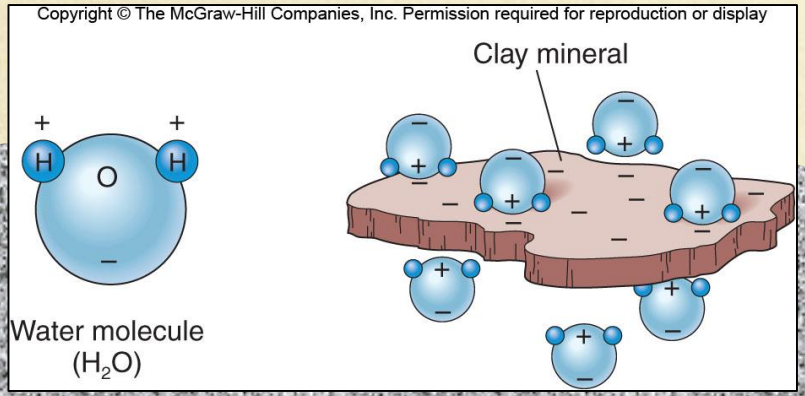
Soil - a layer of weathered, unconsolidated material on top of bedrock between the geosphere, biosphere, hydrosphere, and atmosphere.

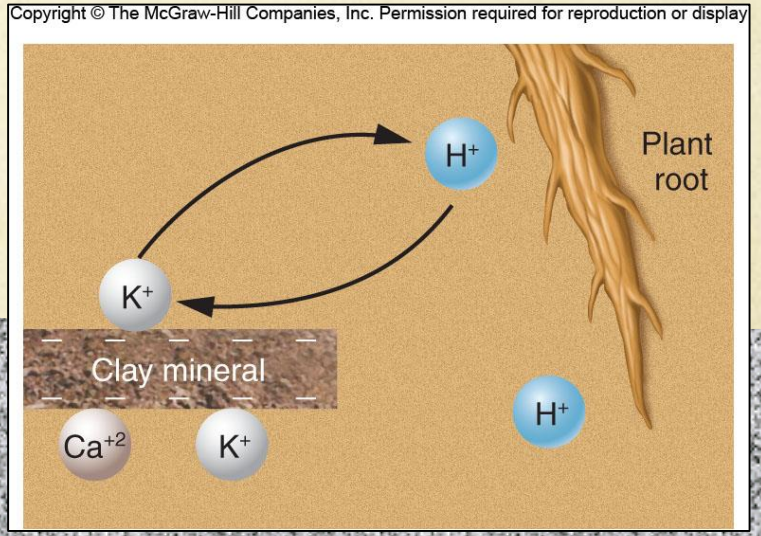
It contains organic matter and can support life.



What is Soil Made of?

- Common soil constituents:
  - **clay minerals**
  - **rock fragments** } **(45%)**
  - **quartz**
  - **water**
  - **organic matter (*humus*) (5%)**
  - **pore space (50%)**





How Many Types of Soils are There?

- The National Cooperative Soil Survey identifies and maps *over 20,000* different kinds of soil in the United States. Most soils are given a name, which generally comes from the locale where the soil was first mapped.

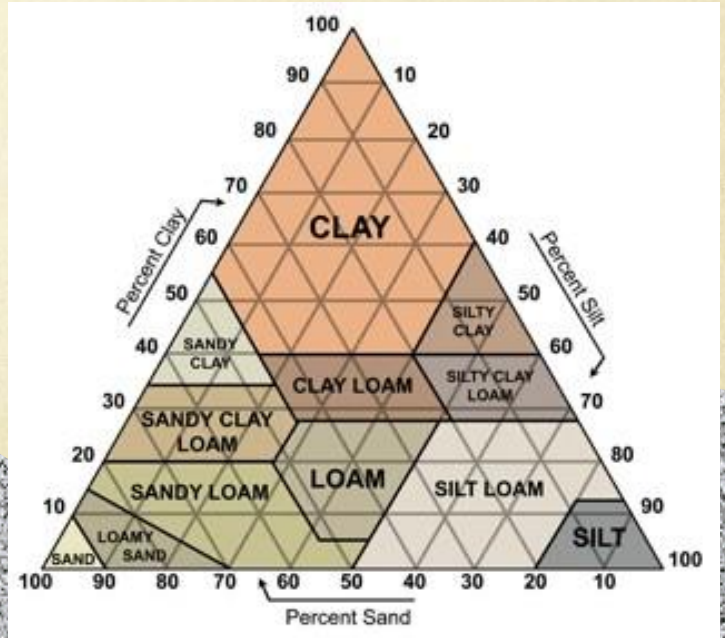
Soil Texture

- *Soil Texture* is the proportion of different sized particles
- Sand, silt, clay particles

Particle Size Range	Classification
0.063 to 2 mm (0.025 to 0.08 in.)	Sand
0.004 to 0.063 (0.00015 to 0.025 in.)	Silt
Less than 0.004 mm (<0.00015 in.)	Clay

The Ideal Soil

- Particle size is important for drainage and plant growth
- Too much sand = water drains too easily
- Too much clay = water doesn't drain well
- <u>Loam</u> – equal parts sand, silt, clay
  - Productive and fertile soil
  - **<u>Friable</u>**: crumbles easily



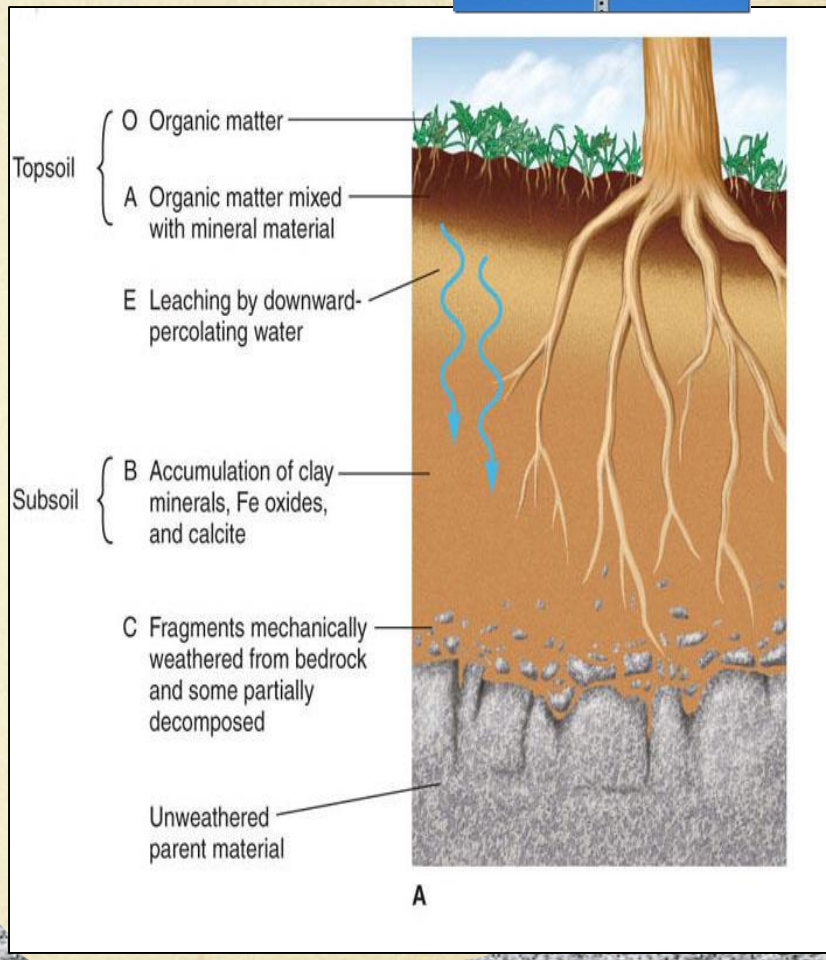
Soil Horizons

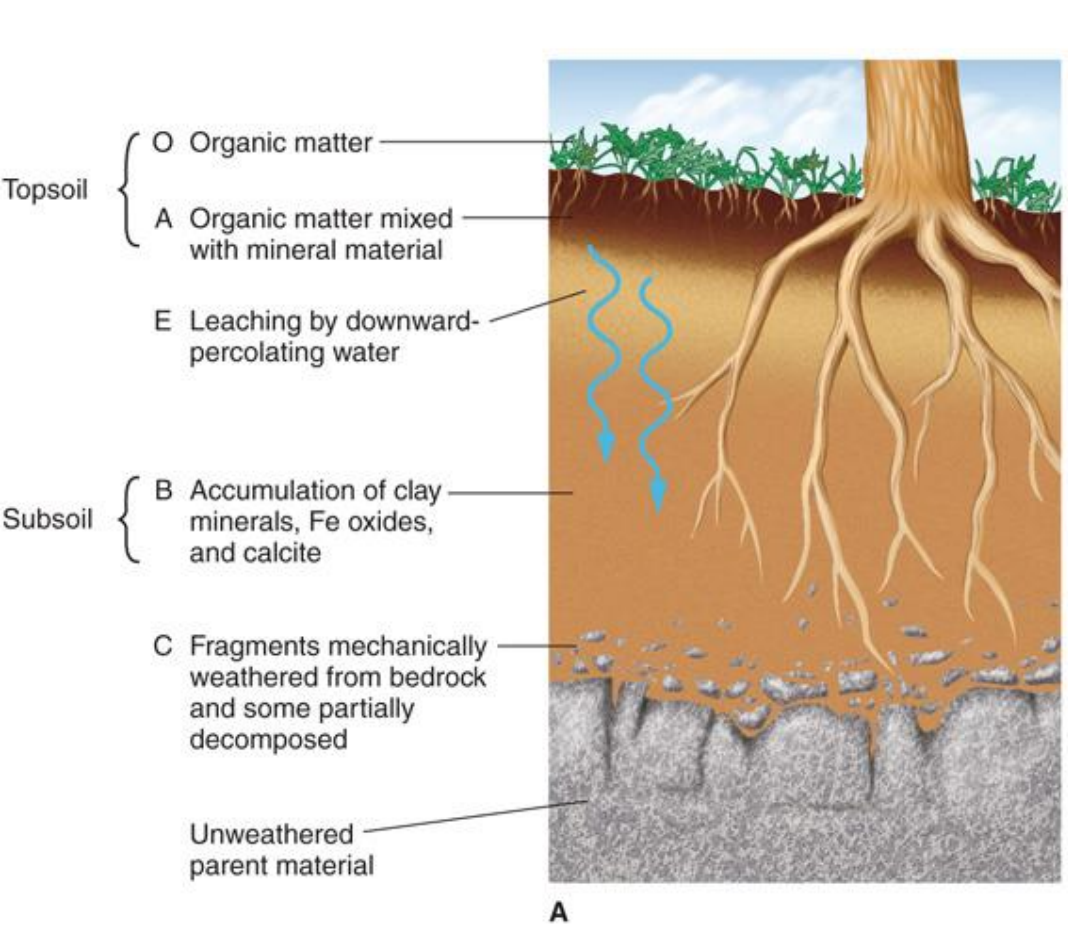
- Distinct layers due to maturity of soils
- Distinguished by appearance and chemical composition
- Transitional boundaries
- Soil profiles – vertical cross sections of soil

Soil Horizons

Soil horizons

- **O horizon -** uppermost layer; organic material
- **A horizon** – dark-colored, rich in organic matter and high in biological activity
- **E horizon -** zone of leaching; fine-grained components removed by percolating water
- **B horizon -** zone of accumulation; clays and iron oxides leached down from above; formation of **hard pan** in wet climates
- **C horizon -** partially weathered bedrock





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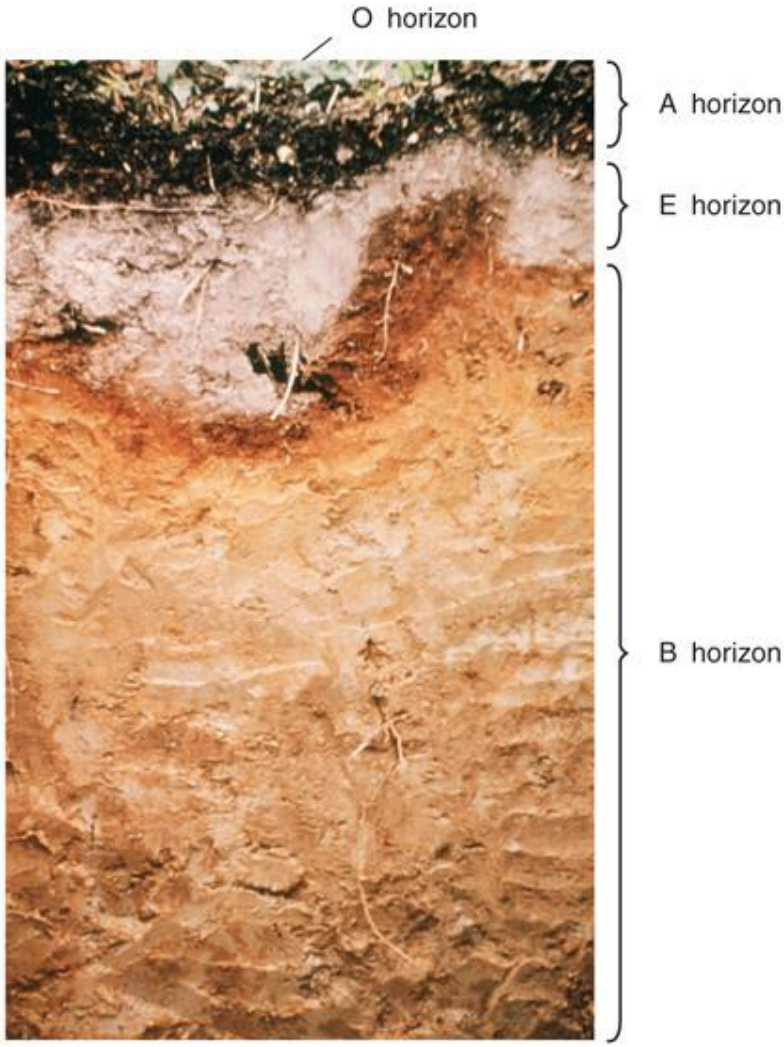
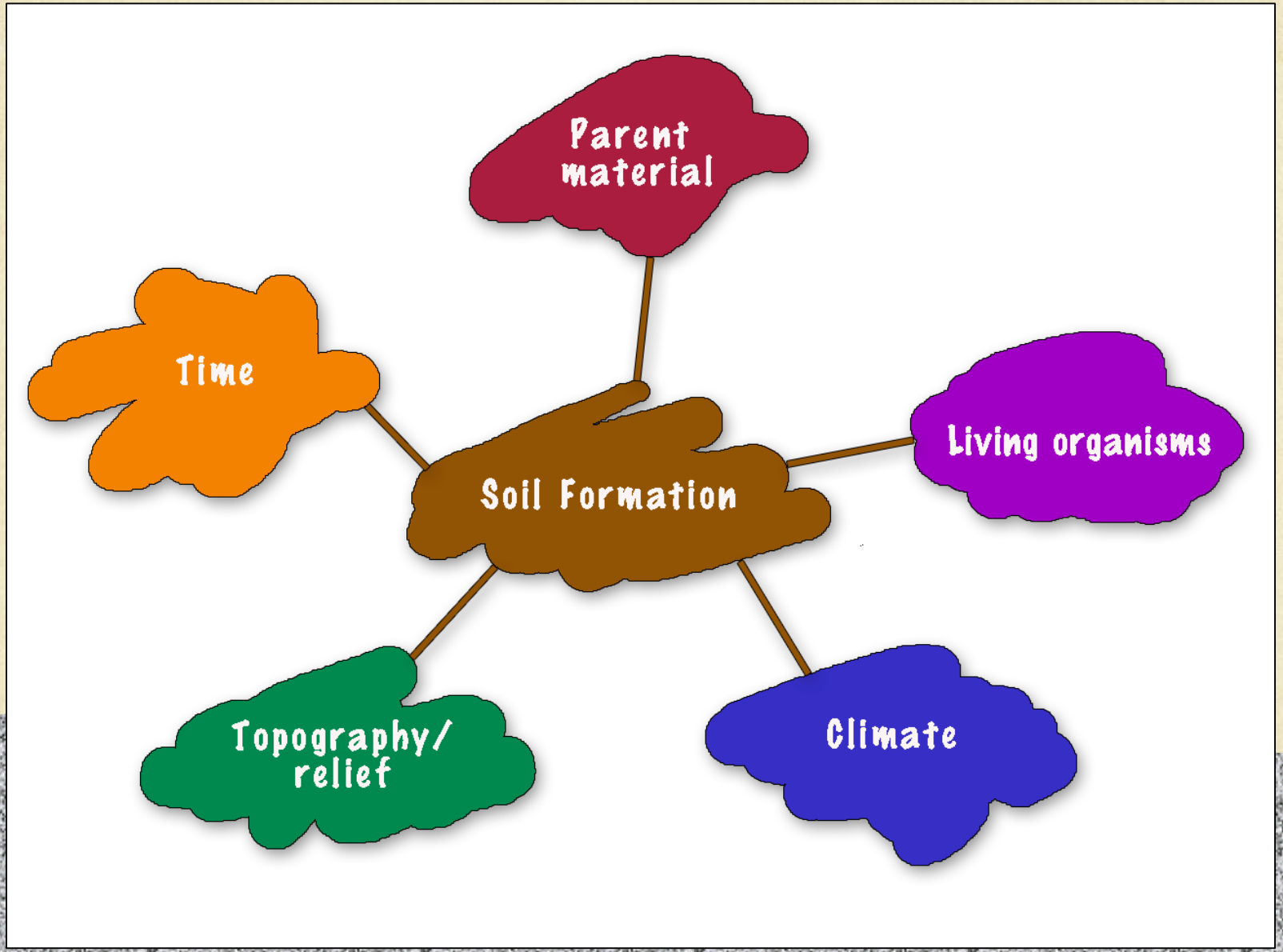


B

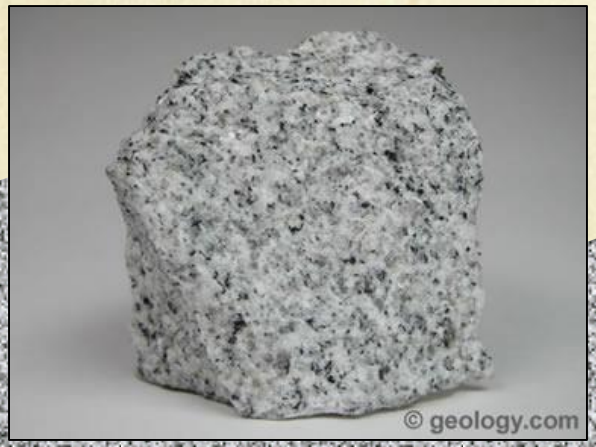
Photo by USDA Natural Resources Conservation Service

Factors Affecting Soil Formation



Parent Material and Soil Development

- Parent material – source of the weathered mineral matter that makes up soil
- Ex. Weathering granite will produce a sandy soil with quartz and feldspar
- Ex. Weathering basalt will not be sandy, no quartz in basalt



Parent Material & Soil Development

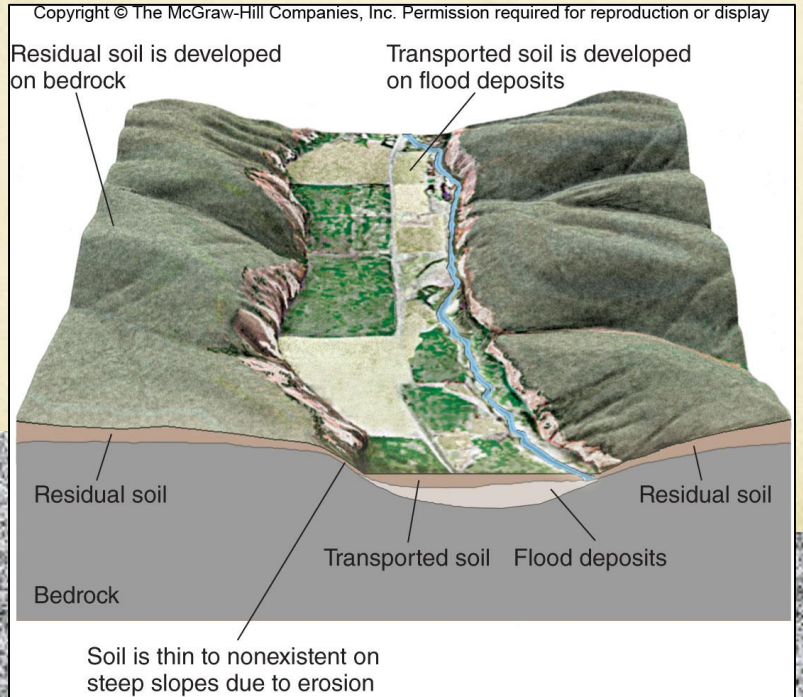
Residual soil - weathering of underlying rock

Transported soil - brought in from elsewhere

- More fertile soils because they come from all over
- Wind-transported soil is called **loess**

Soil composition – determined by parent rock composition

- Evolves with time and chemical weathering



Slope and Soil Development

- Slope and aspect affect the moisture and temperature of soil.
- Steep slopes facing the sun are warmer, just like the south-facing side of a house.
- Steep soils may be eroded and lose their topsoil as they form. Thus, they may be thinner than the more nearly level soils that receive deposits from areas upslope.
- Deeper, darker colored soils may be expected on the bottom land.

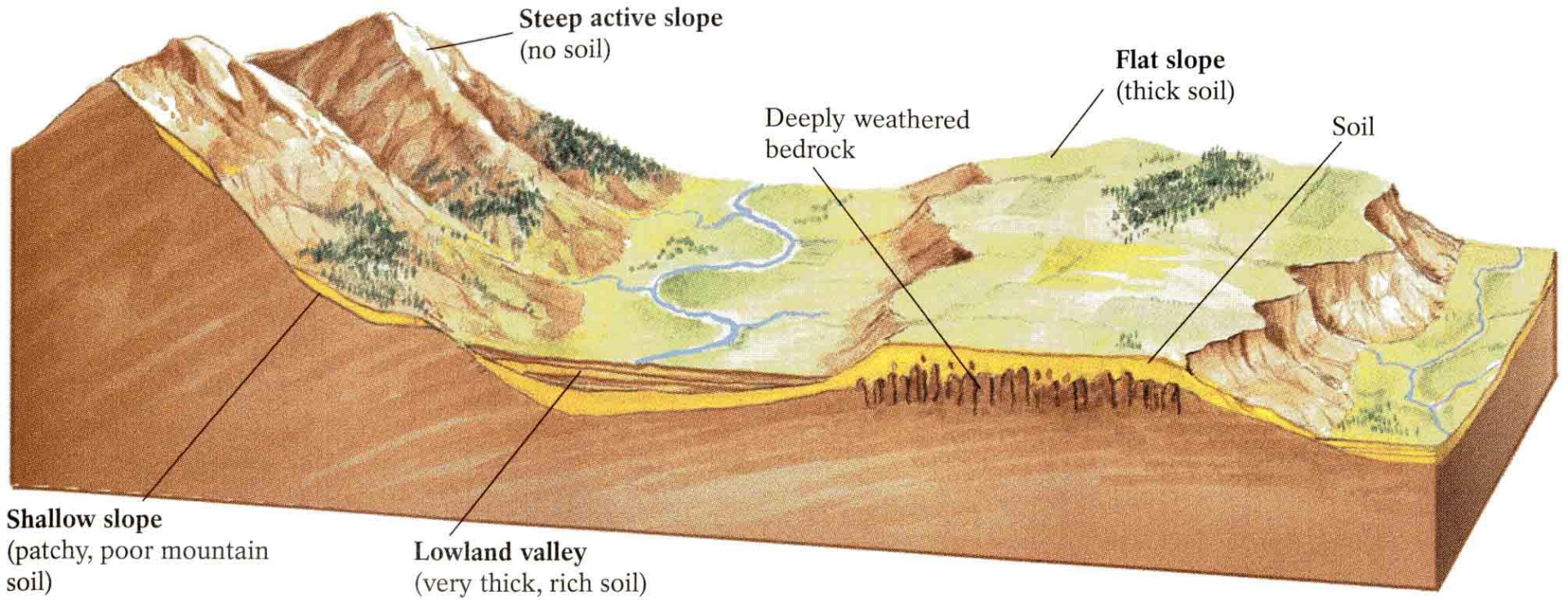
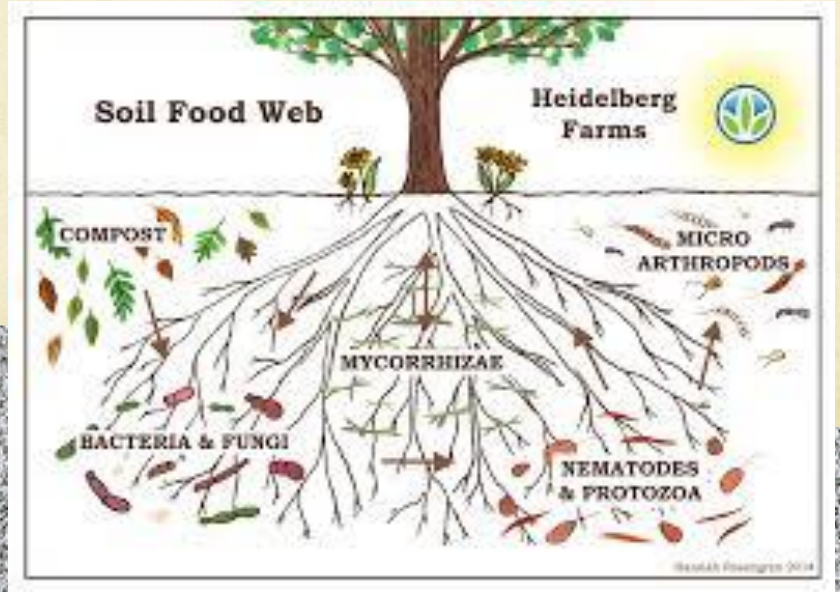
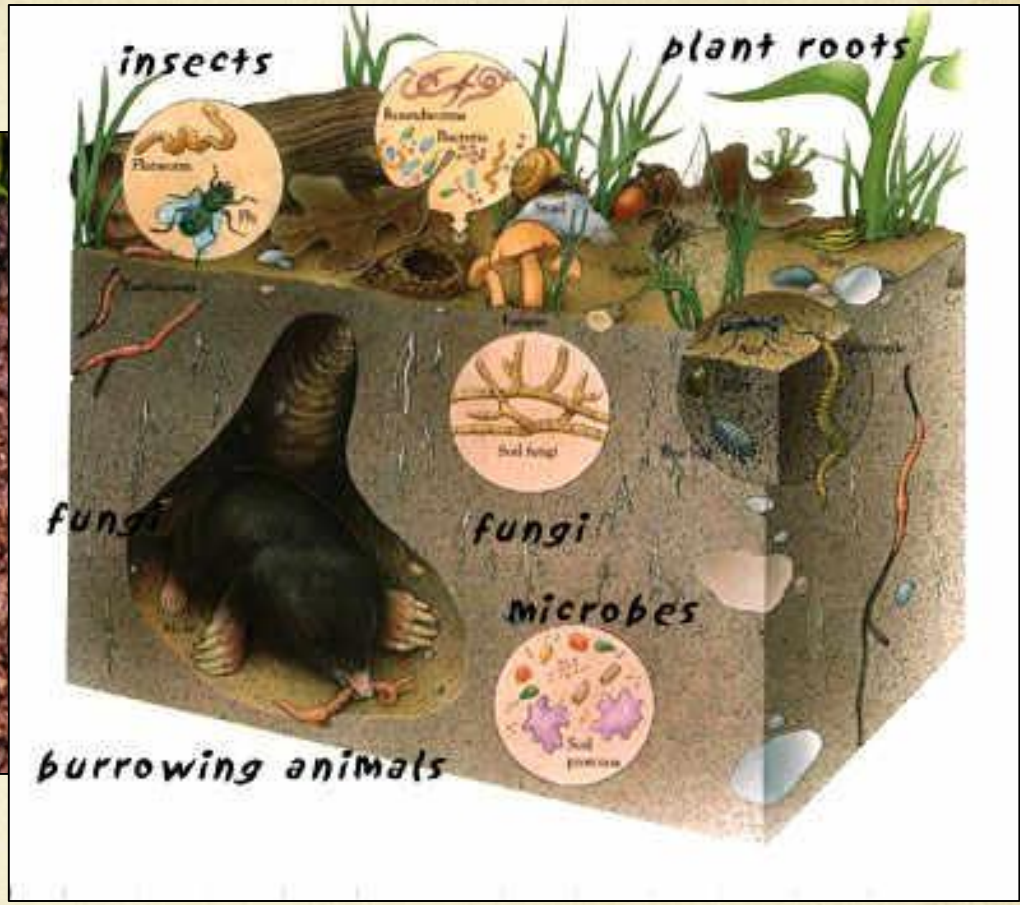


Figure 5-14 The effect of landscape on soil development. Soils are generally thin or nonexistent on steep slopes, because the water required for chemical weathering runs off such slopes and because any soil that does accumulate would wash away downhill. Soils tend to be thickest in lowland valleys, where water and loose material transported from upland come to rest.

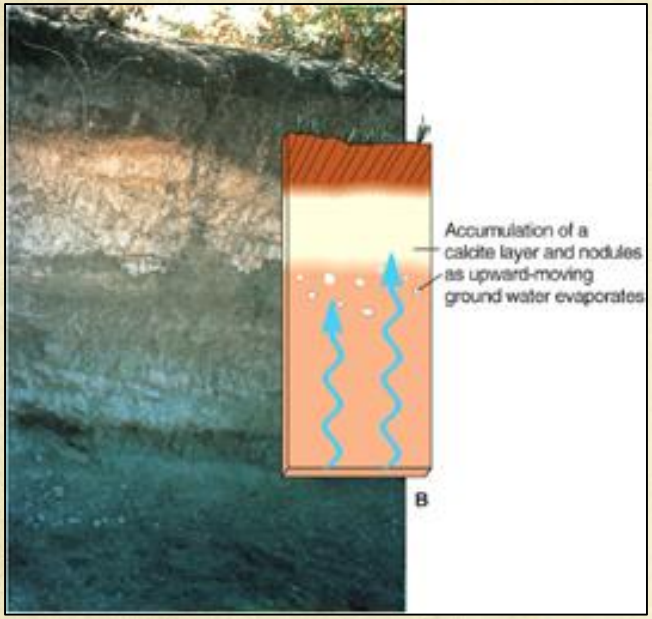
Living Organisms and Soil Development

- Plants, animals, micro-organisms, and humans affect soil formation.
- Animals and micro-organisms mix soils and form burrows and pores.
- Plant roots open channels in the soils.
- Different types of roots have different effects on soils. Grass roots are “fibrous” near the soil surface and easily decompose, adding organic matter. Taproots open pathways through dense layers.
- Micro-organisms affect chemical exchanges between roots and soil.




insects
plant roots
fungi
fungi
microbes
burrowing animals

Climate and Soil Development

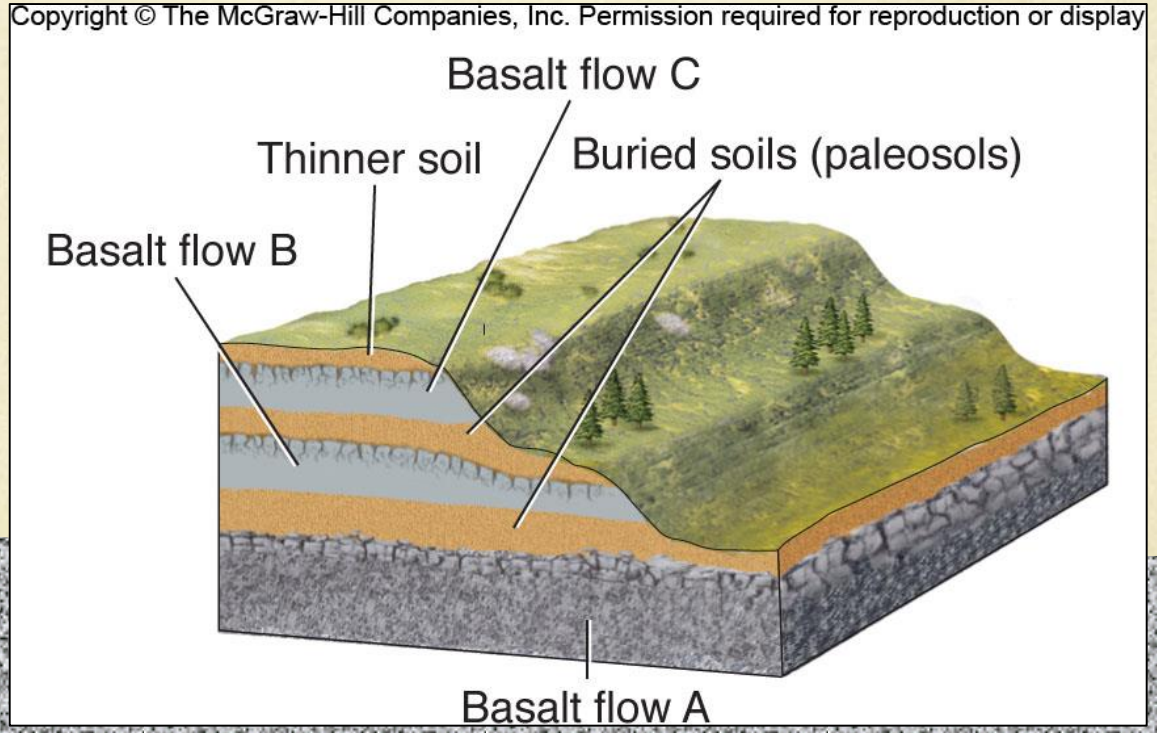


Soil thickness and composition are greatly affected by climate

- Wet climates:
- More chemical weathering and thicker soils
- 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
- Highly leached and unproductive soils (**laterites**)
- Most nutrients come from thick O/A horizons

Time and Soil Development

- **Soil thickness** – increases with time, thicker in wetter climates and areas of low slopes



Soil Erosion

A

B

a: U.S. Agriculture Department, Soil Conservation Service;
b: © BrandX Pictures/Punchstock RF

Soil particles are small and are therefore easily eroded by water and wind

- Water erosion is the most significant type
- Wind erosion is generally less significant
  - Problem in arid and semiarid regions
  - Depleted agricultural soils require increased use of fertilizers
- Rates of erosion influenced by:
  - **Soil characteristics**
  - **Climate**
  - **Slope**
  - **Vegetation**

What Happens to Eroded Particles?

- Soil particles eroded by water and wind are deposited as sediments in streams, flood plains, lakes, and reservoirs
- Although erosion is a natural process, humans have sped up the process in some areas by clearing land

- Between 1870 and 1930 Midwestern farmers plowed 100 million acres
- Drought caused crop failure; Soil was exposed
- Dust storms “Black rollers”
- Solutions: windbreaks, contour plowing, terracing, and crop rotation

Photo by U.S. Department of Agriculture

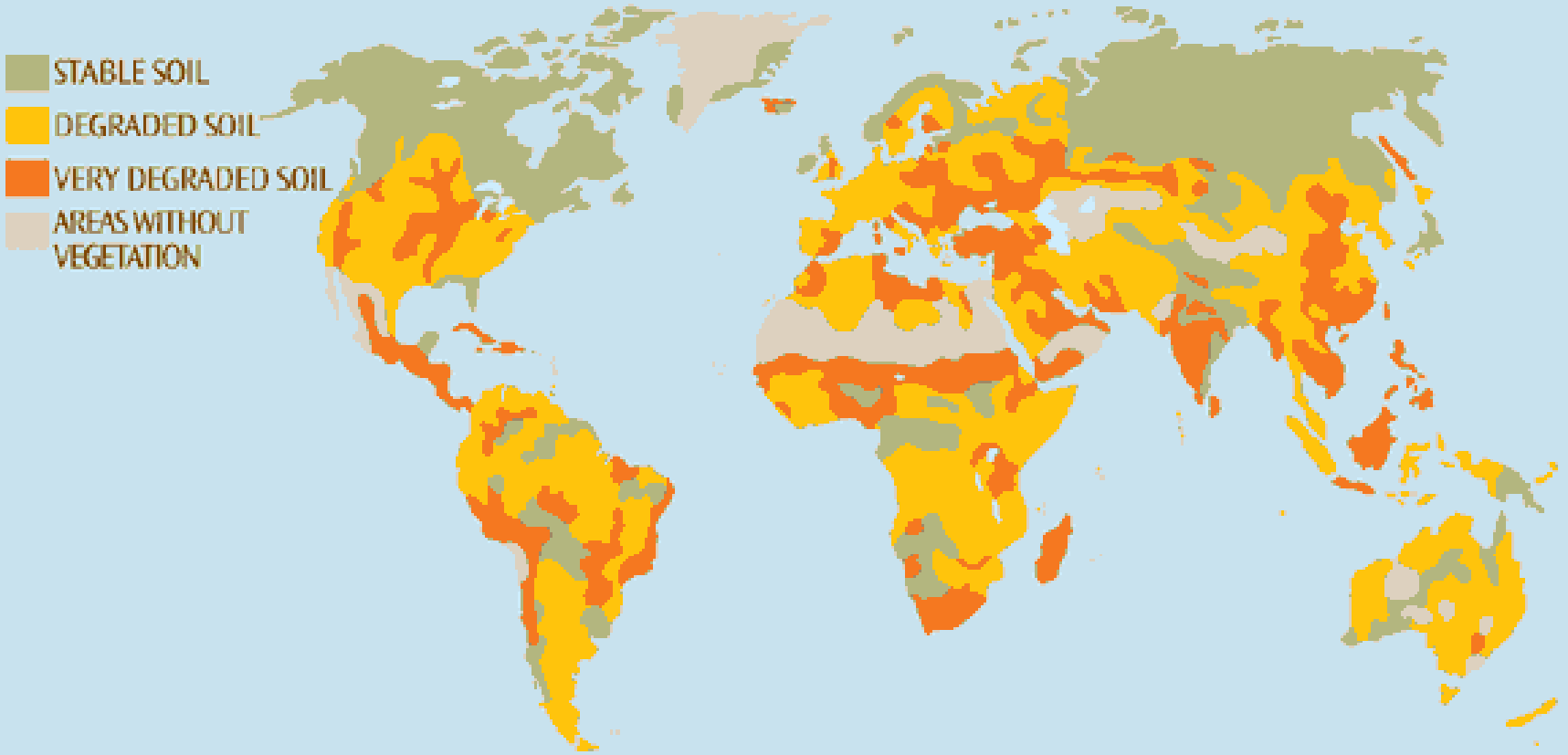
Photo by U.S. Department of Agriculture

Soil Conservation Initiatives

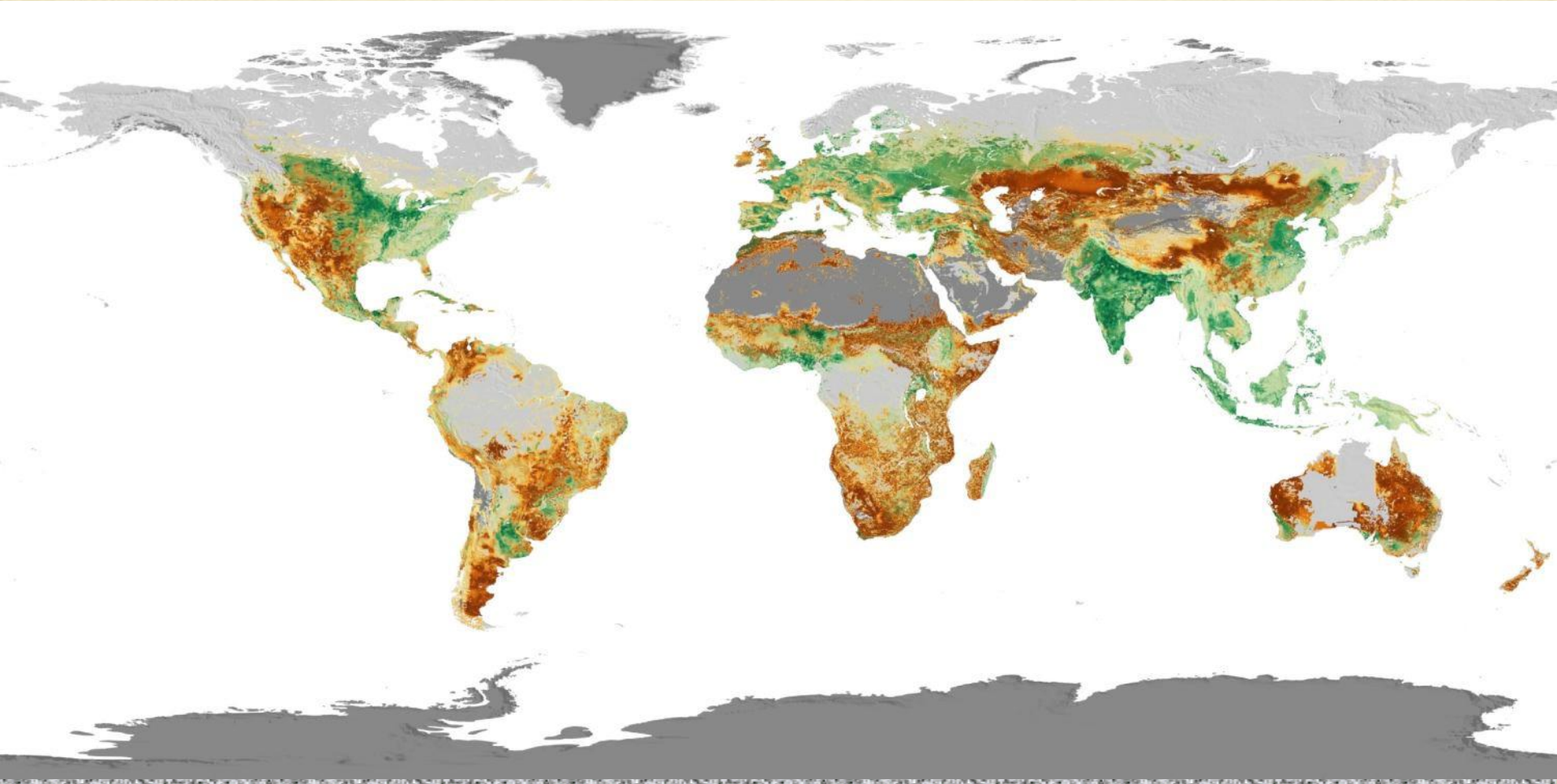
- Emergency Farm Mortgage Act (prevent closures)
- The Farm Bankruptcy Act (Helps farmers keep farms in times of crisis).
- The Soil Conservation Service (took national soil survey and implements soil conservation practices).

Factors Determining Agricultural Land Use

- Soil structure
- Texture
- Drainage
- Fertility
- Rockiness
- Slope
- Rainfall and other climatic conditions


STABLE SOIL
DEGRADED SOIL
VERY DEGRADED SOIL
AREAS WITHOUT VEGETATION

Green = Used for Agriculture



Soil Fertility Replenishment

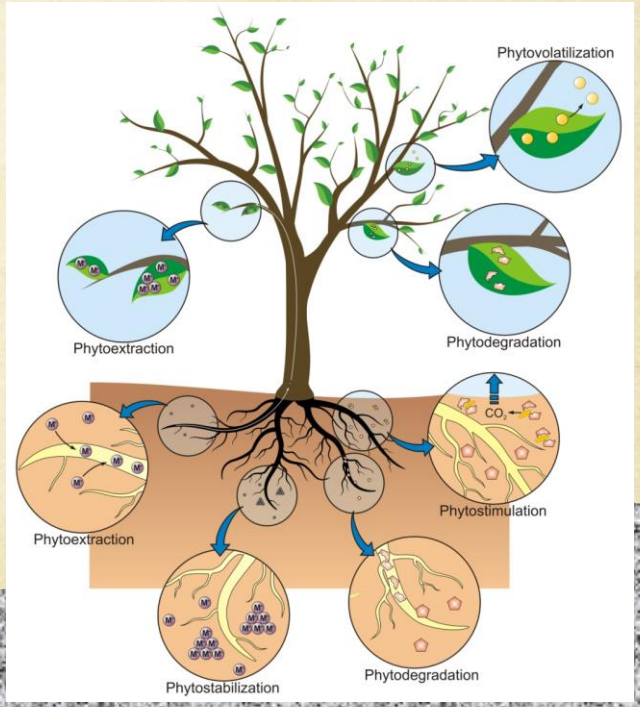
- Fertilizers
- Manure
- Nitrogen-fixing leguminous trees
- Biomass transfer of leaves (nitrogen, potassium, micronutrients).

Soil Quality Management

- Enhance organic matter: leave crop residues, crop rotation, cover crops, manure or compost, low or no tillage, mulch
- Avoid excess tillage
- Manage pests and nutrients efficiently
- Prevent soil compaction
- Keep the ground covered
- Diversify cropping systems

Phytoremediation

- Use of specialized plants to clean polluted soil
- Hyperaccumulators: plants that are able to accumulate high levels of pollutants within their bodies
  - Ex.: mustard greens, sunflowers



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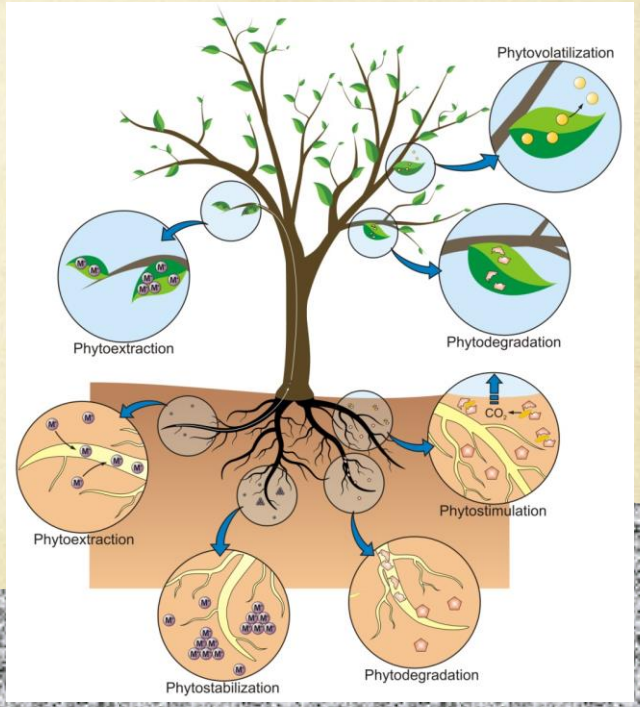


Contour Farming

- Tilling at right angles to the slope of the land

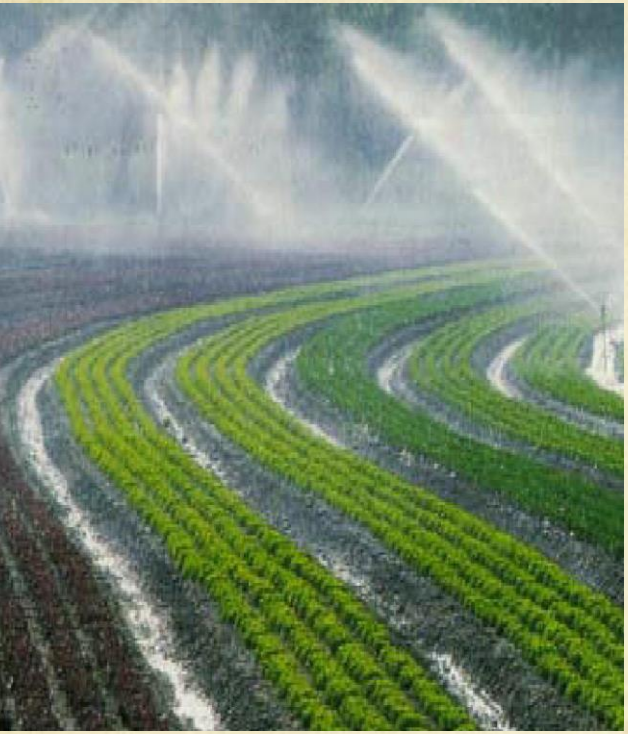
Strip Farming

- Alternating strips of closely sown crops

Terracing

- Used on very steep land

Waterways



- Protected channels for the movement of water
- Goal is to maintain reduction in movement of water and decrease soil erosion

Windbreaks

- Plantings of trees or other plants that protect bare soil from the full force of the wind.

Reduced tillage

- Uses less cultivation to control weeds and prepare soil
- Leaves 15-30% of soil covered with crop residue

Conservation Tillage

- Leave 30% or more of the soil service covered with crop residue.
- Selective herbicides used to kill weeds