Module 15

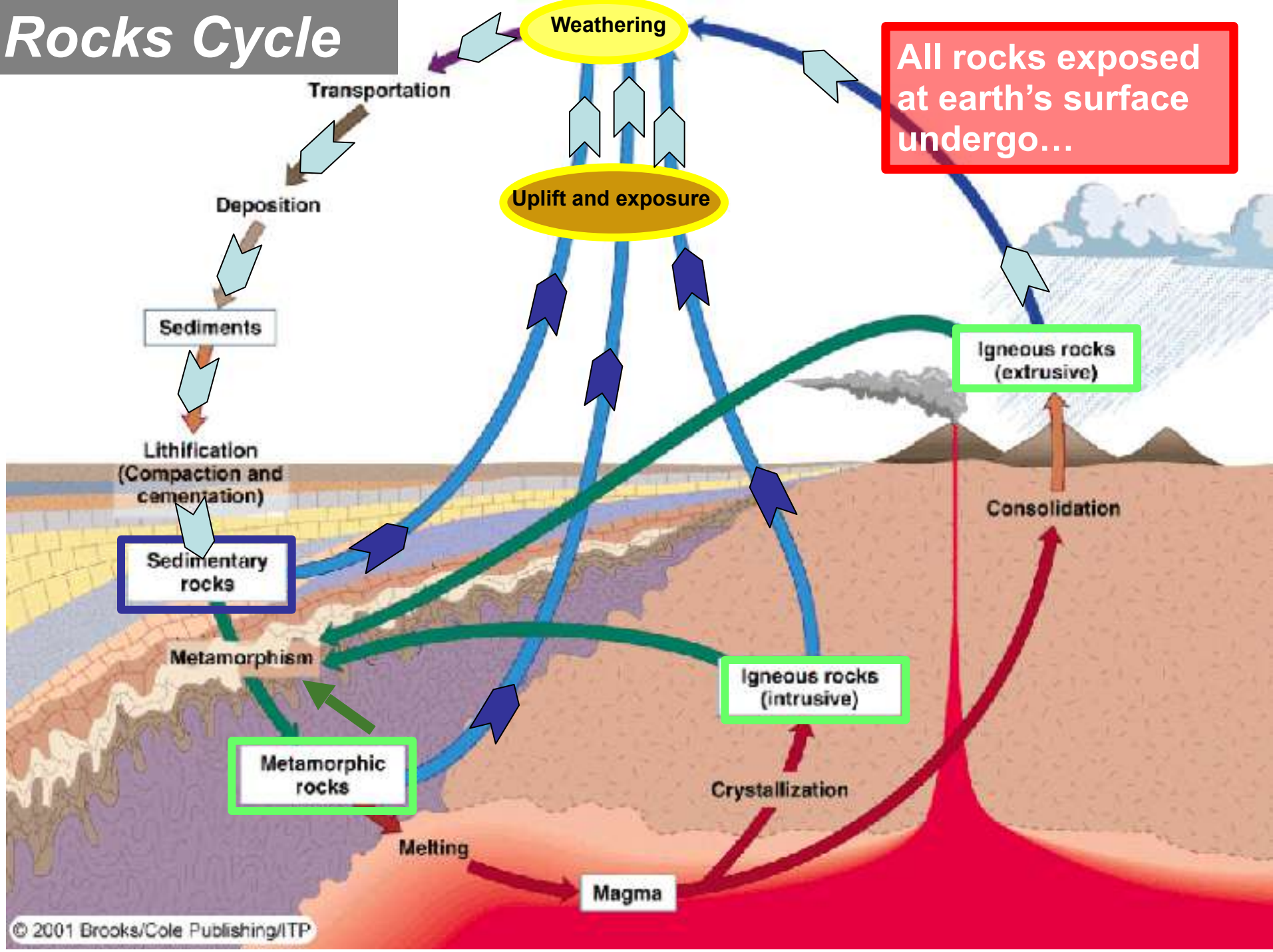
Weathering

WEATHERING

The Dynamic Earth

- **Earth is very dynamic**
- **Temperature (T) and pressure (P) increase with increasing depth below Earth's surface**
- **Tectonic activity uplifts rocks formed at higher T and P deep below Earth's surface to regions of lower T and P closer to the surface**
- **At the lower T and P at or near Earth's surface, the minerals composing the uplifted rocks:**
  - *Are unstable*
  - *Are constantly exposed to agents of weathering, such as O_2, acidic H_2O, rain, wind, ice, etc.*
  - *Are thus relentlessly destroyed by weathering, erosion, and mass wasting*

Rocks Cycle


Weathering
Transportation
Deposition
Uplift and exposure
All rocks exposed at earth's surface undergo…
Sediments
Lithification (Compaction and cementation)
Sedimentary rocks
Igneous rocks (extrusive)
Consolidation
Metamorphism
Igneous rocks (intrusive)
Metamorphic rocks
Crystallization
Melting
Magma
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WEATHERING

Weathering, Erosion, and Transportation

- ***Weathering***
  - **The group of processes that change rock at or near Earth's surface**
- ***Erosion***
  - **The removal of rock particles from their source by flowing water, wind, or glacial ice**
- ***Transportation***
  - **The movement of eroded particles by flowing water, wind, or glacial ice**

WEATHERING

Types of Weathering

- ***Chemical weathering***
  - **Changes the chemical composition of rocks by removing and/or adding ions**

- ***Mechanical weathering***
  - **Breaks rocks into smaller pieces without changing their composition**

Chemical Weathering

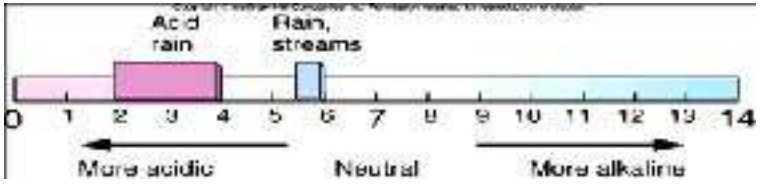
- Chemical weathering removes and/or adds ions by dissolution, hydrolysis, and oxidation
- ***Dissolution***
  - Is removal soluble ions Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+}, SiO_2
  - Is enhanced by acids: H_2CO_3, H_2SO_4, HNO_3, and HCl
- ***Hydrolysis*** is addition of water as the OH^{-} ion
  - Forms clays from olivine, augite, hornblende, biotite, feldspars
  - Forms H_4SiO_4, a cementing agent, from quartz
- ***Oxidation*** is addition of oxygen
  - Iron + oxygen yields hematite (if dry), limonite (if wet)
- ***Water is the most effective chemical weathering agent***

Chemical Weathering

Effects of Chemical Weathering

ACID RAIN

Carbon dioxide, ***nitrogen dioxide***, and ***sulfur dioxide*** produced by burning of fossil fuels react with rain to form ***carbonic***, ***nitric***, and ***sulfuric acids***, ***acid rain*** …



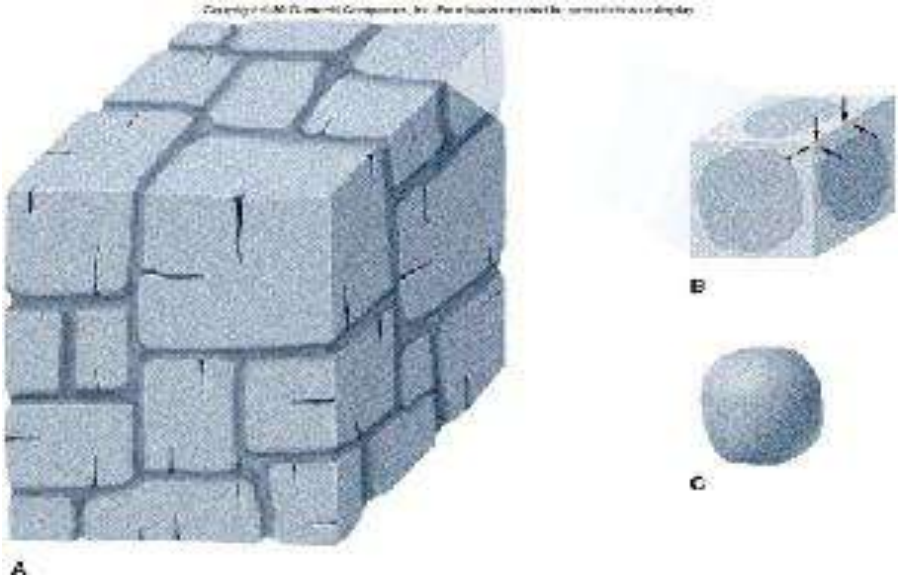
This statue is composed of *marble*

Marble is composed of ***CaCO3***, ***which dissolved by acid solutions***

The statue's facial features were dissolved by acid rain

Chemical Weathering

Effects of Chemical Weathering



Spheroidal weathering occurs because the corners and edges of rocks are more readily chemically weathered than their flat sides

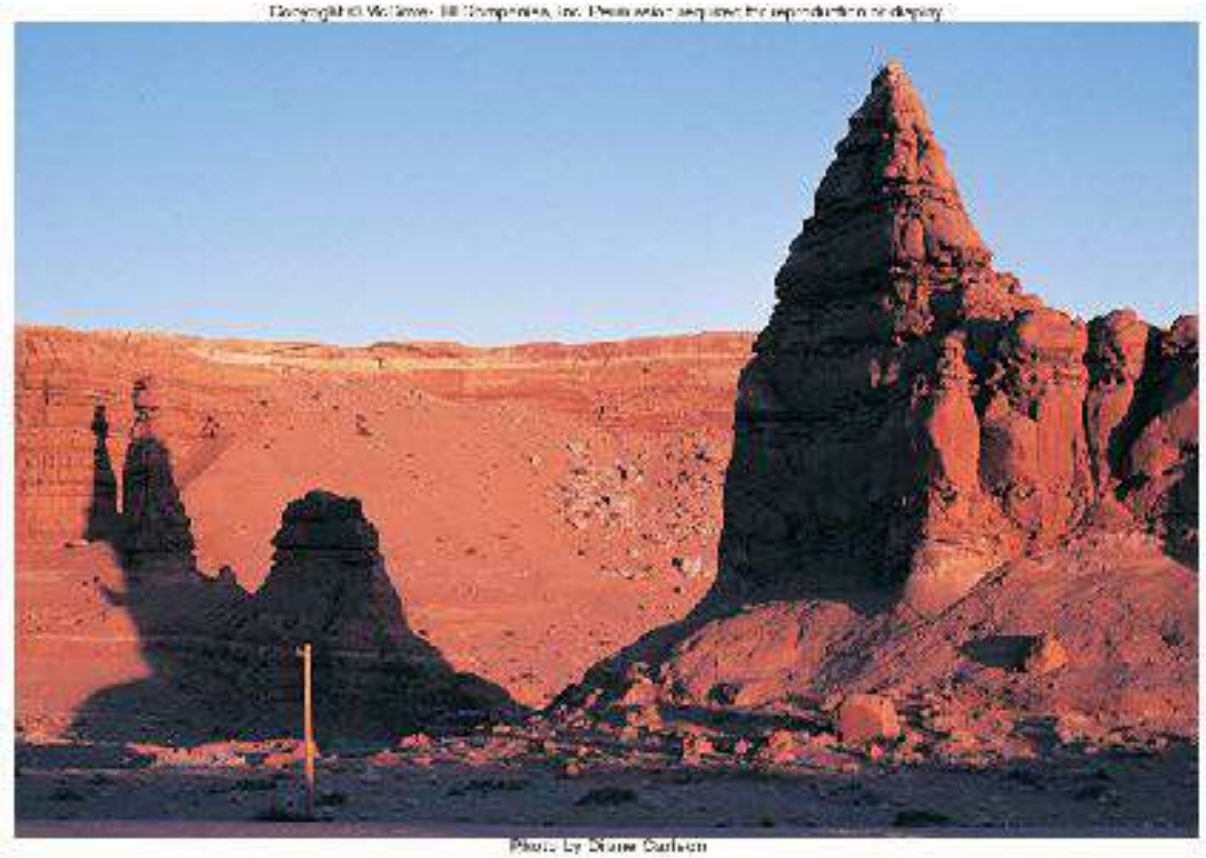
Photo by David McCarty

Spheroidally weathered granite

Spheroidal Weathering

Chemical Weathering

Effects of Chemical Weathering



In arid regions,
iron in the rocks reacts
with O_2 to form hematite,
Fe_2O_3, red rust

Oxidation of Iron

Chemical Weathering

Effects of Chemical Weathering

Oxidation and hydrolysis of pyrite in the rocks produces red-colored water rich in sulfuric acid

Acid mine drainage is a big problem anywhere pyrite is present in rocks exposed at the surface, particularly around, coal mines and gold mines

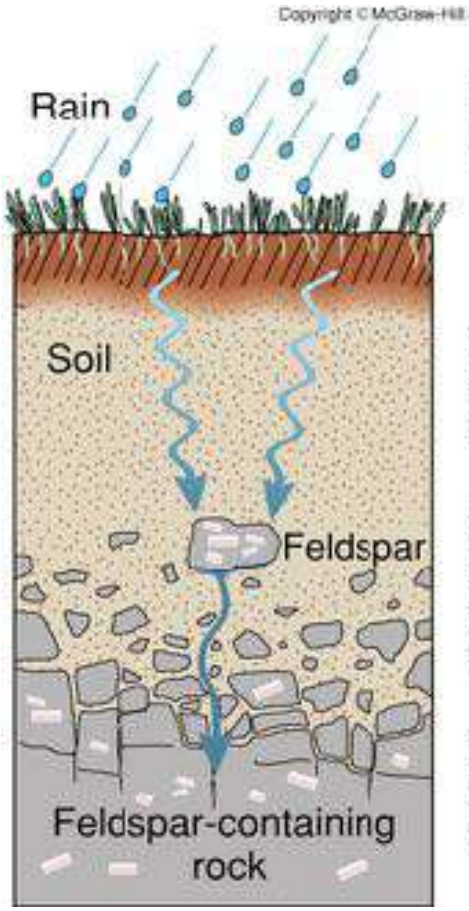
$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{++}(aq) + 4H^{+}(aq) + 4SO_4^{2-}(aq)$$

Acid Mine Drainage

Chemical Weathering

Effects of Chemical Weathering

Water percolating through soils forms clays from the feldspars by hydrolysis and carries away soluble ions and silica



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

Hydrolysis of Feldspars in Soils

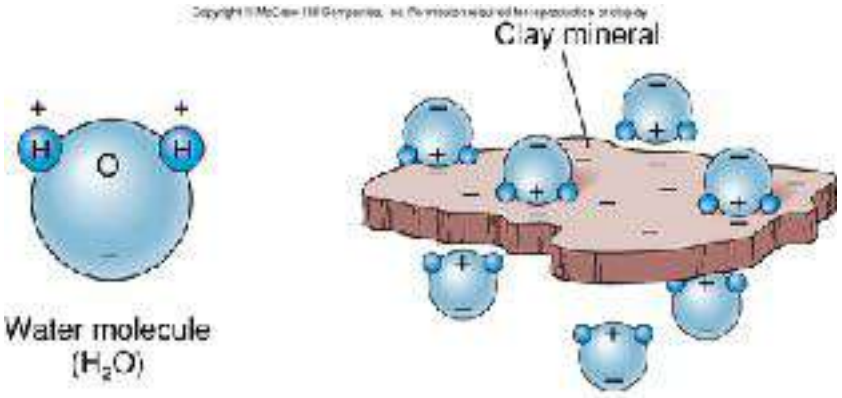
Chemical Weathering

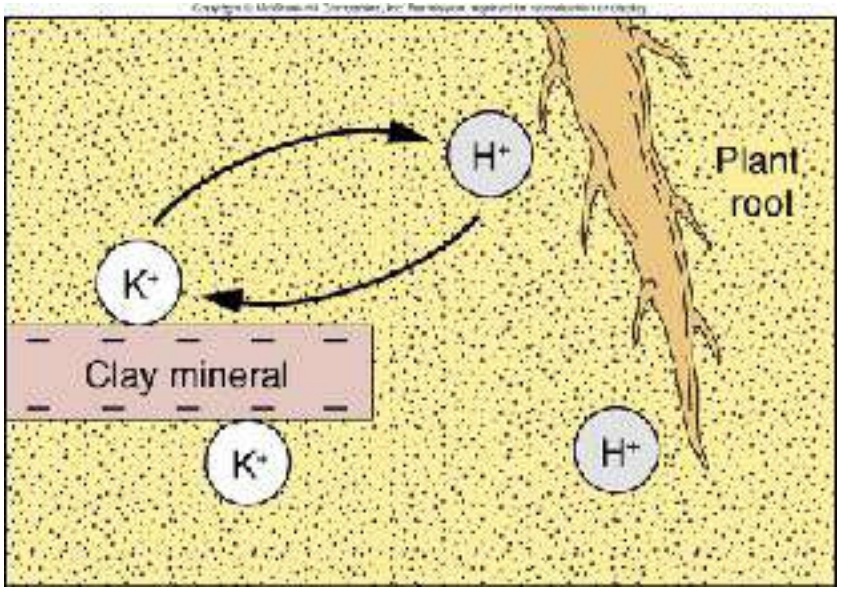
Effects of Chemical Weathering

Chemical weathering by organism

Chemical Weathering

Effects of Chemical Weathering





Negative charges on the flat surfaces of clay minerals attract positive ends of water molecules, which in turn

- **Keeps the soil moist**
- **Enables plants to absorb moisture and exchange ions with the soil**

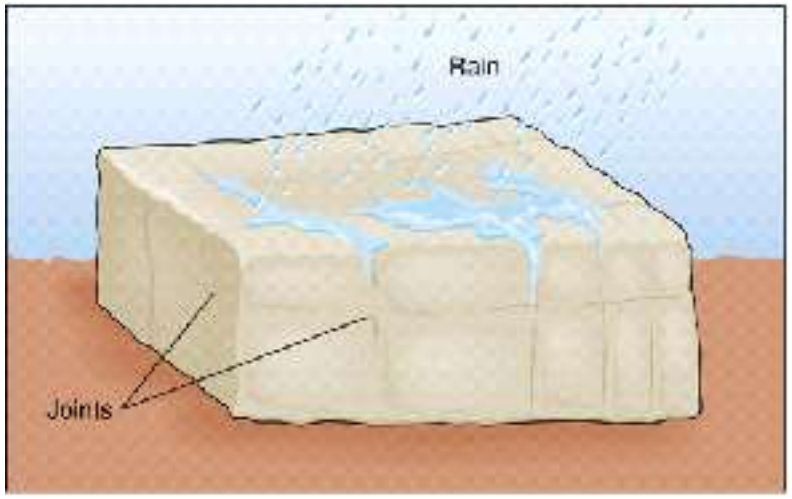
Hydrolysis of Feldspars in Soils

Mechanical Weathering

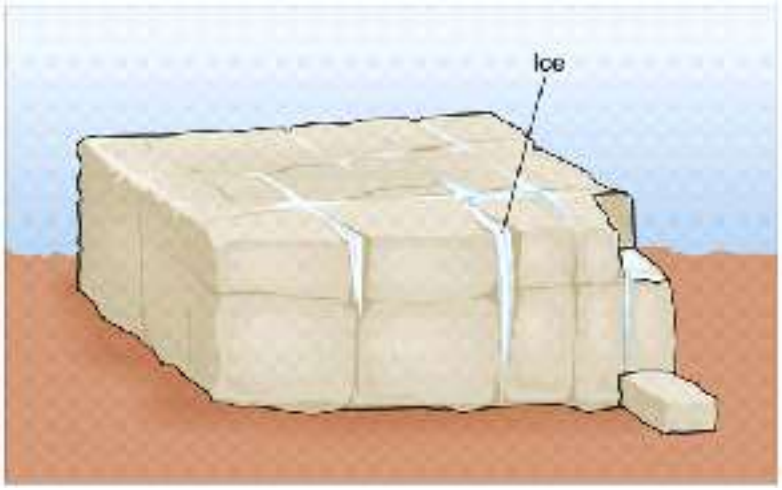
- Mechanical weathering breaks rock into smaller pieces without changing the composition
- Mechanical weathering is caused by
  - ***Frost wedging:*** Expansion of water during freezing
  - ***Unloading:*** Pressure reduction due to removal of overburden causes formation of sheet joints and exfoliation domes
  - ***Thermal expansion or contraction:*** Extreme changes in temperature cause cracks to form in rocks
  - ***Organic fracturing:*** Due to root wedging, burrowing by animals, mining activities, etc.
  - ***Erosional agents:*** moving water, wind, ice

Mechanical Weathering

Frost Wedging

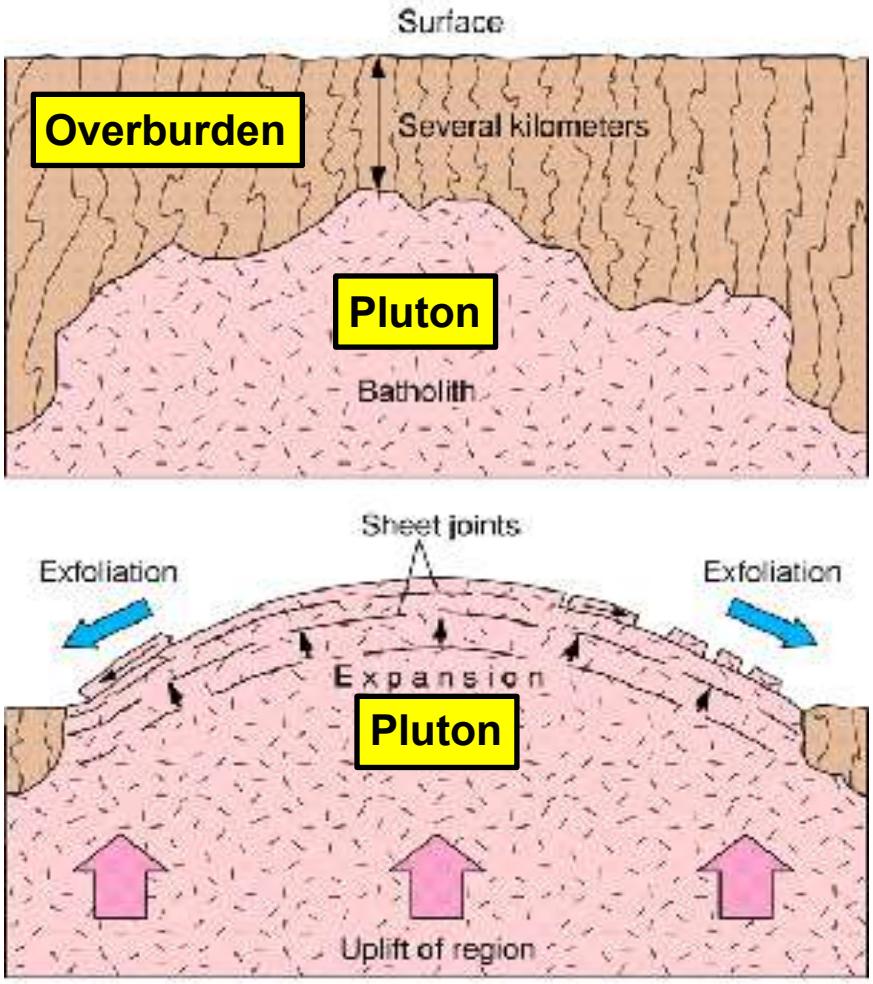


Rain water enters joints, cracks in the rocks



As the water freezes (forms frost) it expands, wedges the cracks further open, makes them wider

Mechanical Weathering



Unloading

Weight of the overburden **(the crust and soil above the pluton) exerts great pressure on the pluton keeps it from expanding**

Uplift **and** ***erosion*** **greatly reduce pressure exerted on the top of the pluton, cause formation of** ***sheet joints***, ***exfoliation***, **and** ***exfoliation domes***

Mechanical Weathering

Unloading

An exfoliating granite dome

Sheet joints produced by unloading

Mechanical Weathering

Root Wedging

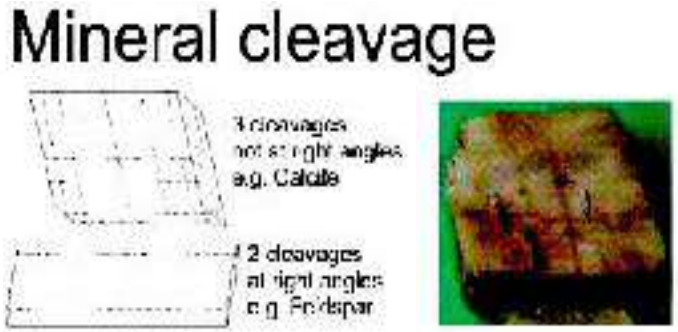
Plants take advantage of cracks in rocks, wedge the cracks wider as their their roots grow larger

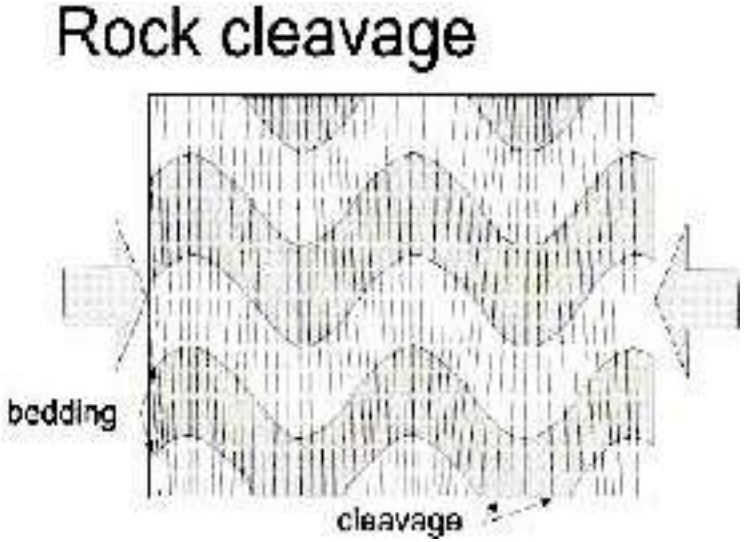
Factors That Influence the Rate of Weathering

- ***Structure***
  - **Structures such as fractures, foliation, cleavage, bedding enhance the rate at which rocks weather**
- ***Mineral composition***
  - **Mafic minerals weather more rapidly than felsic minerals**
- ***Climate***
  - **A warm moist climate most effectively enhances weathering: hydrolysis, dissolution, oxidation**
- ***Topography***
  - **Steep slopes weather less rapidly than horizontal surfaces because most of the rain runs off instead of soaking in**

Factors That Influence the Rate of Weathering

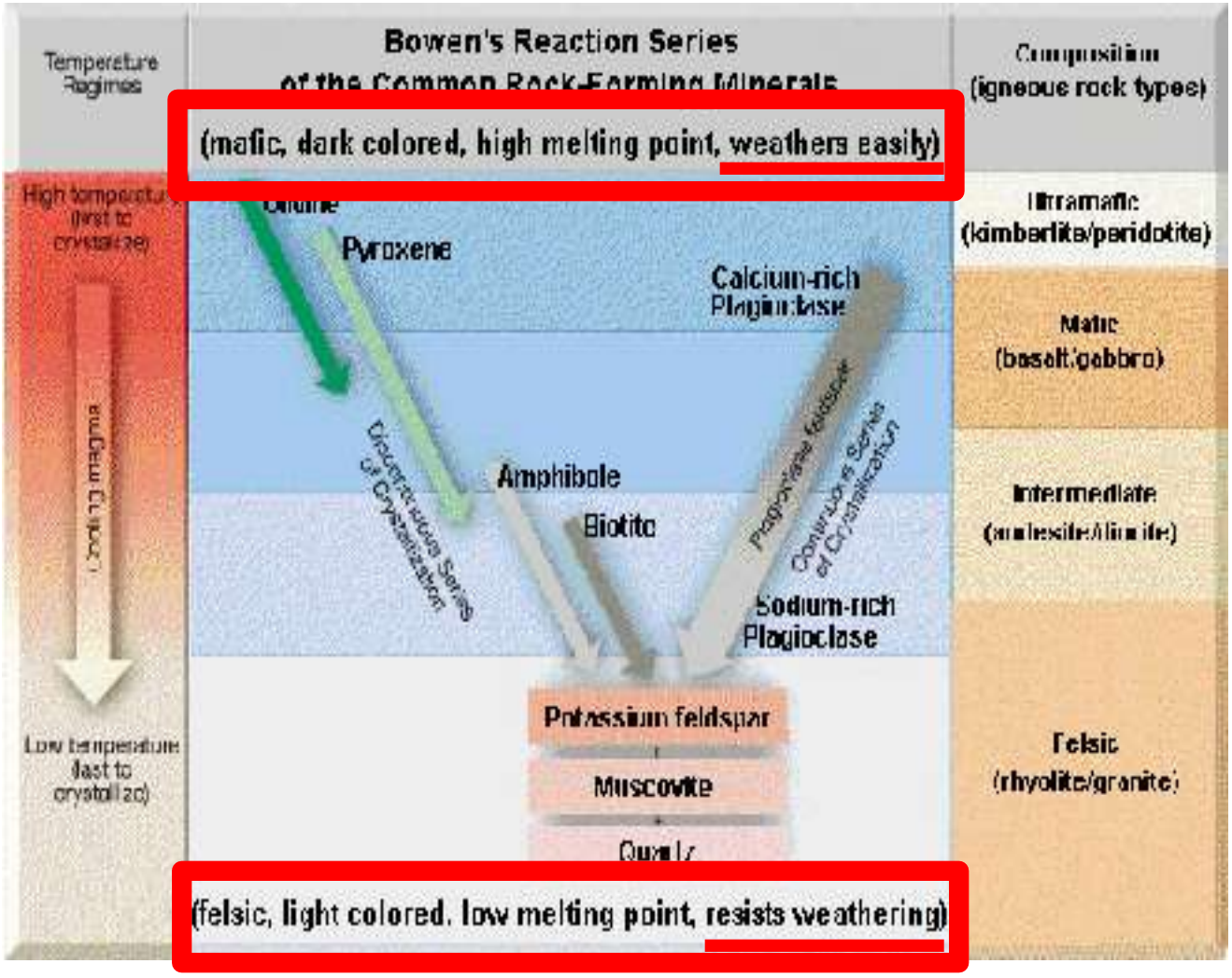
Presence of structure increases the surface area of rocks, which in turn increases the rates at which they weather





Effect of Structure

Factors That Influence the Rate of Weathering



Mafic minerals are much more susceptible to oxidation, dissolution, and hydrolysis than felsic minerals

Effect of Mineral Composition

Factors That Influence the Rate of Weathering

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 minerals +	Ions (Na^+, Ca^{++}, K^+), SiO_2
Ferromagnesian minerals (including biotite mica)	→	Clay minerals +	Ions (Na^+, Ca^{++}, K^+, Mg^{++}), SiO_2, Fe oxides
Muscovite mica	→	Clay minerals +	Ions (K^+), SiO_2
Quartz	→	Quartz sand	
Calcite	→	—	Ions (Ca^{++}, HCO_3^-)

Effect of Mineral Composition

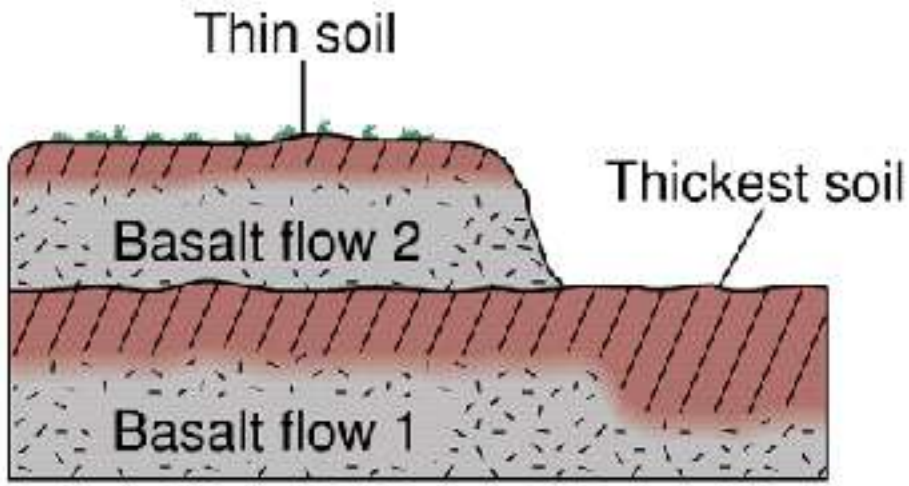
Factors That Influence the Rate of Weathering

Marble (right, composed of calcium carbonate) weathers more readily than slate (left, rich in clays)

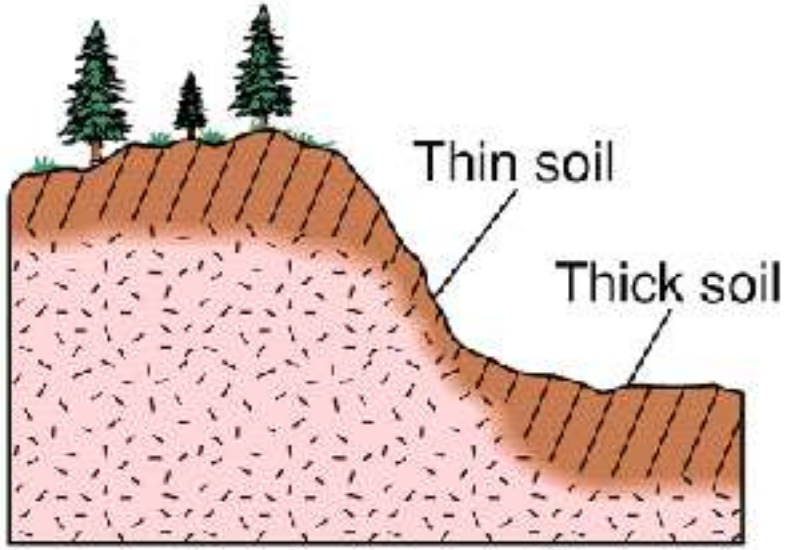
Mudstone (bottom, rich in clays) weathers more readily than sandstone (top, rich in quartz)

Effect of Mineral Composition

Factors That Influence the Rate of Weathering



Exposed part of basalt flow 1 is covered by a thicker layer of soil because it has been exposed to soil-forming processes longer than flow 2



Where underlain by the same rock-type, steep slopes weather more slowly, are covered by thinner soils, than horizontal surfaces

Time and Topography

SOIL

- ***Soil***
  - **A layer of weathered unconsolidated material consisting of *mineral matter*, *organic matter (humus)*, and *pore spaces***
- ***Loam***
  - **A fertile soil consisting of equal amounts of *sand*, *silt*, clay, and *organic matter***
- ***Topsoil***
  - **The dark-colored upper portion of a soil**
- ***Subsoil***
  - **Infertile stony organic-poor soil usually underlying topsoil**
- ***Regolith***
  - **Loose unconsolidated rock material resting on bedrock**

SOIL

Soil Horizons

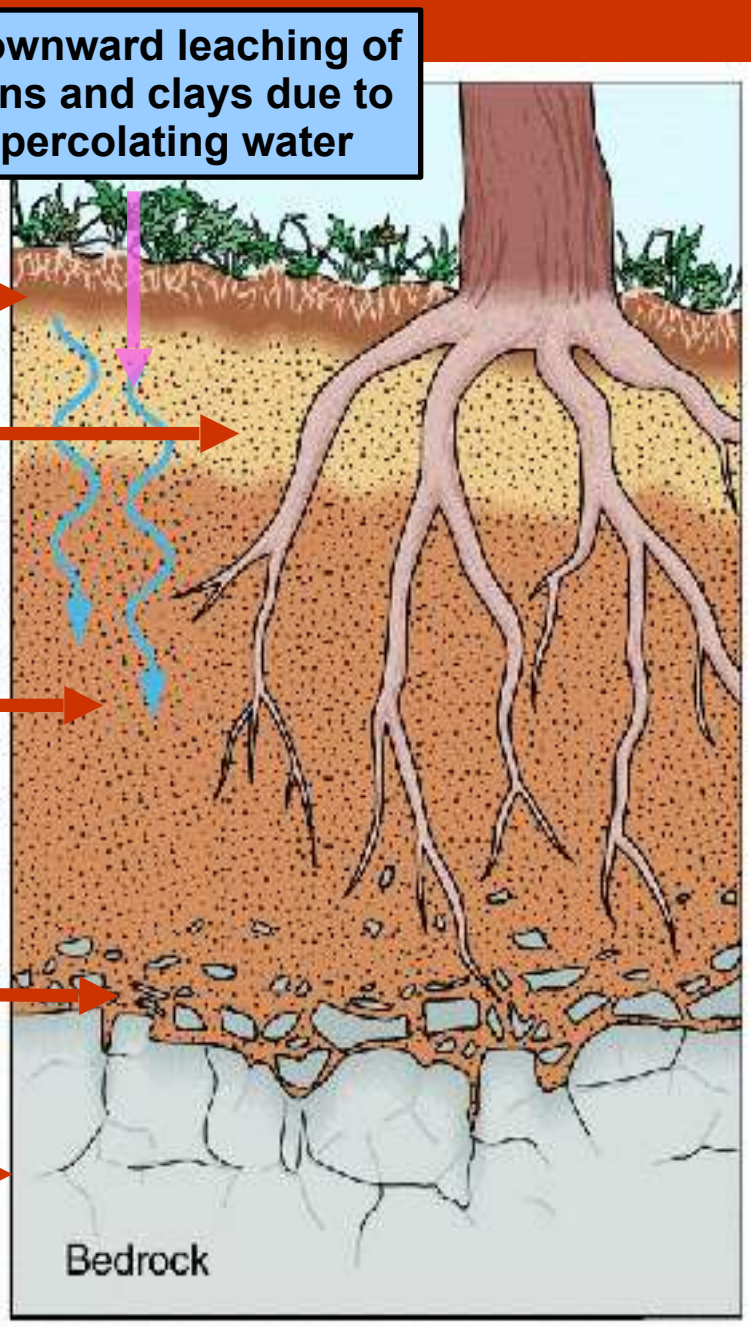
O Organic matter

A Organic matter mixed with mineral matter

B Mineral matter mixed with fine clays and colloids washed down from the top soil

C Rock fragments mechanically weathered from bedrock mixed with partially decomposed rock

D Bedrock



SOIL

Factors That Control Soil Formation

- ***Composition of the bed rock***
  - **Mafic rocks weather more rapidly than felsic rocks**
- ***Time***
  - **Longer time leads to more soil formation**
- ***Climate***
  - **A warm moist climate is most effective**
- ***Topography***
  - **Horizontal surfaces weather more rapidly**
- ***Plants and Animals***
  - **Plants supply nutrients, form acids, and fix nitrogen**
  - **Burrowing animals increase porosity, mix materials**

What will be happened if no weathering process in our planet?