Weathering
Weathering: the disintegration, or breakdown of rock material
Mechanical Weathering: no change in chemical composition--just disintegration into smaller pieces
Chemical Weathering: breakdown as a result of chemical reactions

\[ \text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + 2\text{HCO}_3^- \]
Mechanical Weathering

Physical breakup
  • pressure release
  • water: freeze - thaw cycles
  • crystallization of salt in cracks
  • thermal expansion and contraction

All this increases the total surface area exposed to weathering processes.
**Mechanical Weathering**

*Exfoliation:*
Rock breaks apart in layers that are parallel to the earth's surface; as rock is uncovered, it expands (due to the lower confining pressure) resulting in exfoliation.
Mechanical Weathering
Sheet Joints
(Exfoliation)
Half Dome,
Yosemite, CA
Exfoliated Domes, Yosemite
Stone Mountain, Georgia, showing the product of exfoliation due to unloading
**Frost Wedging**: rock breakdown caused by expansion of ice in cracks and joints
Shattered rocks are common in cold and alpine environments where repeated freeze-thaw cycles gradually pry rocks apart.
Thermal expansion due to the extreme range of temperatures can shatter rocks in desert environments. Repeated swelling and shrinking of minerals with different expansion rates will also shatter rocks.
Role of Physical Weathering

1) Reduces rock material to smaller fragments that are easier to transport

2) Increases the exposed surface area of rock, making it more vulnerable to further physical and chemical weathering
Surface Area and Weathering

Area = 6 \times 1m^2 = 6 \text{ m}^2

Area = 6 \times (1/2m)^2 \times 8 = 12 \text{ m}^2

Area = 6 \times (1/3m)^2 \times 27 = 18 \text{ m}^2

Area = 6 \times (1/10,000m)^2 \times 10^8 = 10^4 \text{ m}^2 = 2.5 \text{ acres}
Rates of weathering

Joints in a rock are a pathway for water - they can enhance mechanical weathering
Chemical Weathering

**Definition:** transformation/decomposition of one mineral into another

*Mineral breakdown*

- carbonate dissolves
- primary minerals $\rightarrow$ secondary minerals
  (mostly clays)

Net loss of elements retained in the soil.
Chemical Weathering

• **Water is the main operator:**
  - **Dissolution**
    • Many ionic and organic compounds dissolve in water
      - Silica, K, Na, Mg, Ca, Cl, CO$_3$, SO$_4$
  - **Acid Reactions**
    • Water + carbon dioxide $\rightleftharpoons$ carbonic acid
    • Water + sulfur $\rightleftharpoons$ sulfuric acid
    • H$^+$ effective at breaking down minerals
Dissolution

\[ H_2O + CO_2 + CaCO_3 \rightarrow Ca^{+2} + 2HCO_3^- \]

water + carbon dioxide + calcite
dissolve into calcium ion
and bicarbonate ion

Biological activity in soils
generates substantial \( CO_2 \)

Bicarbonate is the dominant
ion in surface runoff.
Chemical Weathering

• Oxidation
  - Oxygen dissolved in water promotes oxidation of sulfides, ferrous oxides, native metals

• Organic Activity
  - Plant material makes H+ ions available
Chemical Weathering

- **Hydration**: attachment of water molecules to crystalline structure of a rock, causing expansion and weakness

- **Hydrolysis**: combination of hydrogen and oxygen in water with rock to form new substances
Chemical Weathering

**Solution**: process by which rock is dissolved in water

- Is strongly influenced by pH and temperature
- When water becomes saturated, chemicals may precipitate out forming *evaporite* deposits.
- Calcium carbonate (*calcite, limestone*), sodium chloride (*salt*), and calcium sulfate (*gypsum*) are particularly vulnerable to solution weathering.
Resistance to Weathering

Bowen's Reaction Series
- First to Crystallize
- Last to Crystallize

Goldrich Stability Series
- Fast Weathering
- Slow Weathering
Olivine/pyroxene to clay

+ $H_2CO_3$ (acid)
Feldspars to clay

+ $\text{H}_2\text{CO}_3$ (acid)
Quartz to quartz (!) + anything
Calcite to .......

+ anything

nothing
This photo of Lime Sink was taken on 20 July 1932, over a week after the drawdown, which occurred over the night of 9-10 July.

‘Karst’ landforms develop in areas underlain with limestone.
Biological Weathering

Can be both chemical and mechanical in nature.

- roots split rocks apart
- roots produce acids that dissolve rocks.
- tree throw
- burrowing animals
Weathering

- **Climate**
  - Temperature and moisture characteristics

- **Chemical weathering**
  - Most effective in areas of warm, moist climates - decaying vegetation creates acids that enhance weathering
  - Least effective in polar regions (water is locked up as ice) and arid regions (little water)

- **Mechanical weathering**
  - Enhanced where there are frequent freeze-thaw cycles
Mechanical and Chemical Weathering

- Fracturing, disintegration caused by mechanical weathering exposes more surface area.

- Greater surface area, means more places for chemical action to occur.
THEORETICAL WEATHERING REGIONS

Annual rainfall (in.)

Mean annual temperature (°C)

Mean annual temperature (°F)

Outside normal climatic range

Moderate chemical and physical frost action

Almost no chemical or physical weathering

Strong chemical

Moderate chemical

Strong physical

Moderate physical

Moderate chemical