Making matter smaller

Weathering

Key points

- Know the basic weathering types
- **Be able to discuss chemical weathering** processes including; how different minerals are affected by each process (be able to give examples).
  - Know the **by-products** of each weathering process.
  - Know the **relative stability** of common minerals.
- What the **significance** of weathering is to geomorphology?

Weathering vs. Erosion & Landscape Stability

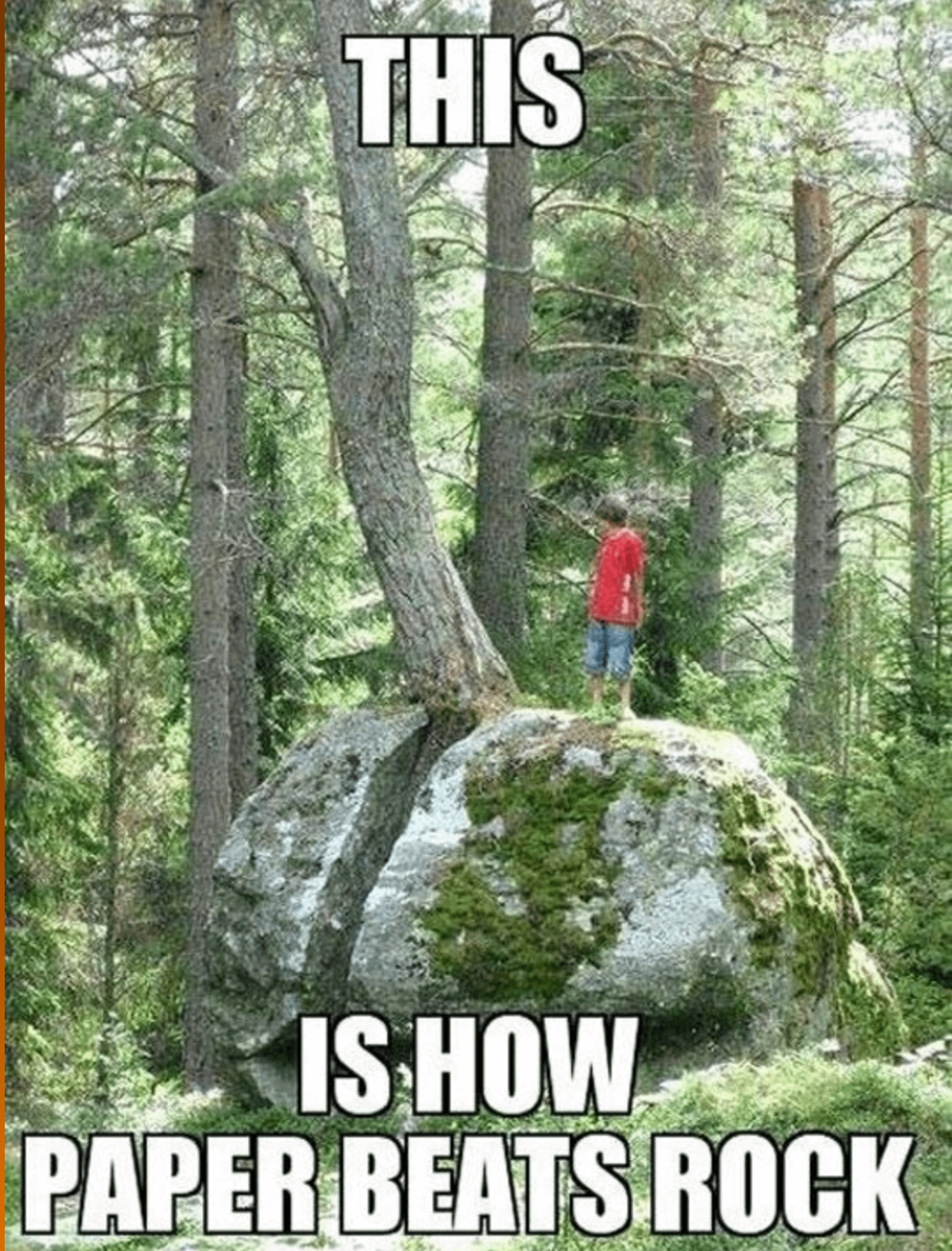
Biologic

Bioturbation

Mechanical

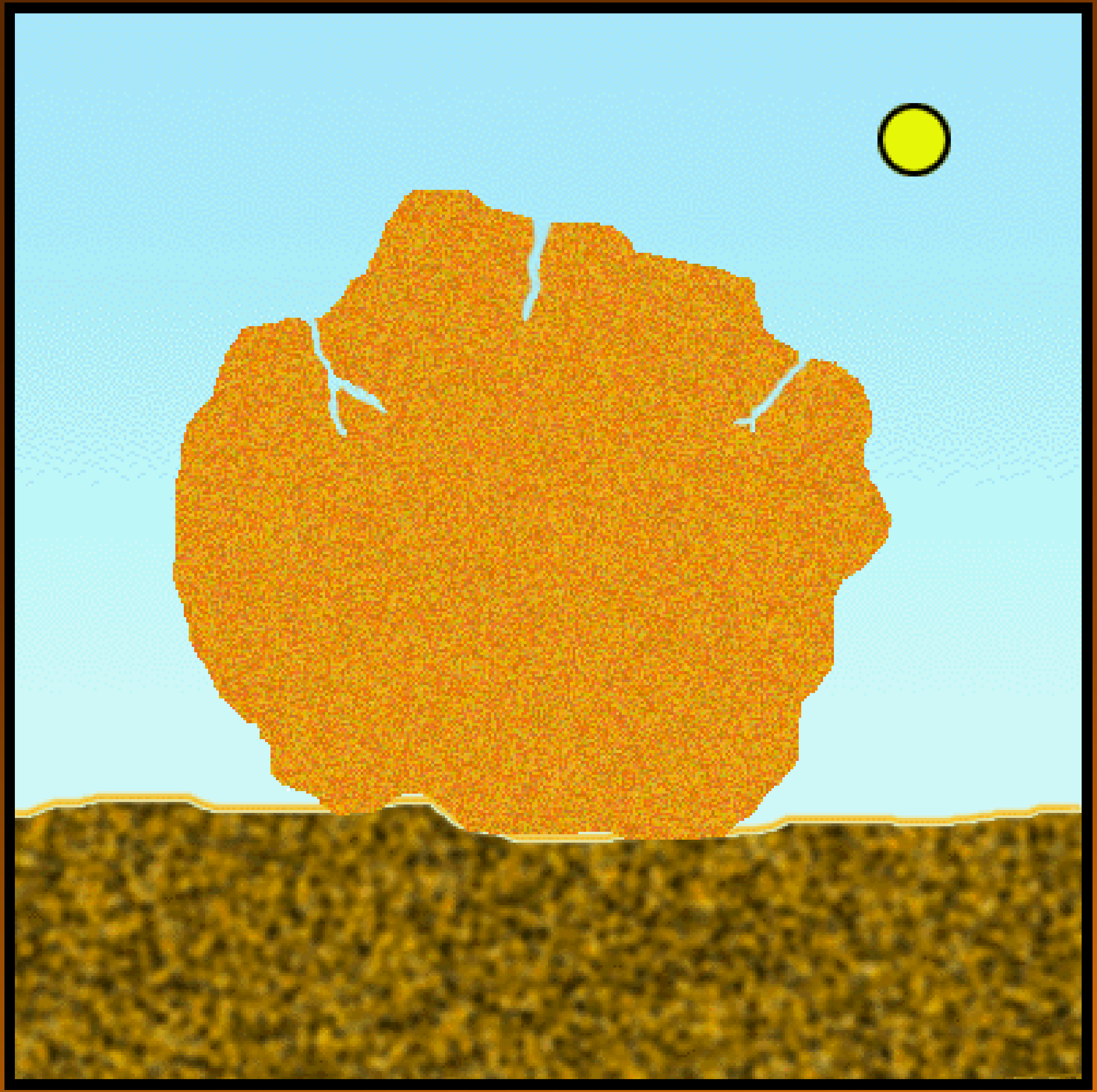
Mechanical weathering

- Physical weathering is the mechanical disintegration of rocks into smaller fragments or individual grains
  - **Frost wedging** (freeze/thaw cycles)
  - **Sheeting** (release of overburden pressure)
  - Break-up of rocks by **plant and animal activity**
- Physical weathering is relatively less important than chemical weathering, and it **operates in concert with chemical weathering**


THIS
IS HOW
PAPER BEATS ROCK

Exfoliation

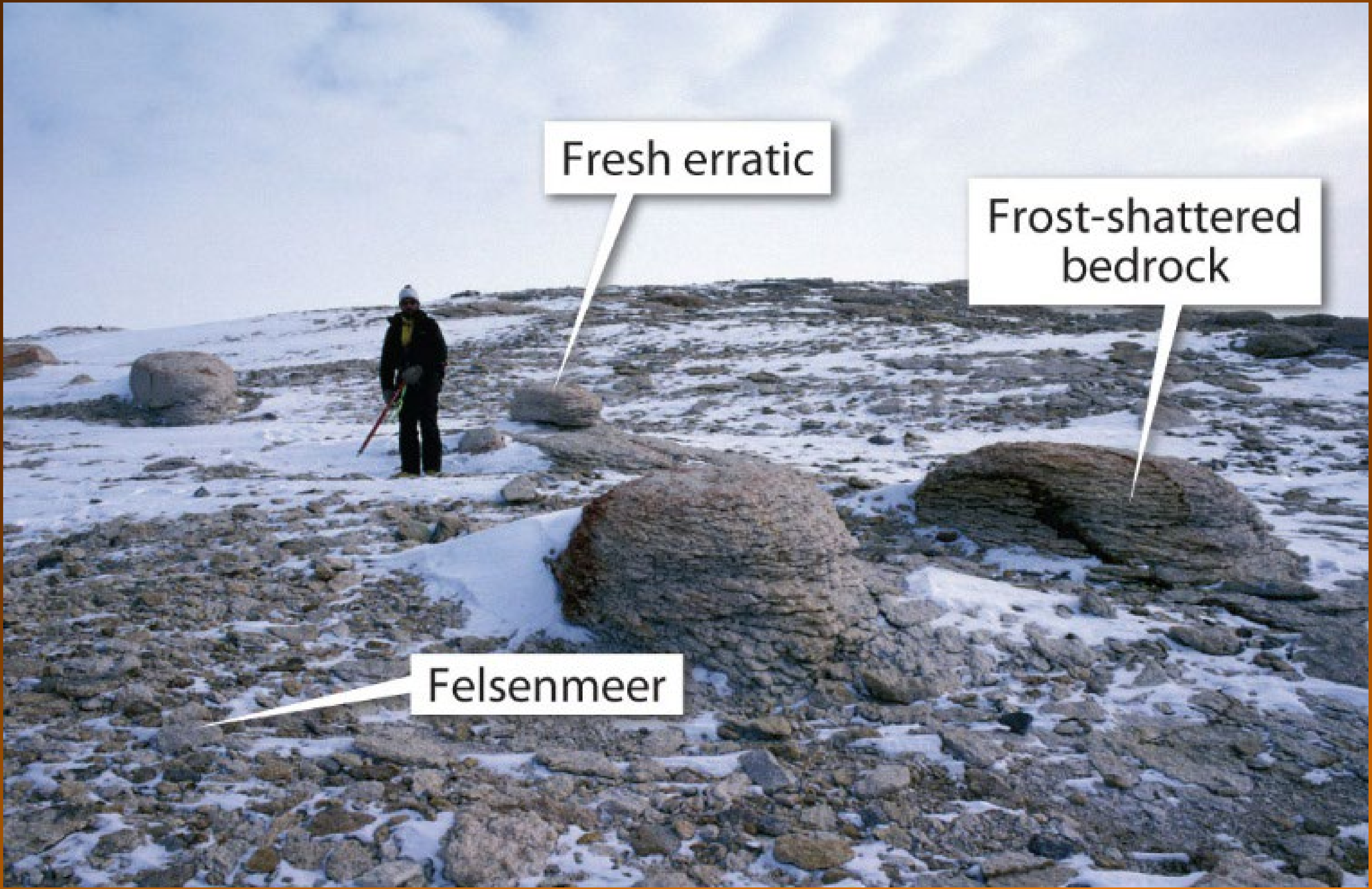
Freeze-thaw - Hydrofracturing



Web adventure: [Frost at work]

Felsenmeer

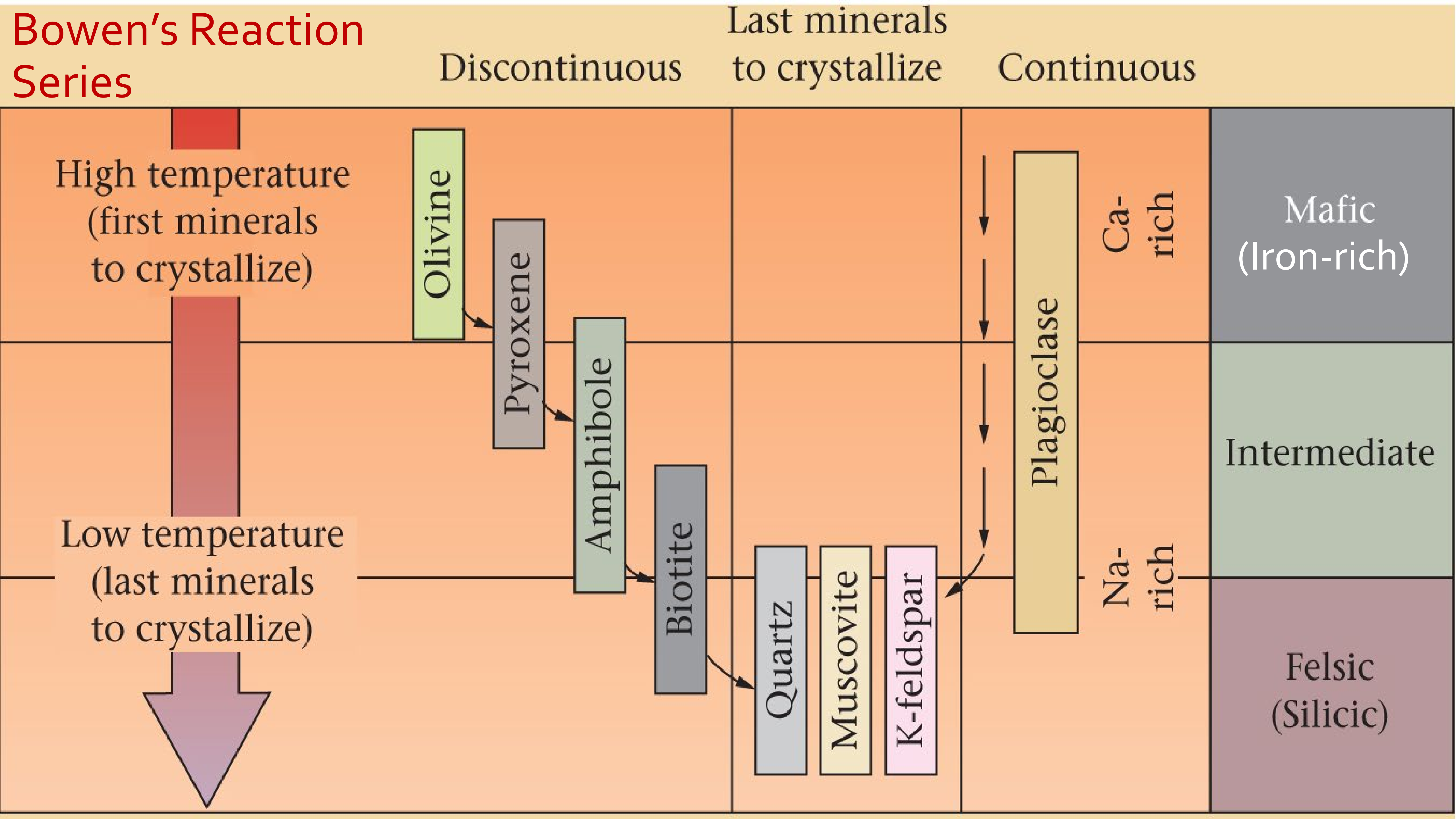
Frost shattered rocks



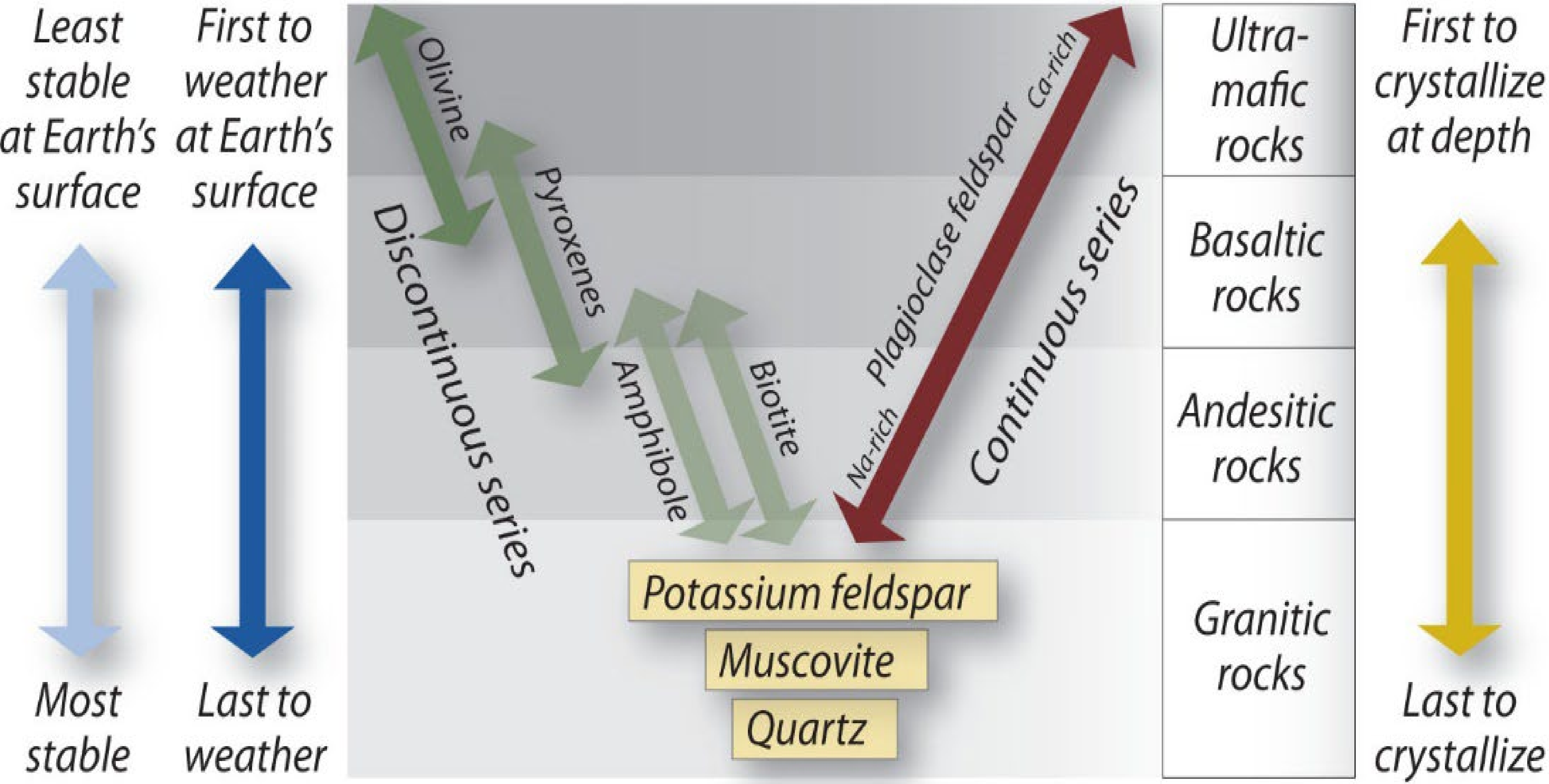
Thermal expansion

Chemical weathering

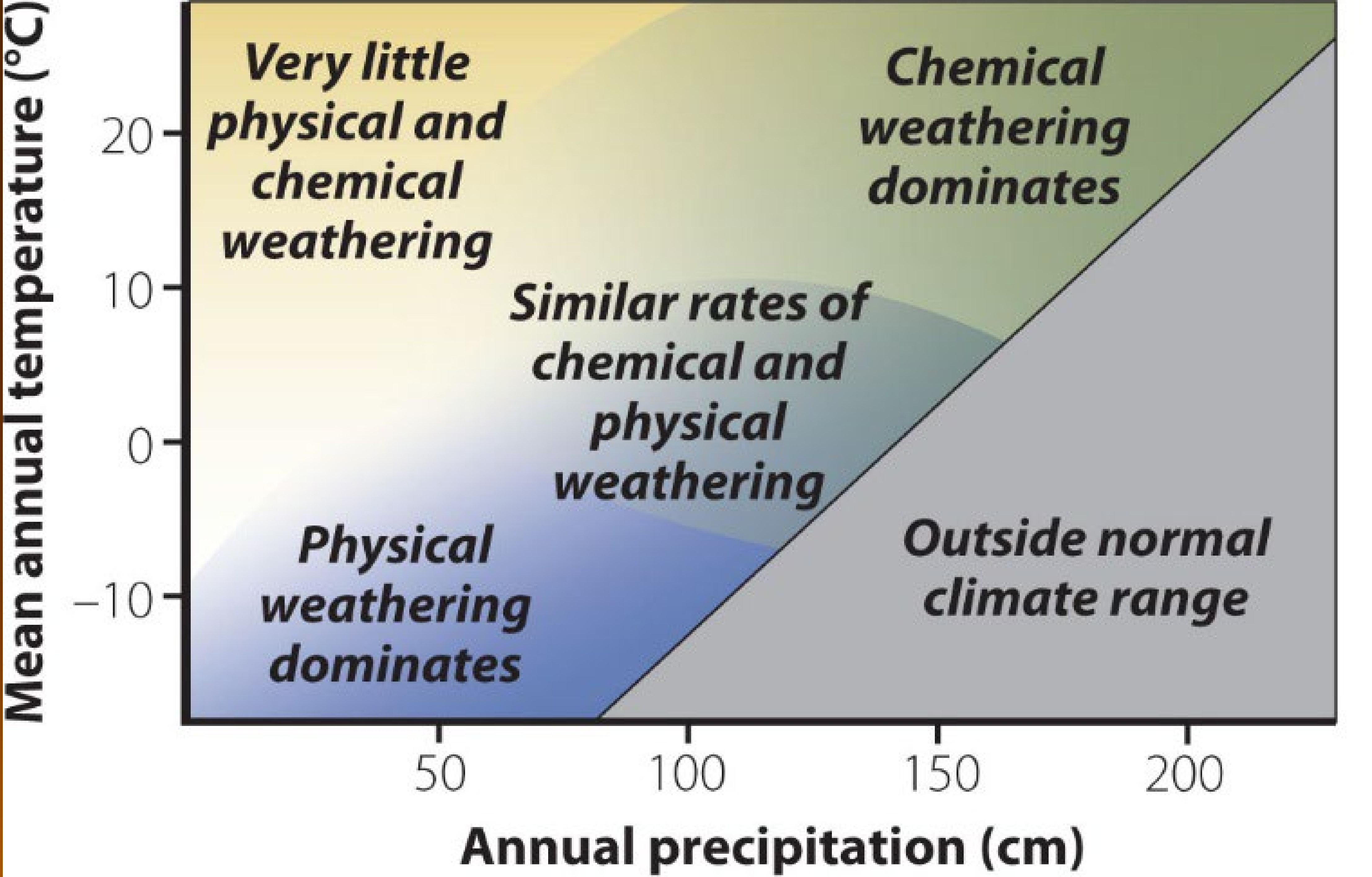
Bowen's Reaction Series



Goldich's Weathering Series/Bowen's Reaction Series



Environmental variability



Fastest Weathering	Halite	**Least Stable**
	Calcite	
	Olivine	
	Ca-plagioclase	
	Pyroxene	
	Amphibole	
	Na-plagioclase	
	Biotite	
	Orthoclase (potassium feldspar)	
	Muscovite	
	Clay (various types)	
	Quartz	
	Gibbsite (aluminum hydroxide)	
Slowest Weathering	Hematite (iron oxide)	**Most Stable**

Hydration

- **Hydration** is the process by which water is added to a mineral forming a new mineral

  anhydrite + water ⇔ **gypsum**

  $CaSO_4 + 2H_2O$ ⇔ Gypsum
  $CaSO_4$ = anhydrite

  - Hydration generally does not produce secondary products, but it does result in a volume increase, and the potential for increased mechanical weathering

Hydration – Dehydration

Oxidation

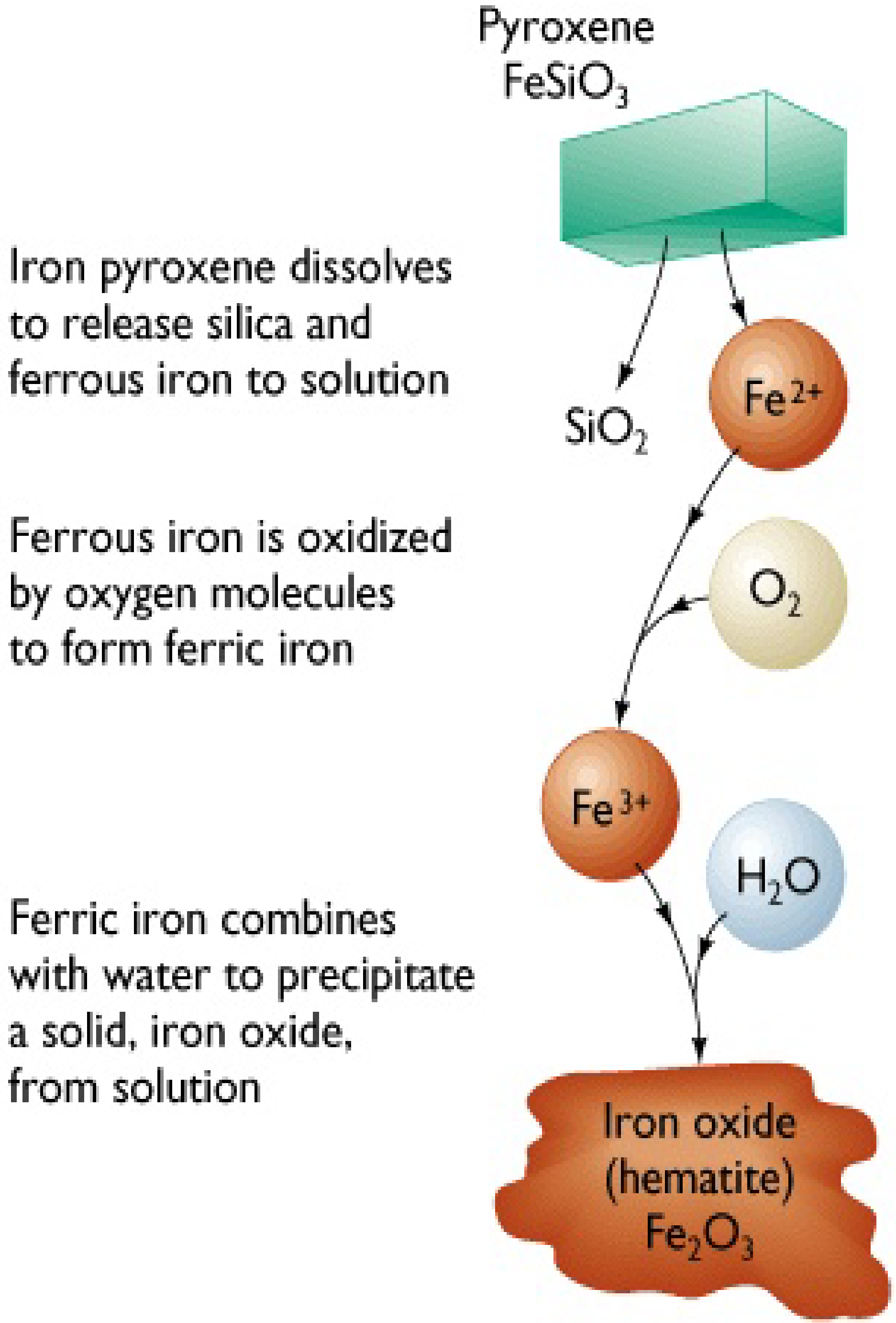
- **Oxidation** the decomposition of iron- and manganese silicates by oxygen dissolved in water

$Fe^{2+} \rightarrow Fe^{3+} + e^-$, where the loss of the electron leads to the loss of other cations, such as Si^4 . This leads the crystal lattice to break.

$$4Fe^{2+}SiO_3 + O_2 \rightarrow 2Fe^{3+}{}_2O_3 + 4SiO_2$$

pyroxene hematite quartz

Oxidation


Pyroxene
$FeSiO_3$
Iron pyroxene dissolves to release silica and ferrous iron to solution
SiO_2
Fe^{2+}
Ferrous iron is oxidized by oxygen molecules to form ferric iron
O_2
Fe^{3+}
H_2O
Ferric iron combines with water to precipitate a solid, iron oxide, from solution
Iron oxide (hematite) Fe_2O_3

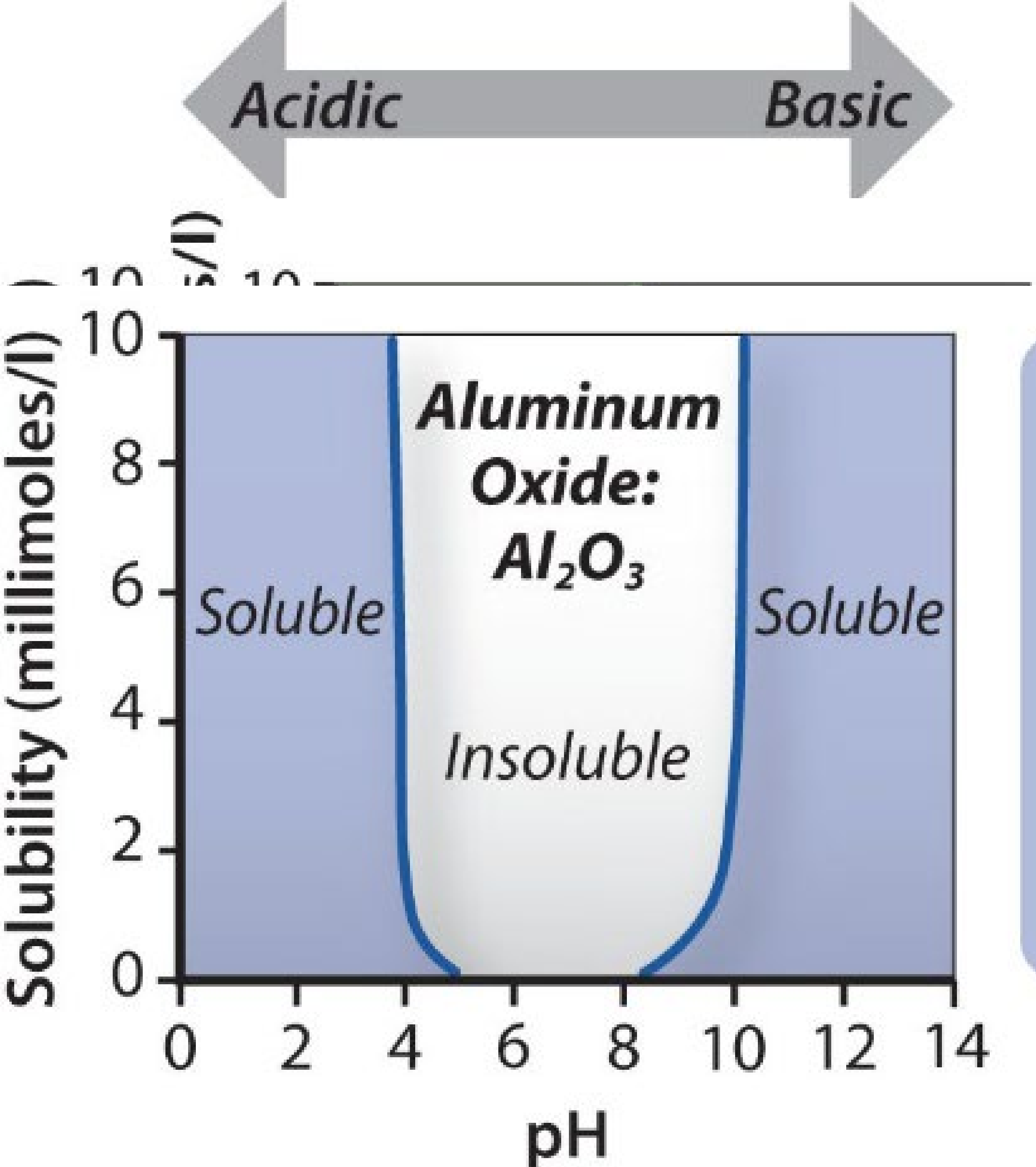
Solution

- Dissolution of soluble minerals upon contact with water
- Highly soluble minerals include
  - Evaporites (gypsum, halite)
  - Calcite
  - Dolomite

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

calcite bicarbonate

Solution

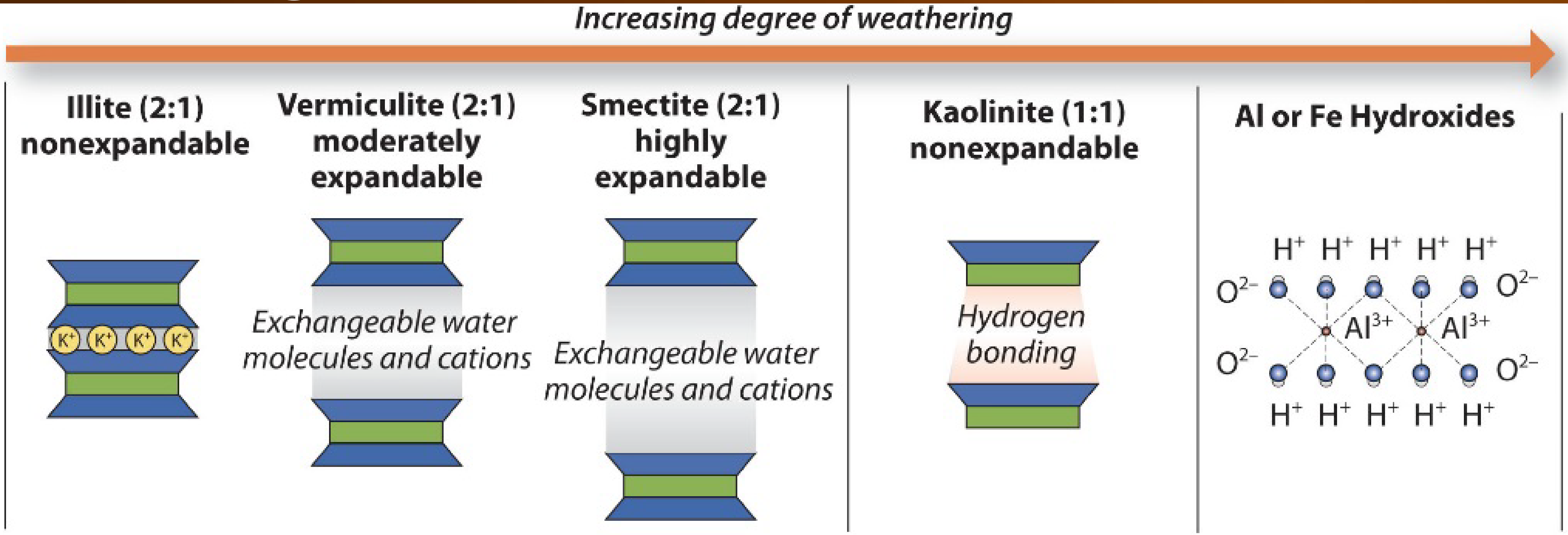


Aluminum oxide is highly soluble in strongly acidic or alkaline solutions but is relatively insoluble in neutral solutions.

Hydrolysis

- **Hydrolysis** the reaction between silicate minerals and acid (H^+) leading to mineral breakdown and the release of metal cations & silica
- Source of acids is CO_2 dissolved in water
  - $CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$
  - Acids also originate from plants
- Feldspars that undergo hydrolysis typically produces secondary clay minerals
  - **Orthoclase (K) feldspar** → kaolinite or illite + silicic acid
  - **Plagioclase (Na) feldspar** → kaolinite or smectite + silicic acid

Forming clay

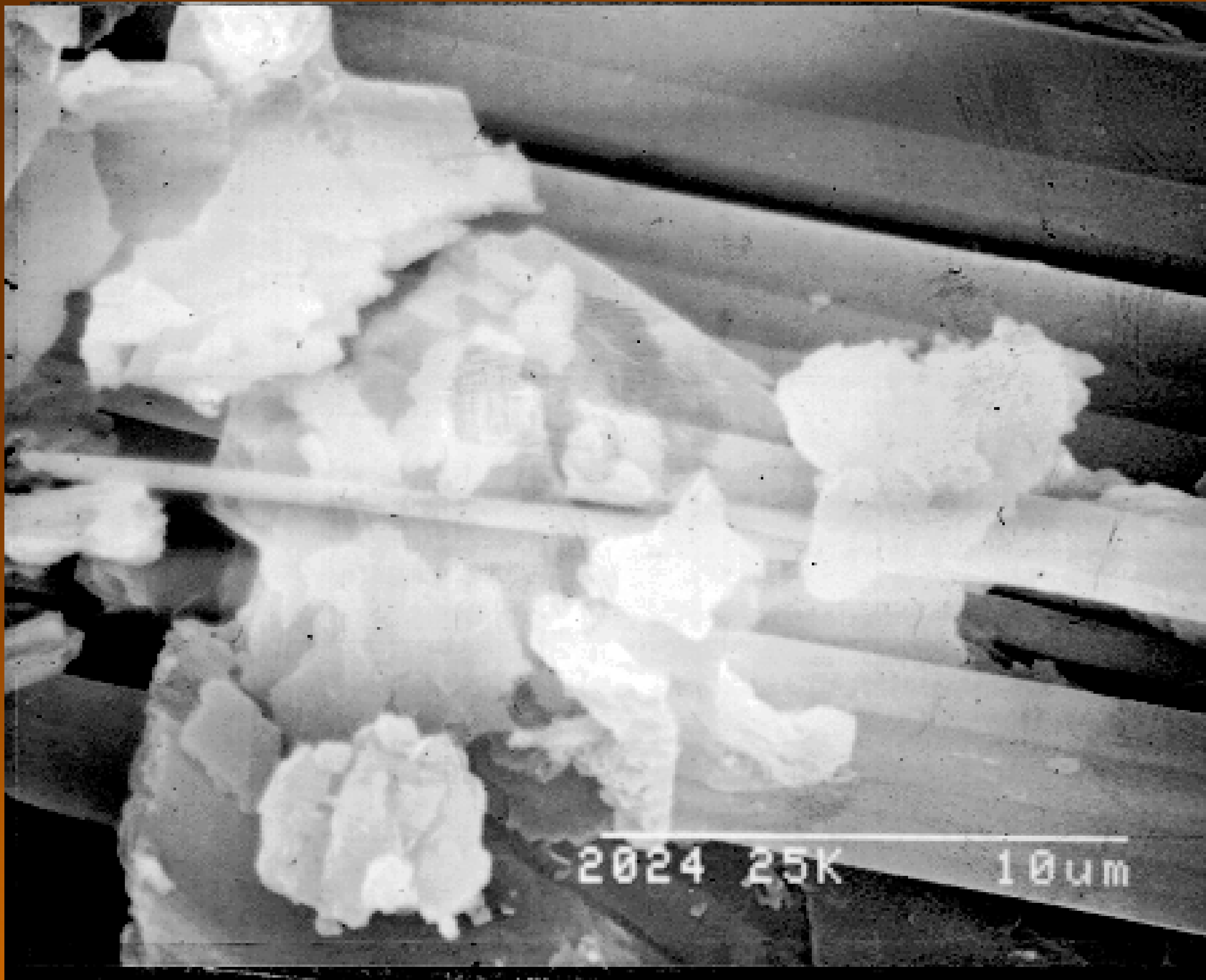


Illite and smectite have a 2:1 structure with alumina sheets sandwiched between silica sheets. They exhibit a wide range of properties, chemical compositions, and **cation exchange capacities** due to substitution of ions between layers.

Kaolinite has a 1:1 structure and low **cation exchange capacity** with alumina and silica sheets held together by strong ionic bonds.

Extremely weathered soils may result in a lateritic residuum of weathering-resistant Fe and Al oxides.

Orthoclase to Kaolinite (Clay)



Important Chemical variables

- ***Rates*** of chemical weathering vary with climate, mineral composition and grain size of the parent rock
  - Chemical weathering is faster in wet climates
  - Chemical weathering rates increase with increasing temperature
  - Coarse grained rocks of a given composition weather more slowly than their fine grained equivalents

Chemical weathering

- Relative stability of sand- and silt-sized common minerals under weathering conditions (note relationship to Bowen's Reaction Series):

	Mafic minerals	Felsic minerals
increasing stability	olivine	
		Ca plagioclase
	pyroxene	
		Ca-Na plagioclase
	amphibole	Na-Ca plagioclase
		Na plagioclase
	biotite	

orthoclase, muscovite, quartz

Products of weathering

- New sedimentary particles:
  - Parent rock **residues**, composed of resistant minerals and rock fragments
  - **Secondary minerals**, largely the result of hydrolysis and oxidation

- *Unless removed by erosion, particulate residues and secondary minerals remain* in situ *to form a* ***soil***

Products of weathering

- Weathering of **igneous and metamorphic** rocks produce *immature soils rich in unstable minerals*.

- Weathering of **siliciclastic sedimentary** rocks produce soils that are *depleted in unstable minerals*

- Weathering of **limestone** produces thin soils with insoluble silicates and iron-oxide residues

Biogeochemical weathering