

Making matter smaller

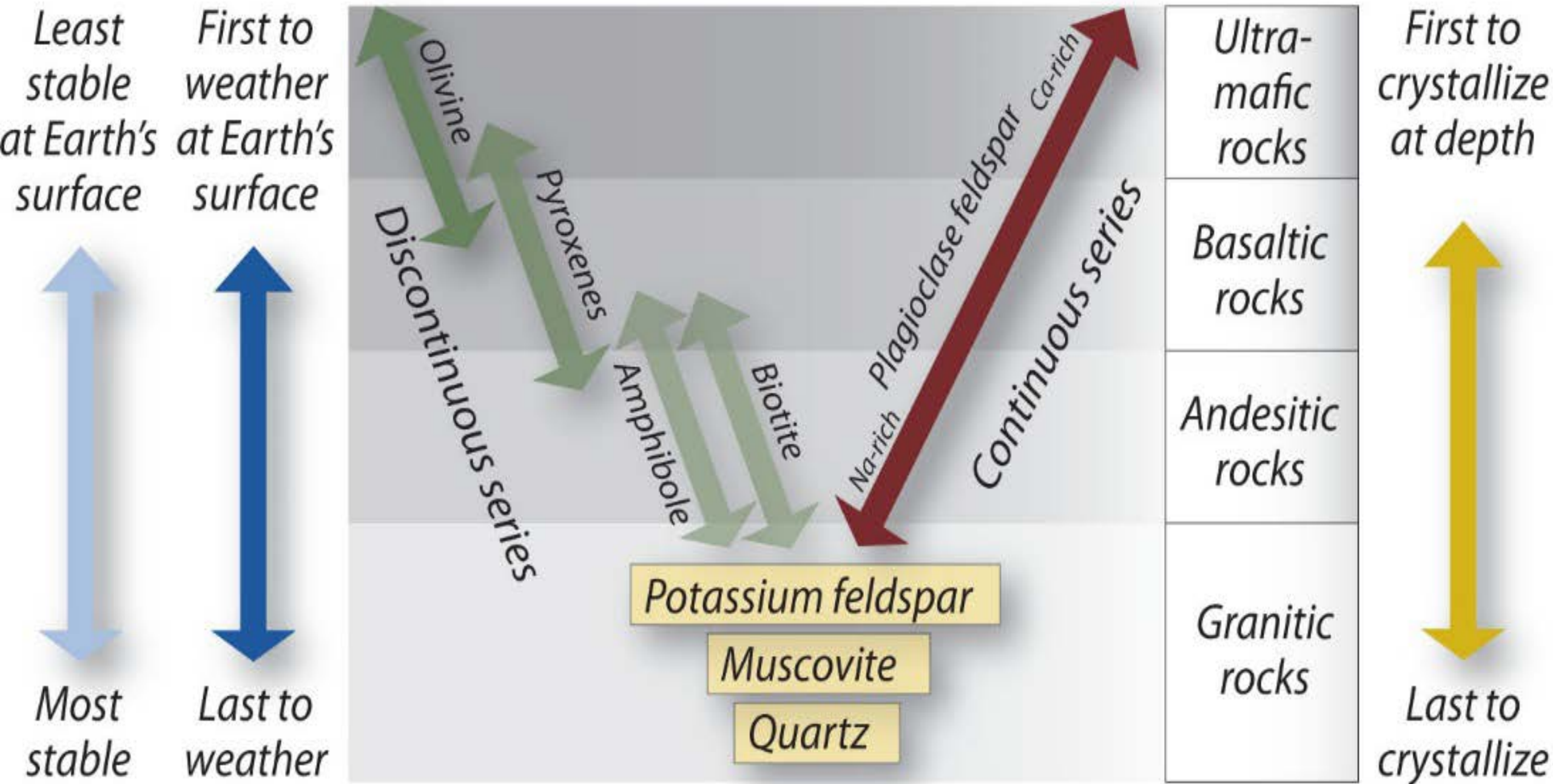
Weathering

Key points

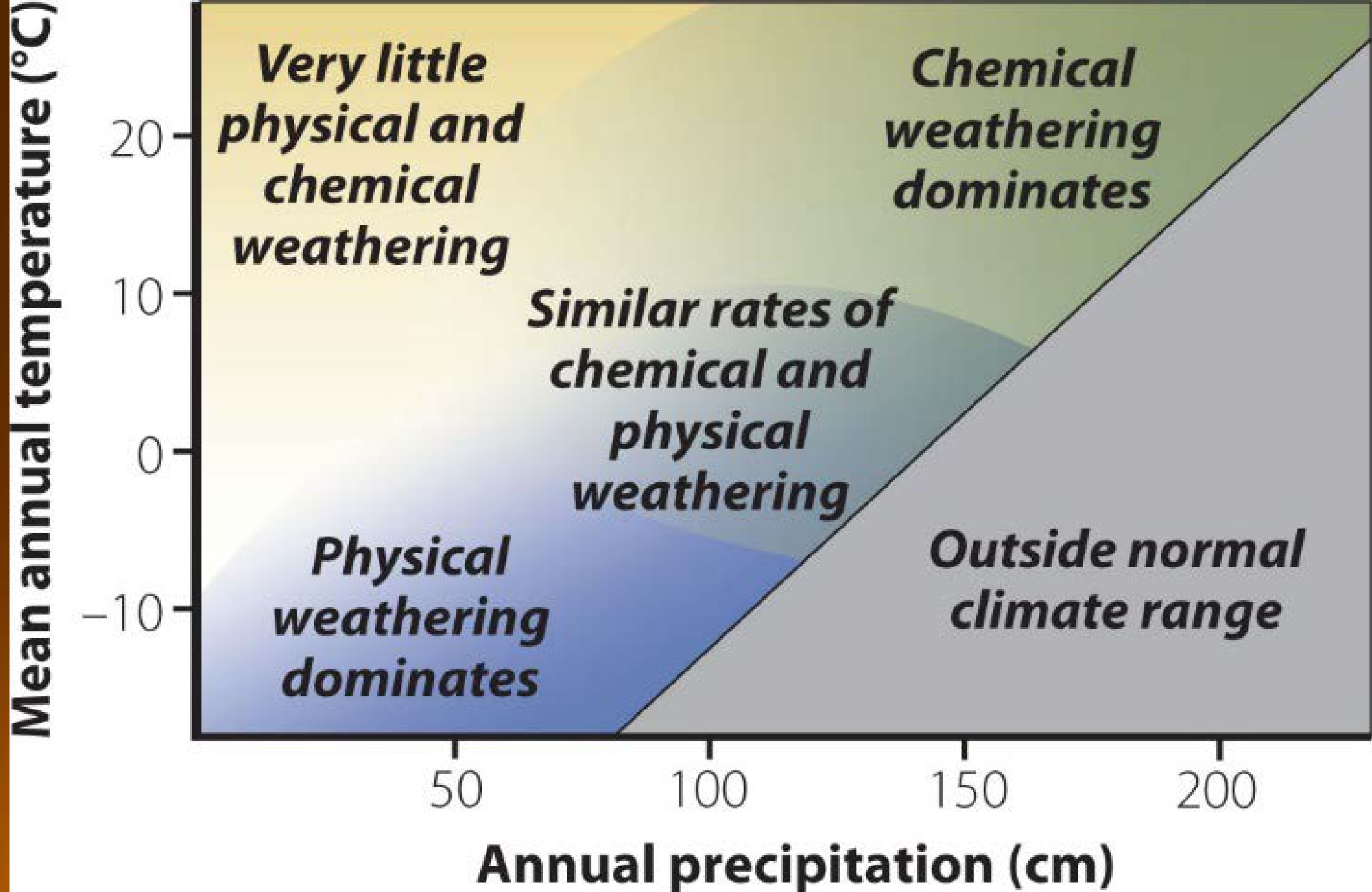
- Know the main kinds of chemical weathering processes and what kinds of minerals are affected by each process (be able to give examples).
- Know the by-products of each subaerial weathering process.
- Know the relative stability of common minerals under weathering conditions
- What is the significance of weathering to geomorphology?
- Be able to discuss the criteria by which **soils and paleosols** can be recognized.

Weathering vs. Erosion & Landscape Stability

Goldich's Weathering Series/Bowen's Reaction Series



Environmental variability



Biologic



Bioturbation



Saprolite – Weathering > Erosion



Mechanical



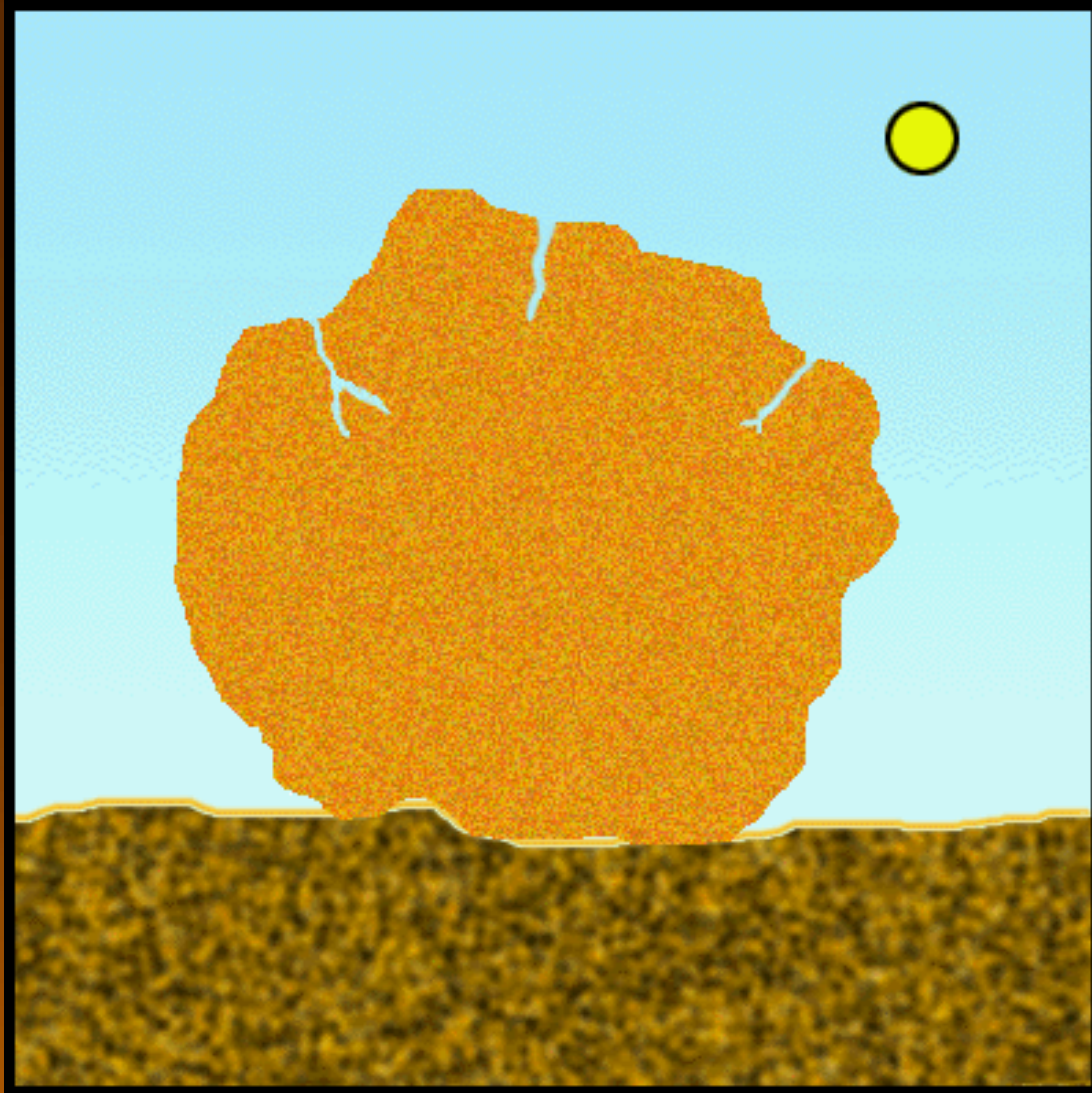
Physical weathering

- 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

Exfoliation



Freeze-thaw - Hydrofracturing



Web adventure: [Frost at work](#)

Felsenmeer

Frost
shattered
rocks

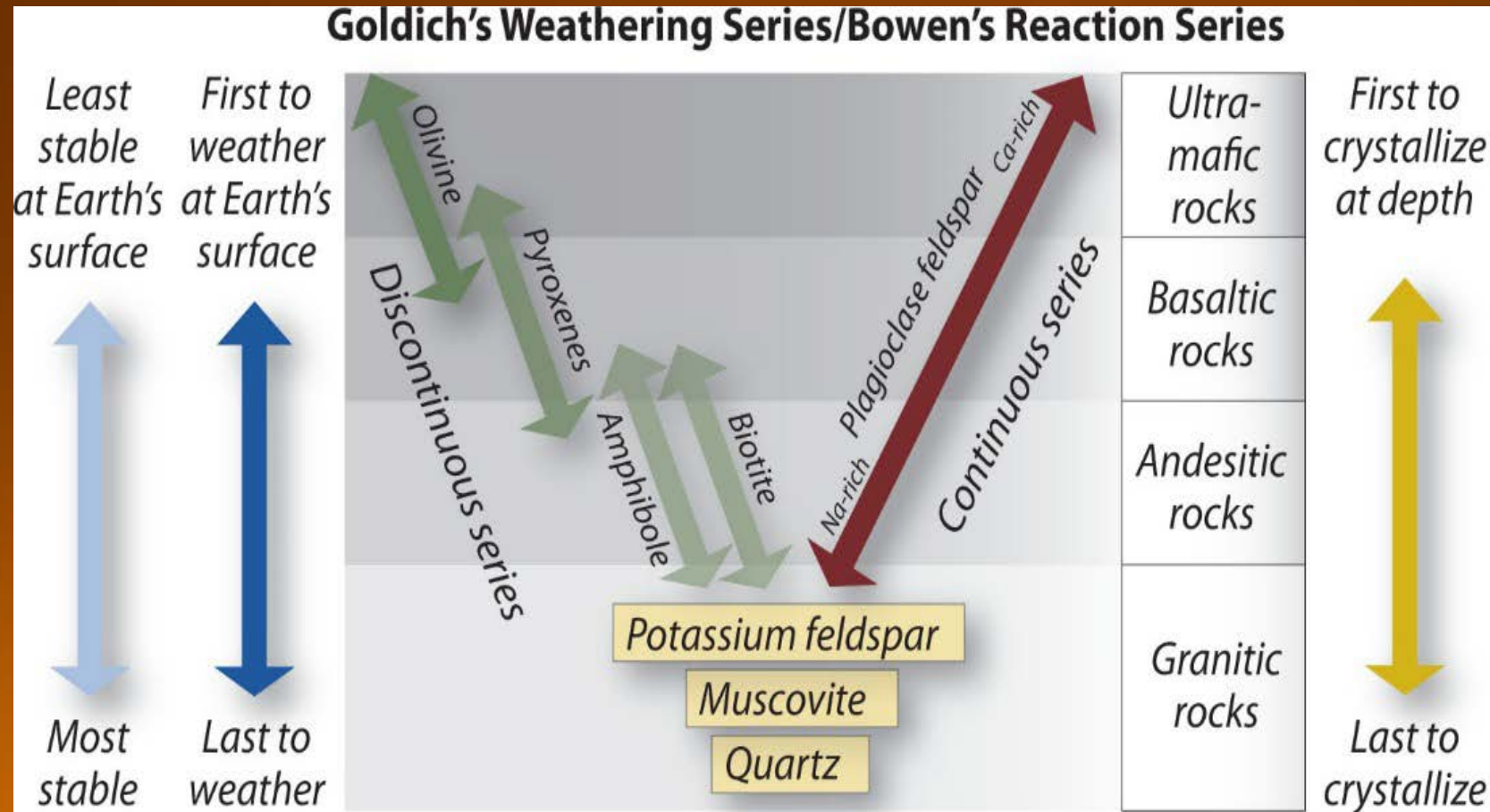


Thermal expansion



Chemical – Breaking bonds

- Metallic, ionic, covalent



Hydration – Dehydration



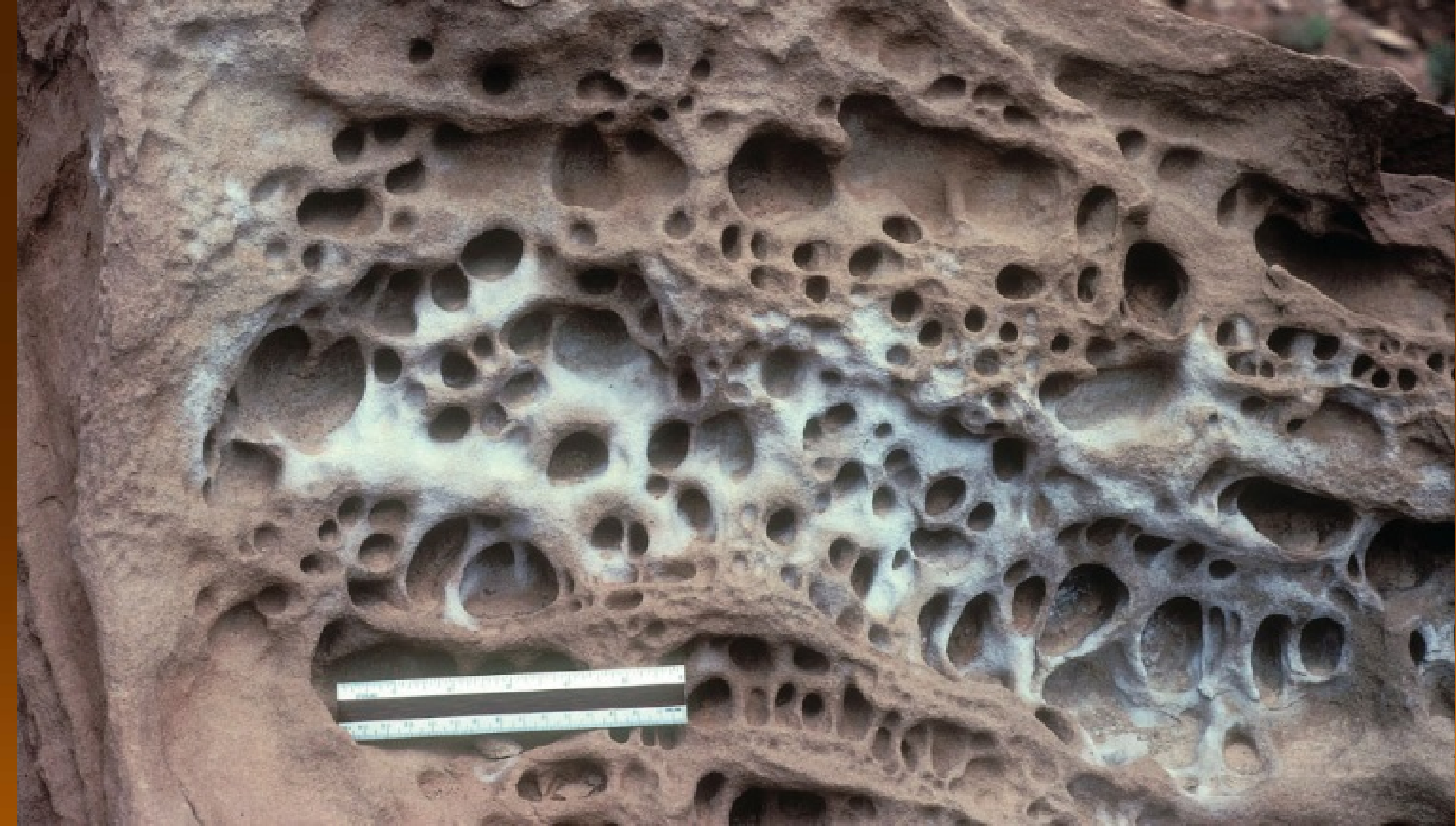
Hydration

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

anhydrite + water \Leftrightarrow gypsum



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



Oxidation

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

$\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^-$, where the loss of the electron leads to the loss of other cations, such as Si^{4+} , in order to maintain electrical neutrality. This leads to collapse of the crystal lattice



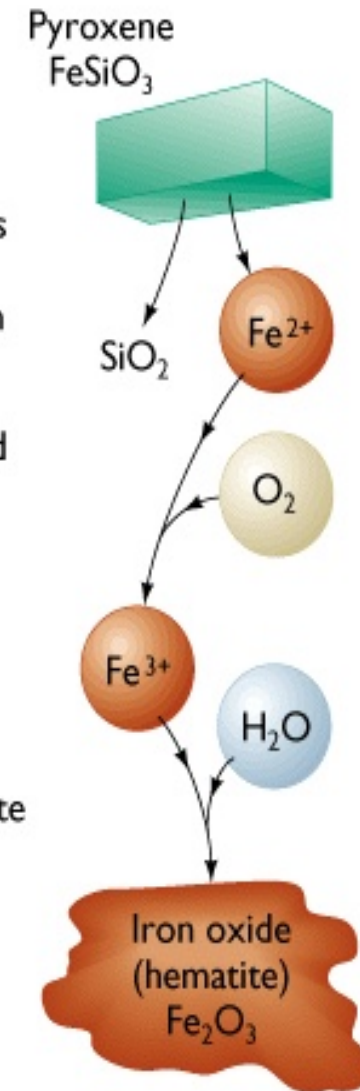
Oxidation



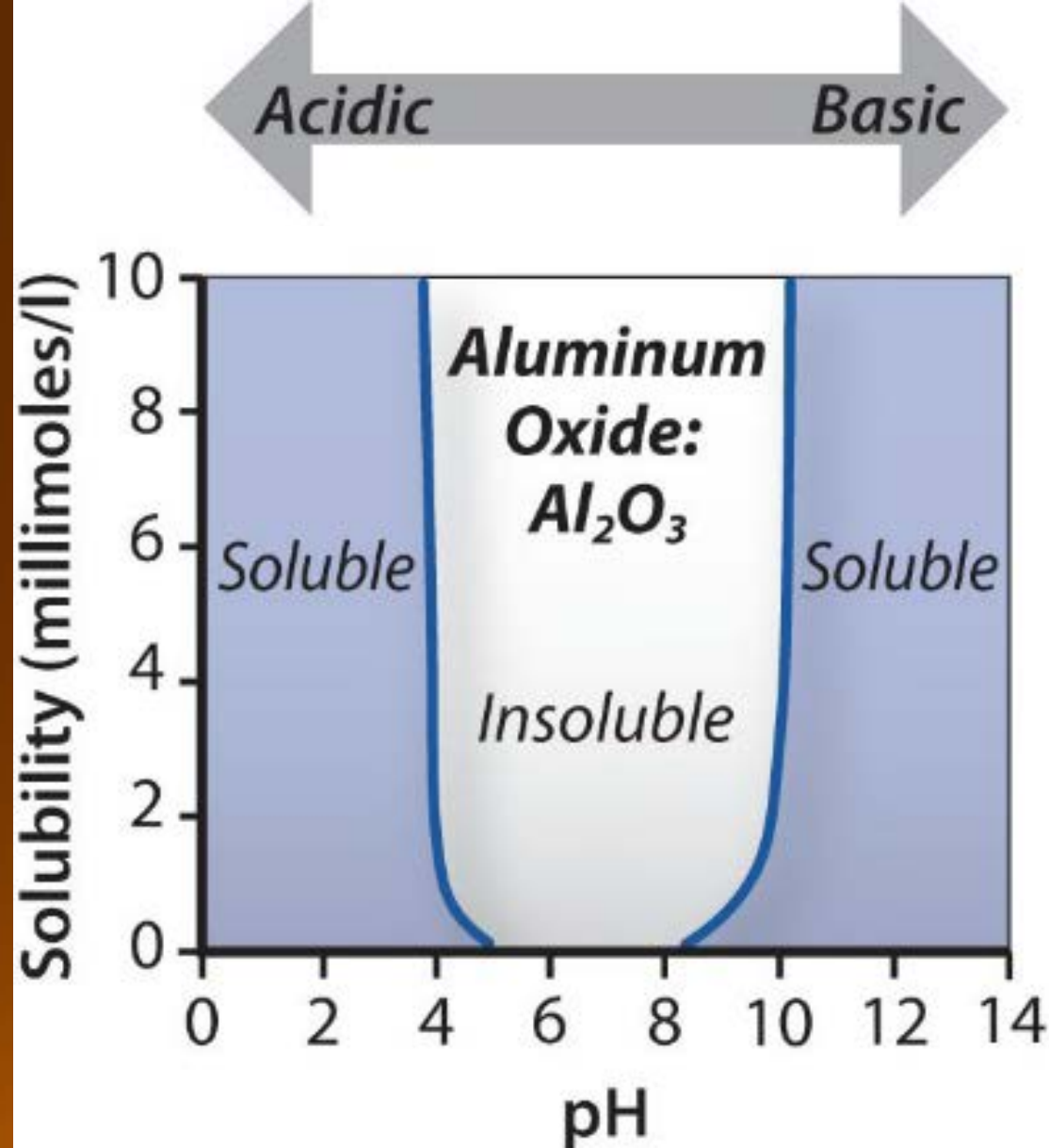
Iron pyroxene dissolves to release silica and ferrous iron to solution

Ferrous iron is oxidized by oxygen molecules to form ferric iron

Ferric iron combines with water to precipitate a solid, iron oxide, from solution



Solution



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

Solution

- Simple solution is the dissolution of soluble minerals upon contact with water
- Highly soluble minerals include
 - Evaporites (gypsum, halite)
 - Calcite
 - Dolomite



calcite

bicarbonate



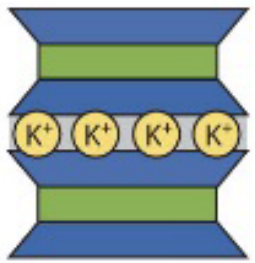
Hydrolysis

- Hydrolysis is the reaction between silicate minerals and acid (H^+) that leads to the breakdown of the minerals and the release of metal cations and silica
- Source of acids is CO_2 dissolved in water
 - $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$
 - Acids also originate from plants
- Feldspars that undergo hydrolysis typically produce secondary clay minerals
 - Orthoclase (K) feldspar \rightarrow kaolinite or illite + silicic acid
 - Plagioclase (Na) feldspar \rightarrow kaolinite or smectite + silicic acid

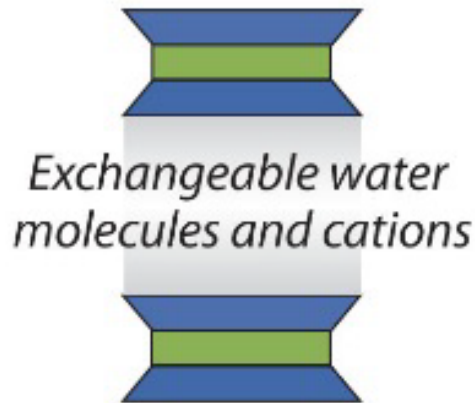
Forming clay

Increasing degree of weathering

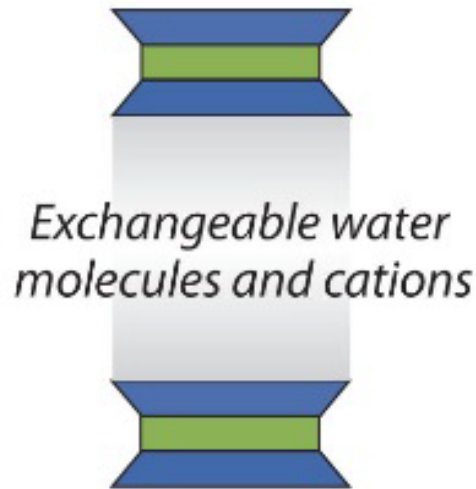
Illite (2:1)
nonexpandable



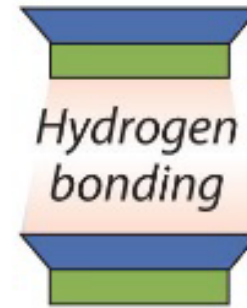
Vermiculite (2:1)
moderately expandable



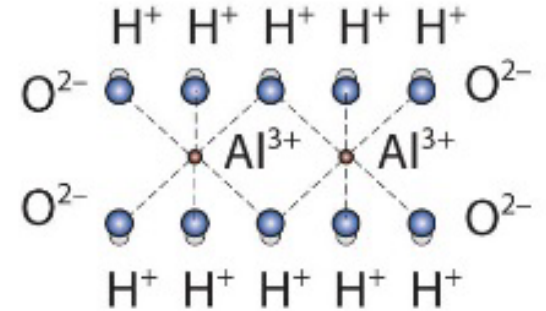
Smectite (2:1)
highly expandable



Kaolinite (1:1)
nonexpandable



Al or Fe Hydroxides

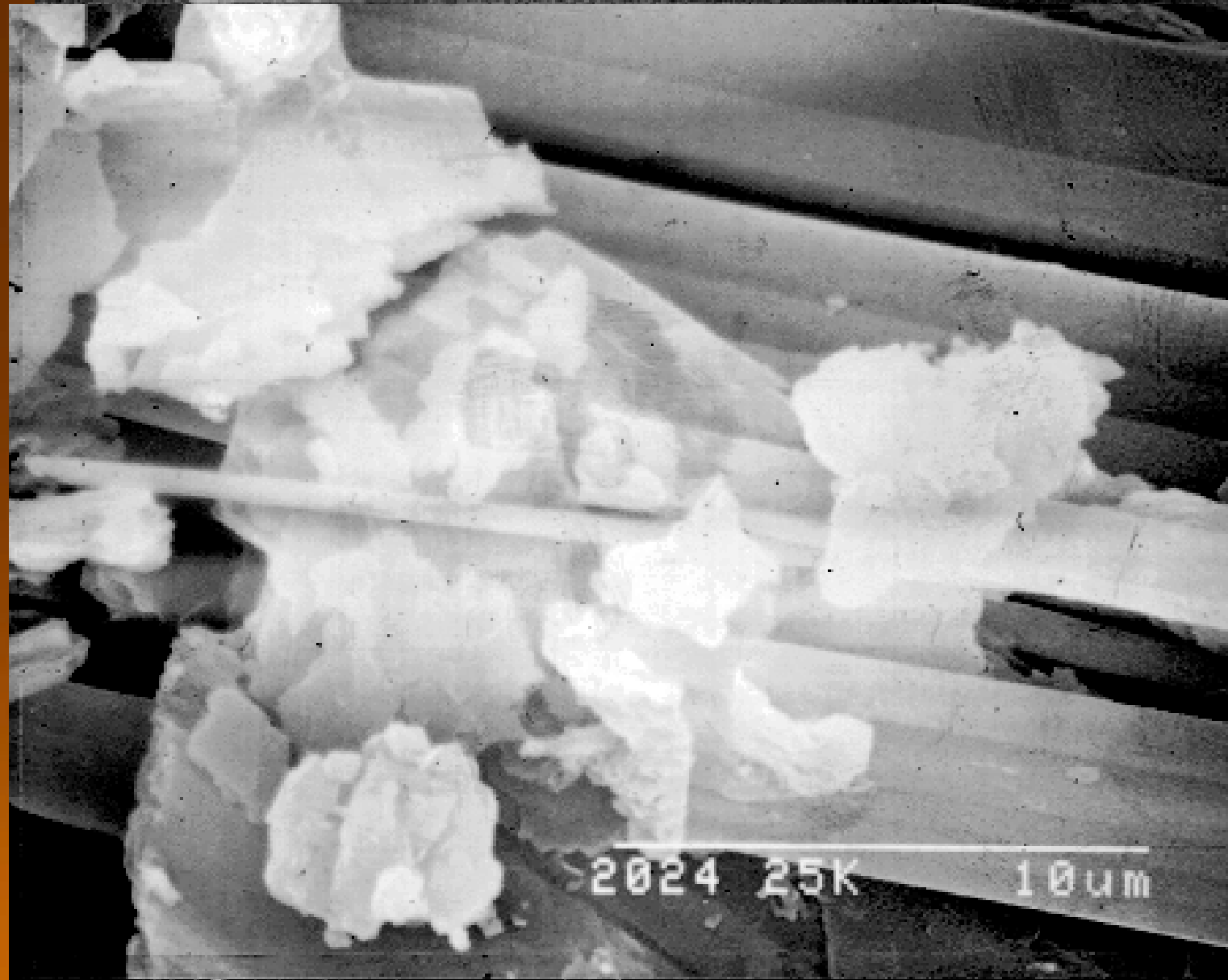


Illite and smectite have a 2:1 structure with alumina sheets sandwiched between silica sheets. They exhibit a wide range of properties, chemical compositions, and **cation exchange capacities** due to substitution of ions between layers.

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)



Ion-exchange (chelation, cation exchange)

- Chelation – moving metal ions (Al, Fe) in a soil through the production of organic compounds/organic acids
- Eg. Conifer forests
- E-horizons
- Cation-Exchange Capacity (CEC)
- Secondary minerals and organic matter exchange cations (e.g. Ca, Mg, K)

Chemical weathering

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

Chemical weathering

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

<i>increasing stability</i> ↓	<u>Mafic minerals</u>	<u>Felsic minerals</u>
	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
- Raw material for chemical sedimentary rocks:
 - Soluble compounds, largely the result of hydrolysis and simple solution
- *Until they are removed by erosion, particulate residues and secondary minerals remain in situ to form a soil*

Products of weathering

- Weathering of igneous and metamorphic rocks produces immature soils rich in unstable minerals. As the soil matures, it retains only the more resistant minerals. Clays, iron oxides or hydroxides, and aluminum hydroxides are present as secondary minerals
- Weathering of siliciclastic sedimentary rocks produces soils that are depleted in unstable minerals (because the unstable minerals were eliminated in a previous weathering cycle)
- Weathering of limestone produces thin soils with insoluble silicates and iron-oxide residues

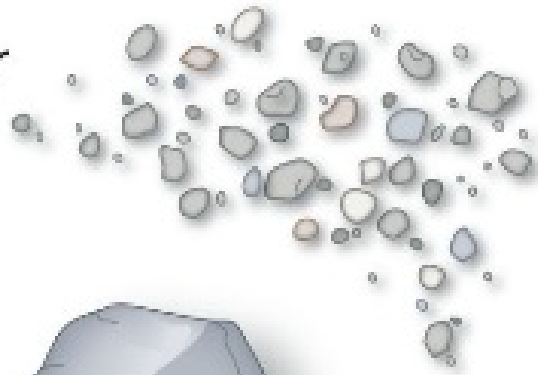
Biogeochemical weathering



Structure

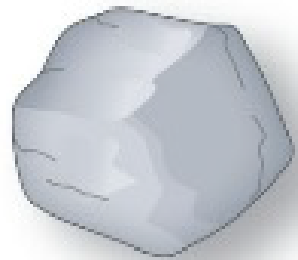
Description

Granular



Spheroidally shaped aggregates. Peds do not adjoin. Common in A horizons.

Blocky



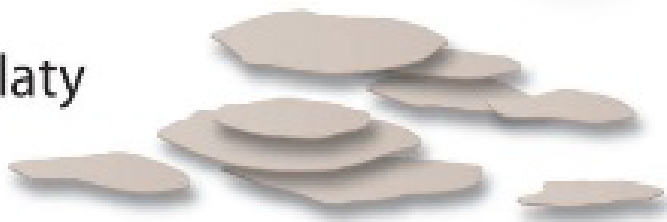
Approximately equidimensional blocks with angular edges. Ped faces adjoin surrounding faces. Common in clay-rich B horizons.

Prismatic or columnar



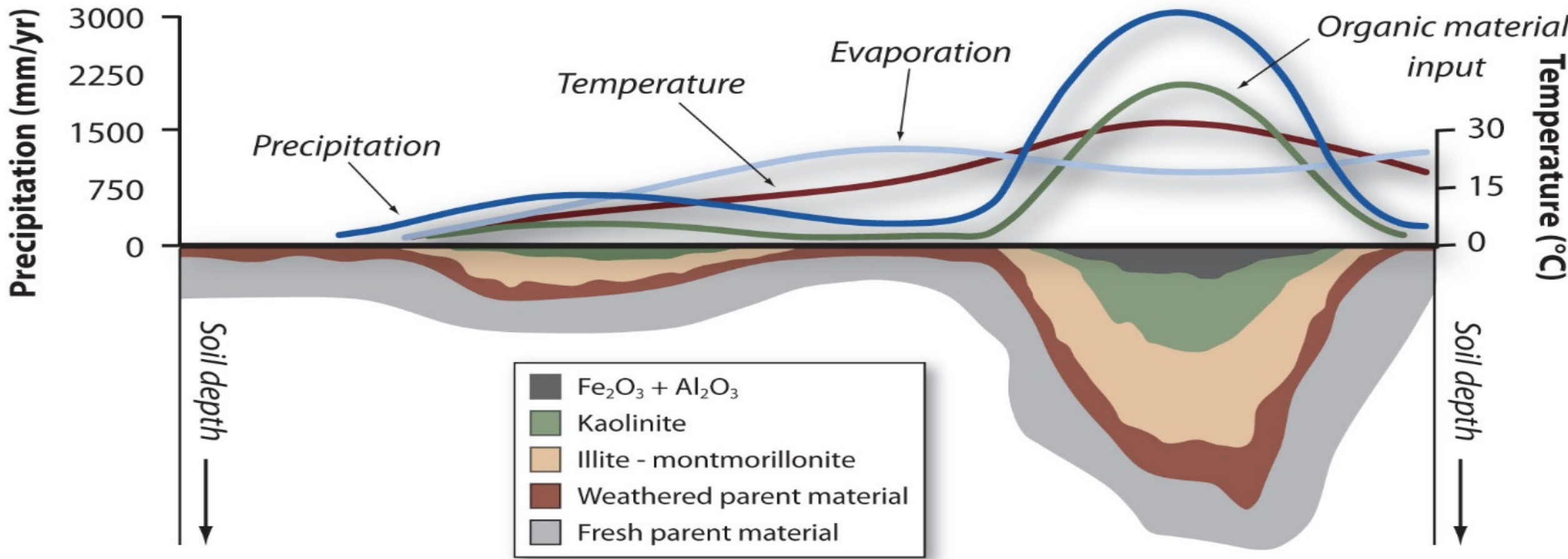
Structures elongate in vertical dimension. Vertical faces adjoin surrounding faces. Common in clay-rich B horizons.

Platy



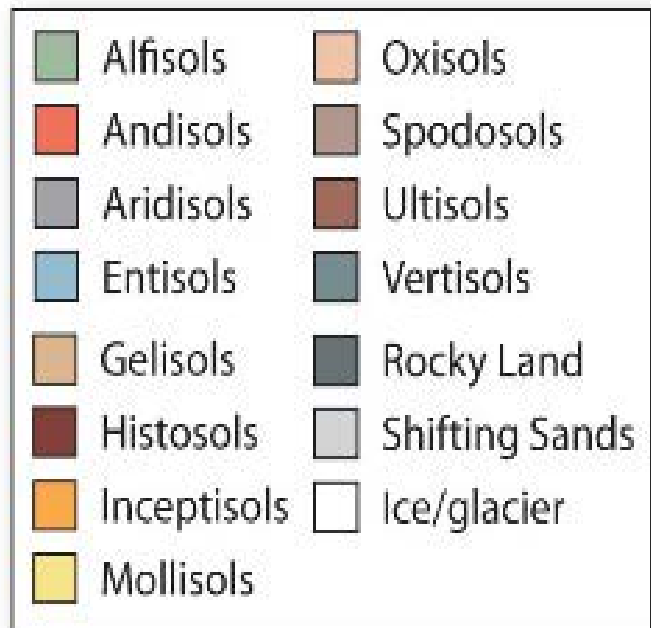
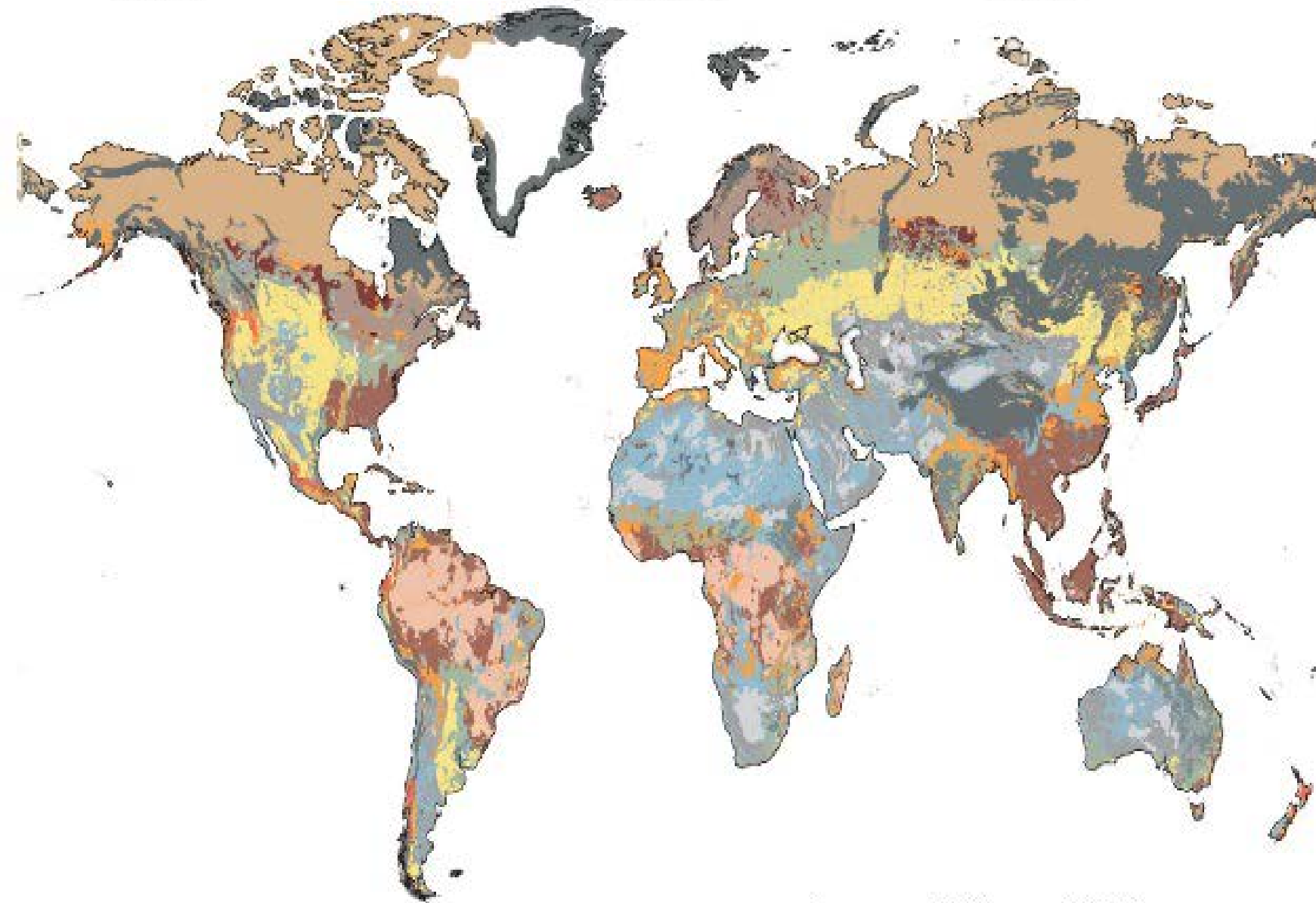
Planar structures are arranged horizontally. Common in E horizons.

Soil structure describes how soils break into **peds** (blocks of soil) when removed from an exposure. These structures reflect active **pedogenic processes** and are distinguishable in the field by their distinct characteristics. For example, prismatic structures form in clay-rich B horizons when the clays shrink and swell with drying and wetting. The discontinuities, or faces, between prismatic peds reflect concentration of tensional forces as the clays shrink.



Strong environmental controls on weathering (i.e., precipitation, temperature, and evaporation) and organic material inputs (i.e., leaf litter fall) lead to strong latitudinal gradients in soil depth and the mineralogy of weathering products. Soils tend to be thickest and most intensively weathered in tropical regions.

Cold ← Temperature → Warm



0 4000 8000
Kilometers