

Weathering and Soils

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

Weathering and soils

- Weathering is the **disintegration** (physical) and/or **decomposition** (chemical) of rocks
- The products of weathering are residual particles, secondary minerals, and dissolved compounds
- Weathering products are the source materials for sediments and soils

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**

Physical weathering enhanced by natural joints in igneous rock



Physical weathering enhanced by tree roots



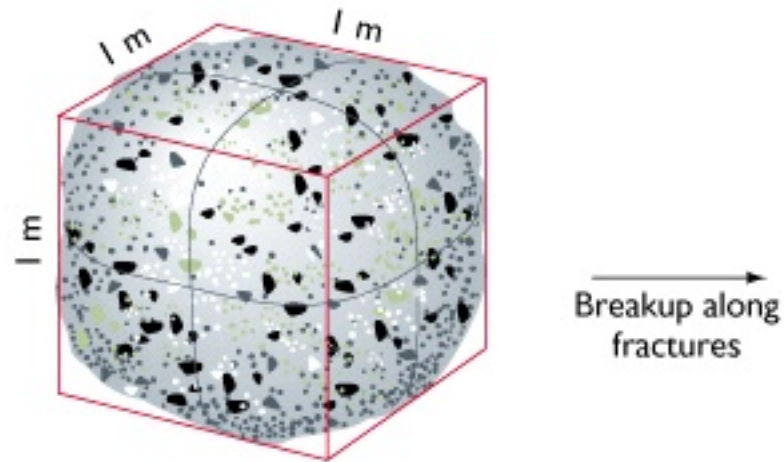
Physical weathering: frost action



Physical weathering: exfoliation (sheeting)

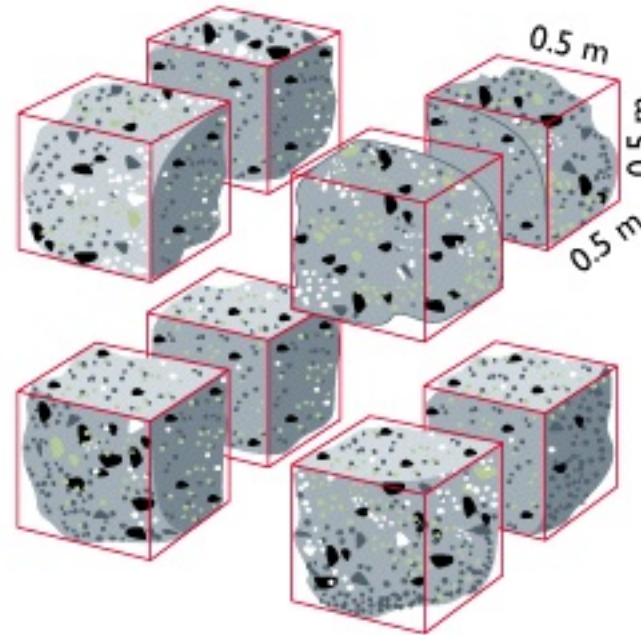


Interaction of physical weathering and chemical weathering



Single boulder, approximately 1 m on a side
Volume = 1 m^3
Surface area = 6 m^2

Breakup along
fractures



8 fragments, each approximately 0.5 m on a side
Volume = $(0.5)^3 \times 8 = 1 \text{ m}^3$
Surface area = 12 m^2

Chemical weathering

- Chemical weathering is the decomposition of rocks by water and atmospheric gases dissolved in water (O_2 , CO_2)
 - Minerals of the parent rock are dissolved and removed in solution
 - New, secondary minerals may form
 - The fabric of the parent rock is disrupted, leaving behind a residue of more resistant mineral grains and secondary minerals

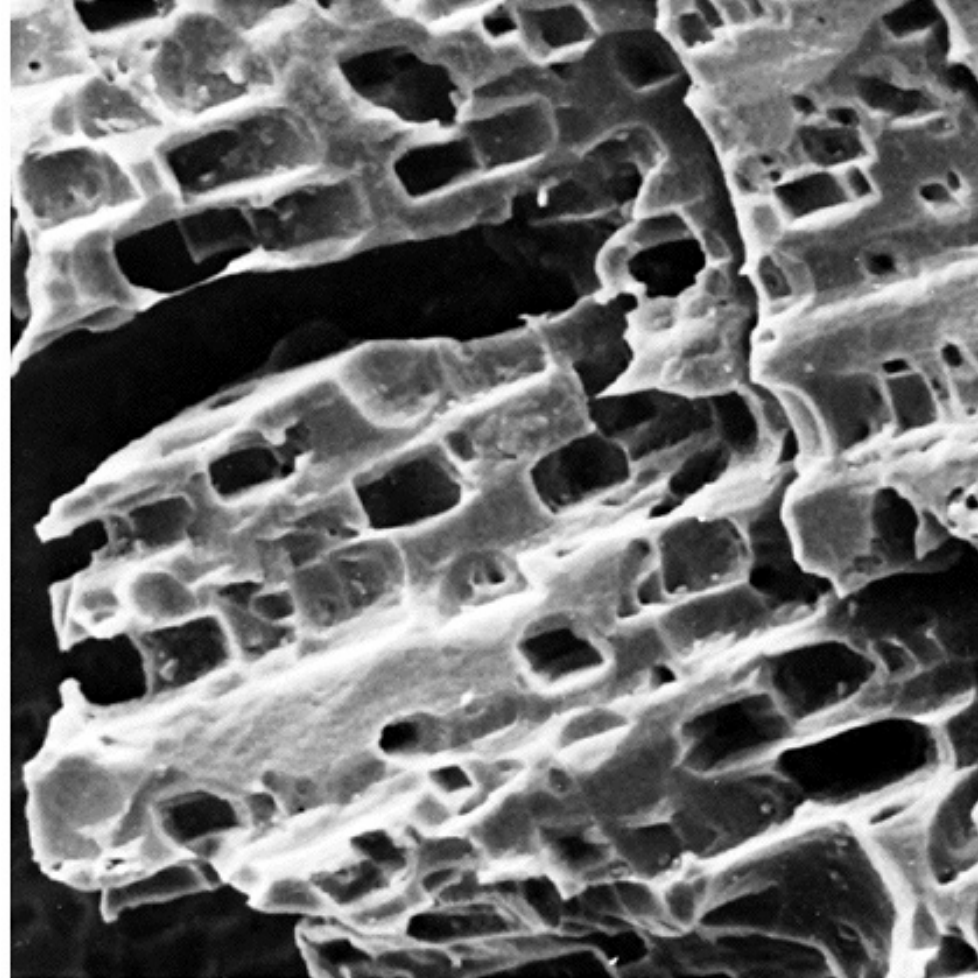
Chemical weathering (continued)

- The **major** types of chemical weathering are
 - Hydrolysis
 - Hydration
 - Oxidation
 - Solution

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

SEM micrograph of feldspar etched by hydrolysis



Hydration

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

anhydrite + water $\rightleftharpoons$ gypsum

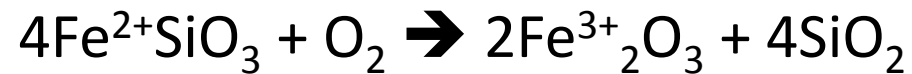


- Hydration generally does not produce secondary products, but it does result in a volume increase, and therefore the potential for mechanical disintegration

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



pyroxene

hematite quartz

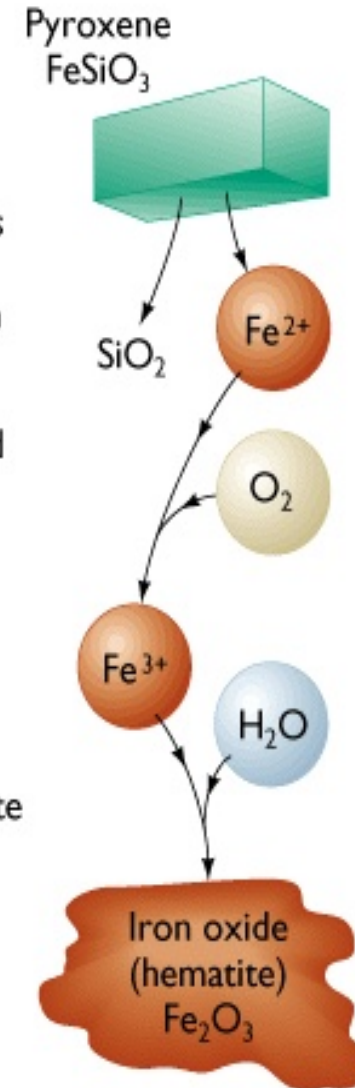
Oxidation



Iron pyroxene dissolves to release silica and ferrous iron to solution

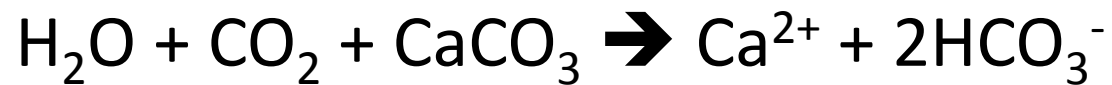
Ferrous iron is oxidized by oxygen molecules to form ferric iron

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



Solution

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



calcite

bicarbonate





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

By-products of
chemical weathering

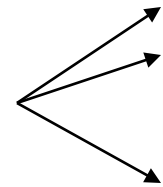


Table 6.2 Stability of Common Minerals Under Weathering	
Stability of Minerals	Rate of Weathering
Most stable	Slowest
Iron oxides (hematite)	
Aluminum hydroxides (gibbsite)	
Quartz	
Clay minerals	
Muscovite mica	
Potassium feldspar (orthoclase)	
Biotite mica	
Sodium-rich feldspar (albite)	
Amphiboles	
Pyroxene	
Calcium-rich feldspar (anorthite)	
Olivine	
Calcite	
Halite	
Least stable	Fastest

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
	biotite	Na plagioclase
		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 **limestones** produces thin soils with insoluble silicates and iron-oxide residues

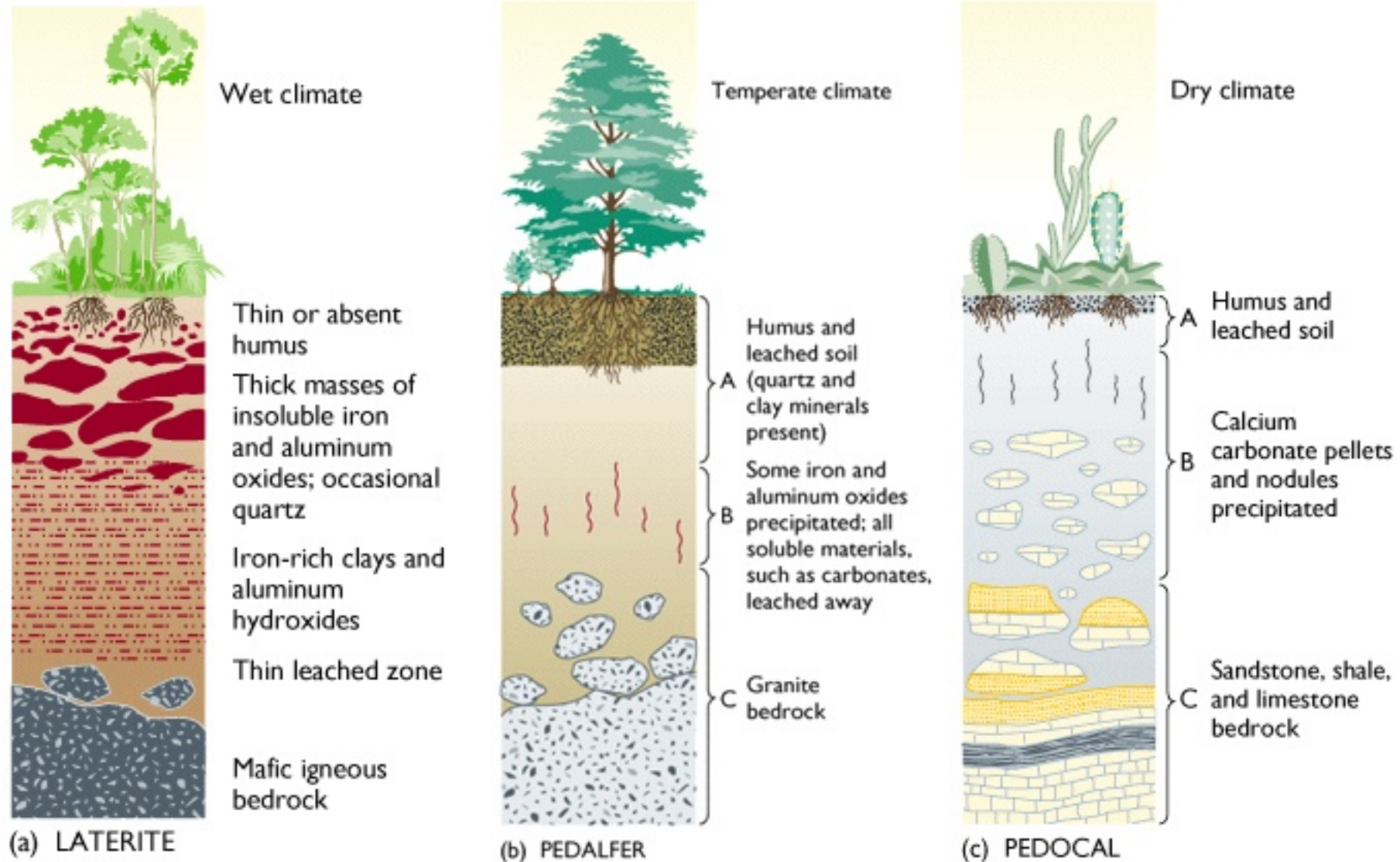
Soils

- Soil above bedrock is made up of:
 - Weathering by-products
 - Residual grains (chemically stable minerals)
 - Secondary minerals (clays, iron oxides, aluminum hydroxides)
 - Organic matter
- Soil type is determined by:
 - Bedrock lithology/Parent material
 - Climate

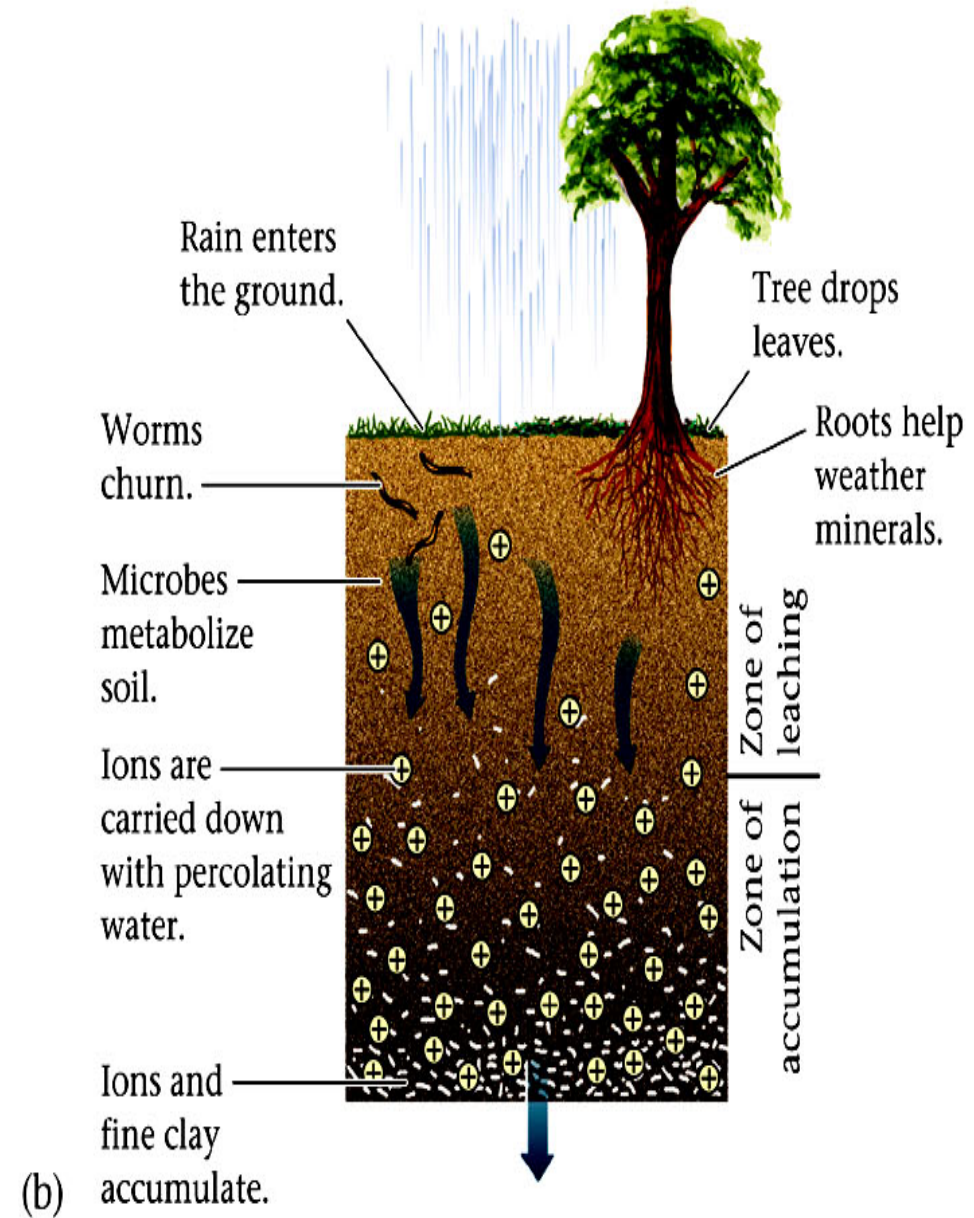
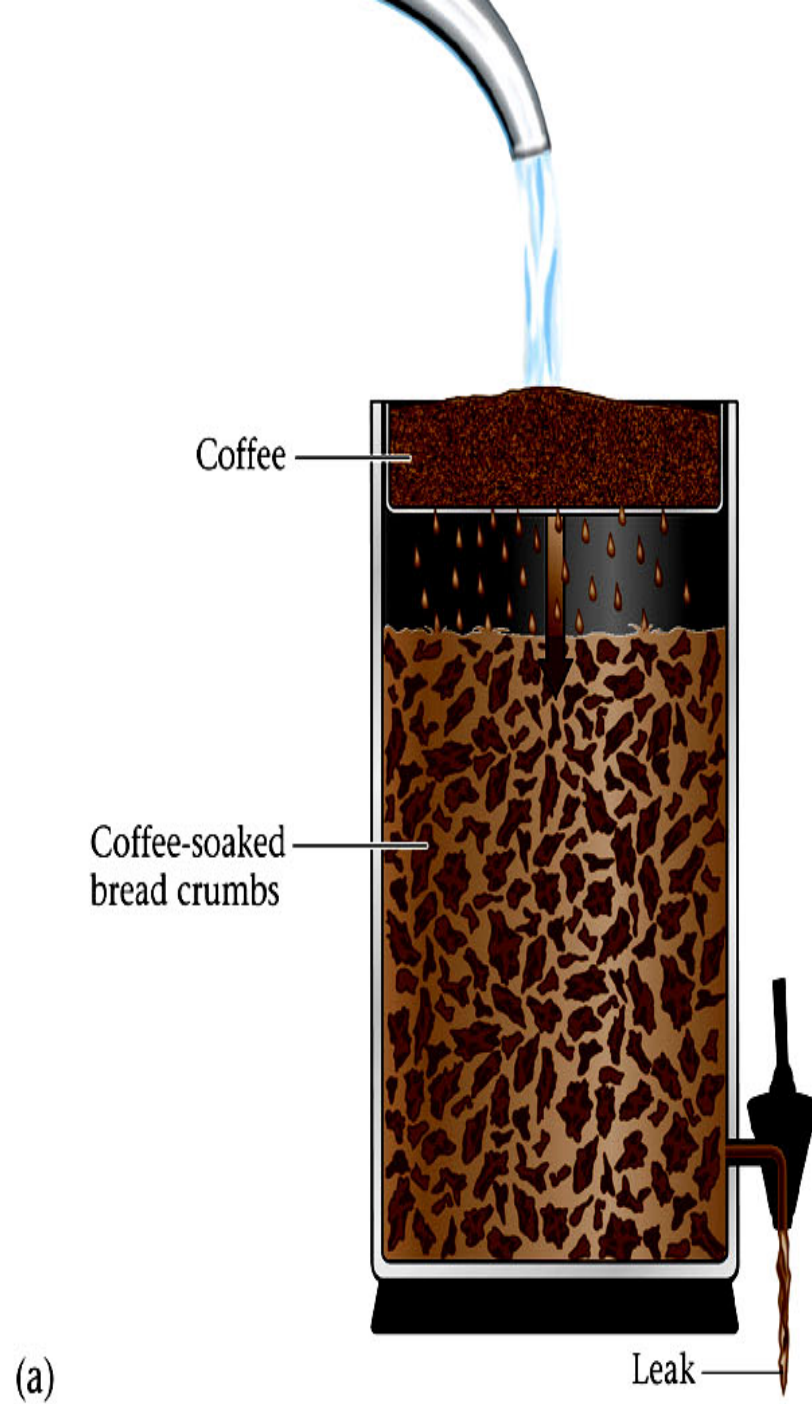
An important concept

- Soil is **NOT** a geologic deposit

Soils and climate



Soil

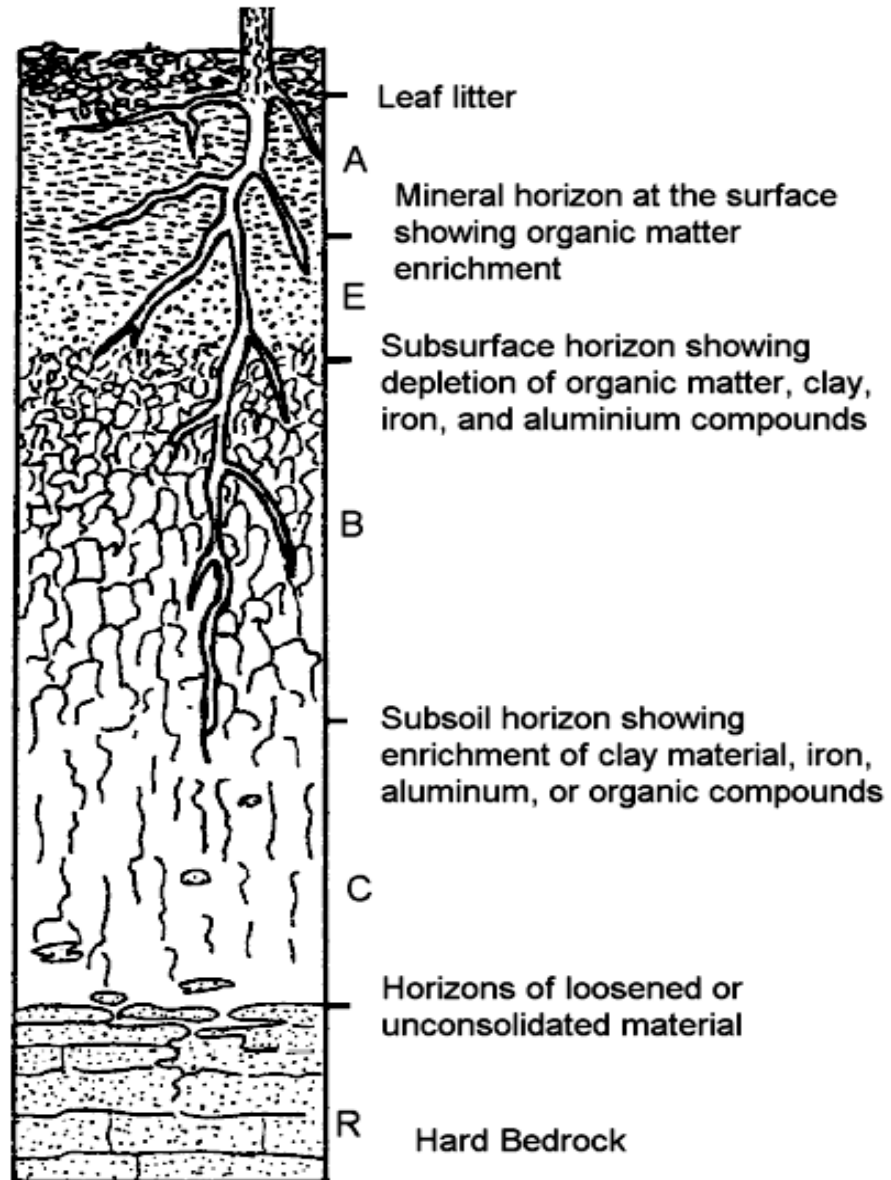




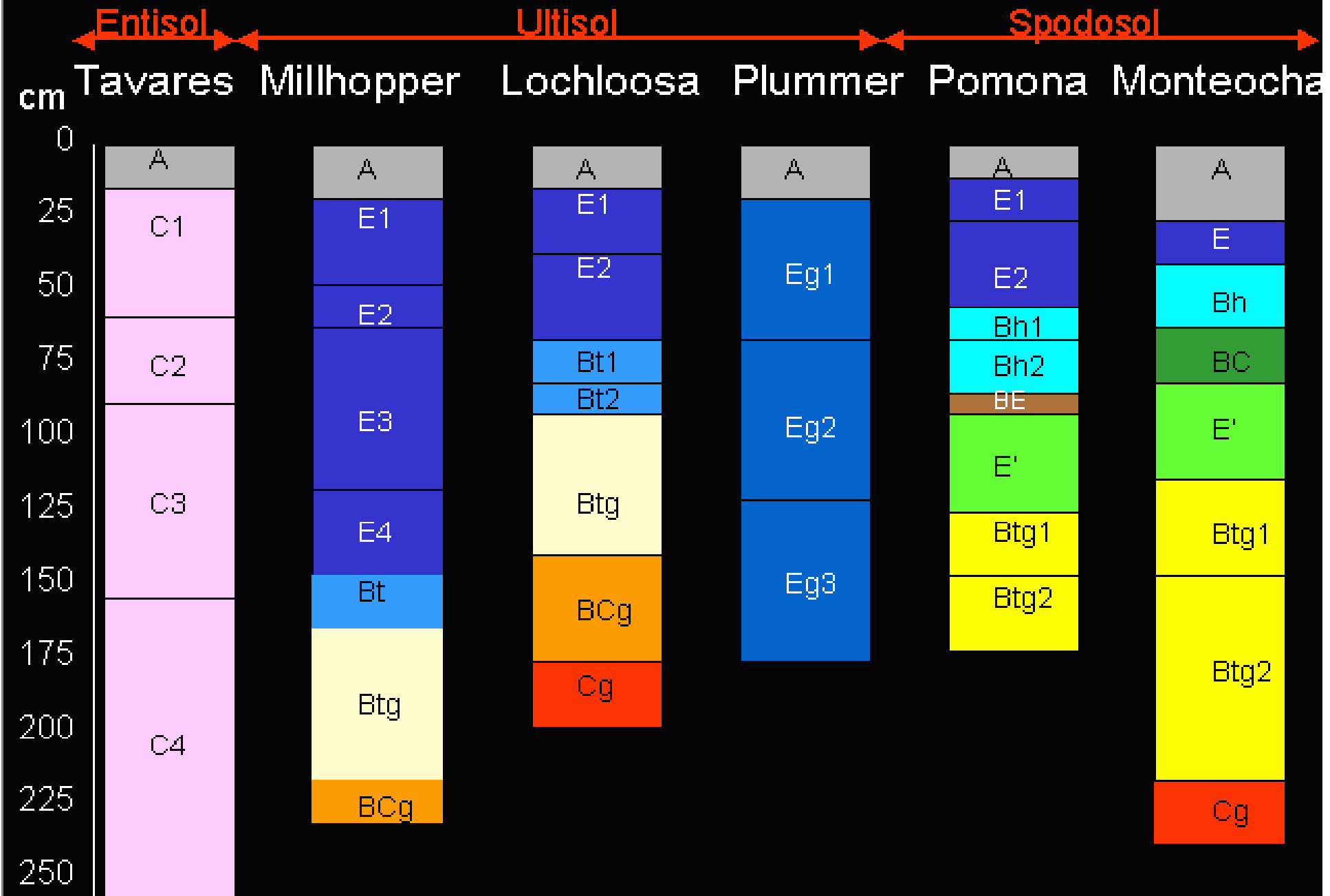
Horizons

- Master horizons: O, A, E, B, C, and R

Soil Profile



Soil Profiles



Soil forming factors

- Hans Jenny (1941) Cl, o, r, p, t
- cl, climate
- o, biotic influence (The Washington Post, Nov. 2, '03)
- r, topographic relief
- p, parent material
- t, time

The two most important factors

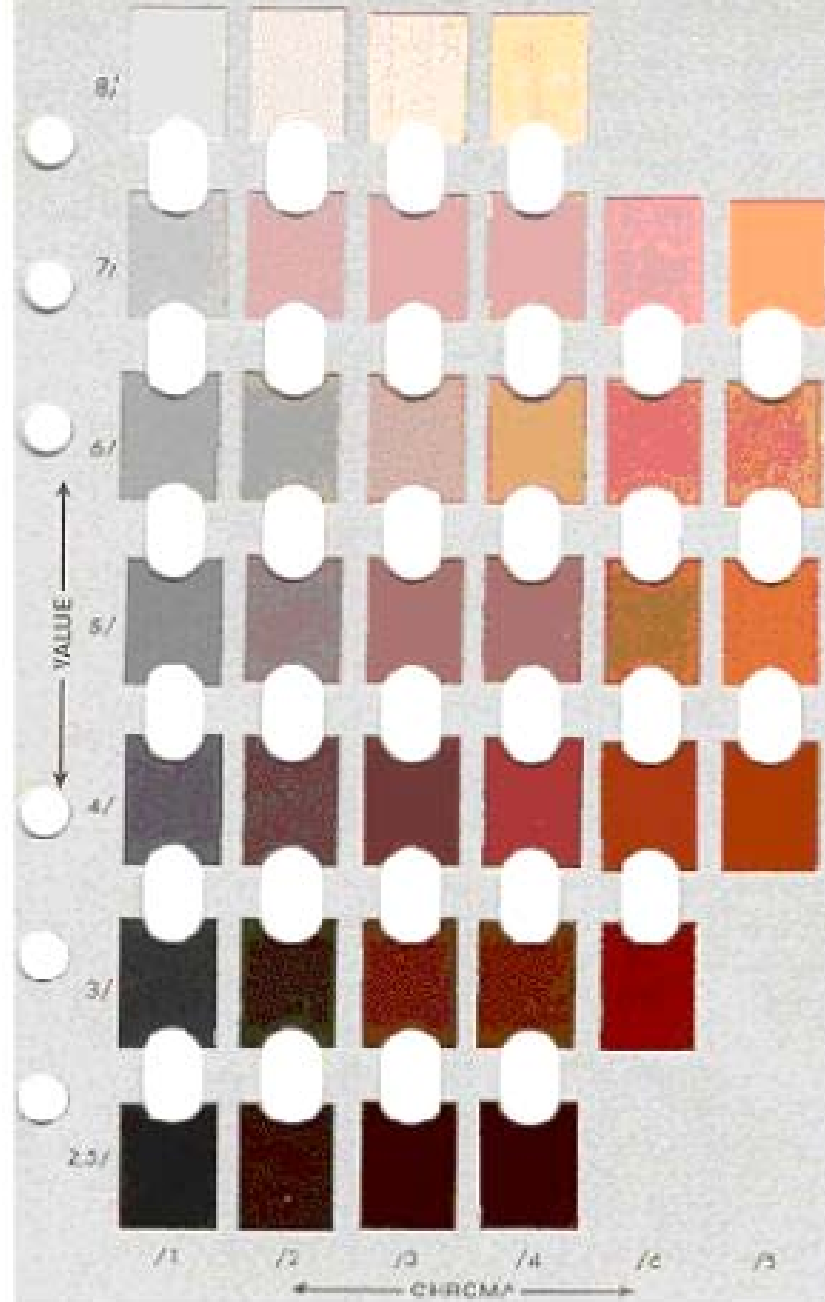
1. Climate
2. Parent material

Describing a soil

- Color
- Thickness
- Structure
- Texture

MUNSELL® SOIL COLOR CHART

2.5YR

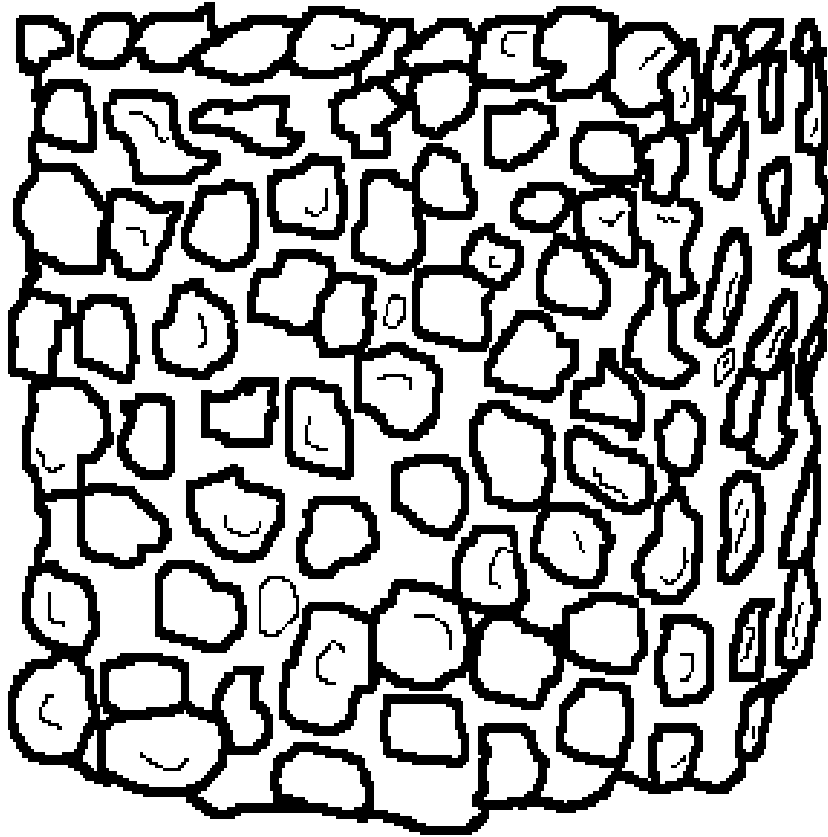




Structure

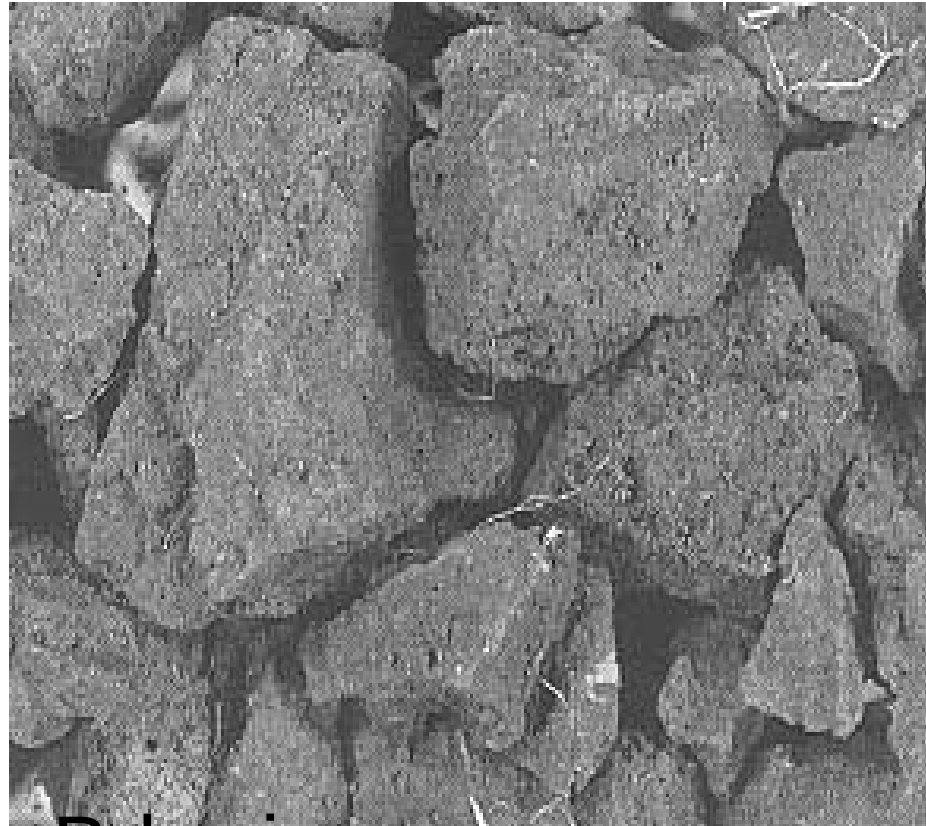
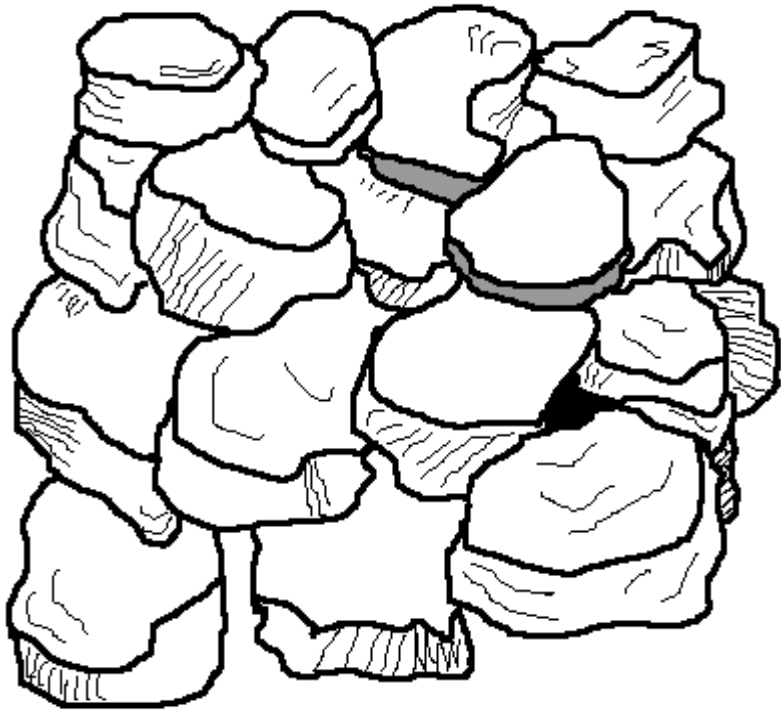
- As a soil develops, soil peds begin to form shapes or a structure

Granular



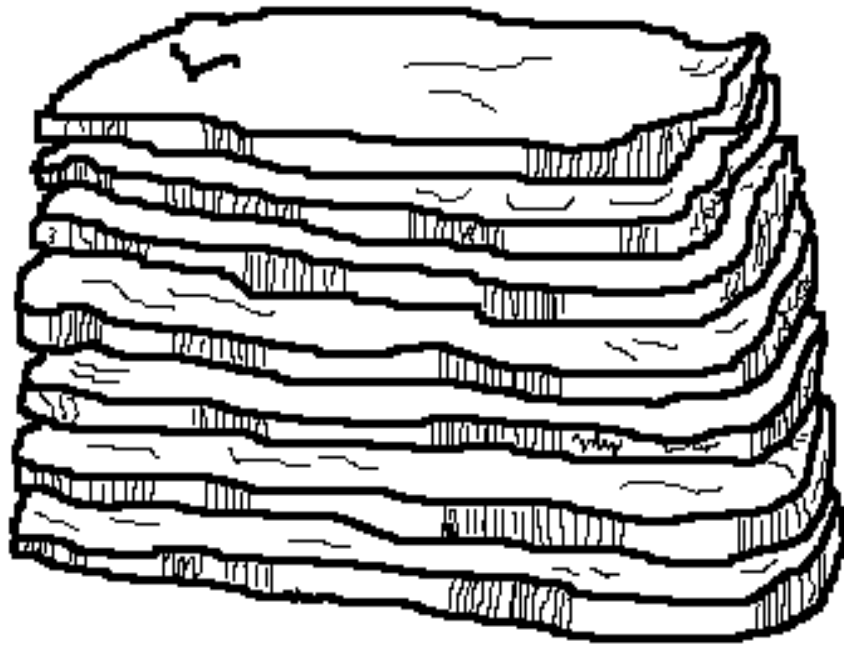
A-horizon

Blocky

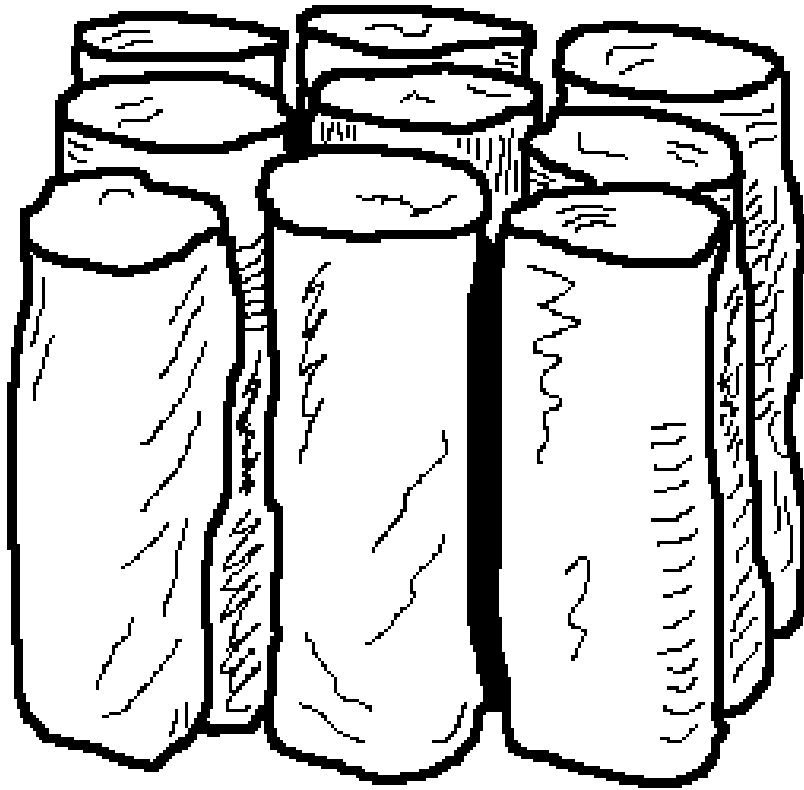


B-horizon

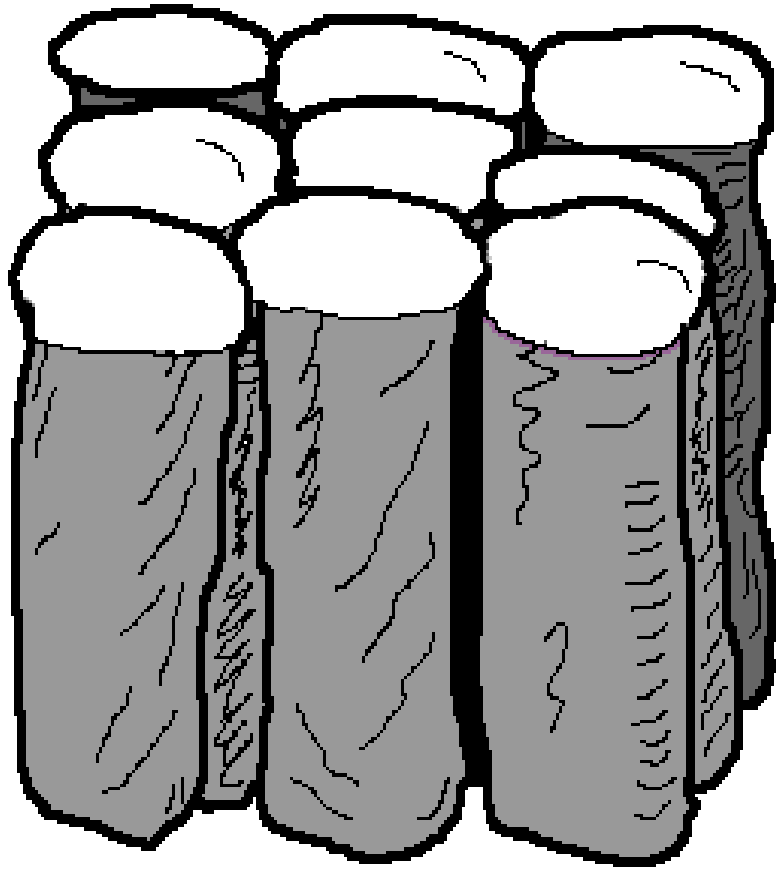
Platy



Prismatic

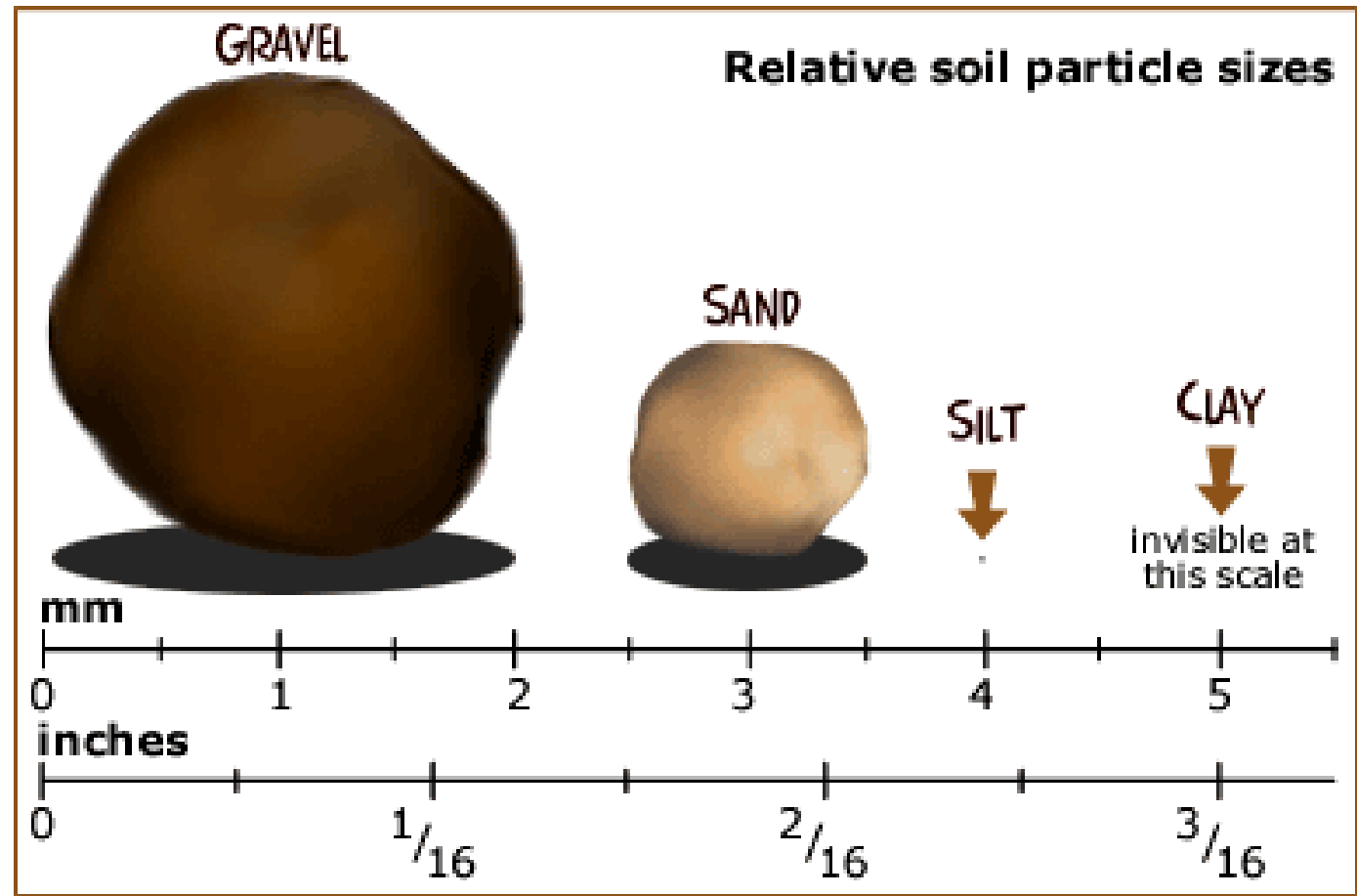


Columnar

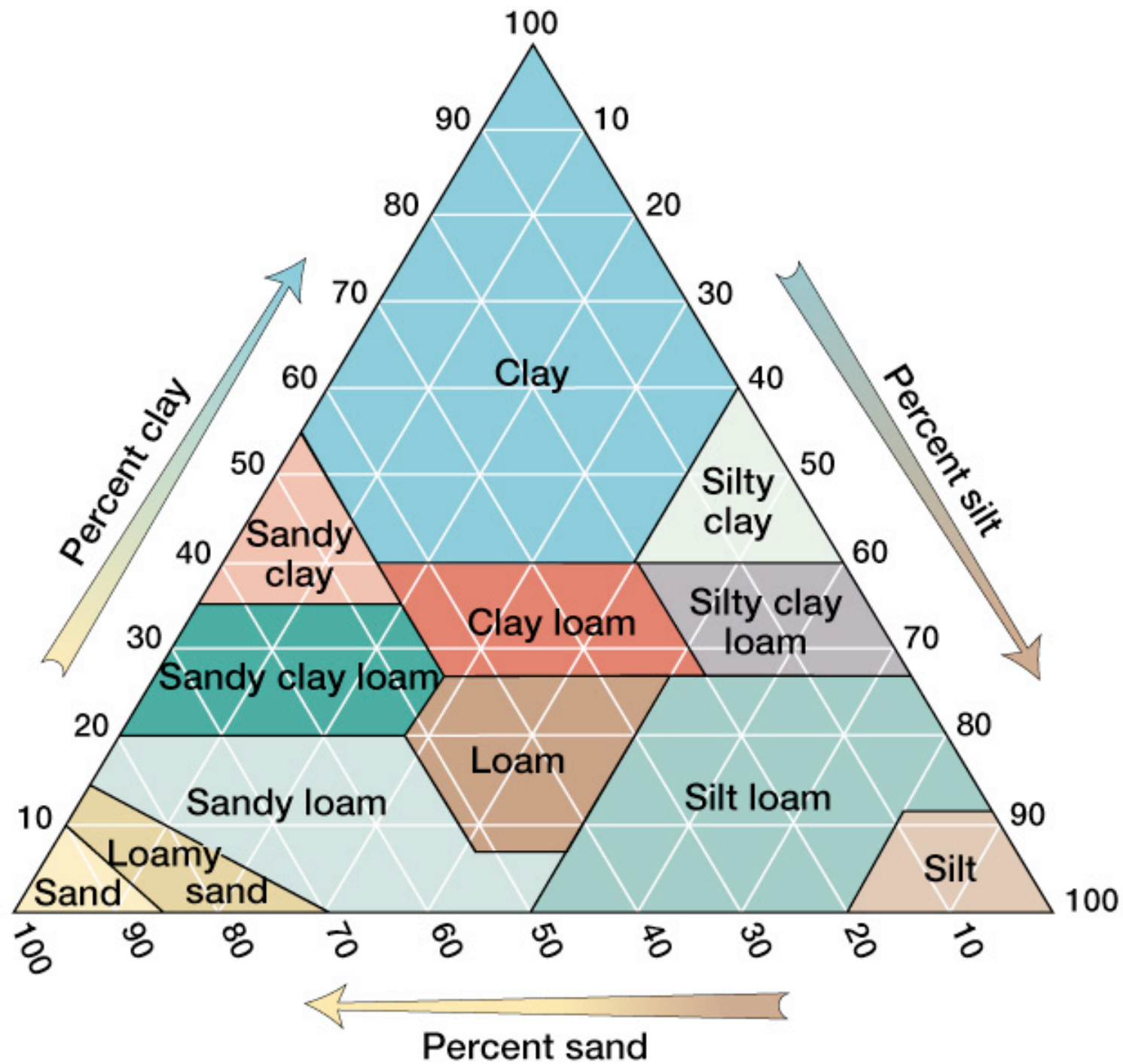


Texture

- Size of the individual peds
 - Sand, Silt, Clay







Paleosols

- Paleosols are ancient or fossil soils preserved in the stratigraphic record
- Paleosols generally occur beneath unconformities
- Paleosols provide good clues for the interpretation of paleoenvironments and paleoclimates

Paleosols

Criteria for recognizing paleosols:

1. Presence of recognizable soil horizons
 - Organic upper horizon
 - Subhorizons exhibiting increasing clay and/or reddish color
 - Uppermost surface sharply truncated
 - Chemically different than parent material including gradational mineral content, with unstable minerals decreasing in abundance up-section
2. Presence of soil structures (e.g. peds)
3. Laterally extensive
4. Root traces, or other disruption of original sedimentary structures by organic activity

Soil structures:
Root traces



Paleosols in Badlands

