Soil Profiles and Soil Forming Factors

July 21st, 2021

SOILS

What is Soil?

Is it the same as dirt? (it's higher-class dirt)

Soil is dirt that has been acted upon by processes in the environment in which it is found

Soil may have had something happen to it which allowed it to change over time

What is Soil?

Soil

- Zone of plant growth
- The essential medium in which most terrestrial life is nurtured
- The upper portion of lithosphere characterized by its ability to produce and store plant nutrients.
- **An infinitely varying mixture of weathered mineral particles, decaying organic matter, living organisms, gases, and liquid solutions**.
- **Definition: Soil can be conceptualized as a relatively thin surface layer (15 cm or 6 inches average worldwide) of mineral matter that normally contains a considerable amount of organic material and *is capable of supporting living plants*.**

Soil is made of:

Four Primary components:

1. Mineral matter (Inorganic materials)
2. Organic matter
3. Water
4. Air

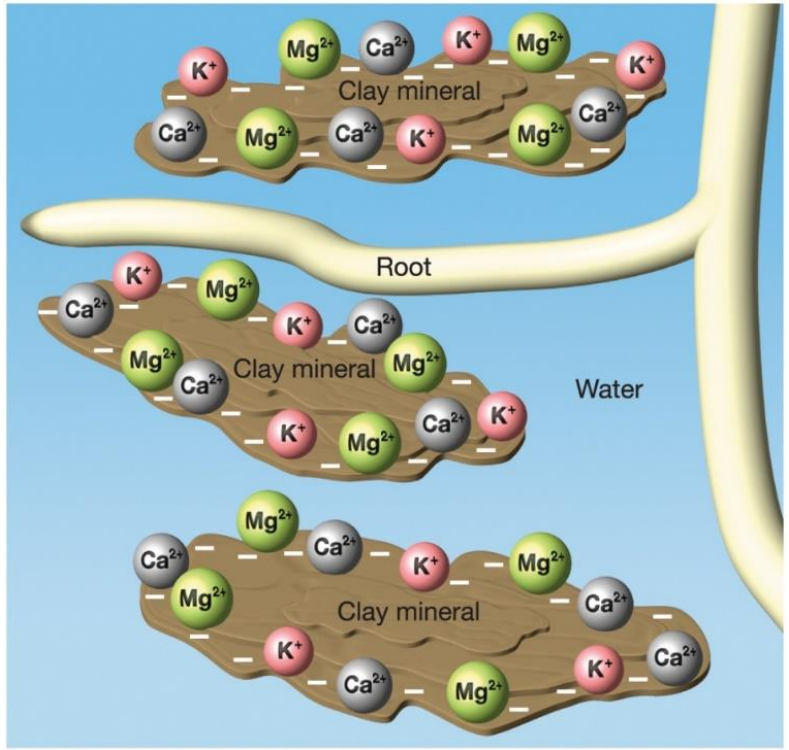
Soil Components

1. **Mineral Particles/ Inorganic materials**

   Bulk of most soil is mineral matter in the form of small but macroscopic particles

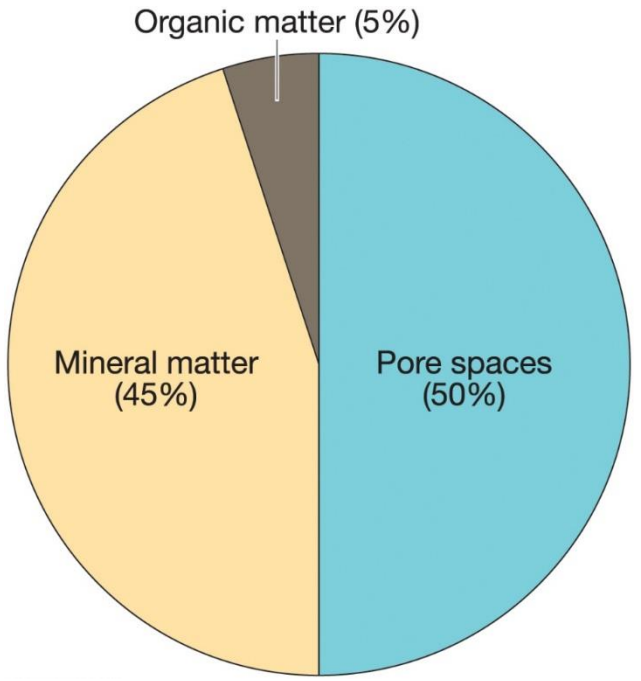
   Cations that act as nutrients for plants , e.g.

   - Ca++, K+, Mg ++



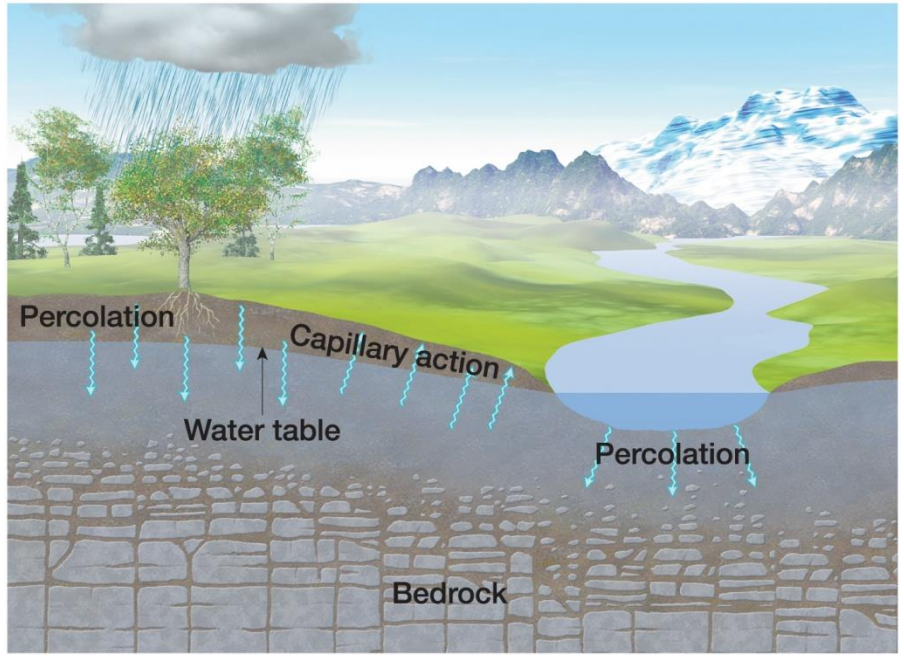
Soil Components

2. **Organic materials**
   - Small percent of soil volume
   - Living organisms, dead organisms, decomposing or completely decomposed organisms
   - Rearrange and aerate soil and yield nutrients through waste products
   - **Litter – leaves, twigs, other dead plant parts on soil surface**
   - **Humus – black gelatinous organic matter that results from decomposed residues**



Soil Components

3. **Soil air**
   - Half volume of average soil is pore spaces
   - Spaces provide ***interstices*** (a labyrinth of interconnecting passageways) among soil particles
   - Pores filled half with air, half with water

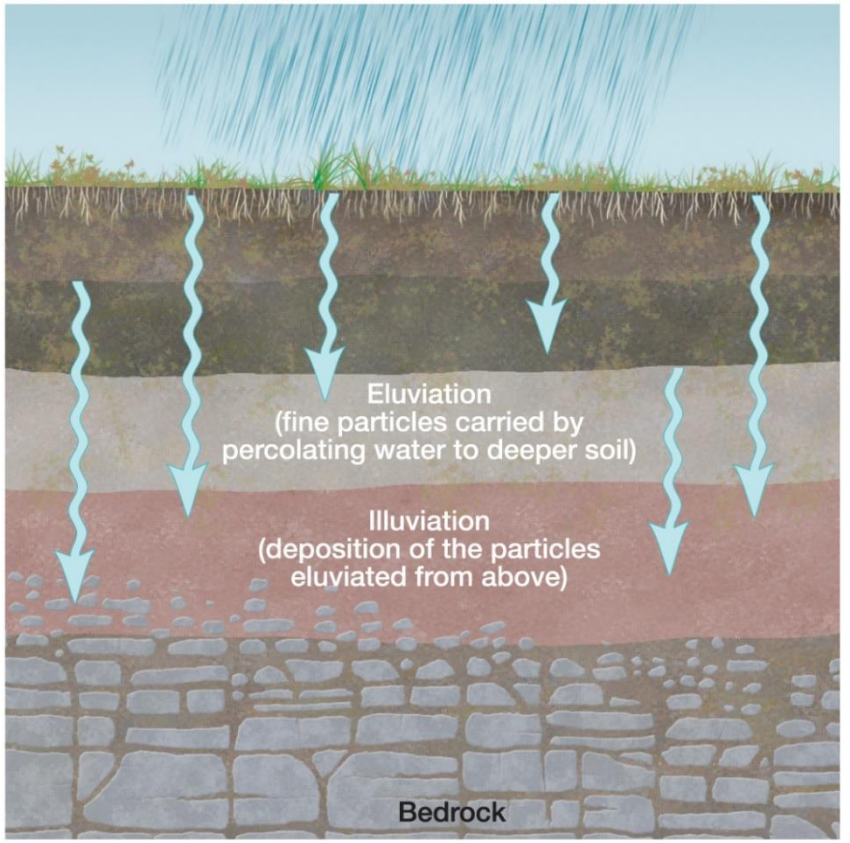


Soil Components

4. **Soil water**
   - Rainfall, snowfall, groundwater through capillary action

Four types:

- Gravitational water – infiltration from above, falls down via gravity
- Capillary water – moisture that is held on soil particle surfaces by surface tension



Soil Properties

Colour (color):

We define the colour of a soil to tell us what is in it. Black soils tell us that there is a lot of organic material

Red soils suggests that there is **iron oxide**

Can also mislead.

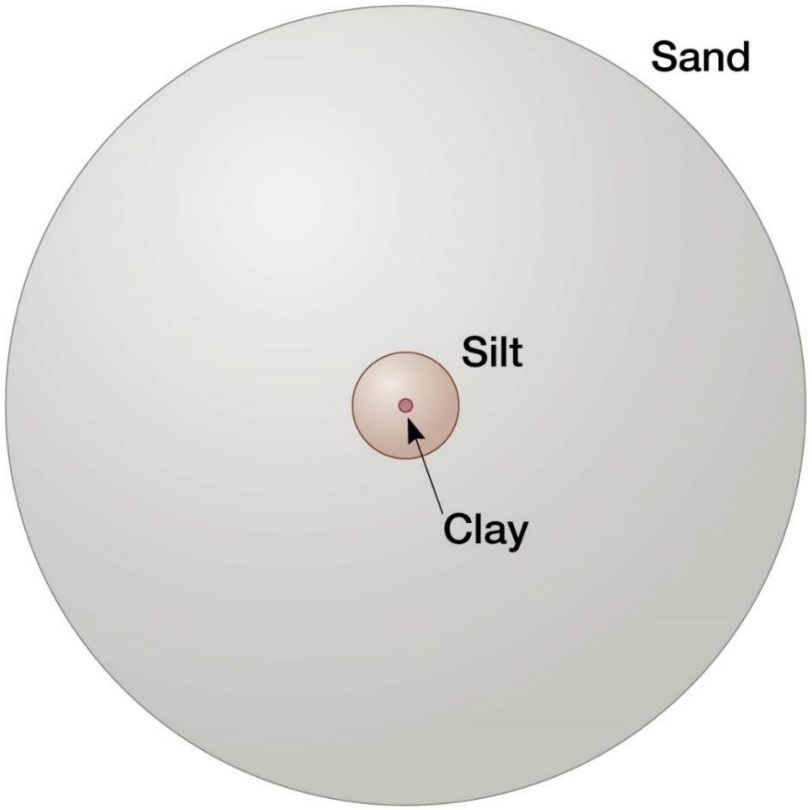
175 gradations of colour

Soil Properties

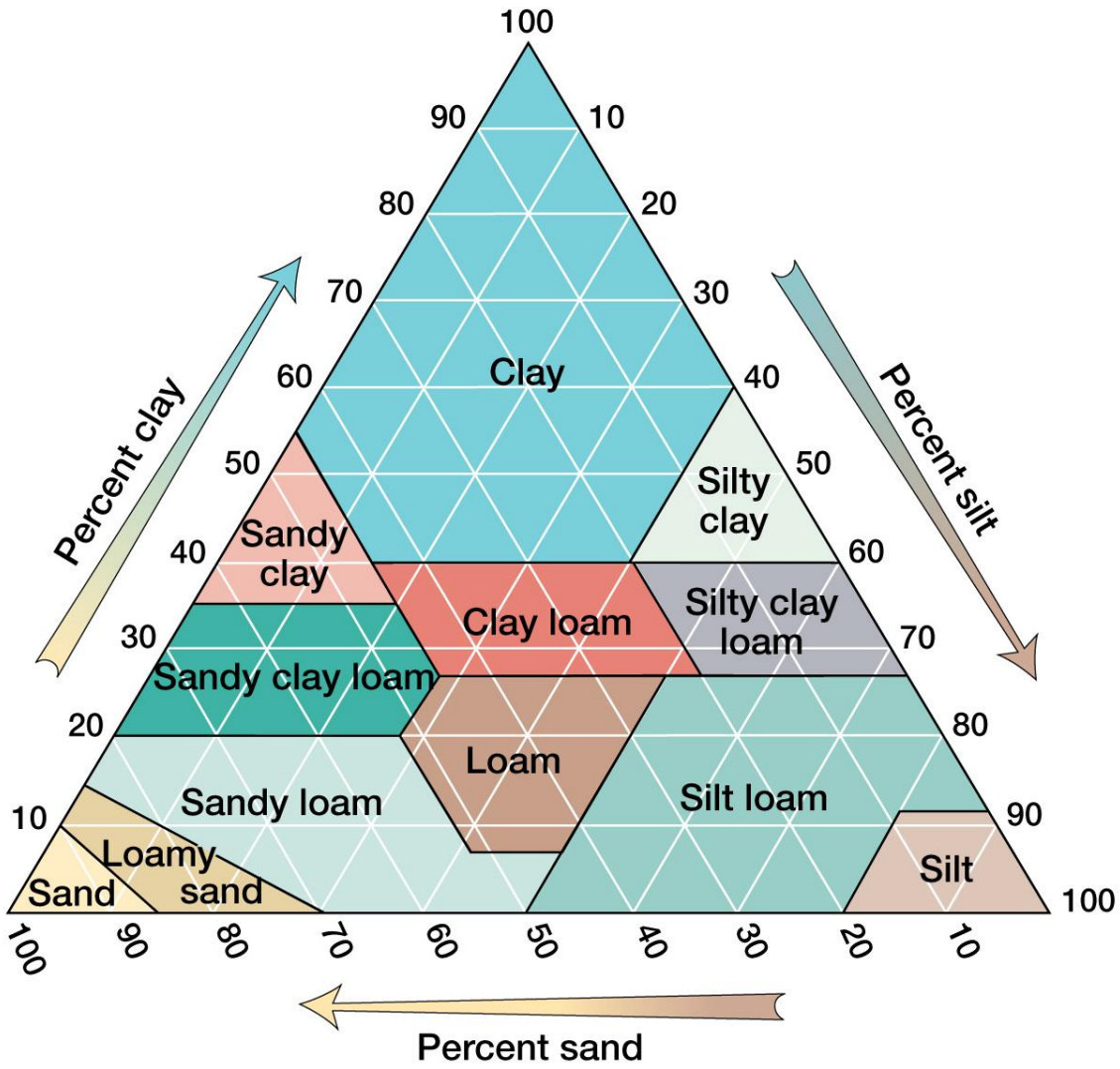
Texture: what is the size of the mineral particles?
Separates—the size groups within the standard classification of soil particle
sizes.
Three principal types of soil separates:

- Sand – Minerals: > 0.05 mm
- Silt – Minerals: 0.05-0.002 mm
- Clay – Minerals: <0.002 mm

Soils that have all three of these are called loams
You can get an idea of soil texture and the kind of minerals that are contained therein by rubbing a soil through your fingers or teeth



Texture triangle



60% sand;

15% clay

25 % silt

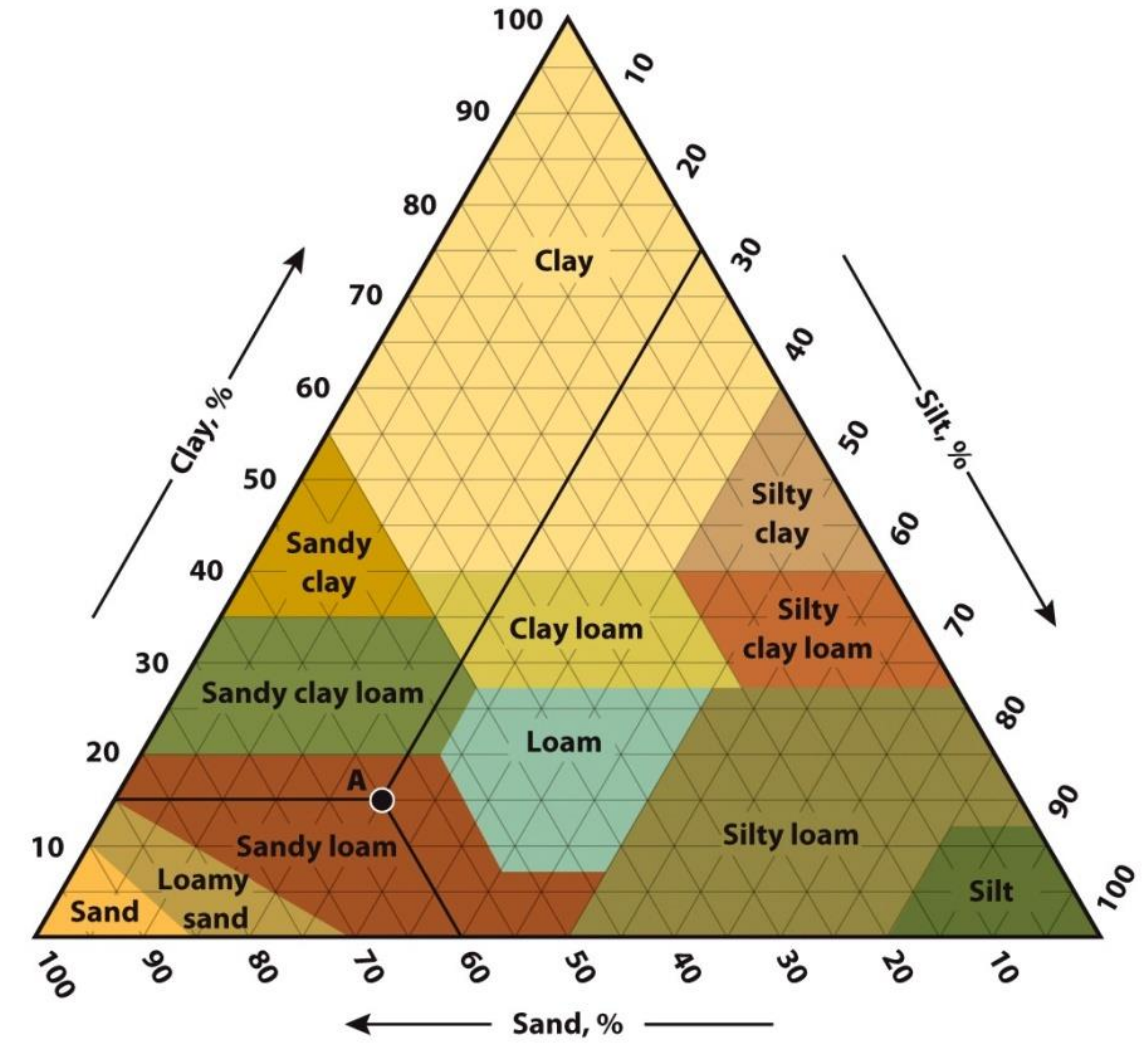
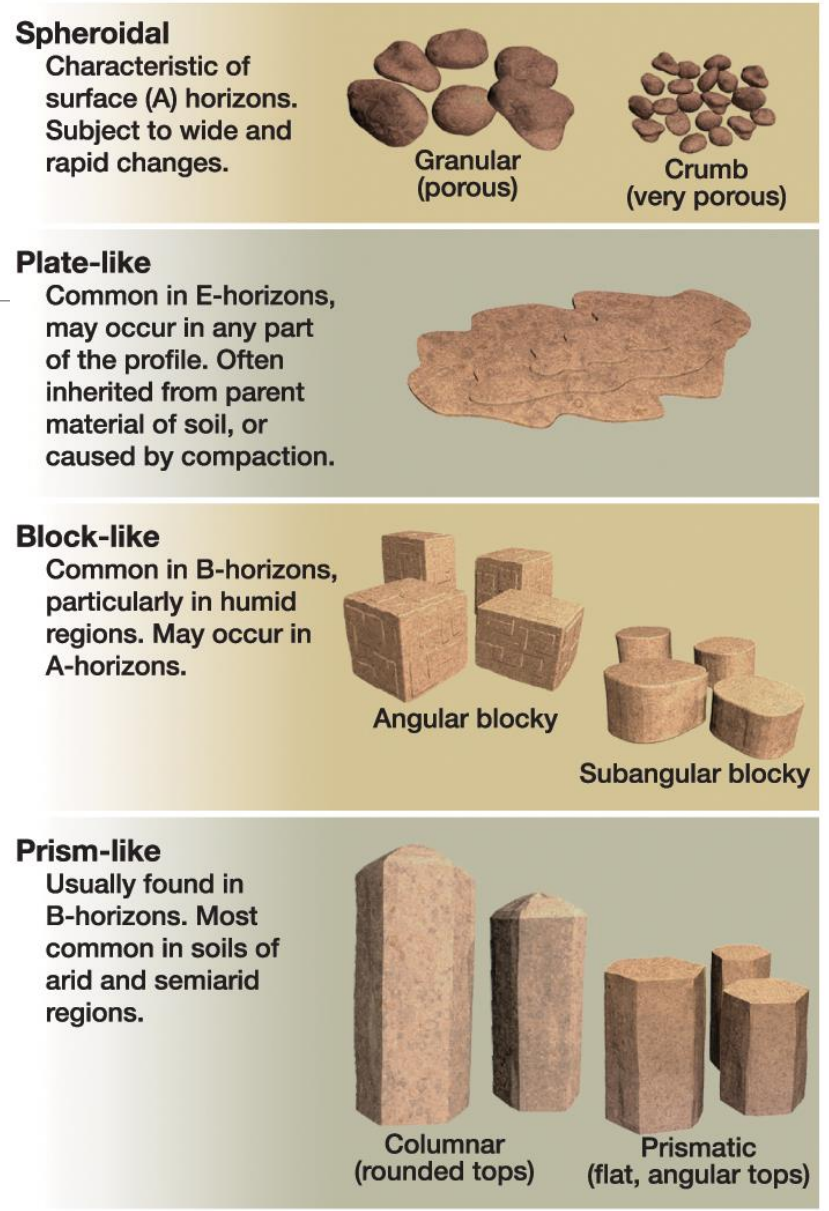


Figure 10.6

Soil Properties

Structure

- Particles aggregate into peds (**a larger mass or clump in which individual soil particles tend to aggregate; determines the structure of the soil**).
- The four basic ped shapes are:
  - Spheroidal
  - plate-like
  - block-like
  - prism-like.
- Structure is key in determining soil's **porosity (soil capacity to hold water)** and **permeability (interconnectivity of pore spaces to allow water through)**

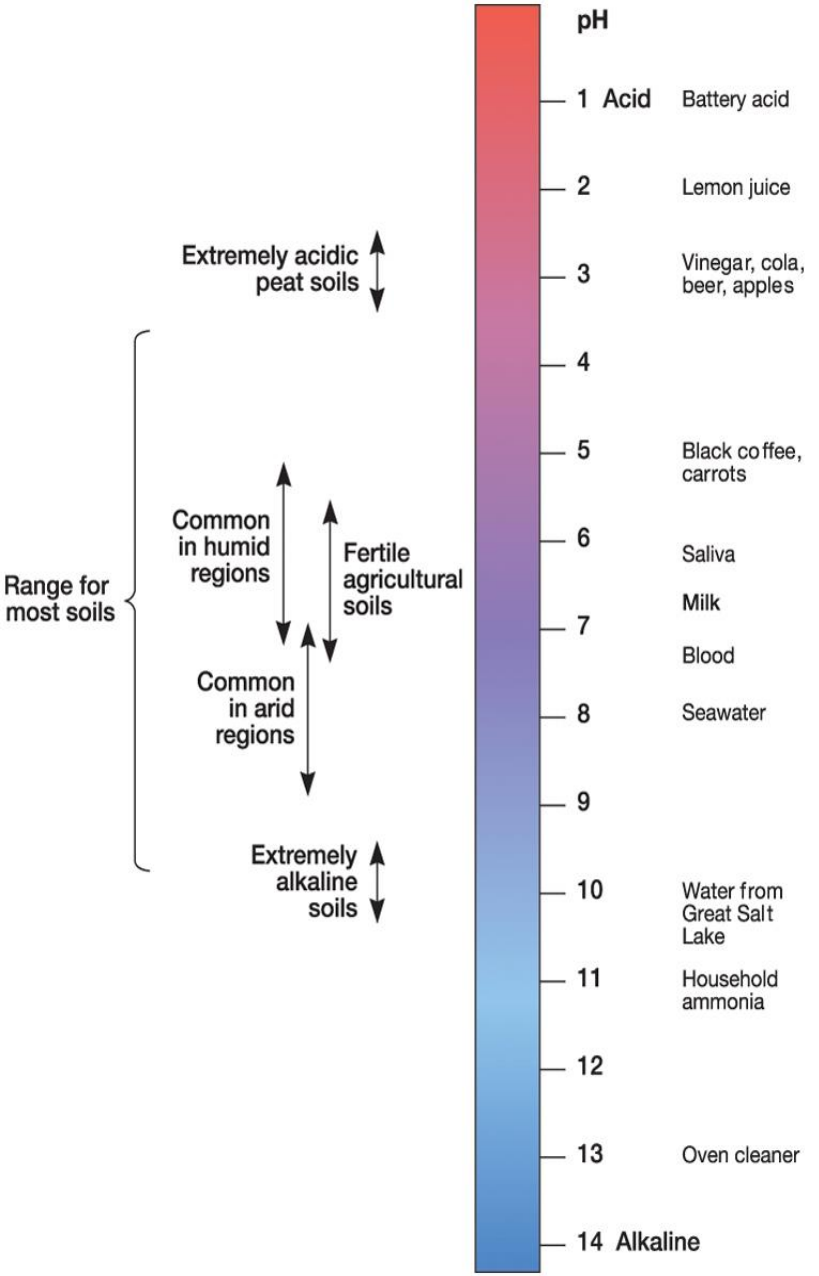


Soil Chemistry

Cation exchange capacity (CEC)

- Attach to negatively charged colloids; capability of soil to attract and exchange cations.

Soil pH -Acidity/Alkalinity



In describing soils: we use a vertical profile:

We look below the surface to get a vertical cross-section of the soil – this is called a ***profile.***

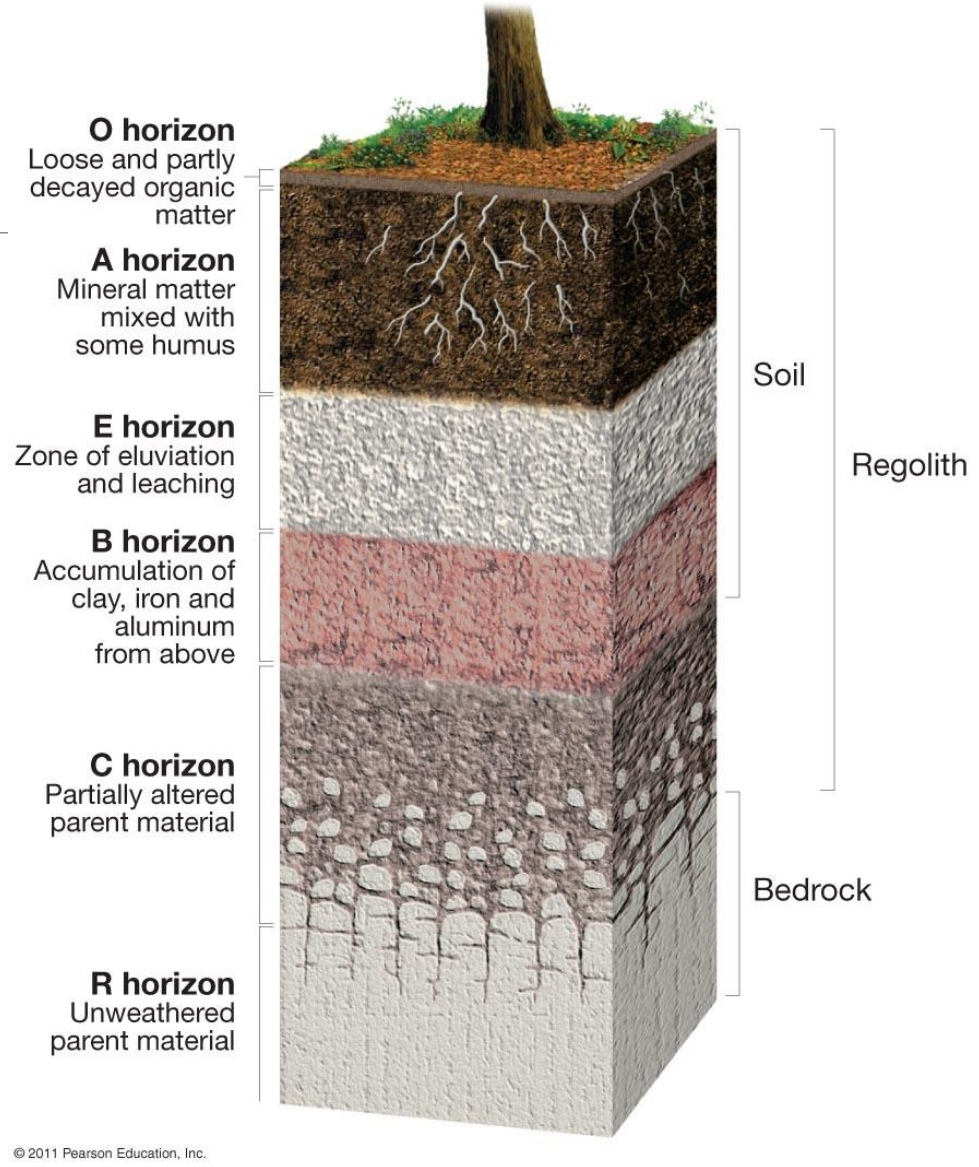
the distinct layers we may see are called Soil Horizons.

By the characteristics of the horizon, we can tell what kind of soil it is.

SOIL PROFILE

Idealized soil profile. A true soil, or solum, consists of the O, A, E and B horizons.

- O (organic litter; not typical for soils to have)
- A (topsoil; mineral and organic)
- E (eluvial layer; concentration of sand and silt particles)
- B (subsoil; mineral layer that contains materials removed from E level)
- C (unconsolidated regolith; no organic matter)
- R (bedrock)



Regolith—a layer of broken and partly decomposed inorganic particles that covers bedrock

Soil Forming Factors

Five factors are involved in forming soil:

- Climate
- Organisms
- Relief (Topography)
- Parent Materials
- Time

The Climatic Factor

In long run, climate is generally the most influential factor.

- Climate also influences vegetation
- Temperature and moisture are most significant.
- High temperatures and abundant moistures accelerate chemical and biological processes in soil
- More Water, more movement of minerals

Organisms - Biology

Organic matter only small fraction of soil volume, but of utmost importance

Gives life to soil from living and dead plants and animals

Earthworms: are most important to soil formation and development.

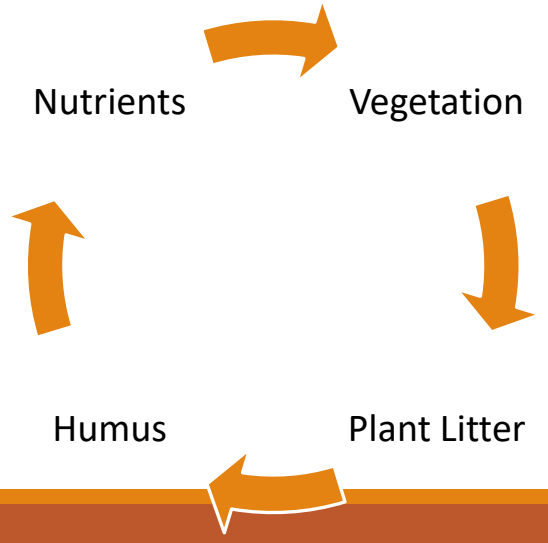
- Tunnels facilitate drainage and aeration, deepening of soil profile,
- Movement creates a crumbly soil structure that is favorable for plant growth,
- Movement brings in leaf litter, which fertilizes subsoil.
- Digestive actions and tunnels increase porosity and help soil impact of raindrops, which helps deter erosion.
- Casts, which are the inorganic material worms excrete, increase nutrients of soil through their physical and chemical nature.
- Movement also brings deeper material to surface, where it can be weathered more rapidly.
- Movement, digestive action, and decomposition of own bodies help promote nitrification.

Organisms - Biology

Microorganisms in the Soil: an estimated three quarters of a soil's metabolic activity is generated by microorganisms.

Microbes decompose organic material into **humus** (a dark adhesive of minute particles ---decomposed organic matter of utmost importance to agriculture). This makes nutrients usable by plants.

Biocycling – the recycling of nutrients in a system from soil to plant.



Relief (The Topographic Factor)

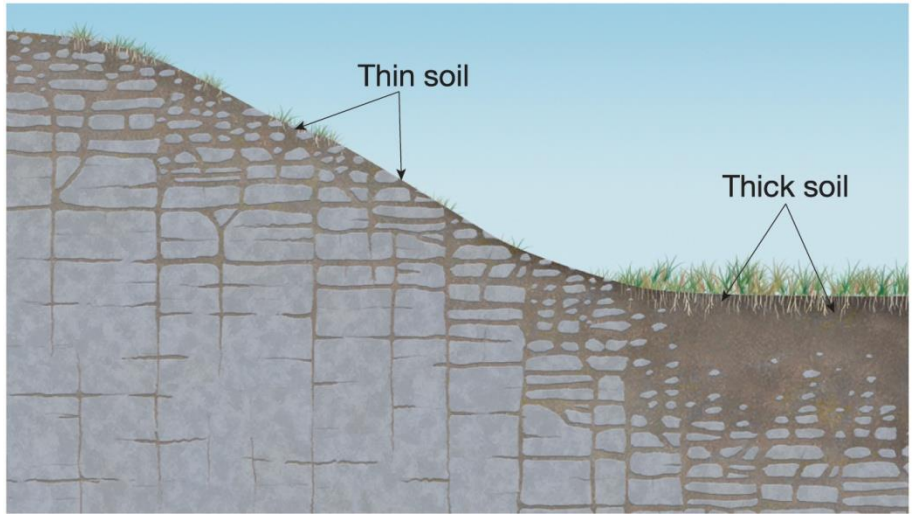
Slope and drainage are main features in this factor.

In what kind of landscape is the soil developing

Water moves down slopes

At the bottom we will have more leaching

Relief (The Topographic Factor)



On flat land, soil normally develops more deeply with the passage of time because there is very little erosion washing away the topmost soil.
On a slope, the rate of erosion is equal to or greater than the rate at which soil is formed at the bottom of the soil layer, with the result that the soil remains shallow.

Parent material (*The Geologic Factor)*

The source of the weathered fragments of rock from which soil is made; solid bedrock or loose sediments that have been transported from elsewhere by the action of water, wind, or ice.

Influences chemical composition of soil and plays role in soil development.

This influence diminishes with time, as other factors become increasingly important.

Time (The Chronological Factor)

How long it takes for the soil to form

Estimates are between 100-200 years for developing an A-Horizon

Therefore changes imperceptible within human lifespan.

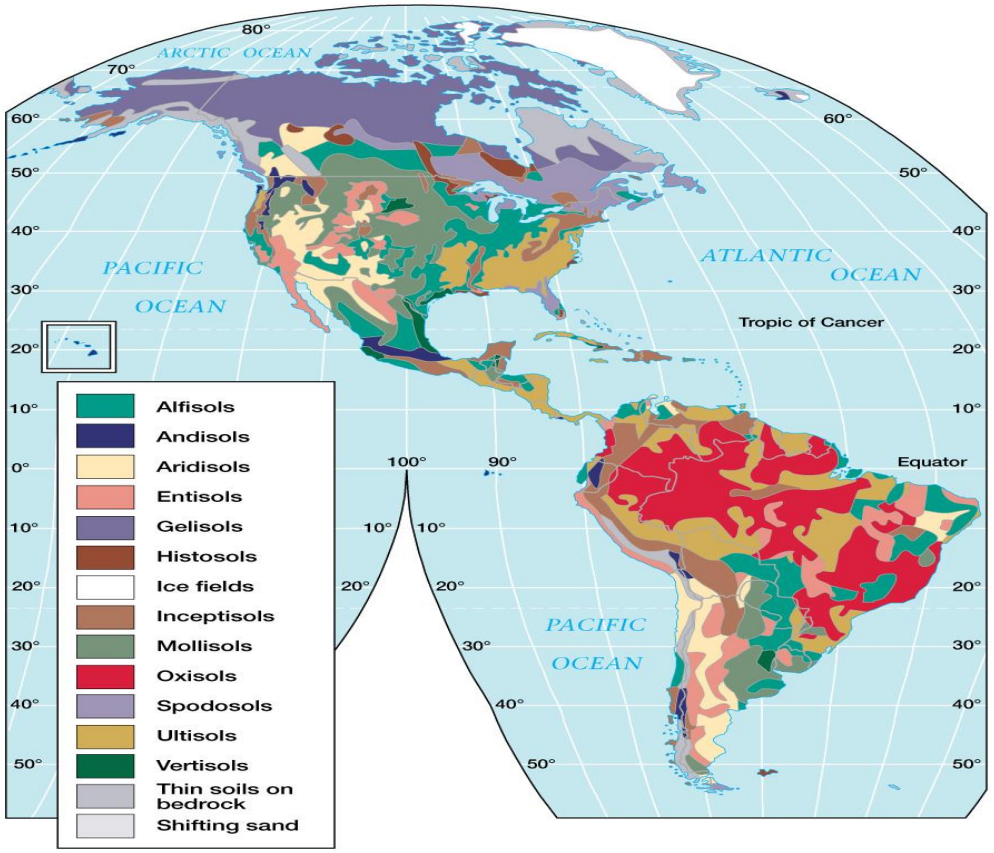
CLORPT

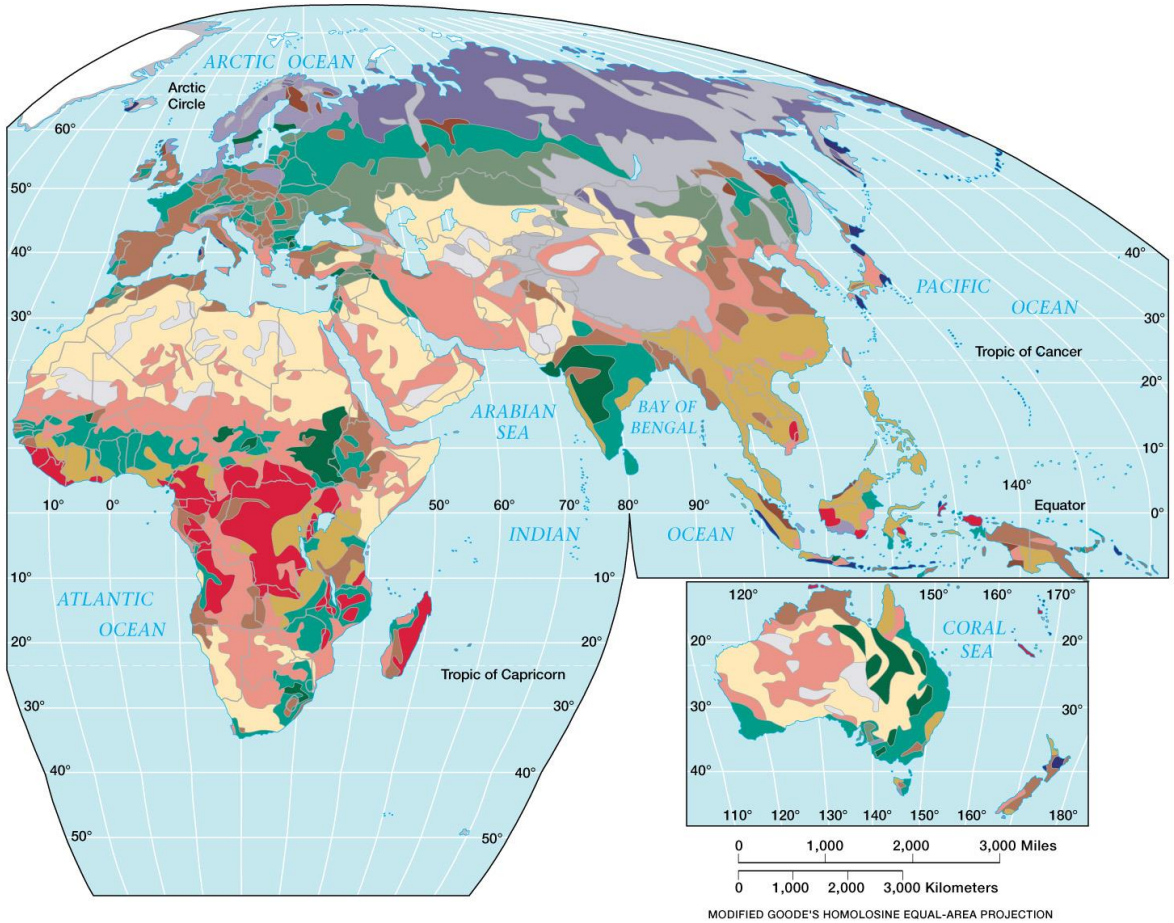
Soil scientist came up with this acronym to shape what soils are like

$s = f(Cl+O+R+P+T)$

Soil Distribution

12 major types





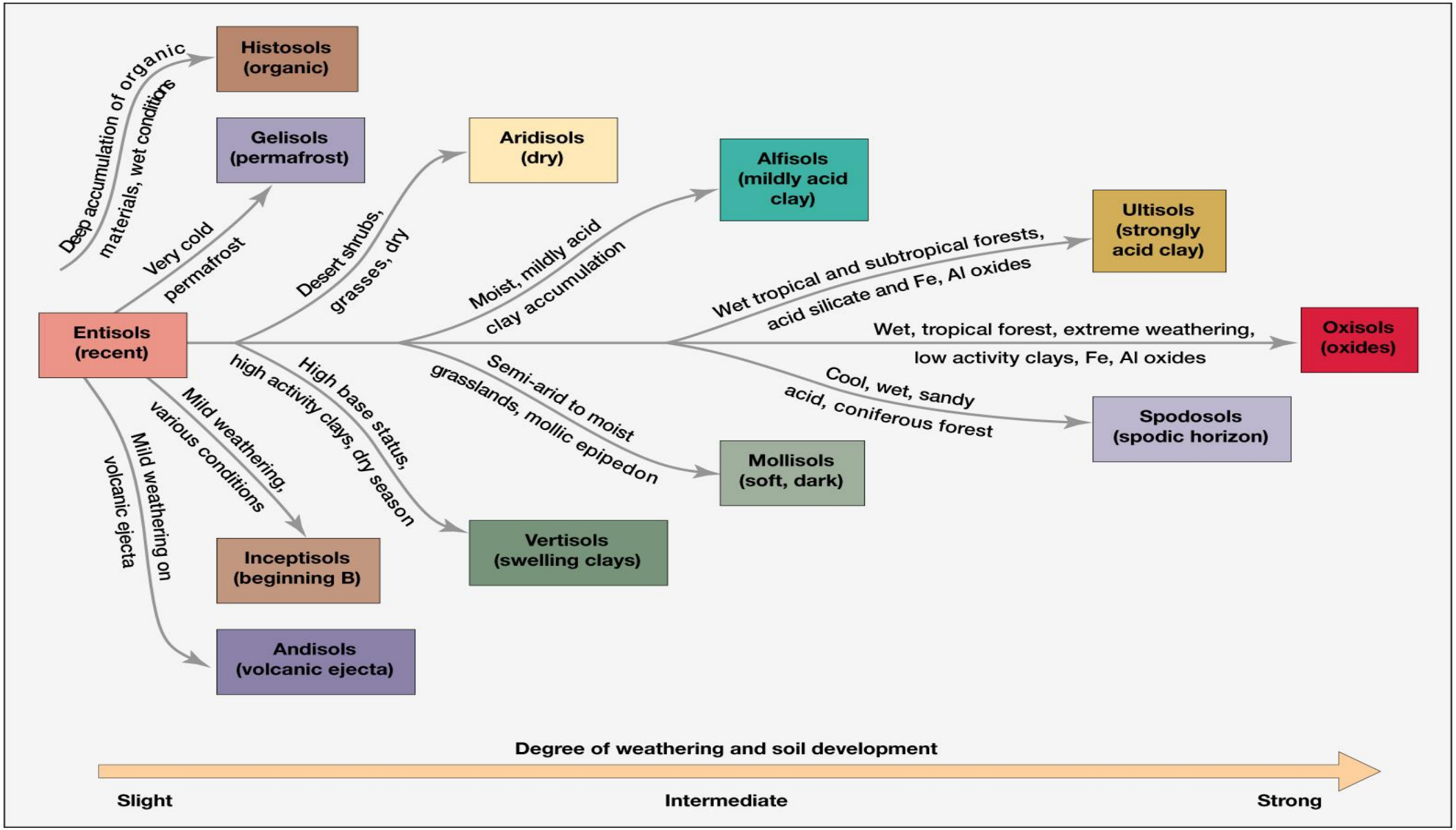
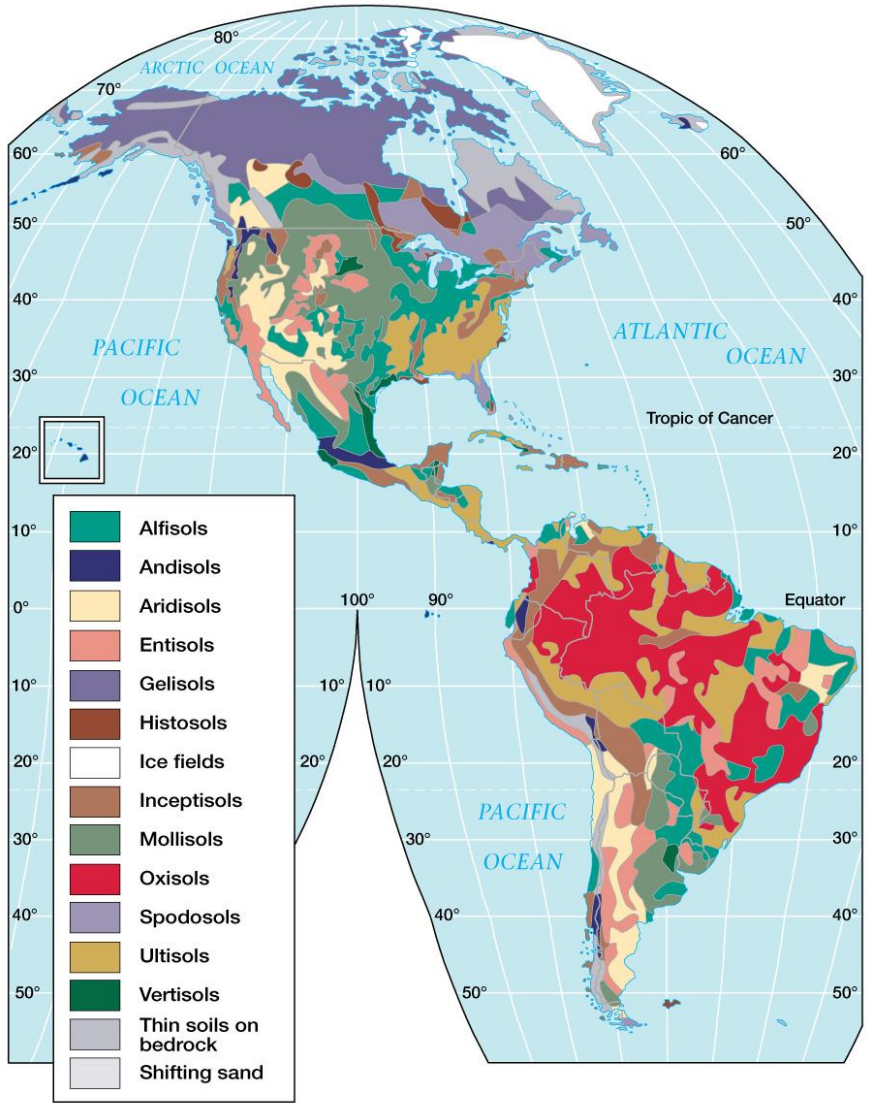


TABLE 12-2 Name Derivations of Soil Orders

Order	Derivation
Alfisols	"al" for aluminum, "f" for iron (chemical symbol Fe), two prominent elements in these soils
Andisols	andesite, rock formed from type of magma in Andes Mountains volcanoes; soils high in volcanic ash
Aridisols	Latin *aridus*, "dry"; dry soils
Entisols	last three letters in "recent"; these are recently formed soils
Gelisols	Latin *gelatio*, "freezing"; soils in areas of permafrost
Histosols	Greek *histos*, "living tissue"; these soils contain only organic matter
Inceptisols	Latin *inceptum*, "beginning"; young soils at the beginning of their "life"
Mollisols	Latin *mollis*, "soft"; soft soils
Oxisols	soils with large amounts of oxygen containing compounds
Spodosols	Greek *spodos*, "wood ash"; ashy soils
Ultisols	Latin *ultimus*, "last"; soils that have had the last of their nutrient bases leached out
Vertisols	Latin *verto*, "turn"; soils in which material from O and A horizons falls through surface cracks and ends up below deeper horizons; the usual horizon order is inverted

Overview of Soil Distribution

Transect Through Eastern North America: From High Latitude (Arctic) to the Gulf Coast



Transect Through Eastern North America: From High Latitude (Arctic) to the Gulf Coast

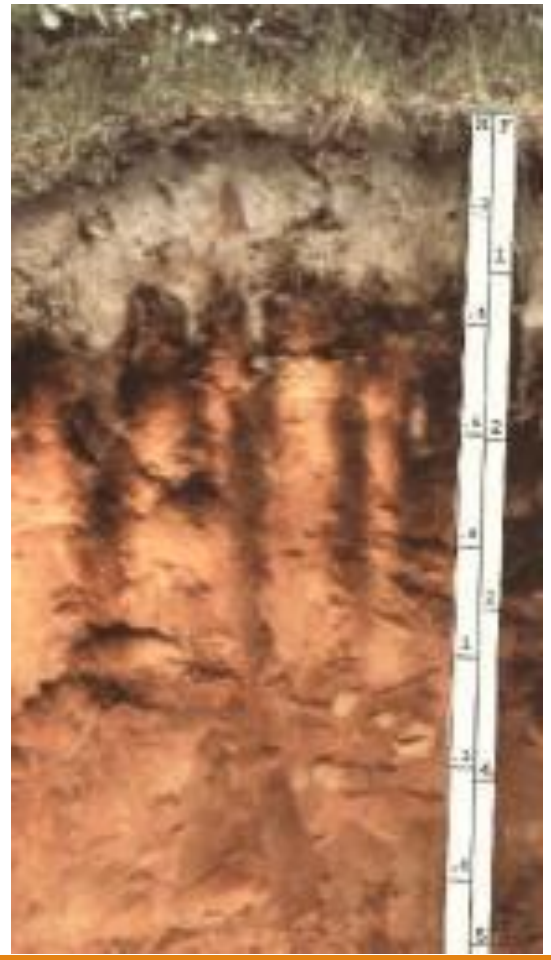
1. **Gelisol:**

- tundra vegetation; permanent ice in the first 1m of the profile
- young soil with minimal profile development, developing only slowly because of cold temperatures and frozen conditions.

Transect Through Eastern North America: From High Latitude (Arctic) to the Gulf Coast

2.Spodosol:

- Needleaf Evergreen forest (sub-arctic) - commonly found in cool, moist environments under coniferous forest vegetation.
- Surface litter composed of pine needles breaks down in the presence of water to form a weak organic acid. Acidic soil water removes base ions in solution to create an acidic soil.
- Easily dissolved materials are leached from surface layers leaving behind the most resistant material like quartz, creating an ashy-gray near-surface layer. ***Spodo (Greek)*** **for ash or pale.**
- Strong O horizon, little or no A horizon – not very much biocycling (organisms to break organic materials down have limited time to work), E horizon is bleached, B horizon red.
- Notoriously infertile.



Transect Through Eastern North America: From High Latitude (Arctic) to the Gulf Coast

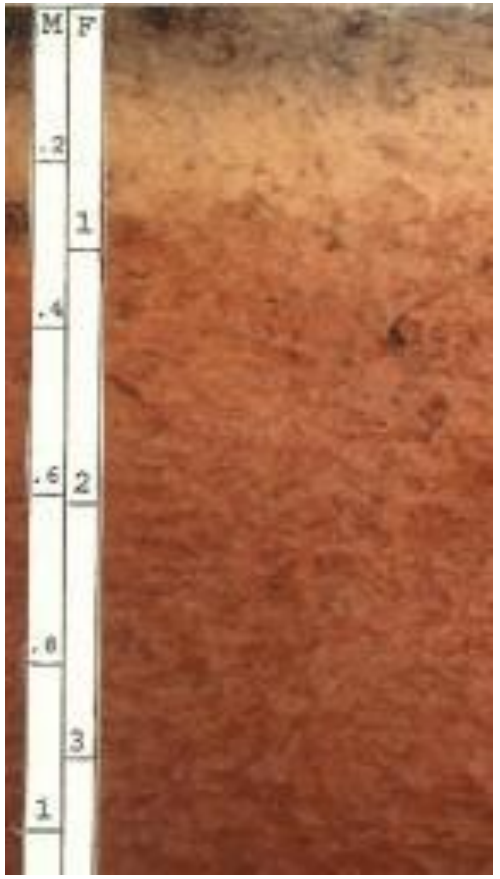
3. Alfisol

- distinguished by a subsurface clay horizon and a medium-to-generous supply of plant nutrients and water.
- Plant leaves are broken down faster, so the O horizon is minimal. There is some mixing with the A horizon below, giving rise to a moderate A horizon.
- Since these are in reasonably wet areas, the E horizon loses a lot of clay, and the B horizon accumulates clay.
- There is no red horizon (bleached)
- Most wide ranging of the mature soils.
- Rank only second to Mollisols in agricultural productivity.

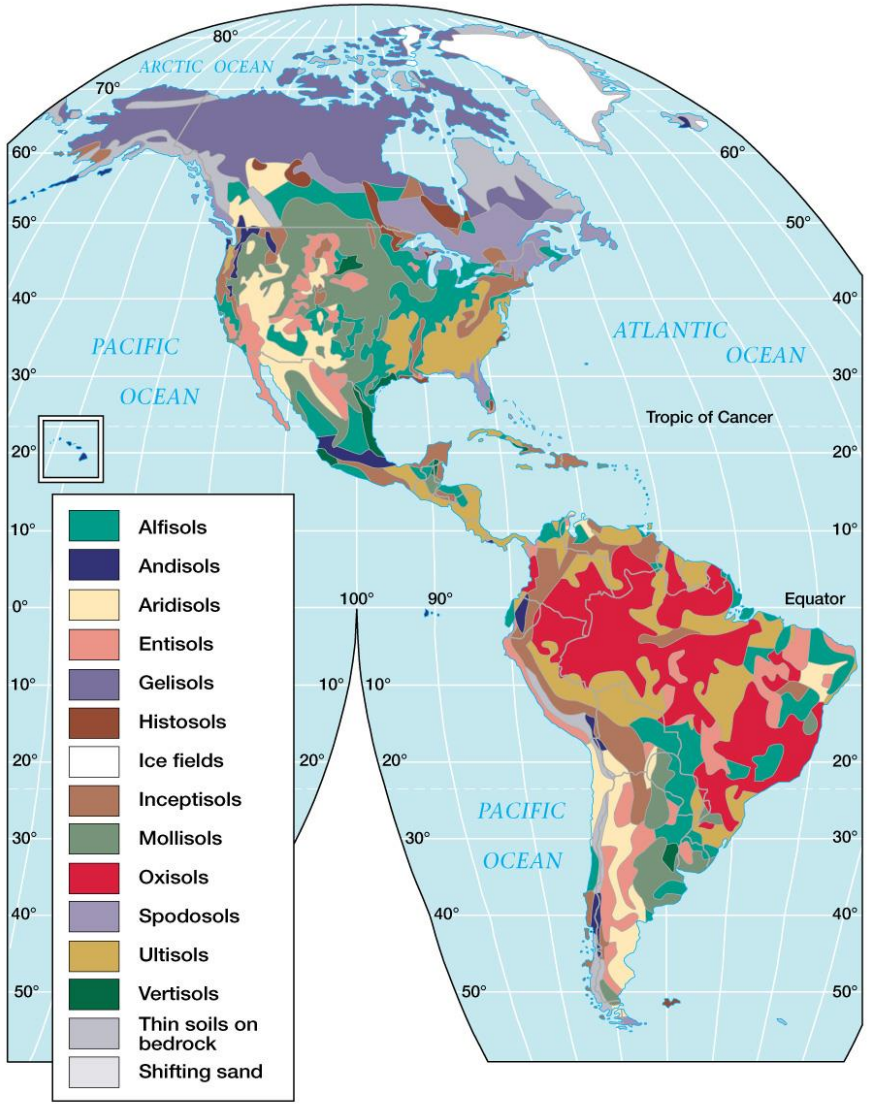
Transect Through Eastern North America: From High Latitude (Arctic) to the Gulf Coast

4. Ultisol

- **a soil order similar to Alfisols, but more thoroughly weathered and more completely leached– older than Alfisols**
- Has relatively low fertility in these deeper soils
- You need to dig 2-3 times deeper to get through to the E and B horizons (E and B are usually reddish)
- Less fertile than the Alfisols because of their age and high weathering.



Transect From Northeast United States to Southeast United States



Transect From Northeast United States to Southeast United States

1. **Mollisols (dark soft soils of grasslands)**
   - **Mollisols are among the most fertile soils on the Earth.**
   - **Born under grassland vegetation, these soils are well-known for their dark brown to black organic rich surface layers**. The O horizon is broken down rapidly by organisms giving rise to a deep and dark A horizon.
   - You have some clay moving into the E and B horizons
   - These soils have a granular structure and soft consistency when dry. Mollisols are rich in calcium and others nutrients, and generally posses high moisture retention.
   - Calcium nodules are found near the base of the soil as calcium carbonate precipitates out of soil water.
   - Mollisols are found in the drier portions of the humid continental climate through the steppe
   - Probably the most productive soil order.

Transect From Northeast United States to Southeast United States

2. Aridisols (dry soils)

•**occupying dry environments that do not have enough water to remove soluble minerals from the soil** e.g. Arizona and the Sub-Tropical desert areas.

•typified by a thin profile that is sandy and lacking in organic matter.

•Not much vegetation cover, so these soils are poorly developed as there is not much organic matter and water to add materials and move materials.

•May have a small A horizon.

•Is one of the most extensive spreads of any soil order, covering nearly one-eighth of Earth's land surface.

•Soils do support some amount of grass, and are used for grazing, can be useful if irrigation is well planned.

Tropical Soils

1. **Ultisols** (clay accumulation with low bases) – we discussed this earlier
2. **Oxisols:**
   - Found in warm, rainy climates under broadleaf, evergreen vegetation like that found in the rain forest.
   - Chemical weathering (especially oxidation) in the presence of warm temperatures combined with heavy rainfall creates a soil rich in iron and aluminum oxides called "sesquioxides".
   - A rich diversity of decomposers, rapid uptake by vegetation, and heavy precipitation quickly removes nutrients from the soil.
   - Biocycling is key to maintaining plant life on these soils.
   - Deep, nutrient poor soil, not well-suited for agriculture.
   - Cleared of vegetation, the exposed surface is easily eroded and become impoverised.

Non-Regional Soils

1. **Vertisols (swelling and cracking clays)**

- a specialized type of soil that contains a large quantity of clay and has an exceptional capacity for absorbing water
- An alternation of wetting and drying (therefore requires wet and dry seasons), expansion and contraction, produces a churning effect that mixes the soil constituents, inhibits the development of horizons, and may even cause minor irregularities in the surface of the land
- Parent materials are called smectite clays. The solid particles of these absorb water into their structure and swell
- During rainy season they expand, dry season they shrink, these opening allows soil particles from the top to mixed with the bottom
- This mixing is vertical, hence the name ***vertisol.***

Non-Regional Soils

2. Entisols (very little profile development) – young soils

•the least developed of all soil orders, with little mineral alteration and well developed horizons.

•These soils are commonly thin and/or sandy and have limited productivity, although those developed on recent alluvial deposits tend to be quite fertile.

3. Histosols (organic soils)

- characterized by organic, rather than mineral, soils, which is invariably saturated with water all or most of the time.
- Considered least important of soil orders; occupy smallest fraction of Earth's land surface.
- These are therefore our wetland soils.
- High accumulation of Organic Matter, also referred to as ***Peat***.
- Burnt for fuel in some parts of the world.

Carbon sequestration

The Department of Energy (2006) refers to carbon sequestration as:

"...***the provision of long-term storage of carbon in the terrestrial biosphere, underground, or the oceans so that the buildup of CO2 (the principal GHG) concentration in the atmosphere will reduce or slow***."

Soil Carbon sequestration:

improves soil health, increased climate resilience, reduced fertilizer use.

saturation, reversibility, difficulty of measurement.