APES CHAPTER 8 NOTES (MRS. BAUCK): EARTH SYSTEMS – SOIL

MODULE 24: Mineral Resources and Geology

I. Geologic Time Scale and Earth Structure

A. geologic time scale – know general layout

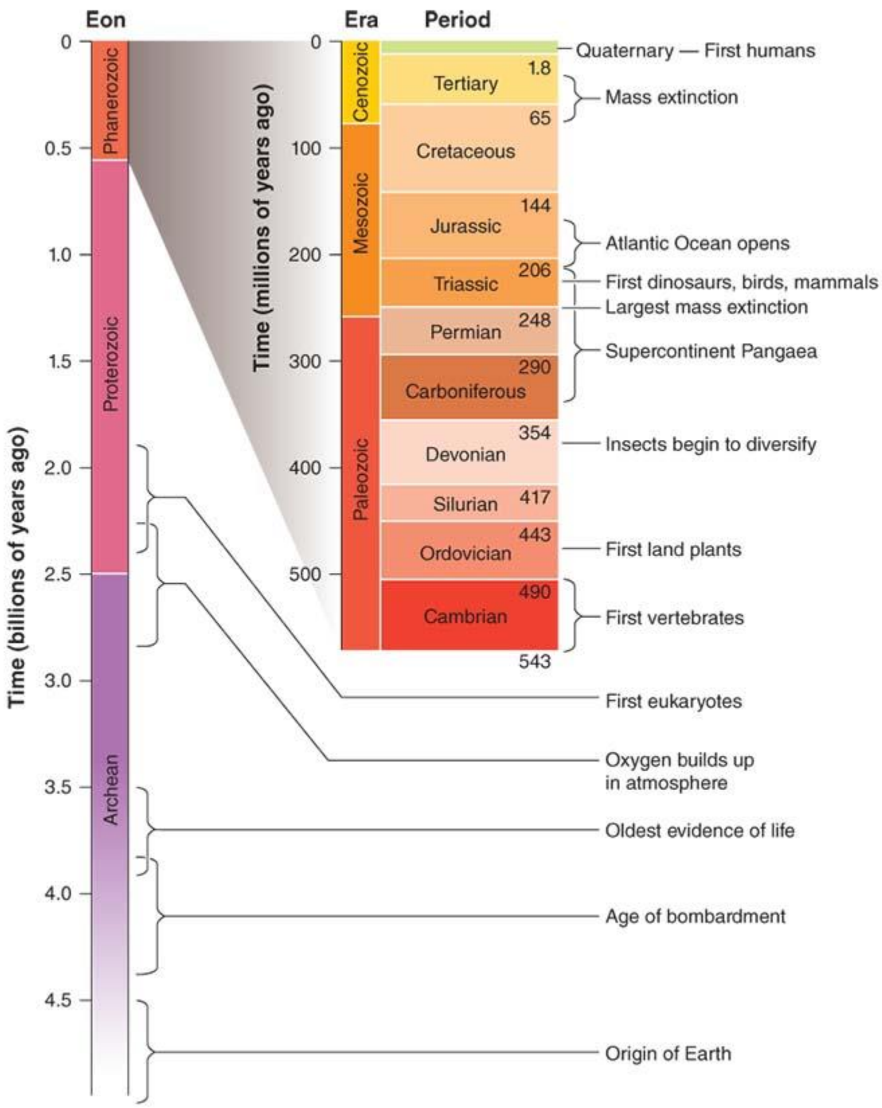


Figure 24.1
Environmental Science for AP®, Second Edition
© 2015 W.H. Freeman and Company

B. Earth's Structure and related terms

1) review terms: **core** (inner and outer), **crust**, **lithosphere**, **mantle**
2) **asthenosphere**—*semi-molten lower mantle*
3) **hot spot**—*area where molten rock from the mantle reaches the lithosphere*

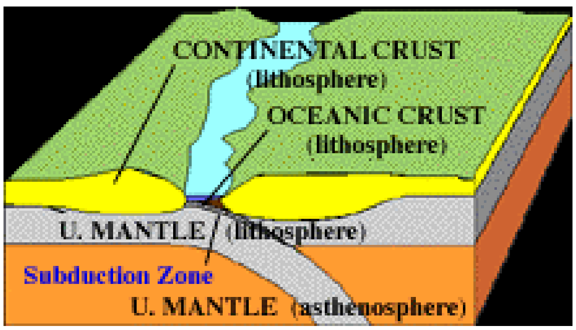
II. Plate tectonics

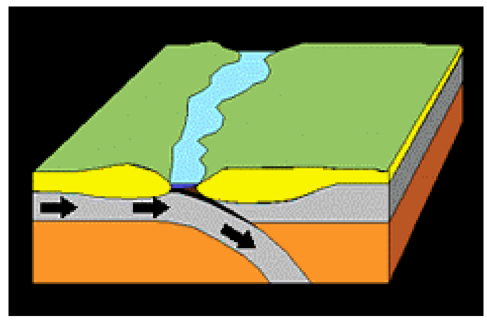
A. general info

1) theory of **plate tectonics**—*the lithosphere is divided into plates, most of which are constantly moving* (major plates, minor plates, microplates)
2) **tectonic cycle**—*sum of processes that build up and tear down the lithosphere*

B. types of plate boundaries

1) **divergent plate boundary**—*plates moving apart*
   a) caused by tensional stress
   b) creates a *normal fault* (**fault**—*fracture in rock due to movement in crust*)
   c) seen in **sea floor spreading**
2) **convergent plate boundary**—*plates moving together*
   a) caused by compressional stress
   b) creates a *reverse fault*
   c) causes mountains and **subduction** (*rock forced underneath and re-melted*)





Source: geocraft.com

3) **transform plate boundary**—*plates slide past each other*
   a) caused by shear stress
   b) creates a *transform fault*

C. **earthquake**—*sudden fault movement causing vibrations at the earth's surface*

1) potential → kinetic energy
2) **epicenter**—*the point on the surface directly above the deep rupture*
3) **Richter scale**—*logarithmic scale; measurement of maximum ground movement*

largest earthquakes in the world: https://earthquake.usgs.gov/earthquakes/browse/largest-world.php

D. volcanoes

1) involve geologic activity: 85% occur along plate boundaries
2) types of cones
   a) shield cone—large, gentle slope, somewhat flat
   b) spatter cone—chunky, irregular surface
   c) composite cone—alternating layers of ash, magma, rock pieces
   d) lava dome (not a true cone)— a magma bulge under the surface

deadliest volcanic eruptions: https://www.usgs.gov/faqs/which-volcanic-eruptions-were-deadliest?qt-news_science_products=0#qt-news_science_products

III. Rocks http://kwanga.net/apesnotes/rock-pics.pdf

A. **Igneous rocks** (“*fire-formed*”)—*from hardened magma and lava*

1) categories
   a) **intrusive**—coarse-grained igneous rocks *below* the surface
   b) **extrusive—**fine-grained igneous rocks *above* the surface
2) composition
   a) granite family—thick felsic magma; feldspar and quartz; light color
   b) basalt family—thin mafic magma; iron and magnesium; dark color
   c) diorite family—little or no quartz
3) igneous rock structures
   a) *intrusions—underground rock formations*
      - batholith—largest; makes up some mountain cores
      - stock—smaller batholith
      - laccolith— arc shapes
      - sill—hardened magma layer in between rock layers
      - dike—vertical magma channels
   b) *extrusions—above-ground rock formations*
      - volcano—extrusive cone formed around a vent
      - volcanic neck—solidified central vent
      - lava flows—flat rock formations
      - lava plateau—lava flow from long large cracks
4) **fracture**—a break in a rock as it cools
5) examples: granite, obsidian, basalt, pumice, rhyolite

B. **Sedimentary rocks** (“settling”)—from **sediment,** being *compacted* and *cemented*

1) background info
   a) *compaction*—weight pressing the pieces together
   b) *cementation*— minerals gluing the pieces together
   c) *types of sediment: sand, silt, clay, gravel, bone chips, pieces of shells, etc.*
2) formation
   a) *clastic—from sediment compaction and cementation*
      - gravel group
        - breccia—made of sharp pierces
        - conglomerate—made of round pebble pieces
      - sand grain group**--** sandstone
      - clay particle group**--** shale
   b) *chemical—from water-soluble minerals*
      - *dissolving* materials in water, precipitation at different temperatures
      - “evaporites”—from evaporation of water, leaving the solids
   c) *organic—from plant or animal remains (coal, limestone)*
3) features
   a) *stratification—layering* of different sediments
   b) ripple marks—wind and water action on sand
   c) mud cracks—shrinking and drying of mud
   d) *fossils*—ancient plant or animal remains
   e) concretions—“nodules” of different composition within the rock (geodes)
4) examples: sandstone, shale, conglomerate, chert, limestone, gypsum

C. **Metamorphic rocks** ("changed form")—*from temperature and pressure extremes, and chemical change*

1) formation
   a) **metamorphism**—a change in rock
   b) *contact metamorphism*—affects a small area; local heating
   c) *regional metamorphism*—affects a large area; tectonics
2) classification
   a) *foliation*
      - visible banding (stripes); from pressure or mineral
      - separation; some can break into sheets
   b) *unfoliated*—no banding
3) examples: marble, slate, quartzite, schist, gneiss

MODULE 25: Weathering and Soil Science

I. Weathering, Erosion, and Deposition – recycling of elements

A. **weathering**— *breaking up of the crust; the wearing down of rock*, liberating the minerals within
   - **physical (mechanical) weathering—***from wind, water, weather, or other environmental events*
      - **leaching**—*water washing away soluble materials from the soil*
   - **chemical weathering—***from chemical reactions between water and atmospheric gases and bedrock*
   - **biological weathering—***from activities of organisms*

B. **erosion**—*movement of weathered particles (usually by wind and running water, sometimes by glaciation)*
   - *splash erosion*—from raindrops
   - *sheet erosion*—from heavier water flow and runoff
   - *gully erosion*—from stream flow

C. **deposition**—*material is laid to rest (deposited) in an area*

D. **desertification** issues
   - *the process of converting areas to deserts (drylands) by* **soil degradation**, *inhibiting or preventing plant growth*
   - *desert pavement* serves to protect the underlying soil from erosion, but when crushed by traffic, further erosion occurs

E. **acid deposition/precipitation** (more later) promotes chemical weathering
   - $pH = -\log [H+]$
   - *0-14 scale*
   - *acid* $pH < 7$ *neutral* $pH = 7$ *base* $pH > 7$
   - *soil pH close to neutral is optimal for most plants and animals*

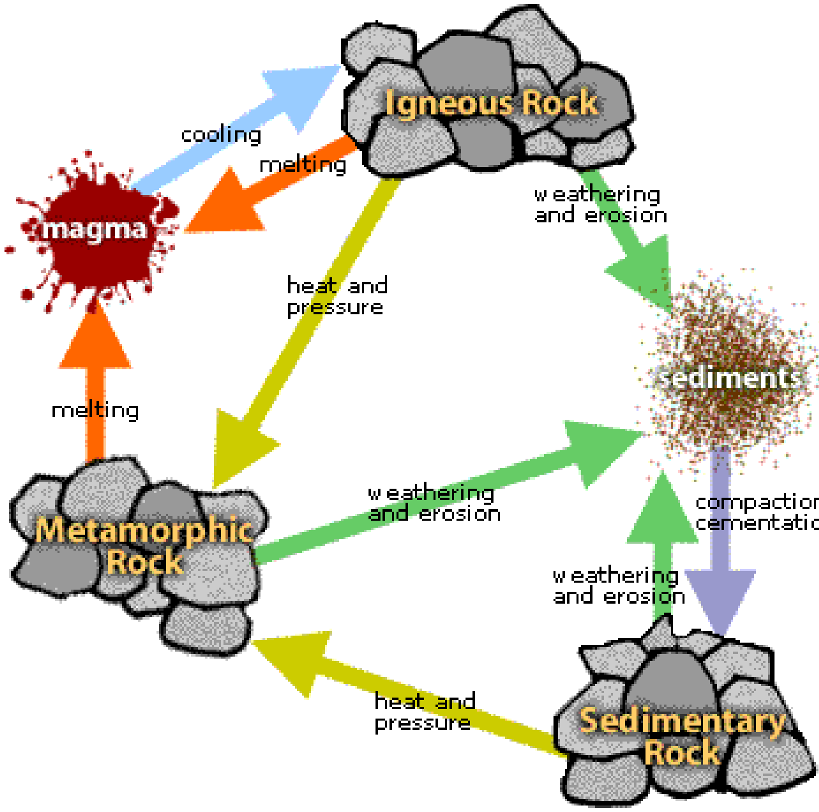
II. The Rock Cycle

A. **rock cycle**—changes in rock forms, from one type to another type

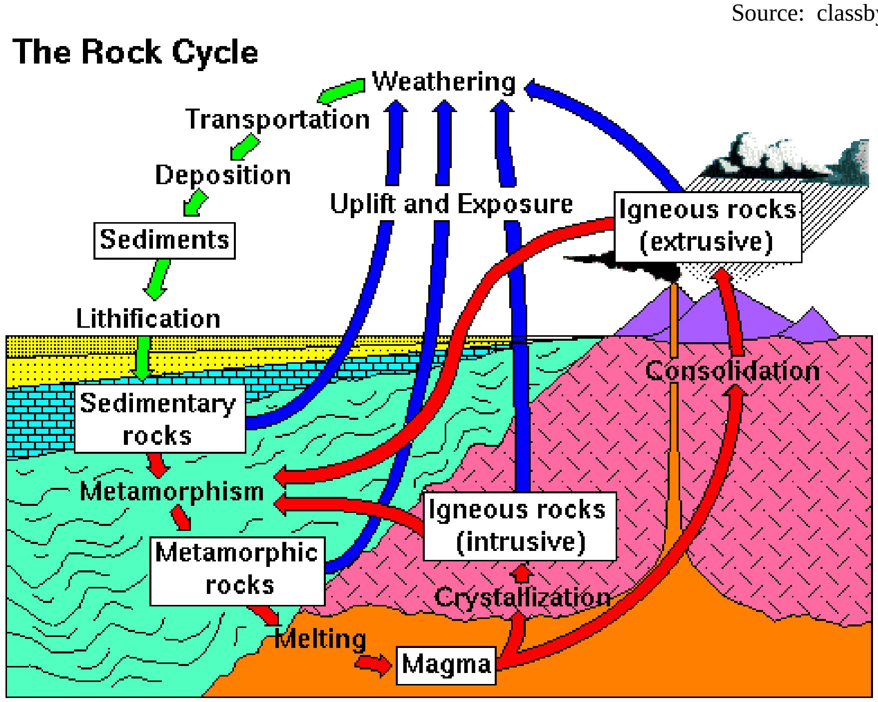
B. summary of processes
   1) formation of *igneous* rock
      a) melting and cooling any existing rock
      b) hardening of magma or lava
   2) formation of *sedimentary* rock: weathering and erosion to form sediment;

compaction and cementation

4) formation of *metamorphic* rock: heating and pressurizing any existing rock



Source: classbythehill



Source: washington.edu

III. Soil: a detritus-based ecosystem

A. factors affecting soil formation

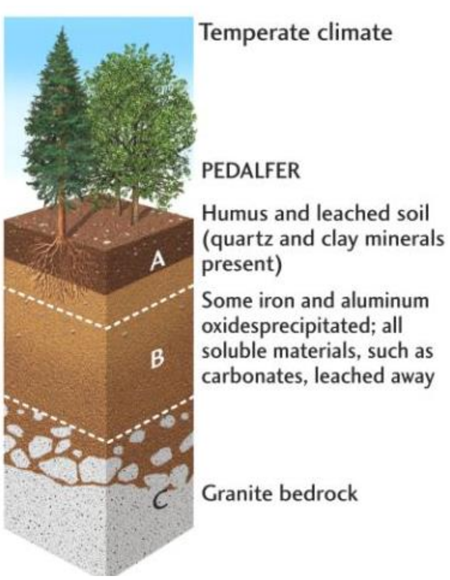
- climate—higher temps and humidity are favorable; also affected by types of decomposing vegetation
- time
- biotic factors
- topography—layout of the land

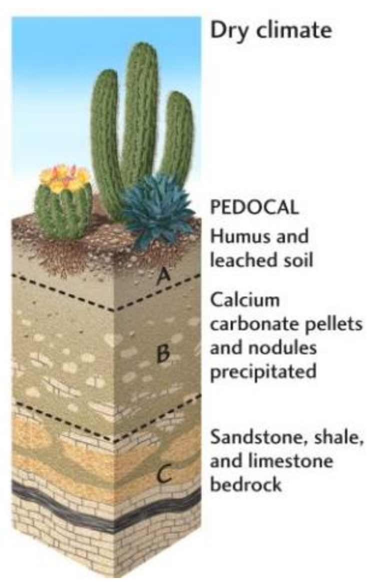
B. soil horizons

- **horizons**—*horizontal soil layers*
- **soil profile**—*vertical "slices" through soil layers*

SOIL PROFILE (some from www.seafriends.org)

Horizon	Description of detailed soil horizons
O	**surface; humus**—*consists mainly of organic matter from vegetation and decomposing animals, which accumulates under conditions of free aeration. "Leaf litter" observed.*
A	**topsoil**—*horizon consisting mainly of weathered rock mixed with some humified (decomposed) organic matter and minerals*
E	**Zone of Leaching; mineral material**; *strongly eluviated (outwashed, leached) horizons having much less organic matter and/or iron and/or clay than the horizons underneath.* Usually pale colored and high in quartz. Leaching varies with the porosity and permeability of the layer.
B	**subsoil;** *illuvial (inwashed) horizon with concentrations in clay, iron, aluminum compounds such as Al_2O_3, or organic matter. Receives leached minerals from E.* **(**Some lime may accumulate, but if the accumulation is excessive, the horizon is named K. K horizon contains appreciable carbonate accumulation, usually lime or calcium carbonate $CaCO_3$. G "gleyed" or sticky clay horizons which form under reducing (anoxic) conditions with impede aeration, reflected in blue, green or grey colors).
C	**weathered parent material** lacking the properties of the solum (A & B horizons) and resembling more the fresh parent material (bedrock)
R	**bedrock; regolith**—the unconsolidated bedrock or parent material

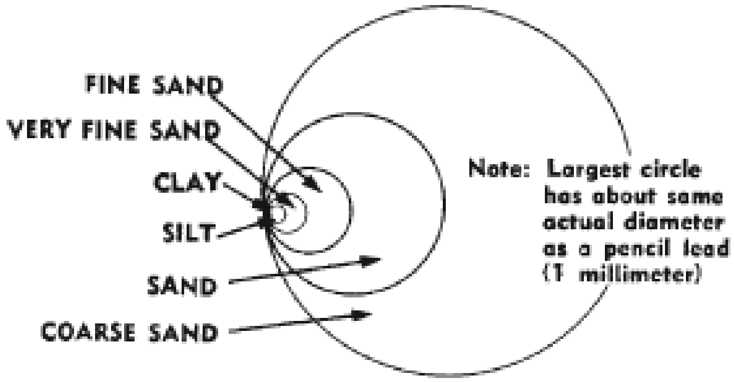




Source: FSU

C. **soil texture**—*classification based on particle size*

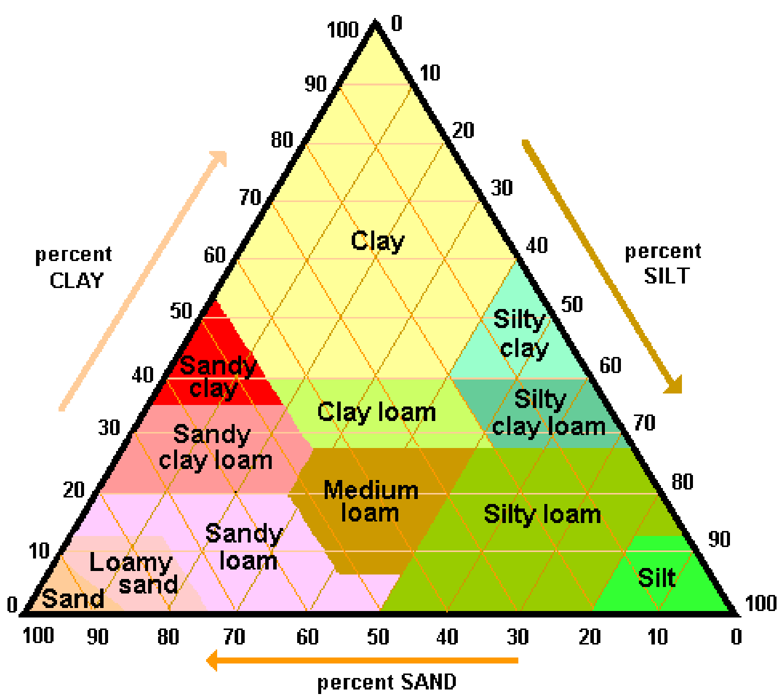
1) **soil separates**—*rock fragments of varying size*: **sand, silt, clay**

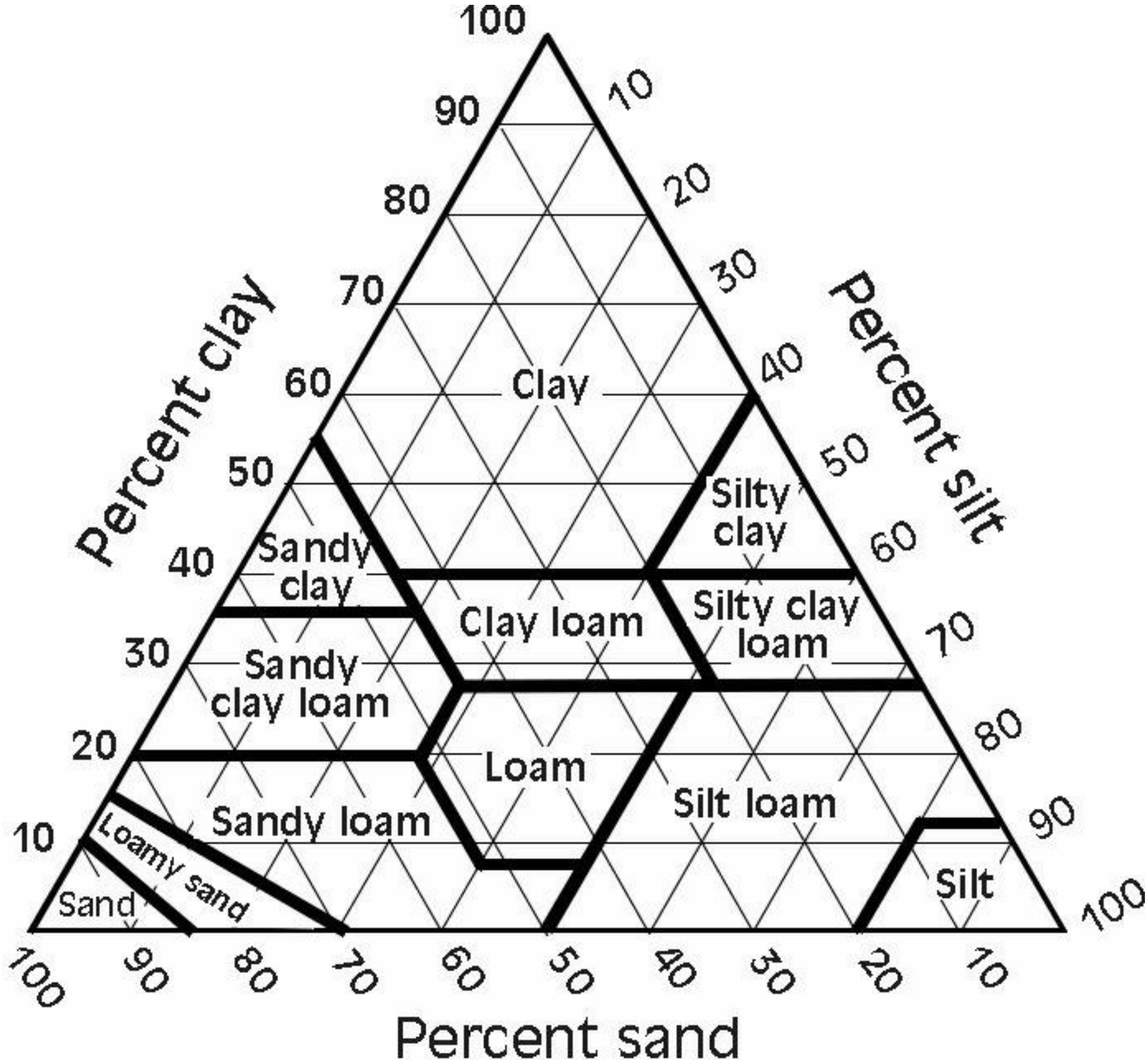


Size of sand, silt and clay particles	
Name	**Particle Diameter**
Very coarse sand	2.0 to 1.0 millimeters
Coarse sand	1.0 to 0.5 millimeters
Medium sand	0.5 to .25 millimeters
Fine sand	0.25 to 0.10 millimeters
Very fine sand	0.10 to 0.05 millimeters
Silt	0.05 to 0.002 millimeters
Clay	below 0.002 millimeters

2) **loam**—*common soil type: 40% sand, 40% silt, and 20% clay*

3) **soil triangle** or **soil texture triangle**—*diagram used to classify soil type*





Source: unl.edu

4) more on soil texture from the usda.gov

“When the organic matter content of a soil exceeds 20 to 35% (on a dry weight basis) it is considered organic soil material, and the soil is called an organic soil. As this material is mostly devoid of mineral soil material, they cannot be described in terms of soil texture. However, the following ‘in lieu of’ texture terms can be used to describe organic soils:

‘peat’; organic material in which the plant parts are still recognizable

‘muck’; highly decomposed organic material in which no plant parts are recognizable

‘mucky peat’; decomposition is intermediate between muck and peat.”

5) soil orders

THE 12 SOIL ORDERS from http://soils.ag.uidaho.edu
1. Gelisols - soils with permafrost within 2 m of the surface 2. Histosols - organic soils 3. Spodosols - acid forest soils with a subsurface accumulation of metal-humus complexes 4. Andisols - soils formed in volcanic ash 5. **Oxisols** - *small O horizon; not rich*; intensely weathered; tropical/subtropical environments 6. Vertisols - clayey soils with high shrink/swell capacity 7. **Aridisols** - $CaCO_3$-containing soils of arid environments with subsurface horizon development; *dryland/desert; not a well-developed profile* 8. Ultisols - strongly leached soils with a subsurface zone of clay accumulation and < 35% base saturation 9. **Mollisols** - *large A horizon, dark, rich; temperate grassland soil* 10. **Alfisols** - moderately leached soils with a subsurface zone of clay accumulation and > 35% base saturation; *well-developed horizons; can be good growing soil with supplements; temperate forest* 11. Inceptisols - soils with weakly developed subsurface horizons 12. Entisols - soils with little or no morphological development

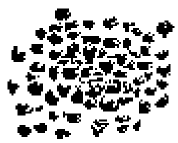
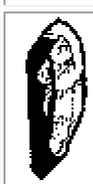
IV. Physical properties of soil

A. **color**, affected by the components in soil (Munsell soil color chart)
B. **soil horizons (horizonation)**
C. **porosity**—*measure of the amount of spaces between the particles in soil*
   - **compaction**—*pressing down; decreases pore space*
D. **permeability**—*the ease with which soil lets other substances pass through it*
   - **soil aeration**—*allowing gases to diffuse in and out of the soil*
E. **texture** – see inside of soil triangle for soil names
F. **consistence**—*how soil resists pressure* from usda.gov
   1) "loose – noncoherent when dry or moist; does not hold together in a mass
   2) friable – when moist, crushed easily under gentle pressure between thumb and forefinger and can be pressed together into a lump
   3) firm – when moist, crushed under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable
   4) plastic – when wet, readily deformed by moderate pressure but can be pressed into a lump; will form a 'wire' when rolled between thumb and forefinger
   5) sticky – when wet, adheres to other material and tends to stretch somewhat and pull apart rather than to pull free from other material
   6) soft – when dry, breaks into powder or individual grains under very slight pressure
   7) hard – when dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger
G. **bulk density** (D = M/V)
H. **capillary action**—*water moving upward in soil, against the force of gravity*
I. **water-holding capacity**—*the ability of soil to retain infiltrated water*
   - **transpiration**—*plants emitting water through their stomata*

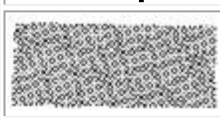
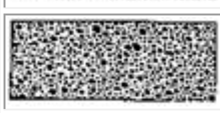
- **infiltration**—*water seeping into an area*
- *evaporative water loss—controlled by the O-horizon*

J. **structure—***the shape of peds and how they are arranged*

Types of Soil Structure from usda.gov

Graphic Example	Description of Structure Shape
	**Granular** – roughly spherical, like “grape nuts” cereal. Usually 1-10 mm in diameter. Most common in A horizons, where plant roots, microorganisms, and sticky products of organic matter decomposition bind soil grains into granular aggregates
	**Platy** – flat peds that lie horizontally in the soil. Platy structure can be found in A, B and C horizons. It commonly occurs in an A horizon as the result of compaction.
	**Blocky** – roughly cube-shaped, with more or less flat surfaces. If edges and corners remain sharp, we call it angular blocky. If they are rounded, we call it subangular blocky. Sizes commonly range from 5-50 mm across. Blocky structures are typical of B horizons, especially those with a high clay content. They form by repeated expansion and contraction of clay minerals.
	**Prismatic** – larger, vertically elongated blocks, often with five sides. Sizes are commonly 10-100mm across. Prismatic structures commonly occur in fragipans.
	**Columnar** – the units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns, in contrast to those of prisms, are very distinct and normally rounded.

"Structureless" Soil Types from usda.gov

Graphic Example	Description of Structure Shape
	**Massive** – compact, coherent soil not separated into peds of any kind. Massive structures in clayey soils usually have very small pores, slow permeability, and poor aeration.
	**Single grain** – in some very sandy soils, every grain acts independently, and there is no binding agent to hold the grains together into peds. Permeability is rapid, but fertility and water holding capacity are low.

V. Chemical properties of soil

A. **nutrient-holding capacity** (**ion-holding capacity**)— *how the soil can “hold on” to important ions (calcium, potassium, phosphate)*

B. **pH—***soil pH close to neutral is optimal for most plants and animals*

C. **ion content:** *oxide, silicon, aluminum, iron, magnesium, calcium, sodium, potassium, and others*

D. **CEC – cation exchange capacity**—*ability of soil to adsorb and release cations*

E. **base saturation** from purdue.edu

"Cations on the soil's exchange sites serve as a source of resupply for those in soil water which were removed by plant roots or lost through leaching. The higher the CEC, the more cations which can be supplied. This is called the soil's *buffer capacity*. *Cations can be classified as either acid-forming or base-forming. The common acidic cations are hydrogen and aluminum; common basic ones are calcium, magnesium, potassium and sodium.* The proportion of acids and bases on the CEC is called the *percent base saturation* and can be calculated as follows:"

$$\%\text{ base saturation} = \frac{\text{Total meq (milli-equivalent) of bases on exchange sites (i.e., meq soil base-forming ions}}{\text{cation exchange capacity}} \times 100$$

"The concept of base saturation is important, because the relative proportion of acids and bases on the exchange sites determines a soil's pH. As the number of Ca^{++} and Mg^{++}ions decreases and the number of H^{+} and Al^{+++} ions increases, the pH drops. Adding limestone replaces acidic hydrogen and aluminum cations with basic calcium and magnesium cations, which increases the base saturation and raises the pH."

VI. Biological Properties of Soil – the realm of the detritivores

A. fungi, bacteria, protozoans – 80-90% of soil organisms
B. earthworms
C. burrowing animals
D. snails, slugs

VII. Mineral resources (some info from Miller/Shlachtman)

A. naturally occurring material in or on the crust that can be extracted and processed into useful materials affordably
B. examples
   1) metallic mineral resource examples — iron, copper, aluminum
   2) nonmetallic mineral resource examples— salt, gypsum, clay, sand, phosphates, soil
C. **crustal abundance**—*average concentration of a specific element in the crust*
D. **ore**—a metal-yielding material that can be economically extracted
E. **reserves**—identified resources that can be extracted economically at current prices using current mining technology
F. **overburden**—soil and rock lying above shallow mineral deposits
G. **mining spoils** or **tailings**—waste material produced by mining
H. types of mining
   1) **surface mining** for *shallow mineral deposits*
      a) **strip mining**– overburden is removed in strips

- "**Area Strip Mining** – terrain is flat; overburden is stripped away and mineral deposit is removed by power shovels then trench is filled with overburden; Spoil Banks are left – wavy series of hills
- **Contour Strip Mining** – terrain is hilly / mountainous; terraces are cut into the side of the hill; overburden is removed and mineral is extracted. Overburden from each new terrace is dumped onto the one below. Highwall – a wall of dirt left in front of the highly erodible bank of soil and rock.
- Restoration is difficult and usually incomplete. Most surface mining in the U.S. is in arid and semiarid regions where soil and climate prevent full restoration. Damage to desert biomes is almost always permanent."

b) **open-pit mining**–large holes are dug to remove ore
c) **mountaintop removal** using explosives; valley receives waste material
d) **placer mining**—sorting through river sediments
e) **dredging**— chain buckets and draglines scrape up underwater mineral deposits

2) **subsurface mining**—*removal of ores too deep to be extracted by surface mining (*100+ m or 328 ft)
a) **room-and-pillar** (**pillar-and-stall**)—mined material is extracted across a horizontal plane, creating horizontal arrays of rooms and pillars. "Pillars" of untouched material are left to support the overburden, and then open areas or "rooms" are extracted underground.
b) **longwall mining—**a "long wall" of coal is mined in a single slice, ~0.6 – 1.0 m thick. The longwall panel (block of coal being mined) is ~1.8-2.5 mi long and ~0.16-0.25 mi wide.
c) issues
   - damages much less of the surface land but more dangerous and expensive than surface mining
   - mines can collapse, trapping and killing miners
   - dust explosions and natural gas
   - prolonged inhalation of mining dust causes lung disease