Soil Mineralogy

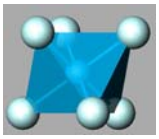
- Primary minerals—
  - inherited from parent material
  - igneous and metamorphic
  - sand and silt fraction (mostly)
- Secondary minerals—
  - formed under “normal” temperature and pressure
  - formed in the soil environment or inherited from sedimentary parent material
  - clay fraction (mostly)

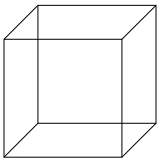
Pauling Rules

- 1. A coordinating polyhedron of anions is found about each cation, the cation-anion distance being determined by the radius sum and the coordination number of the cation by the radius ratio.
- 2. In a stable coordination structure, the total strength of the valency bonds that reach an anion from all the neighboring cations is equal to the charge of the anion.

Coordination Environment

- Tetrahedral
- Octahedral
- Cubic
- Dodecahedral





Radius ratio

- Tetrahedral (4): 0.225-0.414
  - Si^{4+}, Al^{3+}
- Octahedral (6): 0.414-0.732
  - Fe^{3+}, Mg^{2+}, Ti^{4+}, Fe^{2+}, Mn^{2+}, Na^{+}, Ca^{2+}
- Si^{4+} = 0.042 nm, O^{2-} = 0.140 nm
  - ratio = 0.300
- Al^{3+} = 0.051 nm, ratio = 0.364
- Mg^{2+} = 0.066, ratio = 0.471

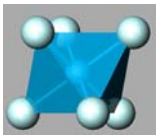
More Pauling Rules

- 3. The existence of edges, and particularly faces, common to two anion polyhedra in a coordinated structure decreases its stability; this effect is large for cations with high valency and small coordination number.
- 4. In a crystal containing different cations, those of high valency and small coordination number tend not to share polyhedron elements with each other.
- 5. The number of essentially different kinds of constituents in a crystal tends to be small.

What does this mean?

- Sharing edges or faces brings the cations closer together and causes repulsion
- Cations such as P^{5+} will not form minerals that share any O (in nature).
- The most stable Si minerals share all the corner O but no edges or faces (quartz).
- Different cations force different geometry and result in less stable minerals.

Building Blocks

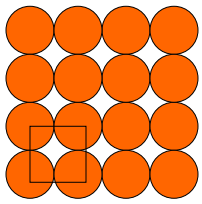
- Si tetrahedra and Al octahedra are the basic building blocks of the clay minerals.
- http://virtual-museum.soils.wisc.edu/

Types of silicate minerals

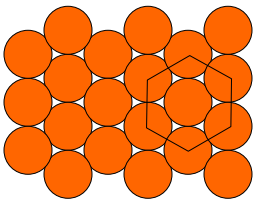
- The different minerals are a results of differences in the sharing of O and the presence or absence of different cations.
- Range from no sharing (nesosilicates) to sharing of each O with 2 Si (tectosilicates)
- Zeolites are an interesting form of tectosilicates.

Basic Structural Concepts

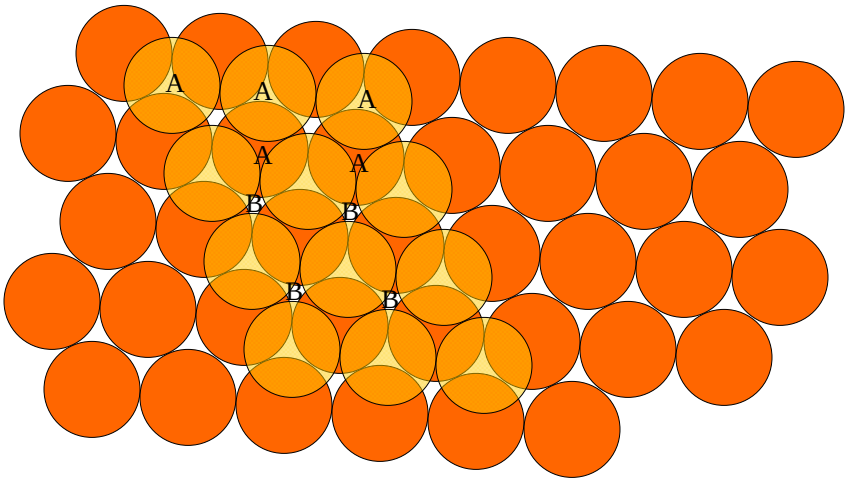
- Cubic Close Packing (CCP).



- Hexagonal Close Packing (HCP).

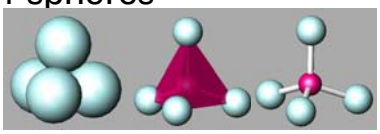


HCP

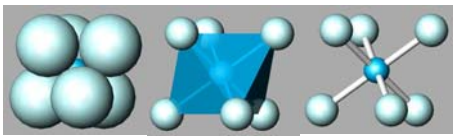


HCP

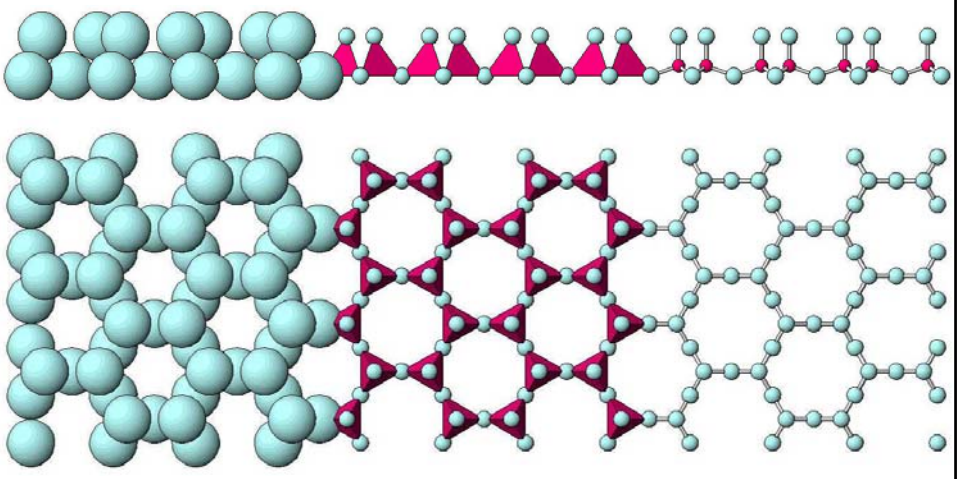
- Two types of voids:
  - A - void constrained by 4 spheres
    - Tetrahedral coordination



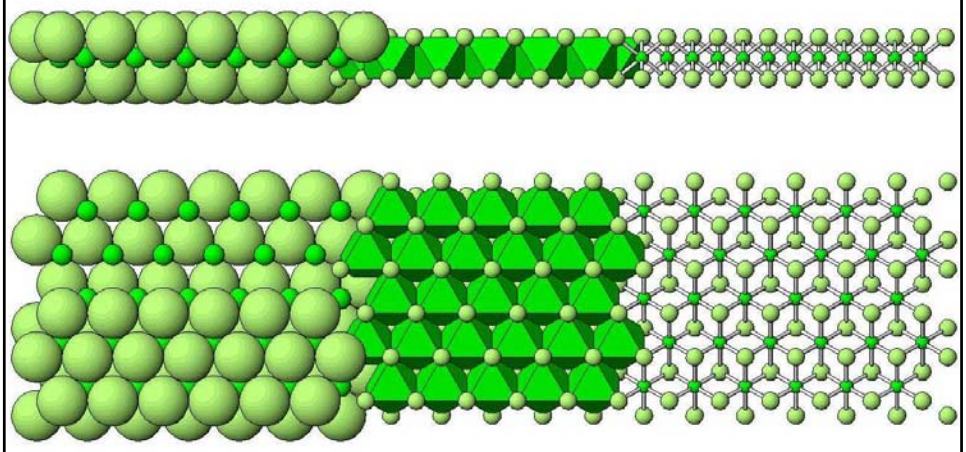
  - B - void constrained by 6 spheres
    - Octahedral coordination



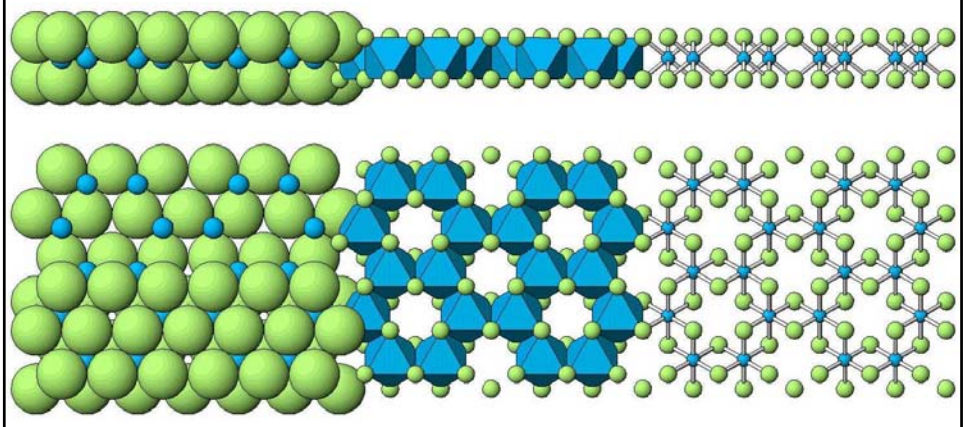
Tetrahedral Sheet



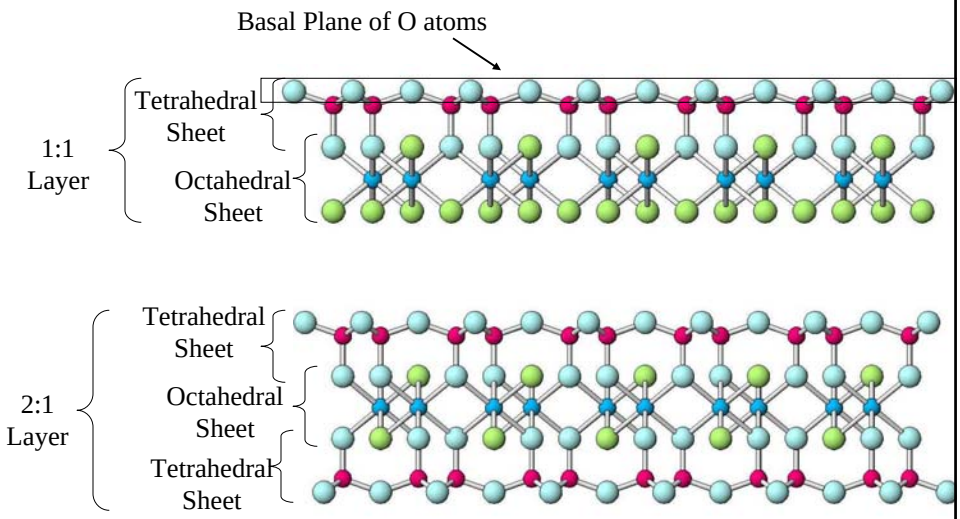
Trioctahedral Sheet



Dioctahedral Sheet



Terminology



Classification of Clay Minerals

- Layer Silicates (phyllosilicates)
  - Number of octahedral and tetrahedral sheets (1:1, 2:1, 2:1:1).
  - Type of octahedral sheet (dioctahedral or trioctahedral).
  - Type, extent, and location of isomorphous substitution
- Oxides, hydroxides, and oxyhydroxides (Fe, Mn, Al)