

Silicate Minerals

Motivations for looking at silicate mineral groups in detail:

1. introduce major mineral groups (basis for later discussions)
2. need to know general formula (Si:O ratios) for major minerals and understanding structures will help (derive, not memorize). The Si:O ratio provides a key component in understanding why certain mineral groups occur in specific types of igneous rocks.
3. illustrate how some physical properties (e.g. cleavage) related to crystal structure

The basic building block (silica tetrahedron) can be combined into larger structures by a process known as *polymerization* (= sharing oxygens between tetrahedra, polyhedra are just as strong). One or more oxygen ions at the apices of the tetrahedra (faces or edges of tetrahedra are never shared) are shared between adjacent silica tetrahedra.

1) Nesosilicates (island)

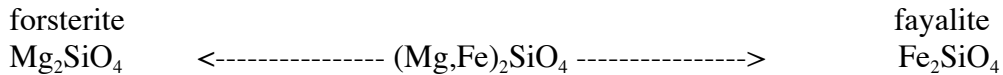
also called orthosilicates

no tetrahedral oxygens shared so $(SiO_4)^{4-}$ is basis with charge -4

general formula: X_2SiO_4 where X is a divalent cation

includes: *olivine*, *garnet* (mantle phases), *aluminosilicates* (e.g. kyanite)

e.g. olivine



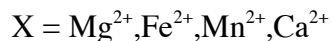
$Fe^{2+} = 0.074$ $RR = 0.56$ so in 6-fold (octahedral) coordination
 $Mg^{2+} = 0.066$

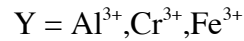
solid solution: ions with similar radii and charge tend to substitute in structure
 continuous variation in properties.

Fo content, introduce shorthand for solid solution composition

illustrate structure

Fe, Mg not particularly systematically distributed >> *fracture equidimensional crystals*





2) Sorosilicates (bow tie)

epidote

one shared oxygen so basis is 2:7 with charge of -6
illustrate structure

3) Cyclosilicates (ring)

2 shared oxygens so basis is multiples of 1:3 with charge of -2
simplest formula is 3:9

illustrate 3 tetrahedra ring

rare: example is benitoite $\text{BaTiSi}_3\text{O}_9$

crystal structure >> trigonal

San Benito County, CA (blue gemstone)

most are higher multiples

e.g. *beryl* ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) $3*2 + 2*3 + 6*4 = 18*2$

Be and Al occur between rings

varieties: *emerald* (deep green)

ring structure >> hexagonal habit

e.g. *tourmaline*

complex B cyclosilicate

hexagonal form

look at in lab, see on field trip

4) Inosilicates (chain silicates)

two types of chains

single chains: *pyroxenes*

two shared oxygens so basis is 1:3

more commonly written as 2: 6

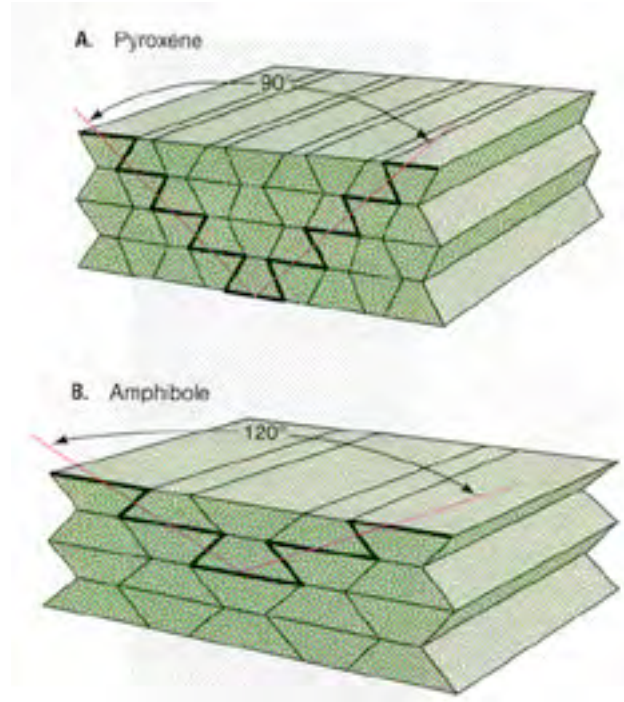
illustrate structure

general formula: $\text{XY Si}_2\text{O}_6$

X site $\text{Ca}^{2+}, \text{Fe}^{2+}, \text{Mg}^{2+}, \text{Na}^+$ in 8-fold coordination

Y site $\text{Mg}^{2+}, \text{Fe}^{2+} [\text{Ti}, \text{Cr}, \text{Al}]$ in 6-fold coordination

illustrate relationship to cleavage directions



double chains: *amphiboles*
 alternate tetrahedra share 2 and 3 oxygens
 basis is 4:11

illustrate structure

general formula: $W_{0-1} X_2 Y_5 Si_8 O_{22} (OH, F)_2$

relationship to cleavage directions

pyroxene - generally shorter, prismatic crystals
 amphibole - generally long, prismatic crystals

5) Phyllosilicates (Greek *phyllos* - leaf)

sheets of tetrahedra so basis is 2:5
 three shared oxygen
 OH- in middle of tetrahedral rings

tetrahedral sheets joined to octahedral sheets

1. brucite $Mg(OH)_2$ - all sites
2. gibbsite $Al(OH)_3$ = two thirds filled

stacking of tetrahedral and octahedral layers
sheets held together by van der Waals forces >> basal cleavage

illustrate structure

muscovite: $K_2Al_4[Si_6Al_2O_{20}](OH)_4$

biotite: Fe, Mg, Al

6) Tectosilicates

all oxygens mutually shared

so basis is 1:2

make up 3/4 of earth's crust (Q, feldspars)

quartz polymorphs

P effect and T effect

feldspars

general formula XY_4O_8

X = Na, Ca, K

Y = Si, Al

two solid solution series

plagioclase series: albite ($NaAlSi_3O_8$) to anorthite ($CaAl_2Si_2O_8$)

alkali series: orthoclase ($KAlSi_3O_8$) to albite

ternary diagram - introduce how to plot on a ternary diagram

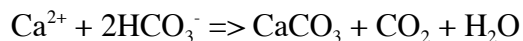
Important non-silicate mineral groups

There are a number of other important mineral groups that are not silicate minerals. Of these the most important are:

Carbonates

calcite (aragonite) - polymorphs of $CaCO_3$

common in marine environments (often aided by biological activity)



what is the likely source of Ca^{2+} ?

bicarbonate is the 3rd most abundant anion in seawater (99.9% salinity from 9 constituents - Cl, Na, SO_4 , Mg, Ca, K, HCO_3 , Br, Sr)

dolomite ($\text{CaMg}(\text{CO}_3)_2$)

Phosphates

apatite ($\text{Ca}_5(\text{PO}_4)_3(\text{F},\text{OH})$)

most abundant phosphate mineral (oxygen minimum)
also in bones, teeth

Sulfates

gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

Halides

Origin of evaporites (e.g. Mediterranean)

Tectonics and ore minerals

One final important group of minerals is the ore minerals. While some (e.g., magnetite) are relatively abundant in rocks, many elements are exceedingly rare. How are these rare elements concentrated into useful quantities?

Example of Pt. Used in catalytic converters (reduce unburned hydrocarbons to CO_2). Average crustal abundance of Pt is 5 ppb. Economical quantities of PGEs found in sulfide deposits in large magma chambers, where PGEs are efficiently scavenged (*compatible* elements in sulfides). Present cost of Pt (\$885/oz).

So major mechanisms of concentrations of rare elements are 1) magmatic processes e.g. by crystal settling (chromites) or in pegmatites and 2) hot hydrothermal fluids.