

# **Silicate Structures**

The building blocks of the  
common rock-forming  
minerals

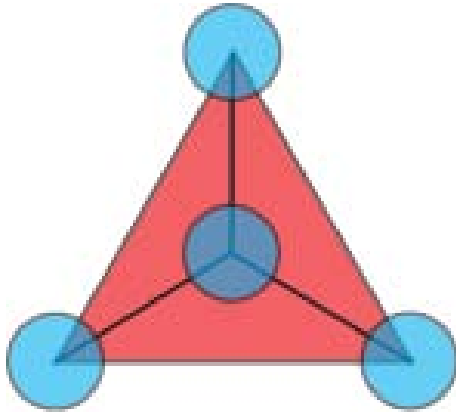
# Mineral classes and the silicates

There are a total of 78 mineral classes

27 of these are the silicates which constitute  
~92% of the Earth's crust

Because the  $\text{SiO}_4$  is not electronically neutral  
( $\text{Si}^{4+} + 4(\text{O})^{2-} = -8$ ) it tends to combine with  
other elements to make a neutral species

**Silicates are compounds where Si and O are abundant and are major mineral components of the earth's crust and mantle**



The basic unit for all silicates is the  $(\text{SiO}_4)^{4-}$  tetrahedron.

The variety of silicate minerals is produced by the  $(\text{SiO}_4)^{4-}$  tetrahedra linking to self-similar units sharing one, two, three, or all four corner oxygens of the tetrahedron.

We will begin with those silicate structure that are completely linked and move toward the less ordered structures that are ***depolymerized***

Quartz and the Feldspars are some of the most common ***framework*** silicates: ratio of Si to O is 1:2



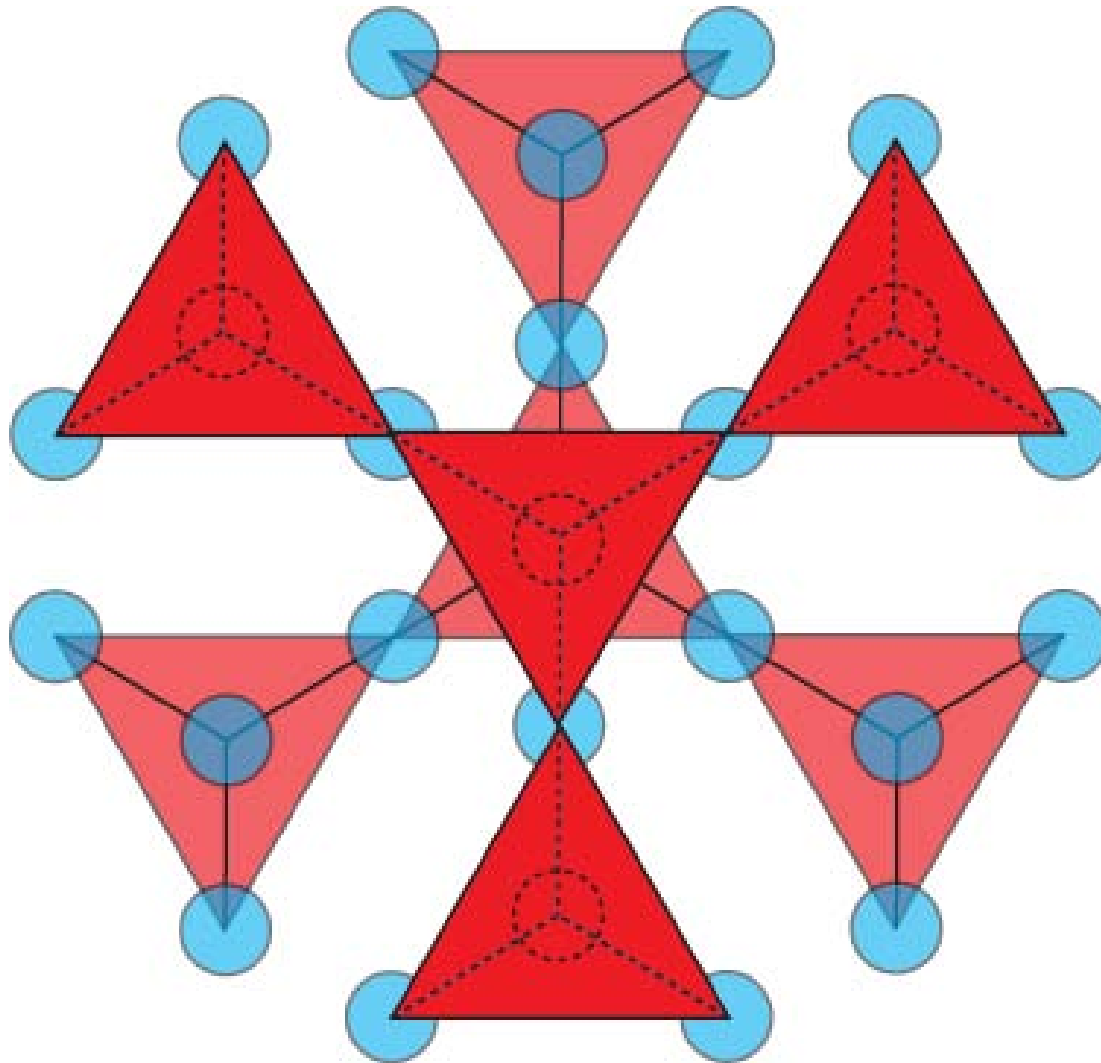
# Tectosilicates – (Framework Silicates)

Infinite 3-dimensional network of  $(\text{SiO}_4)^{4-}$   
or  $(\text{Si}_3\text{Al})\text{O}_8^{1-}$  -  $(\text{Si}_2\text{Al}_2)\text{O}_8^{2-}$   
building blocks

All oxygen atoms are shared between  
two  $\text{SiO}_4^{4-}$  tetrahedron.

Quartz is useful as a source of Si and for silica. It is used in electronics as an oscillator, and is pizelectric.

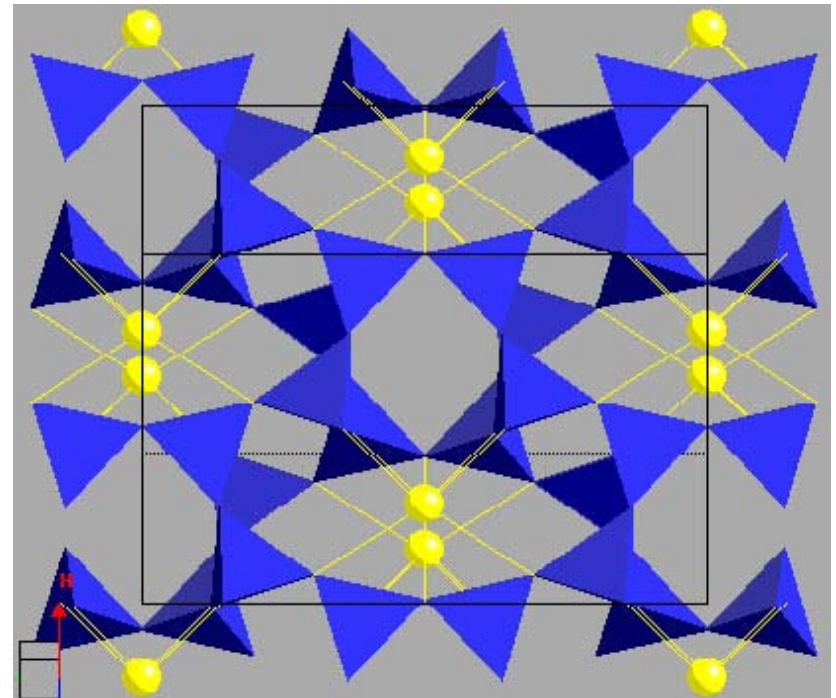
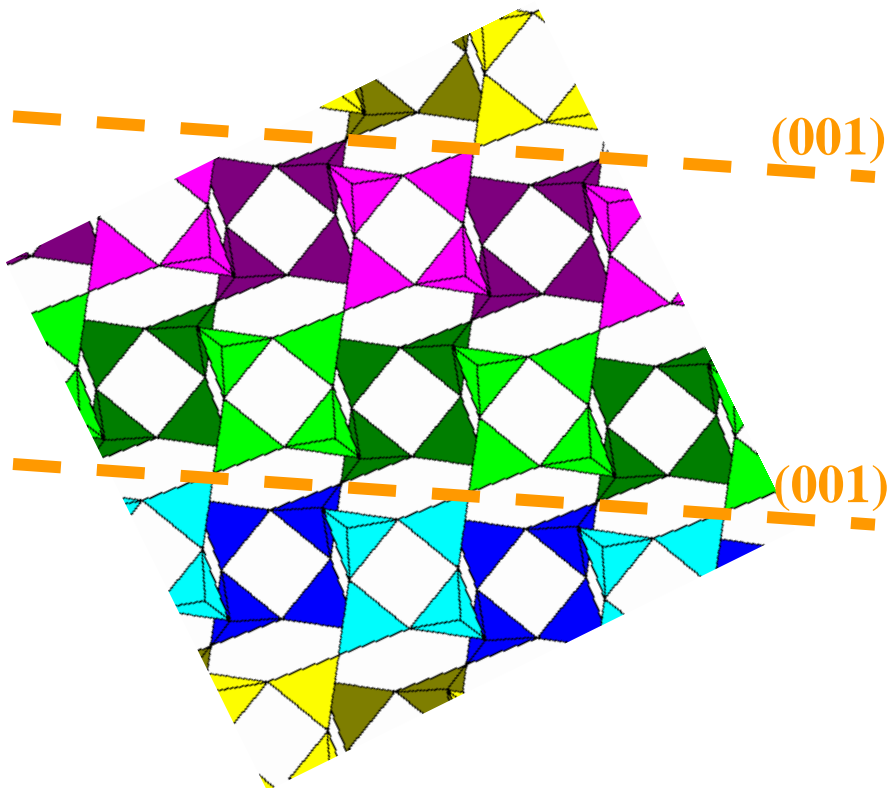
(SiO<sub>2</sub>)  
Infinite tetrahedral network



The structure of feldspar is similar to that of the  $\text{SiO}_2$  polymorphs, consisting of an infinite network of tetrahedra inter-connected via bridging oxygen atoms.

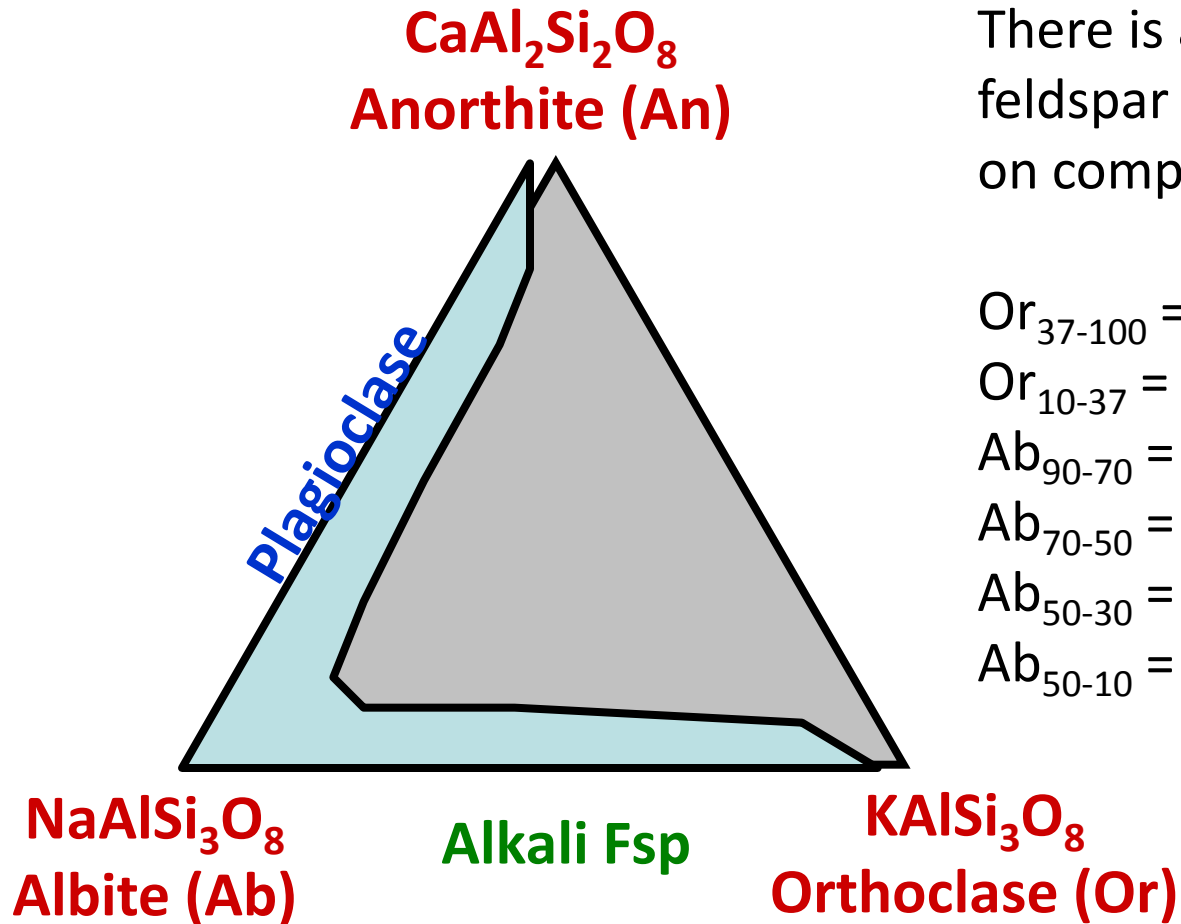
In contrast to the  $\text{SiO}_2$  group, the tetrahedra may be  $\text{AlO}_4$  as well as  $\text{SiO}_4$ .

Minerals are rendered *electrically neutral* as a result of being “stuffed” with alkali or alkali-earth element cations in available voids.



# Feldspar Group

Feldspars are the most common silicates in the Earth's Crust.



There is an “old” system for feldspar nomenclature, based on composition.

Or<sub>37-100</sub> = Sanidine

Or<sub>10-37</sub> = Anorthoclase

Ab<sub>90-70</sub> = Oligoclase

Ab<sub>70-50</sub> = Andesine

Ab<sub>50-30</sub> = Labradorite

Ab<sub>50-10</sub> = Bytownite

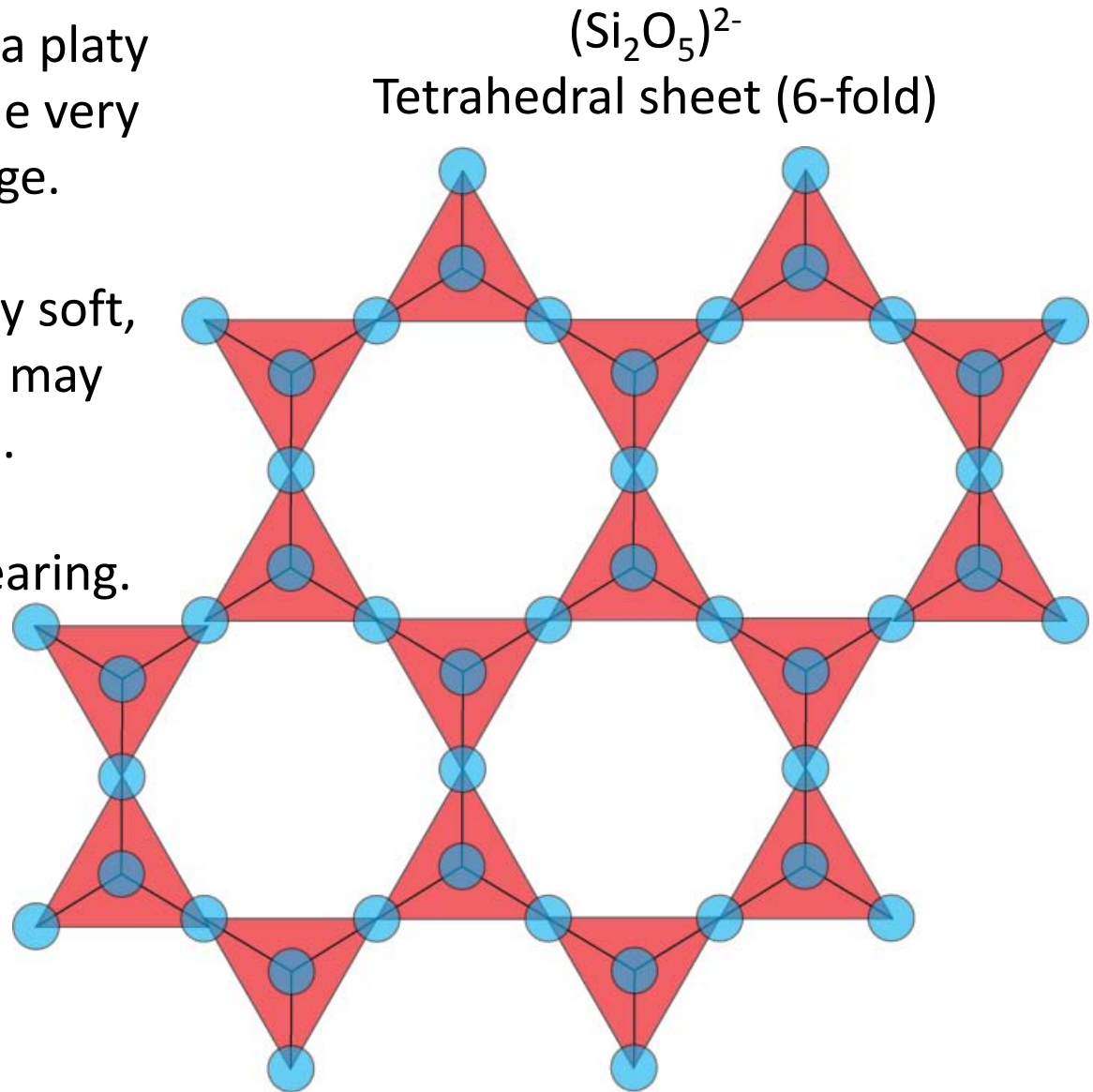


# Phyllosilicates – (Silicate Sheets)

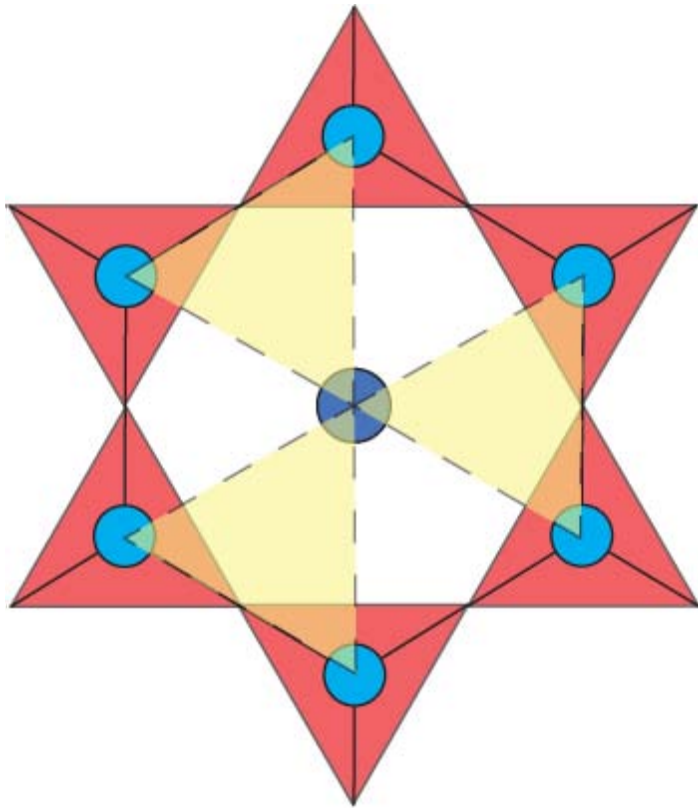
Many members have a platy or flaky habit with one very prominent cleavage.

Minerals are generally soft, low specific gravity, may even be flexible.

Most are hydroxyl bearing.



Each tetrahedra is bound to three neighboring tetrahedra via three basal bridging oxygens.



The apical oxygen of each tetrahedral in a sheet all point in the same direction.

The sheets are stacked either apice-to-apice or base-to-base. All unshared oxygens point away from the tetrahedra: "***apical oxygens***"

In an undistorted sheet the hydroxyl (OH) group sits in the center and each outlined triangle is equivalent.

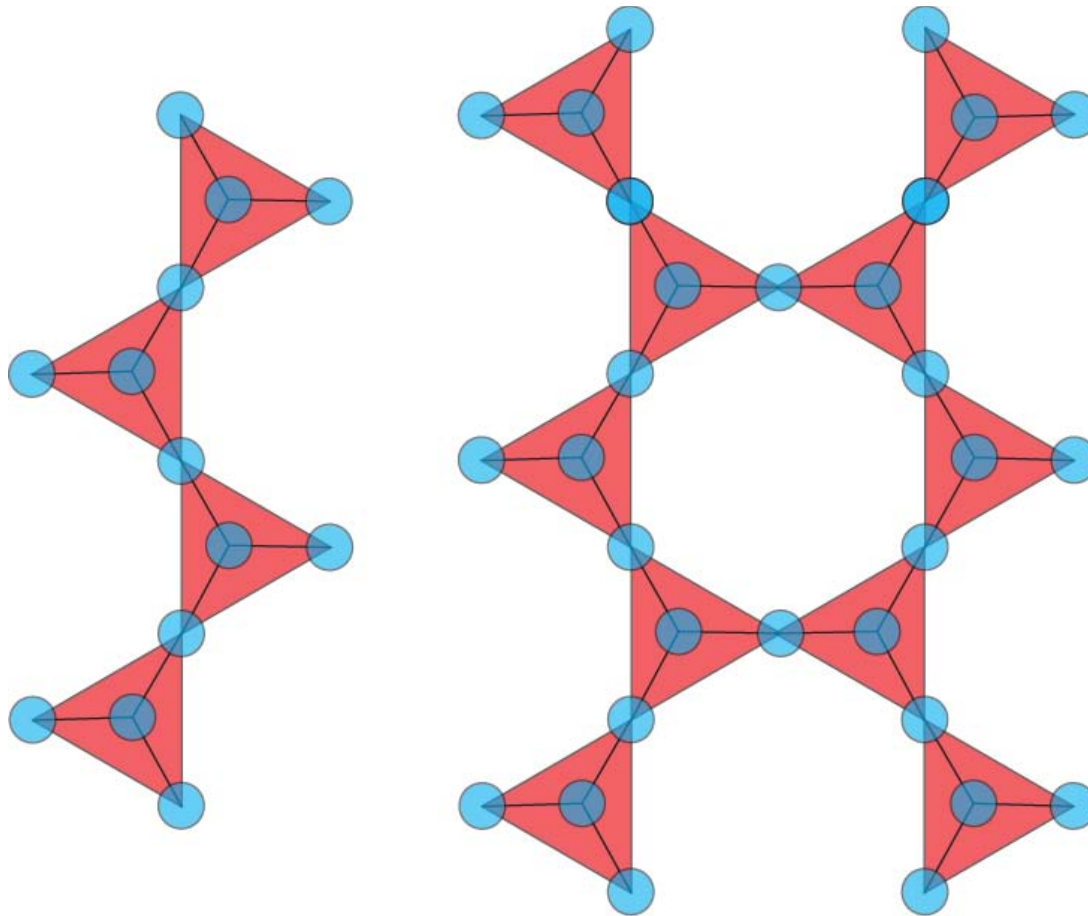
Phyllosilicates have a 2:5 ratio of tetrahedral cations (such as Si) to oxygen

Some of the most common minerals in this group are the micas (e.g. muscovite:  $\text{KAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH},\text{F})_2$ ), but also many clay minerals:

Kaolinite-serpentine:  $(\text{Mg}_3, \text{Al}_2)\text{Si}_2\text{O}_5(\text{OH})_4$

Pyrophyllite:  $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

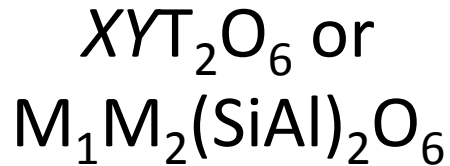
# Inosilicates - (chain silicates)



The most important two mineral groups are the pyroxenes and the amphiboles.

# Pyroxenes

General Formula

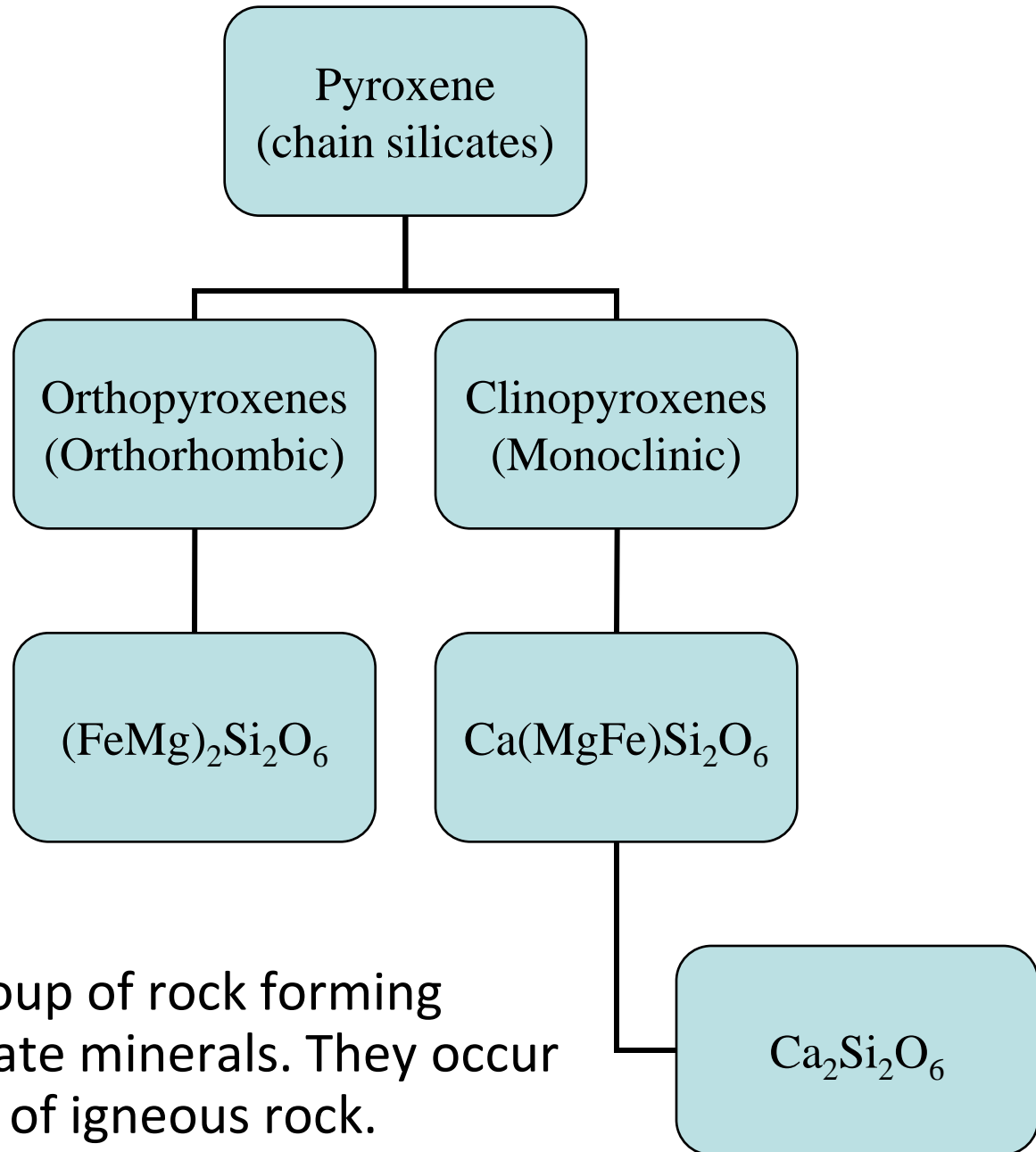


$X(M_2) = Na, Ca, Mn, Fe, Mg \text{ and } Li$

$Y(M_1) = Mn, Fe, Al, Cr \text{ and } Ti.$

$T = Si \text{ and } Al.$

The most important group of rock forming ferromagnesian silicate minerals. They occur in almost every type of igneous rock.



# Amphiboles

Have the idealised general formula:  $A_{(0-1)}B_2^{VI}C_5^{IV}T_8O_{22}(OH)_2$

The A, B and C sites are all octahedrally coordinated, and have four geometries, M1, M2, M3 and M4.

Ex. Tremolite:  $Ca_2Mg_5Si_8O_{22}(OH)_2$

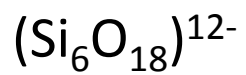
- A-site (M4 geometry) may contain Na, K or □.
- B-site (M4 geometry) may contain Na, Ca, Mg or Fe<sup>2+</sup>.
- C-site (2 x M1, 2 x M2 and 1 x M3) and may contain Mg, Fe<sup>2+/3+</sup> or Al.
- T-site is tetrahedrally coordinated and may contain Si or Al.
- The hydroxyl ions can be replaced by Cl or F.

# Cyclosilicates – (Ring silicates)

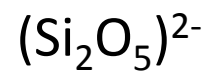
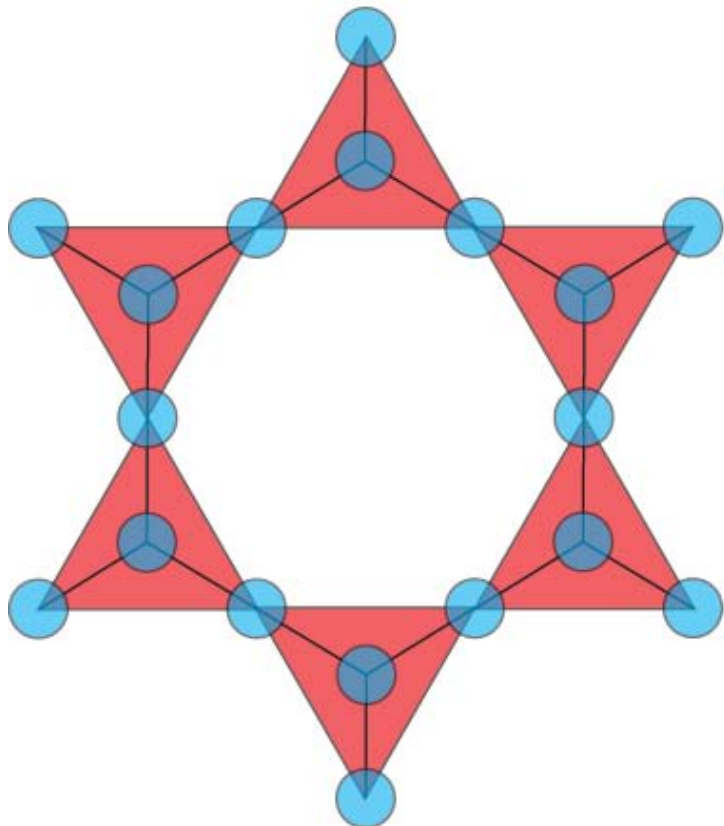
- 3, 4, 6, 8, 9, or 12 membered rings of Si<sup>4+</sup> tetrahedra (though 6-membered are the most common)
- These are similar to the Framework silicates in that the ratio of cations in the tetrahedral site (Si) to oxygen is 1:2
- The high concentration of strongly linked bonds yield relatively dense minerals that are quite hard

Beryl:

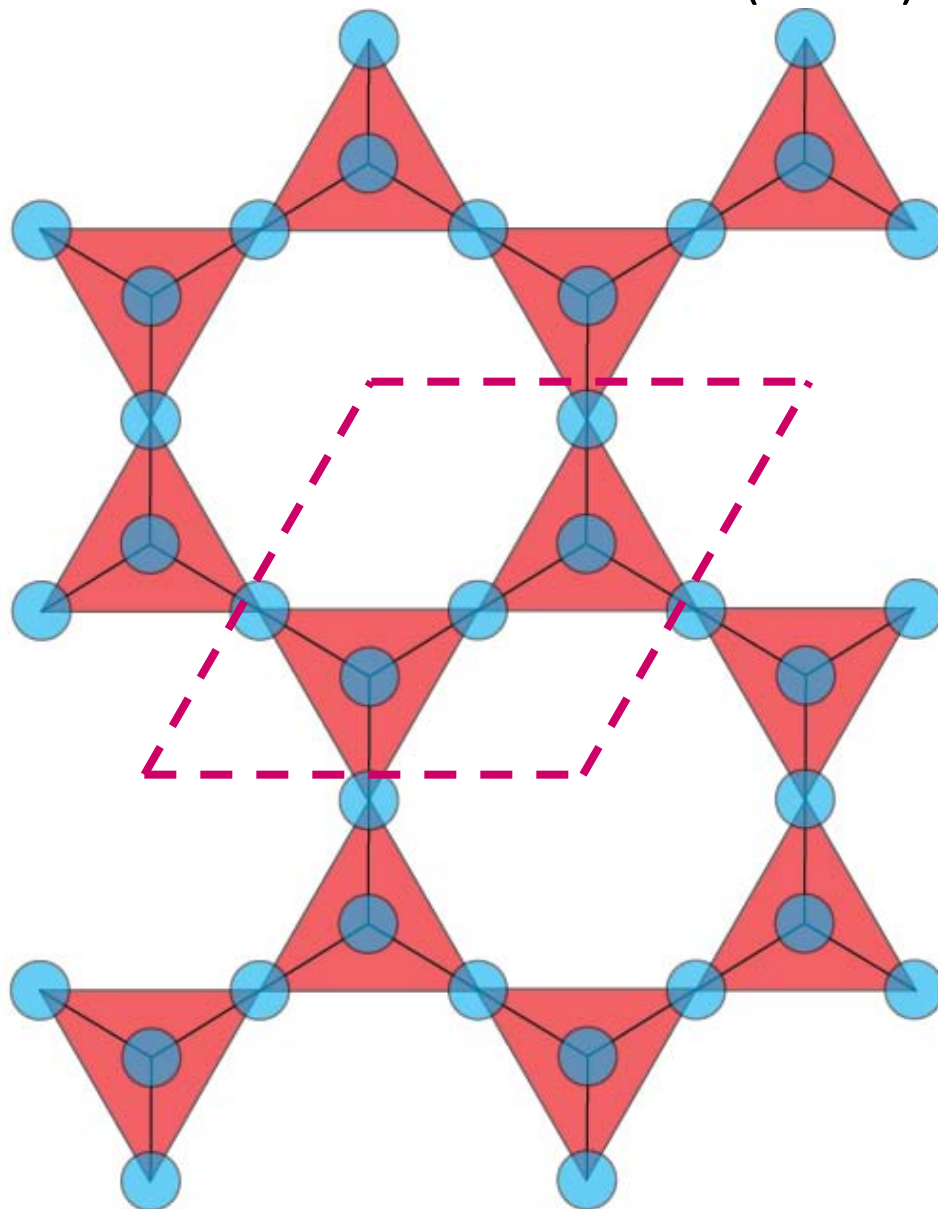




Tetrahedral ring (6-fold)  
Cyclosilicates or Ring silicates



Tetrahedral sheet (6-fold)





# Sorosilicates – (Disilicates)

- SiO<sub>4</sub> tetrahedra in combination with Si<sub>2</sub>O<sub>7</sub> units
- These commonly form edge-sharing linked octahedral chains
- These chains in-turn form sheets by binding with isolated SiO<sub>4</sub> tetrahedra
- While bonds between chains and within sheets are quite strong (large coordination spaces that accept large cations), bonds between sheets are weak leading to the common phenomenon of only 1 direction of perfect cleavage

Epidote:  $\text{Ca}_2(\text{Al, Fe})\text{Al}_2\text{O}(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})$

# Nesosilicates – (Orthosilicates)

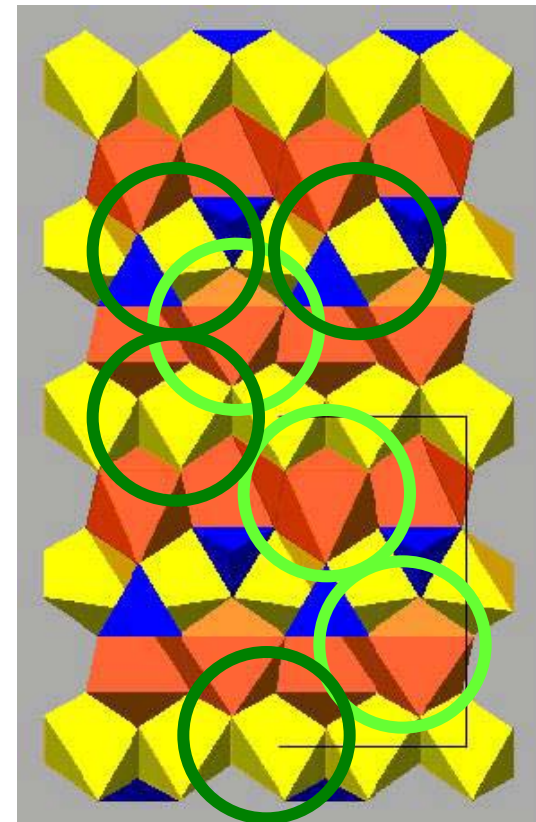
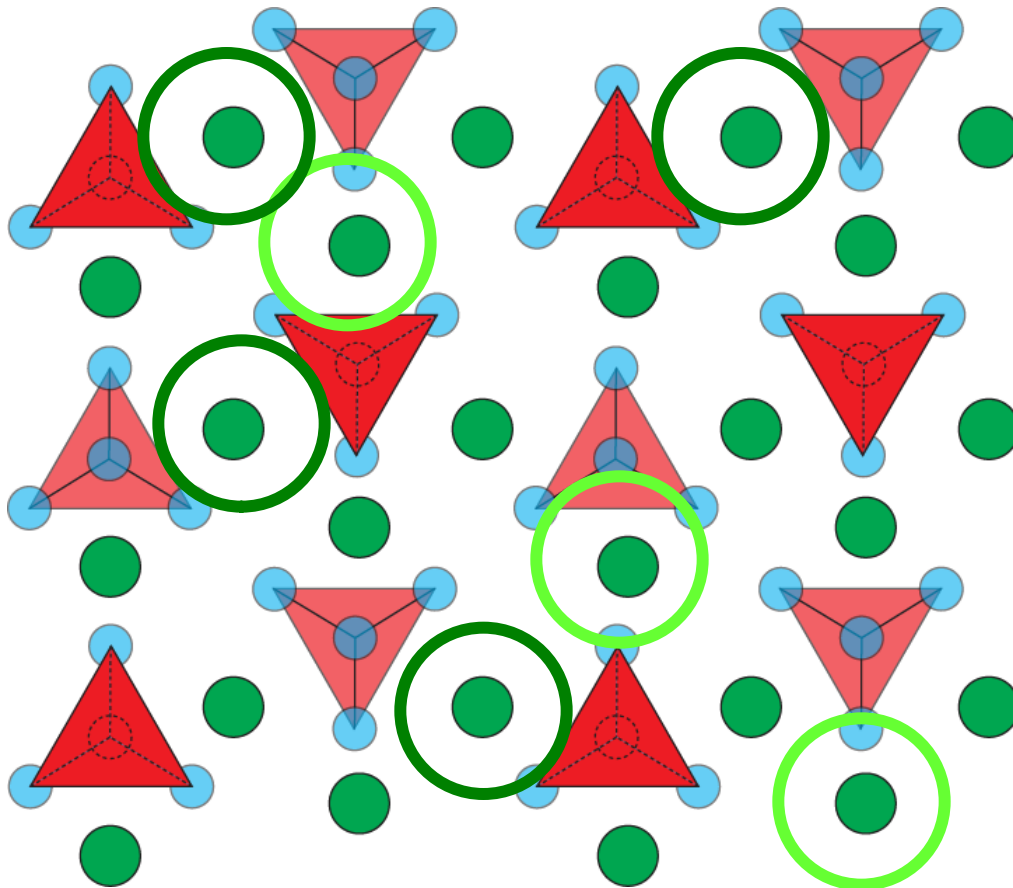
- Isolated  $(\text{SiO}_4)^{4-}$  tetrahedra and bounded to one another via ionic bonds with interstitial cations.
- Dense packing – high density.
- Independent tetrahedral – crystal habits are equidimensional and lack pronounced cleavage.
- $\text{Al}^{3+}$  substitution in T-site generally low.
- Many nesosilicates (but not all) have orthogonal crystallographic systems.

# Olivine (Forsterite-Fayalite)

$(\text{SiO}_4)^{4-}$  tetrahedra linked by divalent atoms in a six-fold coordination.

What shape is the interstitial site?

How many divalent ions are required?



The octahedral sites share edges and are not equivalent

# REVIEW

- 6 major silicate groups: Tectosilicates (Framework), Phyllosilicates (Sheet), Inosilicates (Chain), Cyclosilicates (Ring), Sorosilicates and Nesosilicates
- From Tecto to Neso, these groups represent more depolymerized structures
- There are multiple variations within each of these groups leading to a variety of permutations for each; however, these are the major building blocks of all silicate phases
- In addition to these are the non-silicates of which the carbonates ( $\text{CO}_3$ )<sup>2-</sup> dominate