

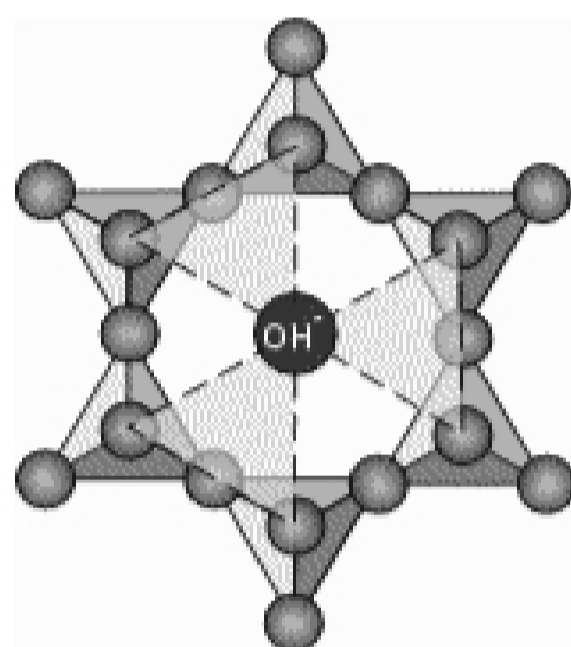
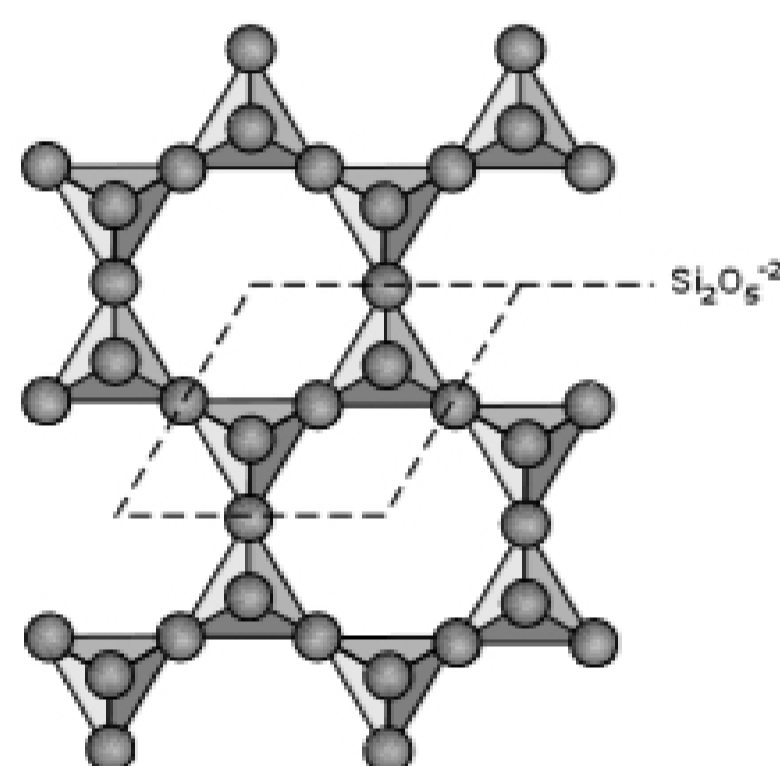
Phyllosilicates (Micas, Chlorite, Talc, & Serpentine)

This document last updated on 29-Nov-2011

Phyllosilicates (Sheet Silicates)

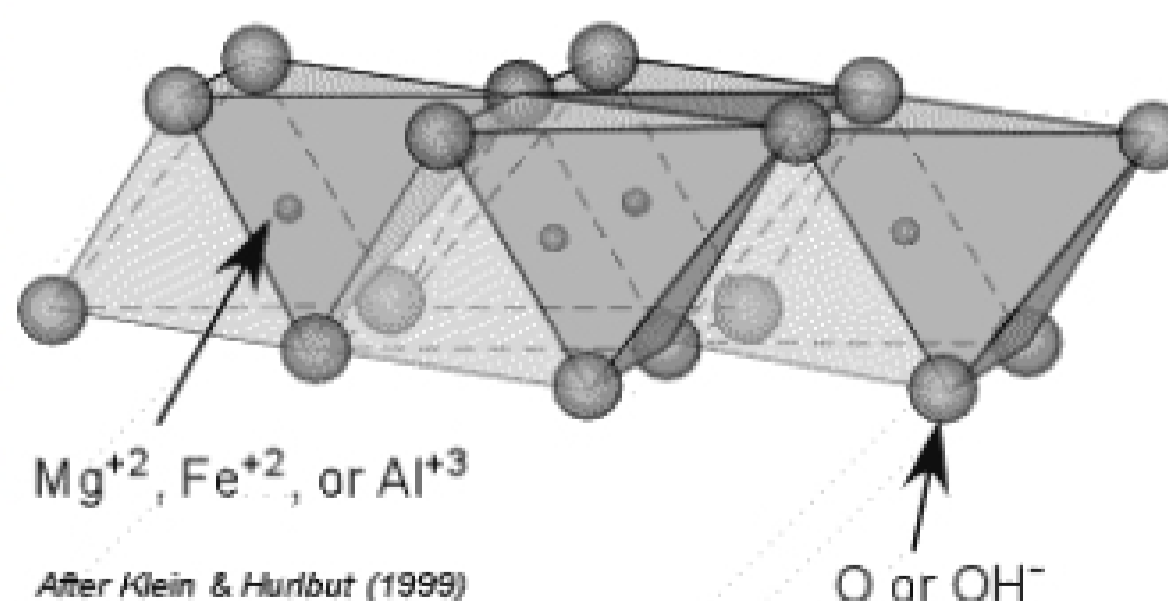
The phyllosilicates, or sheet silicates, are an important group of minerals that includes the micas, chlorite, serpentine, talc, and the clay minerals. Because of the special importance of the clay minerals as one of the primary products of chemical weathering and one of the more abundant constituents of sedimentary rocks, they will be discussed in more detail in the next lecture.

The basic structure of the phyllosilicates is based on interconnected six member rings of SiO_4^{-4} tetrahedra that extend outward in infinite sheets. Three out of the 4 oxygens from each tetrahedra are shared with other tetrahedra. This leads to a basic structural unit of $\text{Si}_2\text{O}_5^{-2}$.



Most phyllosilicates contain hydroxyl ion, OH^- , with the OH located at the center of the 6 membered rings, as shown here. Thus, the group becomes $\text{Si}_2\text{O}_5(\text{OH})^{-3}$. When other cations are bonded to the SiO_4 sheets, they share the apical oxygens and the (OH) ions which bond to the other cations in octahedral coordination. This forms a layer of cations, usually Fe^{+2} , Mg^{+2} , or Al^{+3} , that occur in octahedral coordination with the O and OH ions of the tetrahedral layer. As shown, here, the triangles become the faces of the octahedral groups that can bind to the tetrahedral layers.

The octahedral layers take on the structure of either Brucite [$\text{Mg}(\text{OH})_3$], if the cations are +2 ions like Mg^{+2} or Fe^{+2} , or Gibbsite [$\text{Al}(\text{OH})_3$], if the cations are +3 like Al^{+3} . In the brucite structure, all octahedral sites are occupied and all anions are OH^- . In the Gibbsite structure every 3rd cation site is unoccupied and all anions are OH^- .



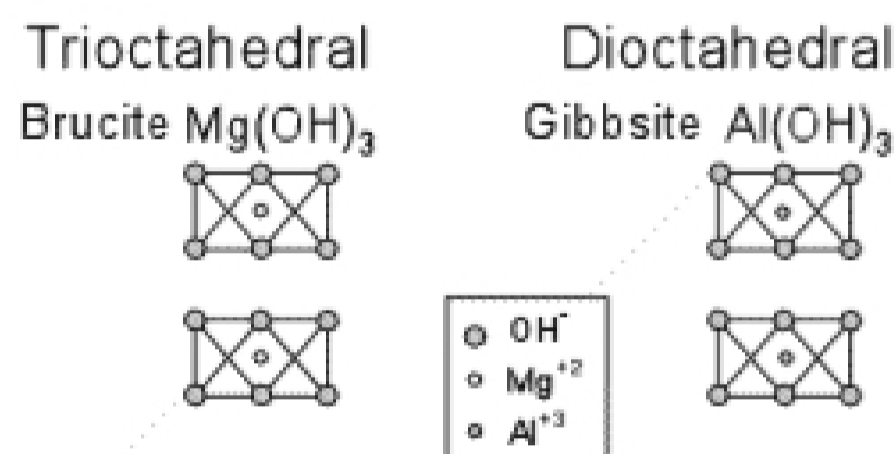
This gives rise to 2 groups of sheet silicates:

1. The **trioctahedral** sheet silicates where each O or OH ion is surrounded by 3 divalent cations, like Mg^{+2} or Fe^{+2} .
2. The **dioctahedral** sheet silicates where each O or OH ion is surrounded by 2 trivalent cations, usually Al^{+3} .

We can build the structures of the various sheet silicates by starting with the octahedral layers similar to the structures of brucite or gibbsite, as shown below.

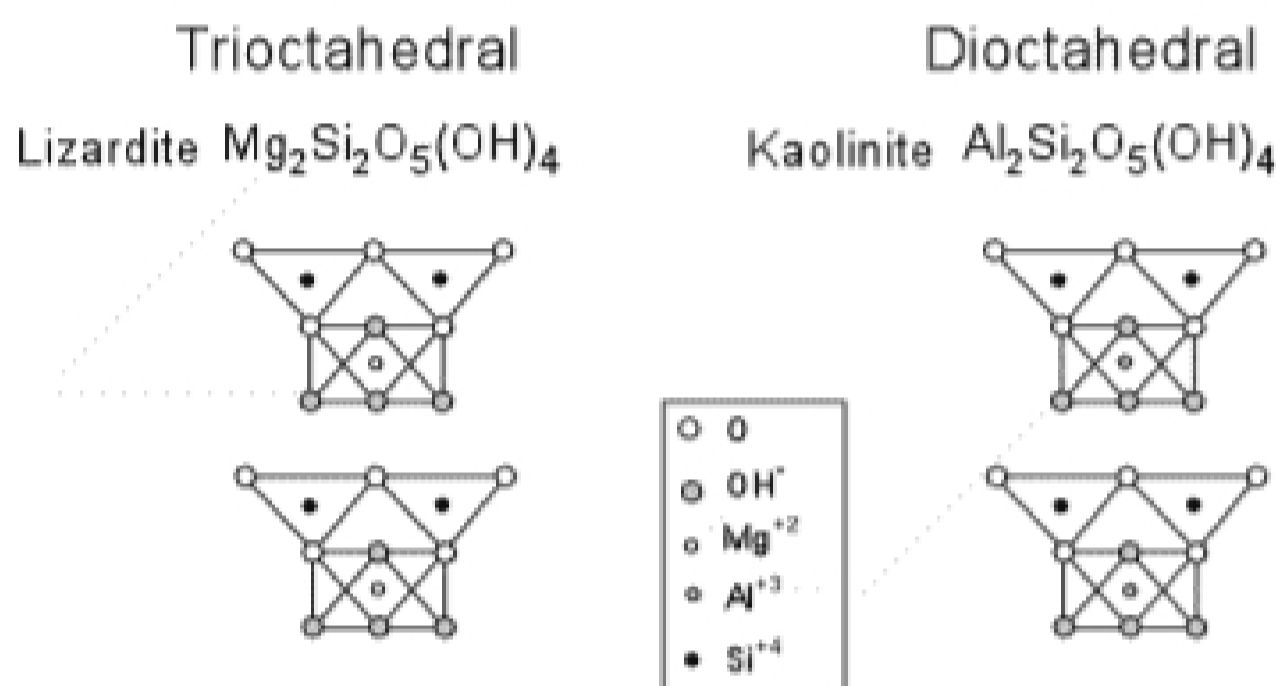
The trioctahedral phyllosilicates are based on the structure where the octahedral layers are similar to brucite, where Mg^{+2} occupies the cation position.

The dioctahedral phyllosilicates are based on the structure where the octahedral layers are similar to gibbsite, where Al^{+3} occupies the cation position.



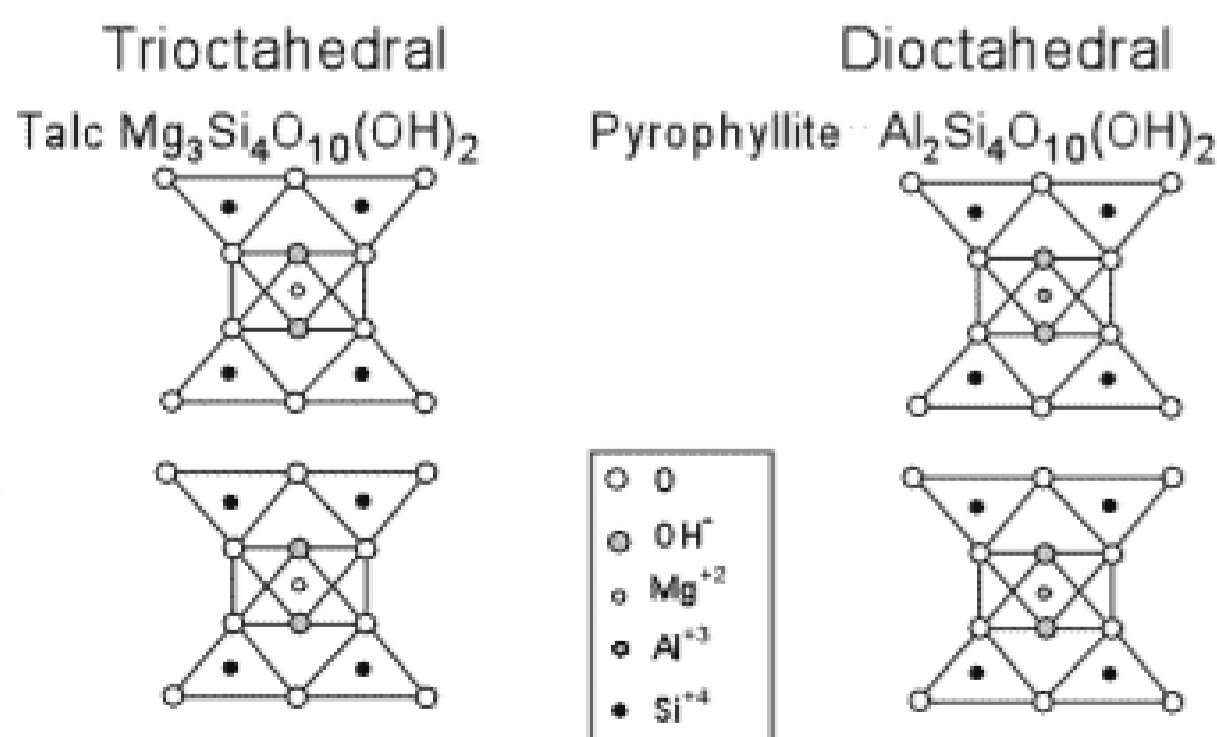
The octahedral sheets in both cases are held together by weak Van der Waals bonds.

If we start with the brucite and gibbsite structures shown above, and replace 2 of the OH ions with O, where the Oxygens are now the apical Oxygens of the tetrahedral sheets, then we get the structure of the serpentine mineral, Lizardite, if the octahedral layer is trioctahedral, containing Mg^{+2} . If the octahedral layer is dioctahedral, containing Al^{+3} , the structure of the clay mineral Kaolinite, is obtained.

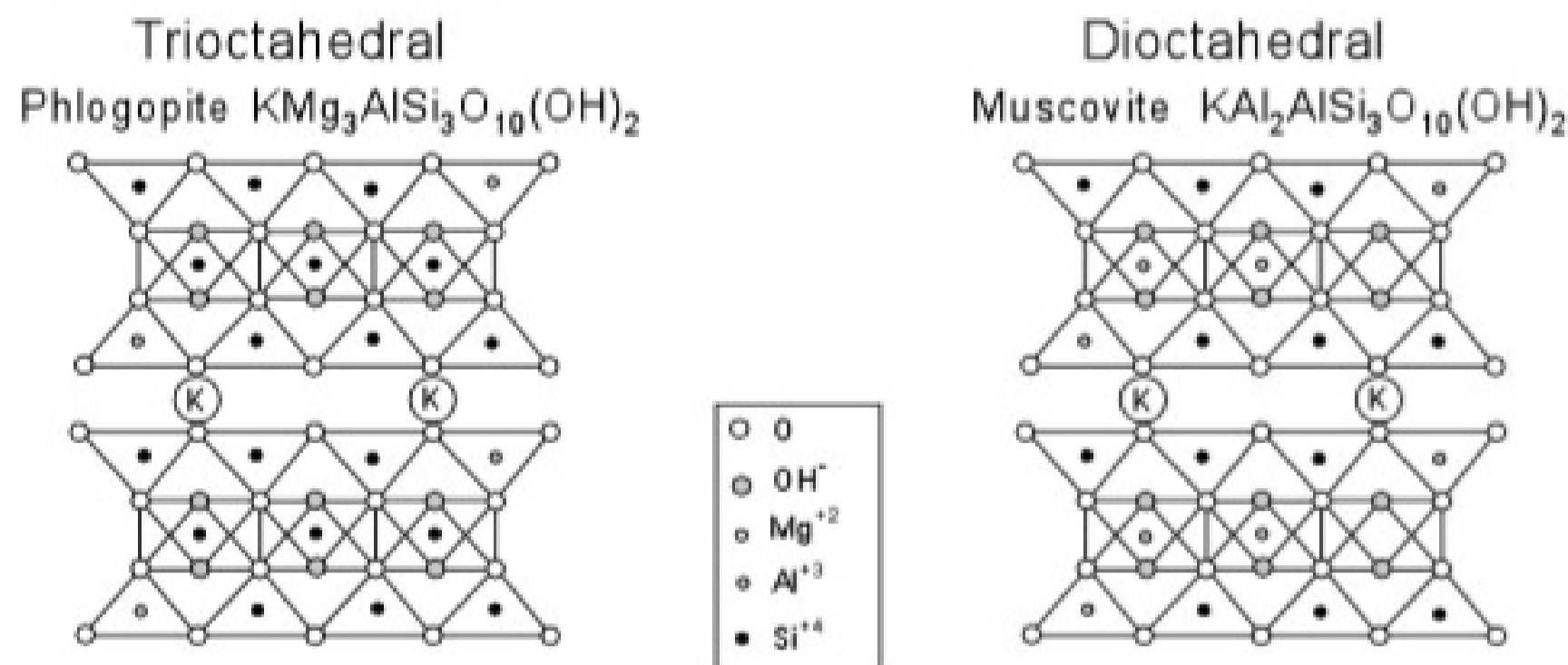


This leads to a tetrahedral - octahedral (T-O) structure, where each T-O layer is bonded to the top (or bottom) of another T-O layer by Van der Waals bonds.

If 2 more of the OH ions in the octahedral layer are replaced by O, and these O become the apical Oxygens for another tetrahedral layer, then this builds the trioctahedral phyllosilicate talc or the dioctahedral pyrophyllite. This becomes a T-O-T layer that can bond to other T-O-T layers by weak Van der Waals bonds.

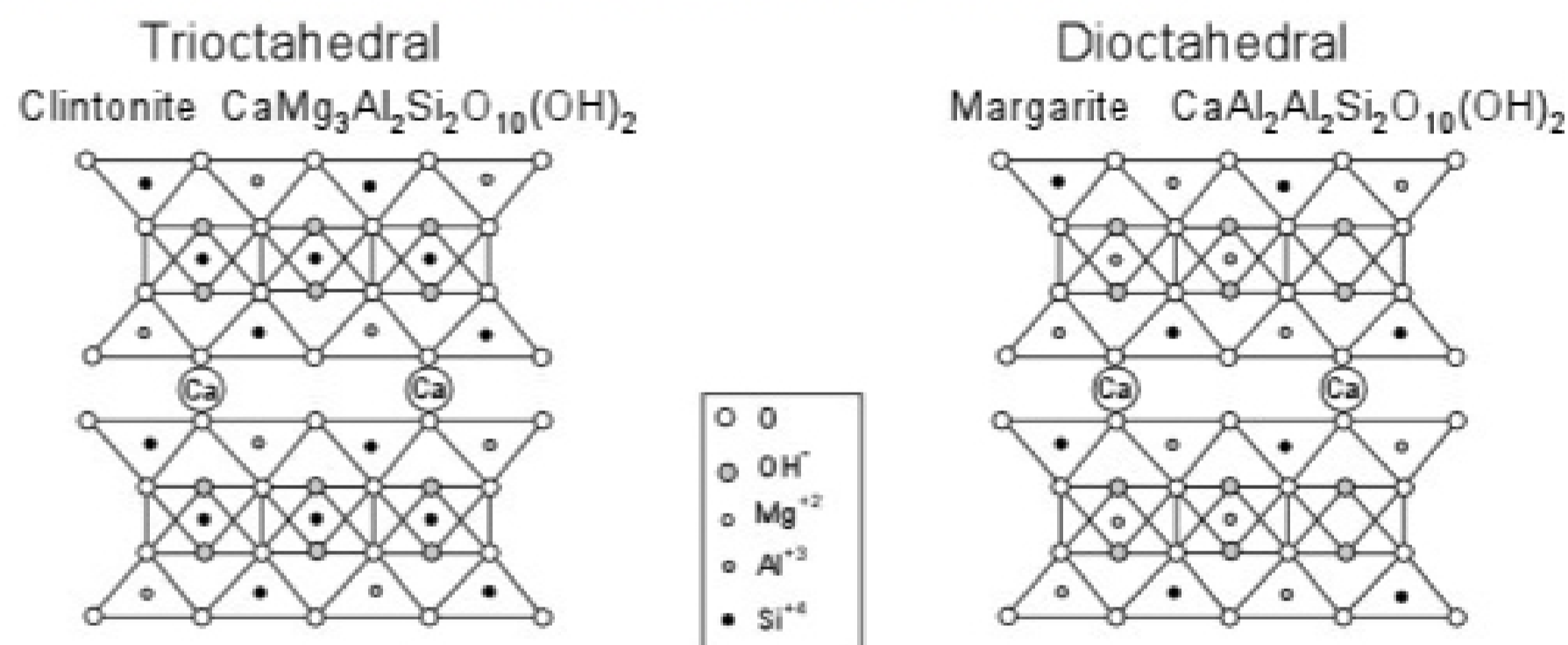


If an Al^{+3} is substituted for every 4th Si^{+4} in the tetrahedral layer, this causes an excess -1 charge in each T-O-T layer. To satisfy the charge, K^{+1} or Na^{+1} can be bonded between 2 T-O-T sheets in 12-fold coordination.



For the trioctahedral sheet silicates this becomes Phlogopite (Mg-biotite), and for the dioctahedral sheet silicates this becomes Muscovite. This makes a T-O-T - T-O-T layer that, again can bind to another T-O-T - T-O-T layer by weak Van der Waals bonds. It is along these layers of weak bonding that the prominent $\{001\}$ cleavage in the sheet silicates occurs.

Replacing 2 more Si^{+4} ions with Al^{+3} ions in the tetrahedral layer results in an excess -2 charge on a T-O-T layer, which is satisfied by replacing the K^{+1} with Ca^{+2} .



This results in the trioctahedral sheet silicate - Clintonite and the dioctahedral sheet silicate - Margarite.

Because of the differences in charge balance between the trioctahedral and dioctahedral sheet silicates, there is little solid solution between the two groups. However, within the trioctahedral sheet silicates there is complete substitution of Fe^{+2} for Mg^{+2} and limited substitution of Mn^{+2} into the octahedral sites. Within the dioctahedral sheet silicates there is limited substitution of Fe^{+3} for Al^{+3} in octahedral sites. In addition, F^- or Cl^- can substitute for $(\text{OH})^-$ in the hydroxyl site. As previously discussed, substitution of F^{-1} stabilizes the mineral to higher pressures and temperatures.

Another group of phyllosilicates that is more of mixture of structural types is the chlorite group. Although chlorite is complex in that the amount of Al that can substitute Mg and Si is