

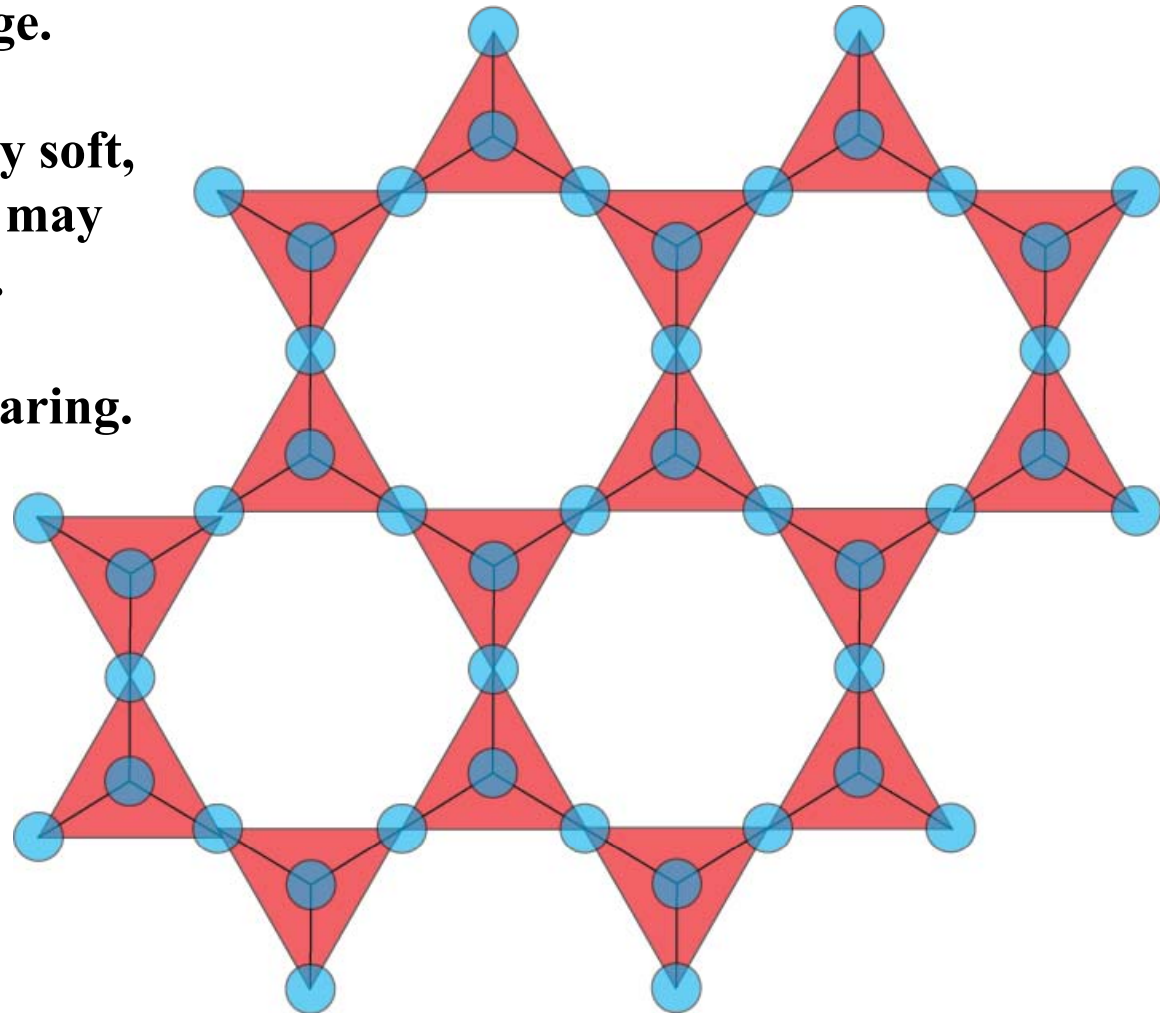
# Phyllosilicates – (Silicate Sheets)

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

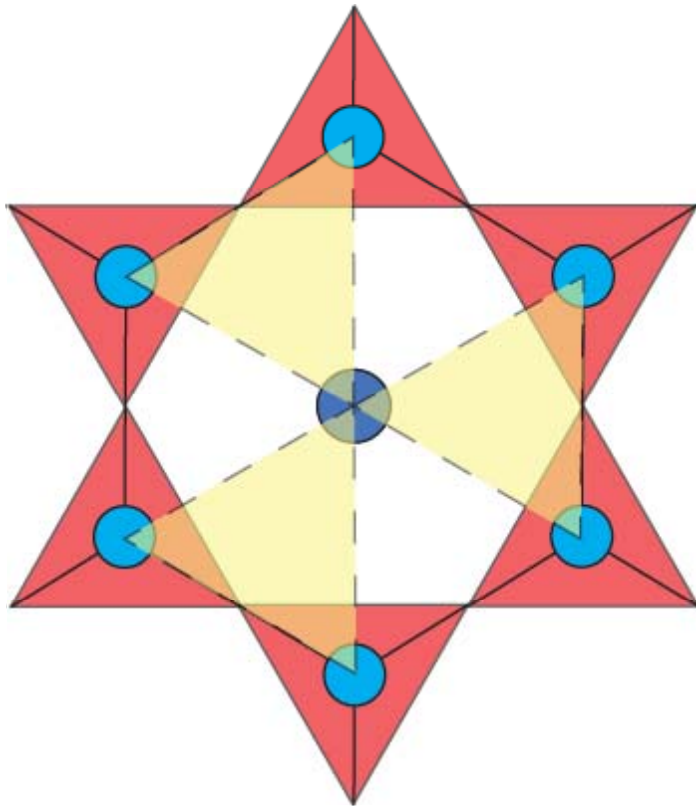
**Minerals are generally soft, low specific gravity, may even be flexible.**

**Most are hydroxyl bearing.**

$(\text{Si}_2\text{O}_5)^{2-}$   
Tetrahedral sheet (6-fold)



**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.**

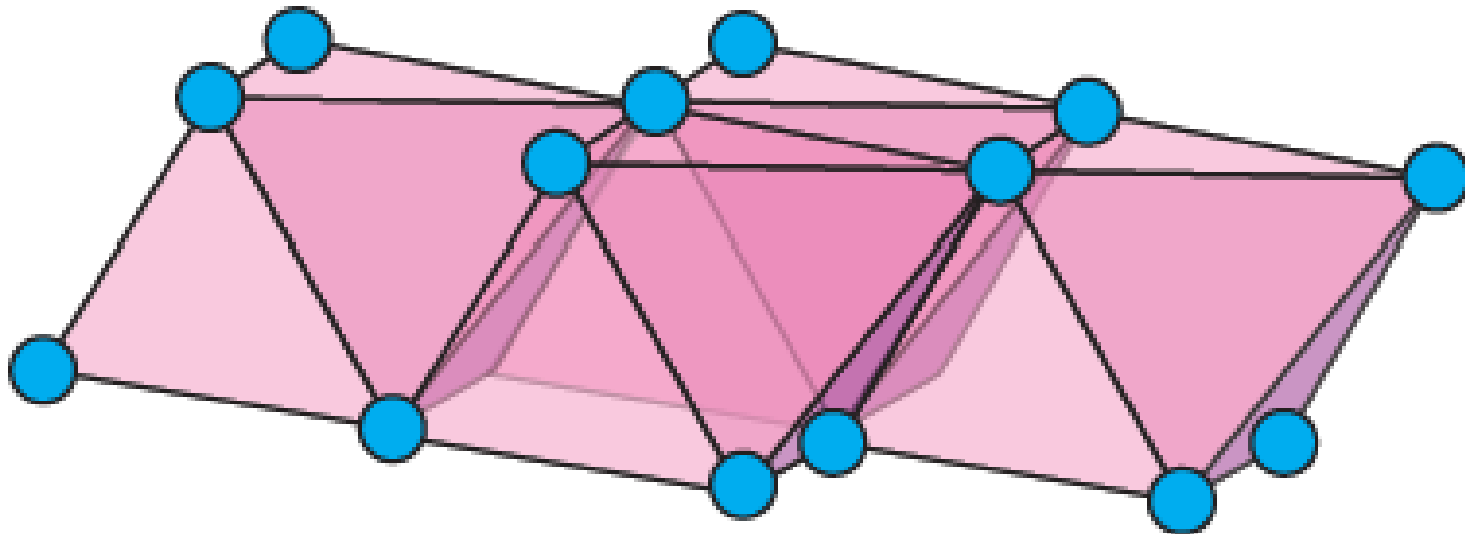
**The sheets are stacked either apice-to-apice or base-to-base.**

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

# Sheets within sheets....

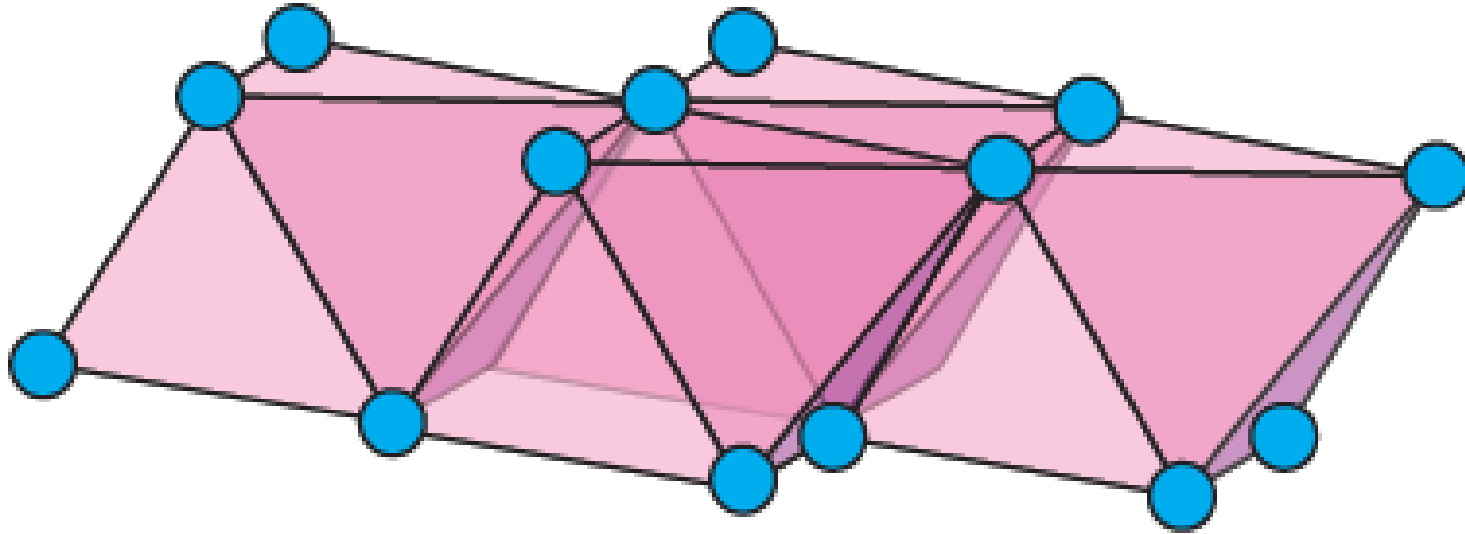
Apical oxygens, plus the  $\text{-OH}$  group, coordinate a 6-fold (octahedral) site ( $\text{XO}_6$ ).

These octahedral sites form infinitely extending sheets. All the octahedra lie on triangular faces, oblique to the tetrahedral sheets.



The most common elements found in the 6-fold site are Mg (or Fe) or Al.

# Dioctahedral vs Trioctahedral



**Mg and Al have different charges, but the sheet must remain charge neutral.**

**With 6 coordinating oxygens, we have a partial charge of -6.**

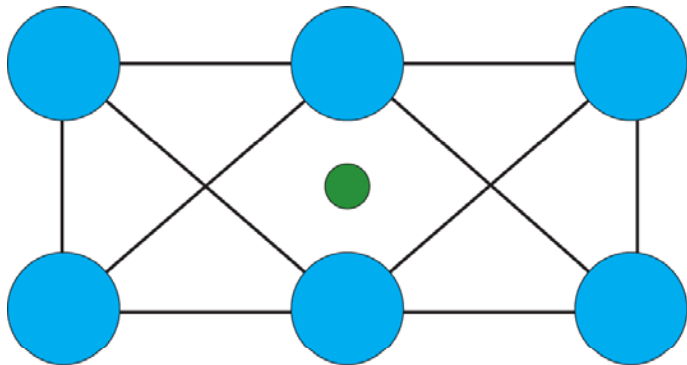
**How many  $\text{Mg}^{2+}$  ions are required to retain neutrality?**

**How many  $\text{Al}^{3+}$  ions are required to retain neutrality?**

**Mg occupies all octahedral sites, while Al will only occupy 2 out of every 3.**

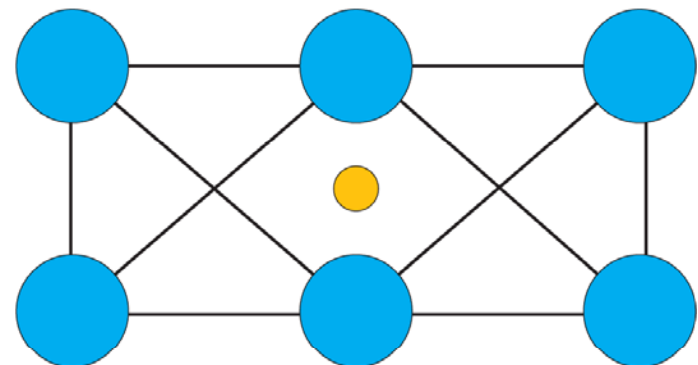
The stacking of the sheets dictates the crystallography and chemistry of each of the phyllosilicates.

### Trioctahedral



**Brucite**

### Diocahedral



**Gibbsite**

*0*



**Hydroxyl**



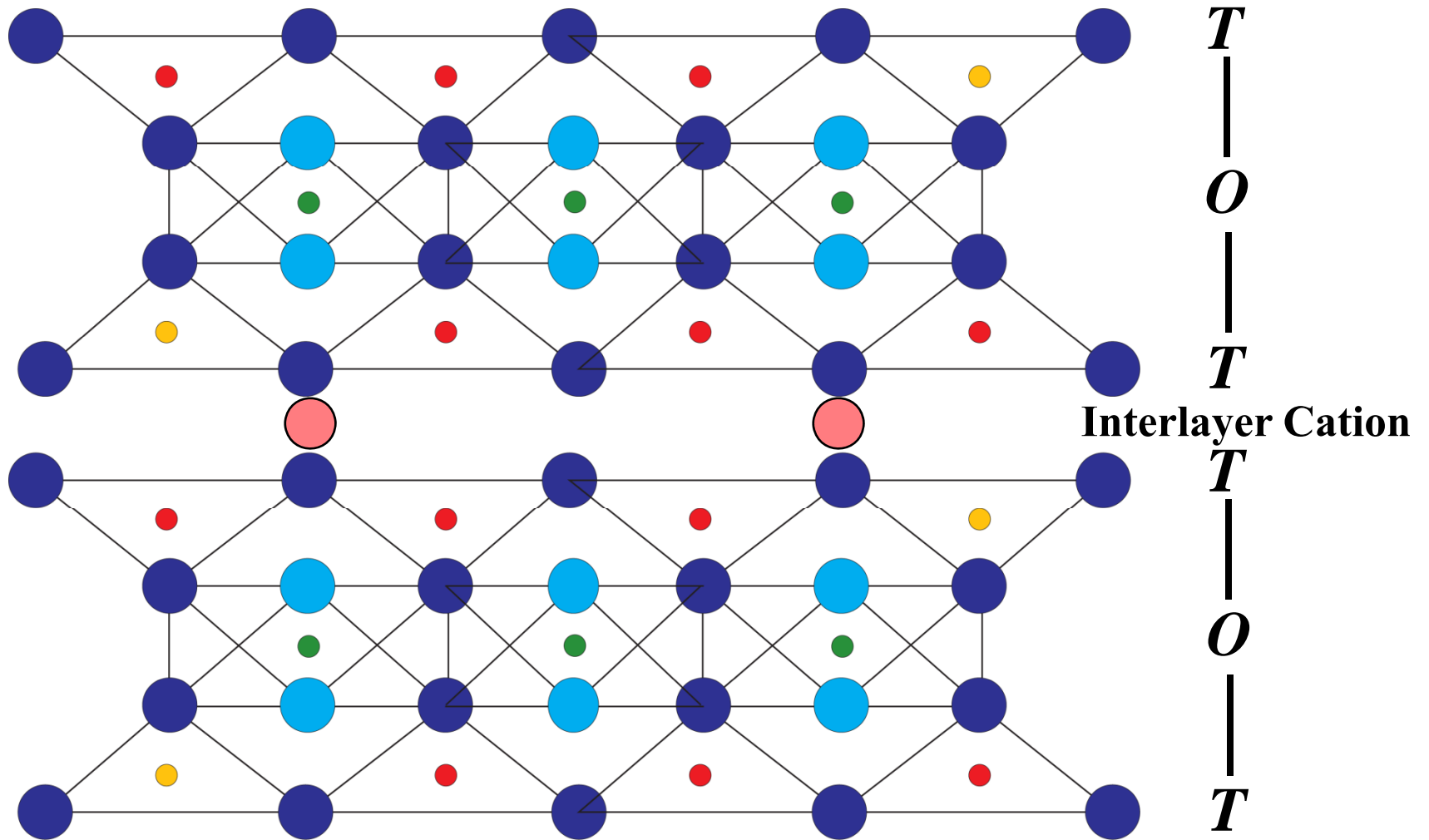
**Magnesium**



**Aluminium**

# Trioctahedral

Is this structure charge neutral?

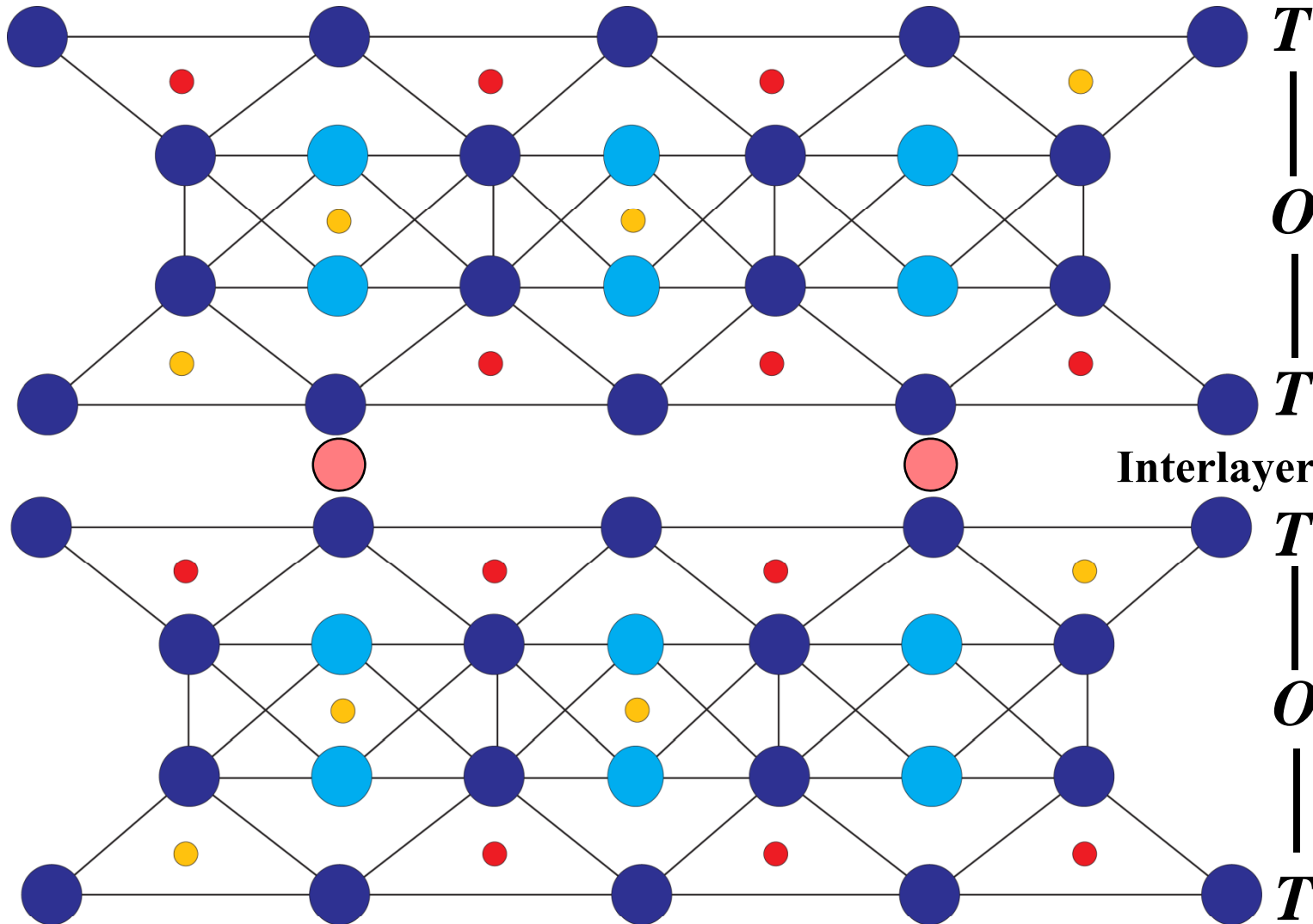


● Potassium (K<sup>+</sup>)

Phlogopite (Mg end-member biotite)

**Diocahedral**

Is this structure charge neutral?



 **Potassium (K<sup>+</sup>)**

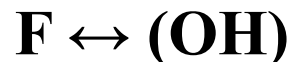
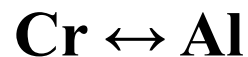
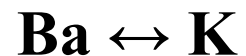
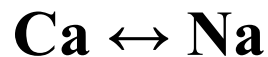
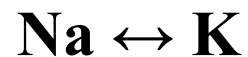
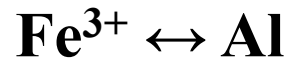
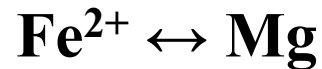
**Muscovite**

# Compositional variation in phyllosilicates

**There is little solid solution between members of the dioctahedral and trioctahedral groups.**

**However, there may be extensive, and substantially complete solid solution within and between end-members of both the dioctahedral and trioctahedral groups.**

**Common ionic substitutions include:**



**Which of these are simple?**

**Which of these must be coupled?**

# The most common/important rock-forming phyllosilicates

**Muscovite (White) Mica –  $\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$ .  
(IMA generalised formula:  $\text{IM}_2\text{T}_4\text{O}_{10}(\text{OH})_2$ )**

**Named after the Moscovy Region of Russia, which mined the mineral for window panes.**

**Muscovite is monoclinic, biaxial negative with  $2V = 30\text{-}47^\circ$ .**

**Commonly colourless, especially in thin section, and show no pleochroism.**

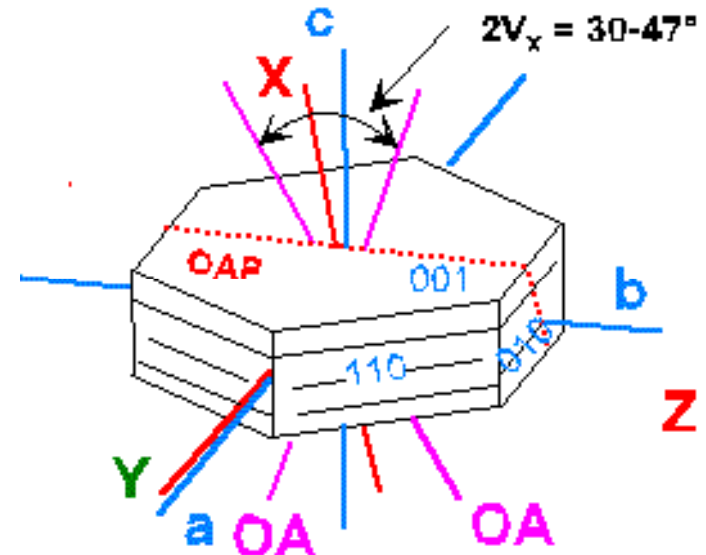
**Vivid second order birefringence colours of blues and greens.**

**Cleavage traces are length slow.**



Extinction angles of muscovite and biotite are the exception to the rule.

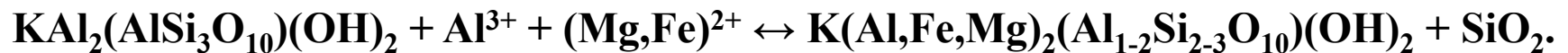
Both species have **STRAIGHT** extinction parallel to their perfect (001) cleavage.



Compositional Variation:



Muscovite-Paragonite solid-solution.



Coupled substitution involving multiple cations and sites.

# The most common/important rock-forming phyllosilicates

**Biotite Mica –  $\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$ .**  
**(IMA generalised formula:  $\text{IM}_3\text{T}_4\text{O}_{10}(\text{OH})_2$ )**

**It has two end-members: Phlogopite (Mg) and Annite (Fe).**

**Biotite is monoclinic, biaxial negative  
with  $2V = 0-25^\circ$ .**

**Typically brown to reddy brown in thin  
section, and strongly pleochroic.**

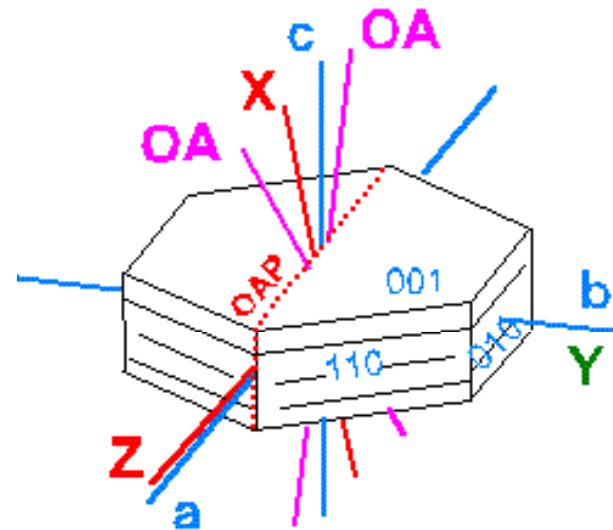
**Third, or even 4th order birefringence  
(sometimes masked by mineral colour)**

**Cleavage traces are length slow.**



**Extinction angles of biotite are straight or a very few degrees to the oblique.**

**Biotite also has perfect cleavage parallel to (001).**



**Compositional Variation:**



**Phlogopite-Annite solid-solution.**

# Petrographic Significance of Ms and Bt.

**What is this reaction?**



**In muscovite there is the following coupled substitution:**



**Leading from  $\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$  to  $\text{K}(\text{MgFe})_2(\text{Si}_4\text{O}_{10})(\text{OH})_2$ .**

**This is the so called phengite substitution and indicates increasing pressure.**

**The breakdown of both muscovite and biotite with increasing pressure are important dehydration reactions, that are often associated with partial melting.**

# Chlorite Group Minerals

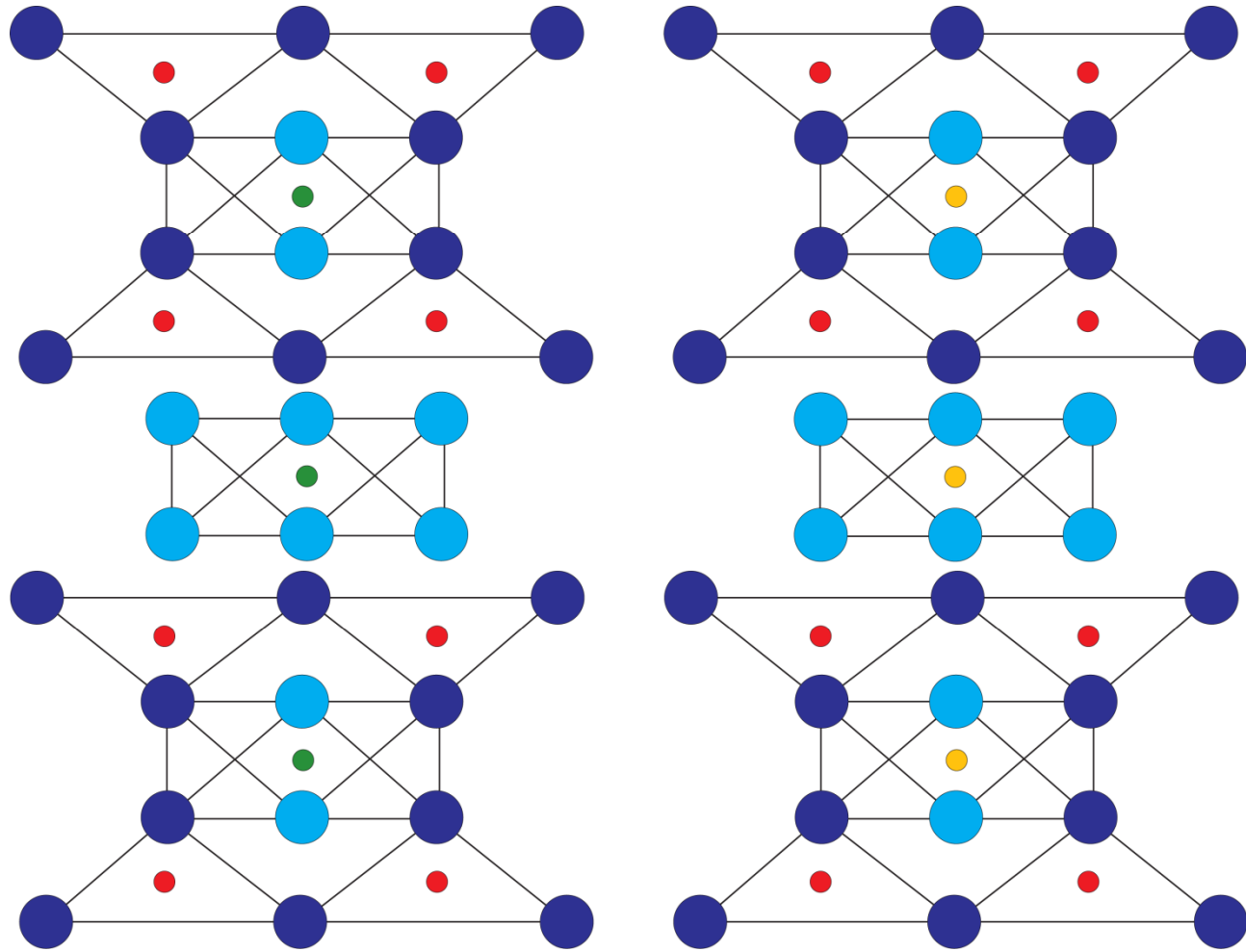
This group of minerals have a layered structure which resembles the micas.

Primary occurrences are in low-grade regionally metamorphosed rocks, hydrothermal alteration products of ferromagneian minerals in igneous rocks, and together with clay mienrals in argillaceous sediments.

Having the general formula  $Y_{12}Z_8O_{20}(OH)_{16}$ , chlorite displays a wide variety of compositional variation.

The structure is monoclinic and consists of regularly alternating negatively charged talc layers, balanced by positively charged brucite layers.

# Chlorite Group Minerals $(\text{Mg,Fe}^{2+},\text{Fe}^{3+},\text{Mn,Al})_{12}[(\text{Si,Al})_8\text{O}_{20}](\text{OH}_{16})$



**Trioctahedral**

**Dioctahedral – Al dominance ( $Y < 12$  cations)**

**Talc or Pyrophyllite structure sandwiching brucite (or gibbsite)**

# Optical Properties

Refractive indices increase with increasing Fe and Al contents.

Fe-rich chlorites are biaxial negative. Mg-rich chlorites are negative.

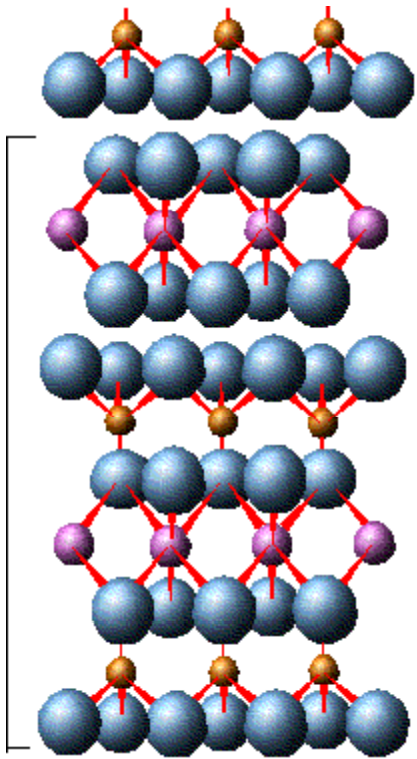
The sign of elongation of chlorites is opposite to the optic sign and is much easier to obtain, especially in fine-grained examples.

Pleochroism strengthens with Fe content.

Mn chlorite – orange-brown; Nickel – yellow/green; Chromium – pinks/violet.

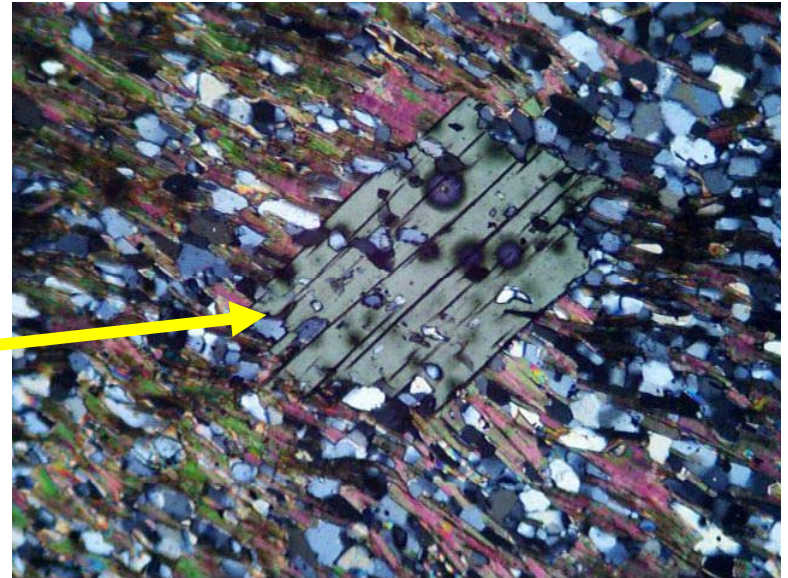
For the most part, mildly pleochroic with 1st order grey birefringence.

Anomalous colours include browns (Mg-rich) and violet-blues (Fe-rich).



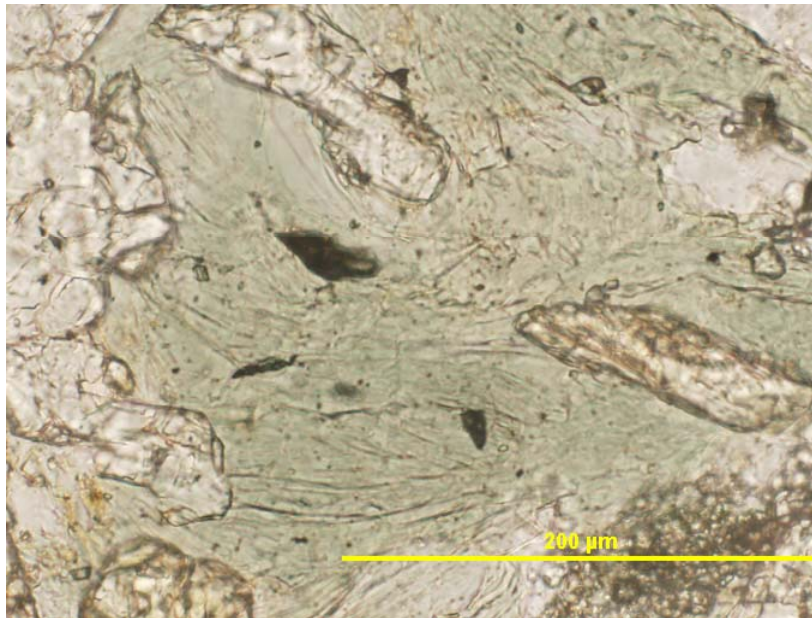
**Alternative view of chlorite structure**

**Radiation damage halos in chlorite in XPL.**



DC120 Fri, May 7, 1999 4:21:56 PM Exposure 0.0098 secs Zoom Factor 2.3 chlorite (xp); Petrel Cove, SA, 195c

**PPL view of chlorite.**



**Name derived from the Greek for green**

#33

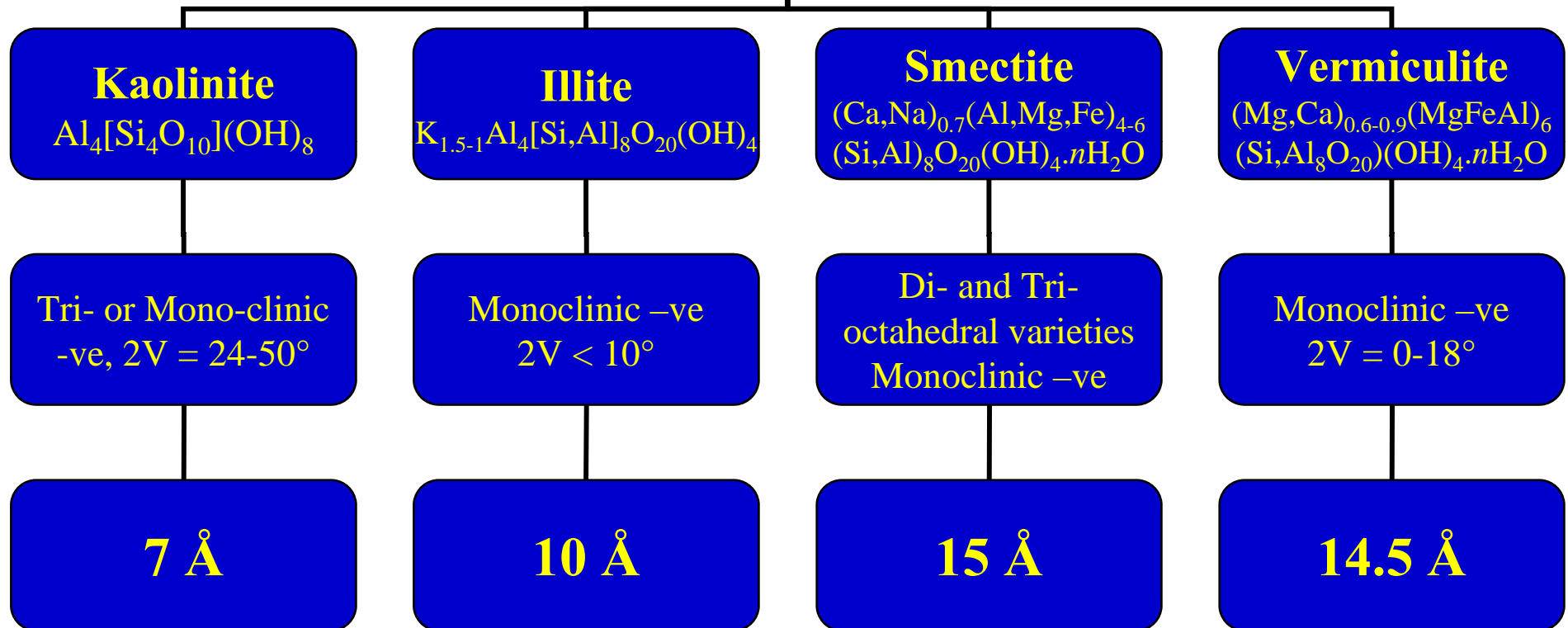


**Chlorite**

# Clay Minerals

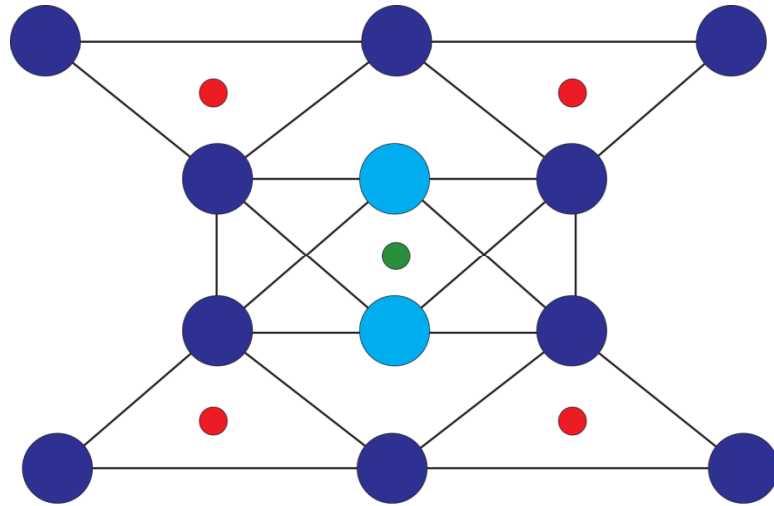
There are four important layered clay minerals, differentiated analytically by basal spacing.

## Clay Minerals



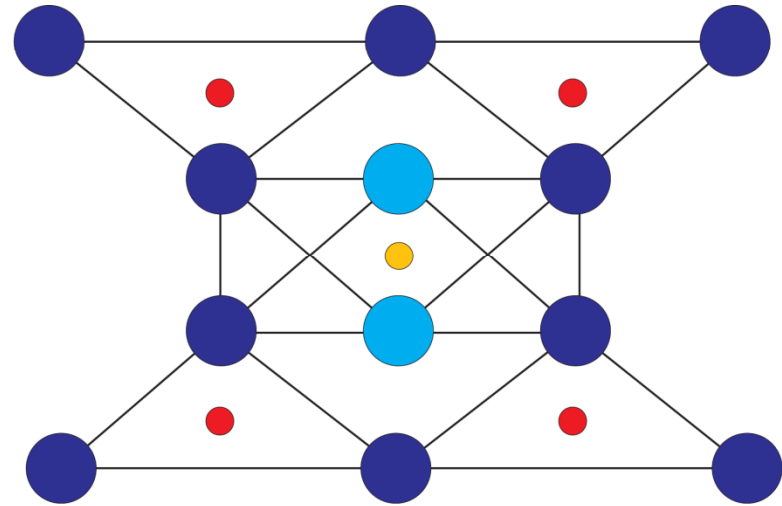
Layer separation is variable depending on the degree of dehydration

## Trioctahedral

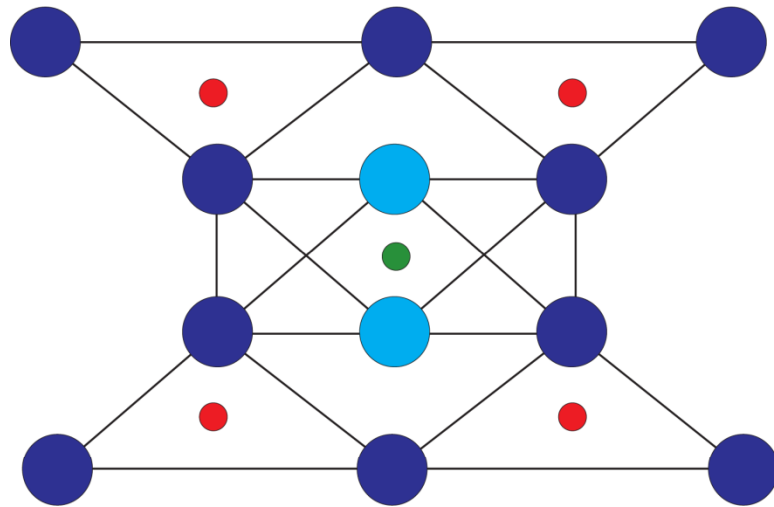


*T*  
|  
*O*  
|  
*T*

## Diocahedral

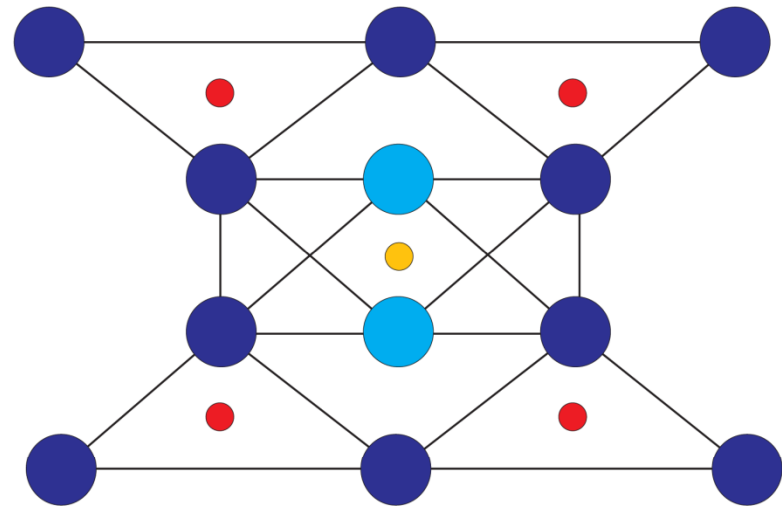


The T-O-T sheets are electrically neutral, are stable structures bonded by van der Waals bonds.



**Talc**

*T*  
|  
*O*  
|  
*T*



**Pyrophyllite**

Chemically, all clay minerals are hydrous silicates, of Mg or Al.

On heating, they lose adsorbed and constitutional water and at high temperatures yield refractory materials.

Particles of clay may be crystalline or amorphous, platy or fibrous, and in most cases very small and beyond the scale of resolution afforded by the petrological microscope.

Compositional variation is possible by partial replacement of Si, Al and Mg.

Decomposition products vary, as do their cation exchange properties, according to the nature of their interlayer cations and residual surface charges.

Uses include drilling muds, catalysis, paper manufacturing, ceramics and refractory ware.