

Lecture 9: Silicates: Mica and Feldspar

Phyllosilicates

Joining two chains of SiO_4^{4-} tetrahedra leads to the double chains in amphibole. Adding more chains indefinitely leads to sheets of SiO_4^{4-} tetrahedra that are the building blocks of phyllosilicates. The other building blocks are octahedral sheets.

The octahedral sheets may contain divalent or trivalent cations. When the cations are divalent, every cation site is filled and the sheet is called a trioctahedral sheet. When the cations are trivalent, one out of every three cation sites is empty to maintain charge balance and the sheet is called a dioctahedral sheet.

Phyllosilicates are divided into two major groups based on whether they contain trioctahedral or dioctahedral sheets. There is little solid solution between members of the dioctahedral and trioctahedral groups, so their compositions usually are not represented on ternary or quaternary diagrams like pyroxene and amphibole.

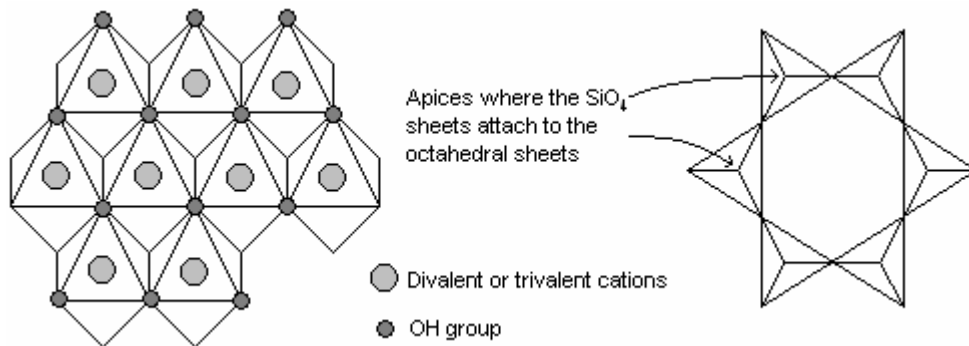
Trioctahedral phyllosilicates

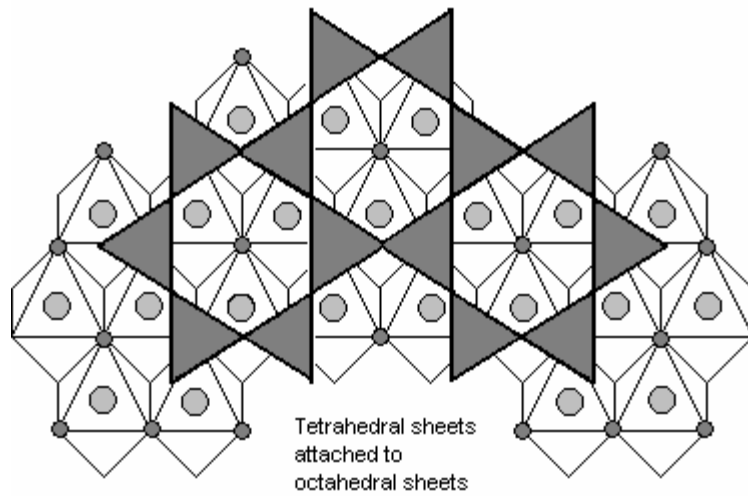
Lizardite	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
Talc	$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
Phlogopite	$\text{KMg}_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
Clintonite	$\text{CaMg}_3(\text{Al}_2\text{Si}_2\text{O}_{10})(\text{OH})_2$

Dioctahedral phyllosilicates

Kaolinite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$
Pyrophyllite	$\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$
Muscovite	$\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
Margarite	$\text{CaAl}_2(\text{Al}_2\text{Si}_2\text{O}_{10})(\text{OH})_2$

The structures of phyllosilicates may be derived by starting with octahedral sheets that contain hydroxyl groups and adding tetrahedral sheets. These octahedral sheets are identical to those in periclase, MgO , except that the apices of the octahedra are hydroxyl groups instead of oxygen.

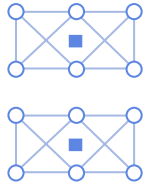




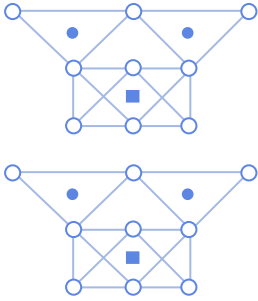
Coordinating one tetrahedral sheet to one octahedral sheet results in the structure of lizardite or kaolinite, depending on whether the octahedral sheets are dioctahedral or trioctahedral. Coordinating two tetrahedral sheets to one octahedral sheet results in the structures of talc or pyrophyllite, also depending on whether the octahedral sheets are dioctahedral or trioctahedral. These layers of coordinated sheets are joined to each other by weak van der Waals bonds, producing excellent cleavage and a greasy feel.

Dioctahedral

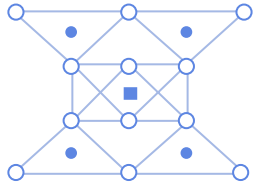
Gibbsite



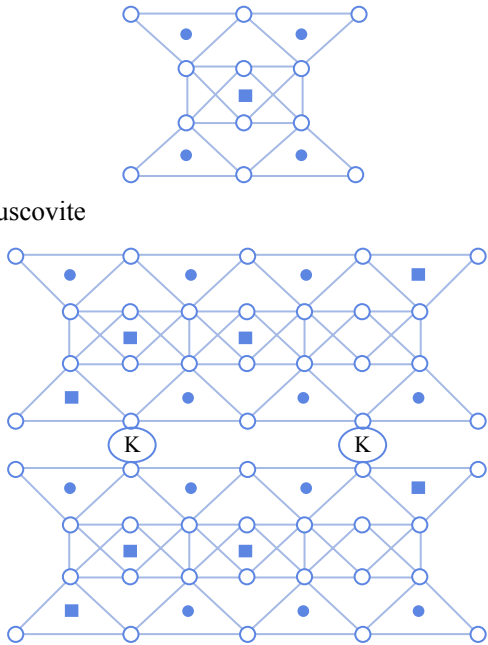
Kaolinite



Pyrophyllite

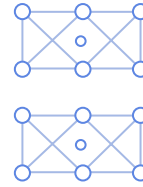


Muscovite

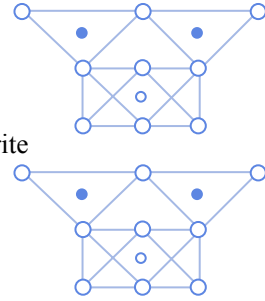


Trioctahedral

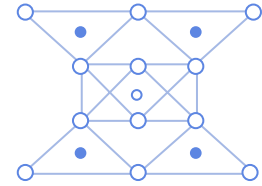
Brucite



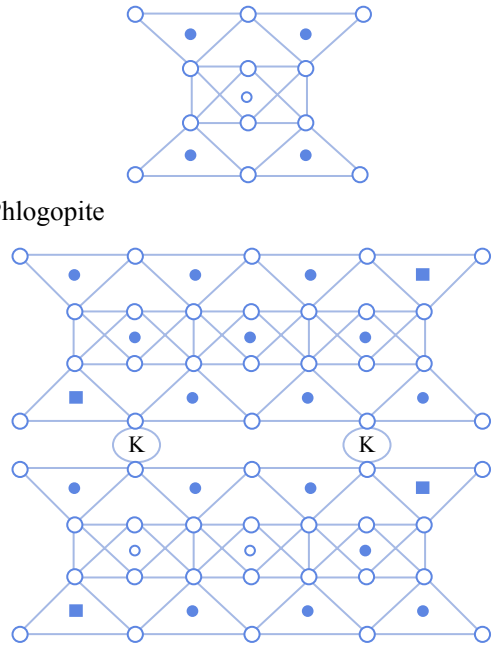
Antigorite



Talc



Phlogopite



o

o

t

o

t

o

t

o

t

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o

t

t

o

t

Interlayer cation

t

o

t

of

o = octahedral
t = tetrahedral

○ Oxygen ○ Hydroxyl ● Silicon ■ Aluminum ○ Magnesium

Making phyllosilicates that contain large metal cations like Ca^{2+} and K^+ requires creating a charge deficit by substituting Al^{3+} for some of the Si^{4+} . If Al^{3+} replaces one in every four Si^{4+} , K^+ offsets the charge deficit. It occupies 12-coordinated sites between tetrahedral-octahedral-tetrahedral (t-o-t) layers. If Al^{3+} replaces half of the Si^{4+} , Ca^{2+} offsets the charge deficit. In phyllosilicates containing K^+ and Ca^{2+} , the t-o-t layers are more firmly held together than those in talc or kaolinite, making minerals like muscovite and phlogopite harder and less greasy.

Tectosilicates

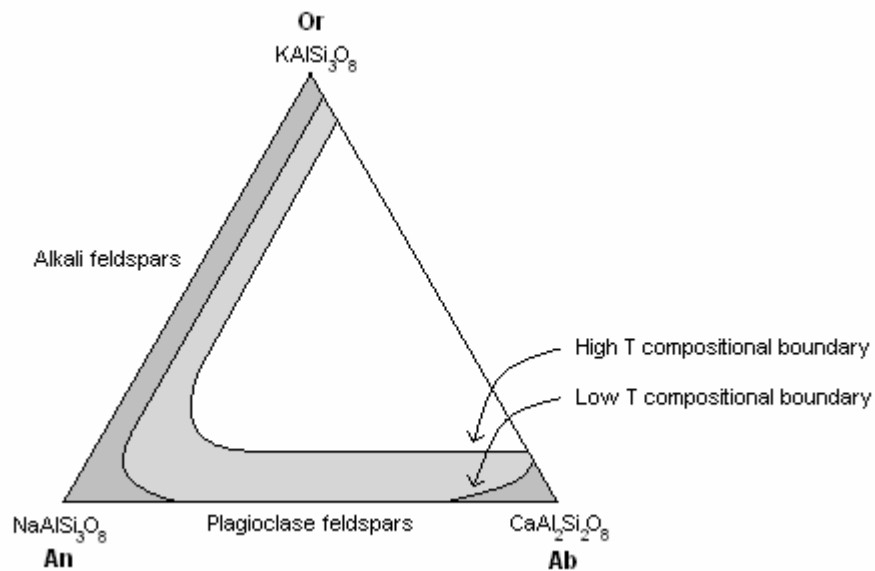
Tectosilicates represent over sixty percent of the rocky crust of the Earth. The two most important groups are the silica group and feldspar group.

Silica Group

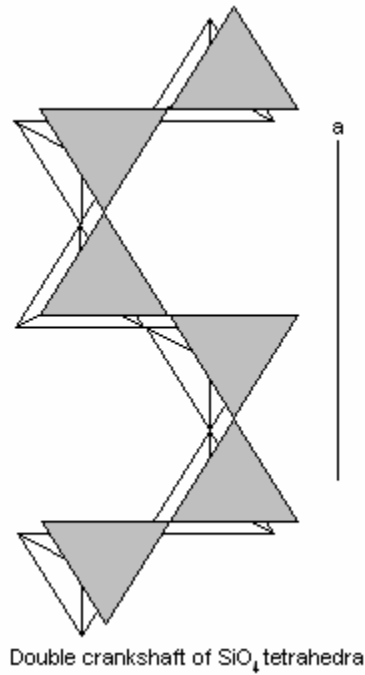
SiO_2 has eight naturally occurring polymorphs. Of these eight, only low quartz, low tridymite, and low cristobalite are common. Stishovite and coesite, the most dense of the polymorphs, have been discovered only in very small amounts and form from the high temperatures and pressures of meteorite impacts.

Feldspar Group

Feldspars are the most abundant minerals in the crust. The compositions of most feldspars can be represented by the ternary system anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$)—albite ($\text{NaAlSi}_3\text{O}_8$)—orthoclase (KAlSi_3O_8). Certain compositions within this system can only be attained at elevated temperatures, and consequently the ternary diagram contains compositional boundaries that move toward the interior with higher temperatures. Feldspars with compositions between anorthite and albite are called plagioclase feldspars. Those with compositions between albite and anorthite are called alkali feldspars.



The structures of feldspars are based on tetrahedra arranged in four-membered rings that are linked to form double crankshaft chains. Large metal ions like K^+ , Na^+ , or Ca^{2+} fill available voids. The structure of the double crankshaft, and consequently mineral symmetry, is controlled by the distribution of aluminum and silicon among the tetrahedra. High temperatures of formation correspond to more disordered and more symmetric feldspars. Lower temperatures of formation cause the Al-Si distribution to be more ordered and reduce symmetry.



Consider, for example, the polymorphs of orthoclase and their symmetries. The high temperature polymorph, sanidine, has a completely disordered Al-Si distribution and is monoclinic. The low temperature polymorph, microcline, has an ordered Al-Si distribution and is triclinic. This example shows how the structural state of feldspars can be used as indicators of a rock's temperature of formation.