Properties of Common Minerals

Figures from Winter's web page (2002)

Groups Considered

- Framework silicates
- Sheet silicates
- Pyroxenes
- Amphiboles
- Other Silicates
- Non Silicates

Framework Silicates

- Feldspars
- Feldspathoids
- Silica polymorphs

Feldspars

- Simple chemistry
- Substitution of Na for K or NaAl for CaAl
- Crystal systems
  - Monoclinic (orthoclase, sanidine)
  - Triclinic (plagioclase, microcline)
- Tabular habit

Feldspar Twinning

- Simple twins (two parts)
  - Carlsbad
  - Common in monoclinic feldspars
- Polysynthetic twins
  - Albite and others
  - Common in triclinic feldspars

K-spars

- Orthoclase, Sanidine, Microcline
- All optically negative
- All have n ~ 1.53
- Distinguished by 2V
  - Sanidine 2V = 0-30º
  - Orthoclase 2V = 30-70º
  - Microcline 2V = 70-90º
- Microcline has Scotch plaid twins

Plagioclase

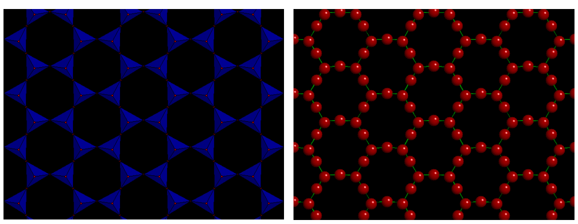
- Refractive index increases with Ca content
  - Varies between 1.53 (Ab) to 1.57 (An)
- 2V is large and varies with composition
- Optic sign depends on composition (+/-)

Common Sheet Silicates

- Muscovite
- Phlogopite
- Biotite
- Chlorite

Sheet Structures

Classified on the basis of Si-O polymerism



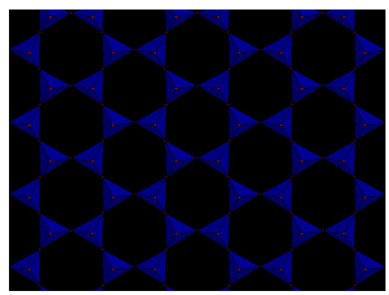
$[Si_2O_5]^{2-}$ Sheets of tetrahedra

micas talc clay minerals serpentine

Phyllosilicates

SiO_4 tetrahedra polymerized into 2-D sheets: $[Si_2O_5]$

Apical O's are unpolymerized and are bonded to other constituents



Building Blocks

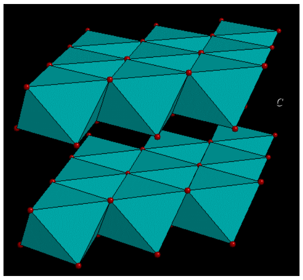
- Tetrahedral layers
- Octahedral layers
- Large Cation layers
- Week bonds along (001)

Common Sheet Properties

- Crystals are platy parallel to (001)
- Perfect cleavage follows (001)
- 2V is small (0-40º)
- Extinction is parallel to (001)
- BxA perpendicular to (001)
- Optic sign can be determine by 1st order plate

Brucite: $Mg(OH)_2$

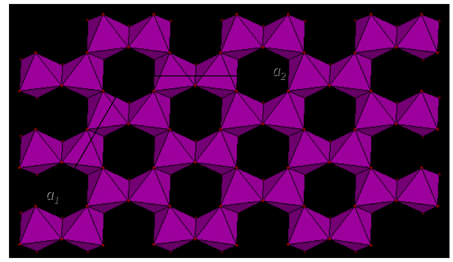
Octahedral layers can be understood by analogy with hydroxides



Layers of octahedral Mg in coordination with (OH)

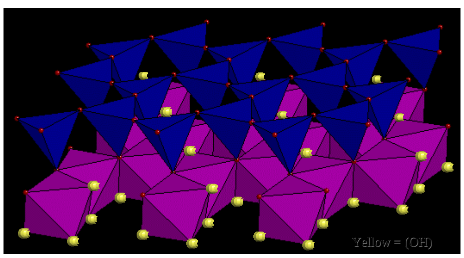
Large spacing along *c* due to weak van der waals bonds

Gibbsite $Al(OH)_3$



- Layers of octahedral Al in coordination with (OH)
- Al^{3+} means that only 2/3 of the VI sites may be occupied for charge-balance
- Brucite-type layers may be called trioctahedral and gibbsite-type dioctahedral

Kaolinite: Al_2 [Si_2O_5] $(OH)_4$



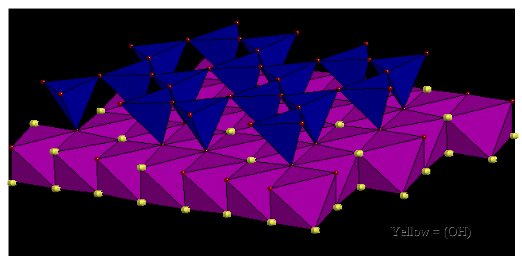
T
O
- vdw
T
O
- vdw
T
O

T-layers and dioctahedral (Al^{3+}) layers

(OH) at center of T-rings and fill base of VI layer →

weak van der Waals bonds between T-O groups

Serpentine: Mg_3 [Si_2O_5] $(OH)_4$



T
O
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T-layers and trioctahedral (Mg^{2+}) layers

(OH) at center of T-rings and fill base of VI layer →

weak van der Waals bonds between T-O groups

Mica Properties

- All micas are optically negative
- 2V is small (0-40°)
- (001) sheets give BxA figures
- Birefringence is large (0.035-0.045)
- “Birds eye” effect is obvious due to bent cleavages

Chlorite

- $(Mg, Fe)_3$ [$(Si, Al)_4O_{10}$] $(OH)_2$ $(Mg, Fe)_3$ $(OH)_6$
- T - O - T - (brucite) - T - O - T - (brucite) - T - O - T
- Very hydrated $(OH)_8$
- Low-temperature stability
- Low-T metamorphism and alteration product of mafics

Chlorite Optics

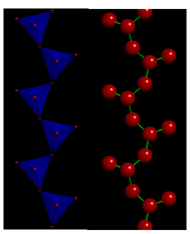
- 2V is small (0-20°)
- Birefringence is low (0.001-0.010)
- Some optically positive, some negative
- Extinction parallel to (001)
- Some types have strong dispersion
- Some types weakly pleochroic

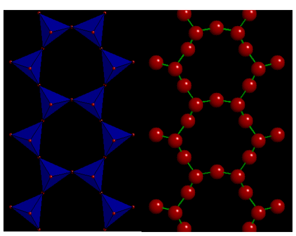
Other Sheet Silicates

- Talc
  - Pale green, high birefringence
- Stilpnomelane
  - Pleochroic (yellow to brown or green)
- Chloritoid
  - Hour glass inclusions, polysynthetic twins, cross fractures, inclined extinction

Mineral Structures

Silicates are classified on the basis of Si-O polymerism





$[SiO_3]^{2-}$ single chains pryoxenes pyroxenoids

Inosilicates

$[Si_4O_{11}]^{4-}$ Double tetrahedra amphiboles

Amphiboles

- Two cleavages at 120º
- Crystals elongate parallel to c
- Extinction Z^c small (10-20º)
- Color and pleochroism generally strong
- Optic sign negative
- 2V is large (70-90º)

Amphibole Groups

- Non calcic amphiboles
  - Anthophyllite (orthorhombic)
  - Cummingtonite (monoclinic)
- Calcic amphiboles
  - Tremolite-actinolite
  - Hornblende-oxyhornblende
- Sodic amphiboles
  - Glaucophane, Riebeckite, Arfvedsonite

Amphibole Chemistry

See handout for more information

General formula:

$$W_{0-1}\ X_2\ Y_5\ [Z_8O_{22}]\ (OH, F, Cl)_2$$

W = Na K

X = Ca Na Mg Fe^{2+} (Mn Li)

Y = Mg Fe^{2+} Mn Al Fe^{3+} Ti

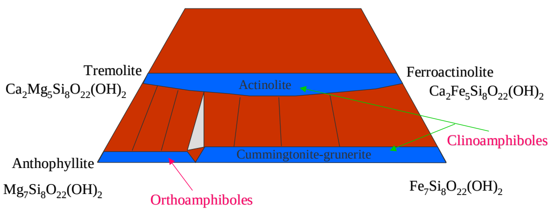
Z = Si Al

Again, the great variety of sites and sizes → a great chemical range, and hence a broad stability range

The hydrous nature implies an upper temperature stability limit

Amphibole Chemistry

Ca-Mg-Fe Amphibole "quadrilateral" (good analogy with pyroxenes)



Al and Na tend to stabilize the orthorhombic form in low-Ca amphiboles, so anthophyllite ↔ gedrite orthorhombic series extends to Fe-rich gedrite in more Na-Al-rich compositions

Hornblende

- Strongly pleochroic
- Z^c = 20º
- Birefringence = 0.020
- $2V_x$ = 70º
- Can be named green or brown hornblende
- Reddish varieties are oxyhornblende and kaersutite (Ti-rich hornblende)

Amphibole Chemistry

Hornblende has Al in the tetrahedral site

Geologists traditionally use the term "hornblende" as a catch-all term for practically any dark amphibole. Now the common use of the microprobe has petrologists casting "hornblende" into end-member compositions and naming amphiboles after a well-represented end-member.

Sodic amphiboles

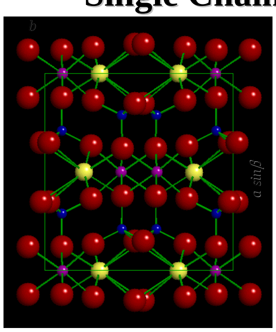
Glaucophane: $Na_2 Mg_3 Al_2 [Si_8O_{22}] (OH)_2$
Riebeckite: $Na_2 Fe^{2+}_3 Fe^{3+}_2 [Si_8O_{22}] (OH)_2$

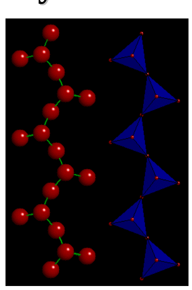
Sodic amphiboles are commonly blue, and often called "blue amphiboles"

General Pyroxene Characteristics

- Two cleavages at 87º
- Stumpy crystals
- Z^c large for monoclinic minerals
- Colorless or weakly pleochroic
- Optic sign positive
- 2V is moderate (40-60º)

Single Chains- Pyroxenes





Diopside (001) view blue = Si purple = M1 (Mg) yellow = M2 (Ca)

Pyroxene Chemistry

The general pyroxene formula:

$$W_{1-P} (X,Y)_{1+P} Z_2O_6$$

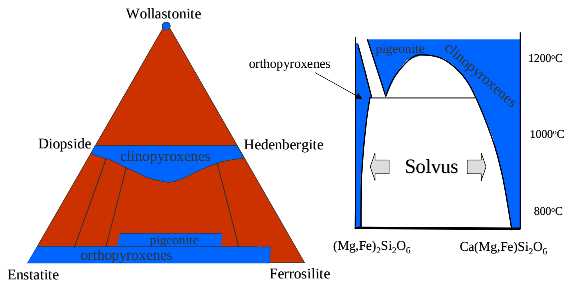
Where
- W = Ca Na
- X = Mg Fe^{2+} Mn Ni Li
- Y = Al Fe^{3+} Cr Ti
- Z = Si Al

Anhydrous so high-temperature or dry conditions favor pyroxenes over amphiboles

Pyroxene Chemistry

The pyroxene quadrilateral and opx-cpx solvus

Coexisting opx + cpx in many rocks (pigeonite only in volcanics)



Enstatite and Hypersthene

- Non-calcic Pyroxenes
- Enstatite
  - $2V_z$ = 60-90º
  - Birefringence = 0.008
- Hypersthene
  - $2V_x$ = 50-90º
  - Birefringence – 0.014
  - Weakly pleochroic pink to pale green

Diopside and Augite

- Colorless
- Birefringence of 0.020-0.030
- $2V_z$ = 60º
- Z^c = 40º
- Pigeonite has $2V_z$ = 0-30º

Sodic Pyroxenes

- Aegerine ($NaFeSi_2O_6$)
  - Strongly pleochroic in green
  - X^c = 2-6º
  - High birefringence (~0.050)
- Jadeite ($NaAlSi_2O_6$)
  - Moderate birefringence (~0.020)
  - Z^c = 30º

Independent SiO_4 Tetrahedra

- Olivine Occurrences:
  - Principally in mafic and ultramafic igneous and meta-igneous rocks
  - Fayalite in meta-ironstones and in some alkalic granitoids
  - Forsterite in some siliceous dolomitic marbles
- Monticellite $CaMgSiO_4$
  - Ca → M2 (larger ion, larger site)
  - High grade metamorphic siliceous carbonates