GY 302: Crystallography & Mineralogy

Lecture 26: Class VIII-Silicates
Tektosilicates part 2: Feldspars

Instructor: Dr. Douglas Haywick
Last Time

Class VIII Minerals (Tektosilicates)

1. Quartz Group
# Tektosilicate Minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>SiO₂ (multiple varieties)</td>
<td>Trigonal</td>
</tr>
<tr>
<td>*Cristobalite</td>
<td>SiO₂</td>
<td>Tetragonal</td>
</tr>
<tr>
<td>Coesite</td>
<td>SiO₂</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Chalcedony</td>
<td>SiO₂</td>
<td>“non crystalline”</td>
</tr>
<tr>
<td>Opal</td>
<td>SiO₂·nH₂O</td>
<td>“non crystalline”</td>
</tr>
<tr>
<td>crystalline”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*”Chert”</td>
<td>SiO₂ (multiple varieties)</td>
<td>“non crystalline”</td>
</tr>
</tbody>
</table>

Basic chemical composition: \( \text{SiO}_2 \)
Tektosilicate Minerals (Quartz Group)

Quartz
[SiO₂]

Crystal: Hexagonal (Trigonal)
Pt. Group:  32
Habit: bipyramidal, massive, drusy etc.
SG: 2.65;  H: 7
L: vitreous; Str: colourless
Col: colourless (varied)
Clev: poor [0110]
Optics: Uniaxial (-); bir=0.009
  n_w=1.544; n_e=1.553
Occurrence: widespread

Name Derivation: From the German “quarz” of uncertain origin
Quartz Varieties $[\text{SiO}_2]$ 

Agate - banded variety of chaledony  
Amethyst - purple  
Avanturine - translucent chalcedony  
Carnelian - flesh red chalcedony  
Cat's Eye - chatoyant  
Chalcedony - microcrystalline quartz  
Chert - cryptocrystalline quartz  
Chrysoprase - apple green chalcedony  
Citrine - yellow  
Flint - microcrystalline quartz  
Hornstone - flint  
Jasper - red or brown chalcedony  
Moss Agate - variety of chaledony  
Plasma - green chalcedony  
Prase - leek green chalcedony  
Rock Crystal  
Rose Quartz - rose colored  
Sapphire Quartz - blue colored  
Smoky Quartz - brown to black  
Tiger Eye - entombed asbestos
“Chert”
[SiO$_2$]

Crystal: N/A
Pt. Group: N/A
Habit: microcrystalline
SG: 2.09-2.65; H: 5.5 to 7
L: dull, waxy; Str: white
Col: varied
Clev: none
Optics: N/A
Occurrence: sedimentary

Chert is a rock name. Numerous varieties of chert have been identified.
Tektosilicate Minerals (Quartz Group)

Lechatlerite (‘‘Fulgurite) [SiO₂+ contaminants]

Crystal: N/A
Pt. Group: N/A
Habit: Amorphous?
SG: 2.20; H: 7.0?
L: dull; Str: white
Optics: N/A
Col: white
Clev: none
Occurrence: lightning strikes

Lightning strikes may pass 1,000,000 volts of electricity into the ground fusing quartz sand into “glass”.

http://www.mindat.org/gphotos/0707699001129998806.jpg
Six Quartz Polymorphs

Displaceive polymorphic transformations require relatively minor changes in the crystal lattice (e.g., modification of $\alpha$, $\beta$ or $\gamma$ crystallographic angles). There is generally no change in energy at the transformation threshold so polymorphic transformations are instantaneous and reversible.

If you heat “quartz” above 600 °C it transforms to the $\alpha$-polymorph (also known as high quartz). When the temperature falls below 600°C it transforms back to the $\beta$-polymorph (also known as low quartz).
Quartz Phase Diagrams

Olivine-Enstatite-Quartz System
Quartz: Last Words

Except for 2 situations:

1) Nephaline*-bearing rocks

\[ \text{NaAlSiO}_4 + 2\text{SiO}_2 \rightarrow \text{NaAlSi}_3\text{O}_8 \text{ (albite)} \]

2) Corundum-bearing rocks

\[ \text{Al}_2\text{O}_3 + \text{SiO}_2 \rightarrow \text{Al}_2\text{SiO}_5 \text{ (Sil/And/Ky)} \]

* A feldspathoid; you’ll hear about these next time
Today’s Agenda

Class VIII Minerals (Tektosilicates)

1. Feldspar Group
# Tektosilicate Minerals (Feldspars)

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potassium Feldspar Group</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanidine</td>
<td>KAlSi$_3$O$_8$</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>KAlSi$_3$O$_8$</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Anorthoclase</td>
<td>(Na, K)AlSi$_3$O$_8$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Microcline</td>
<td>KAlSi$_3$O$_8$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>v. Amazonite</td>
<td>KAlSi$_3$O$_8$</td>
<td>Triclinic</td>
</tr>
<tr>
<td><strong>Plagioclase Feldspars</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albite (Ab)</td>
<td>NaAlSi$_3$O$_8$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Oligoclase</td>
<td>An$_{10-30}$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Andesine</td>
<td>An$_{30-50}$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Labradorite</td>
<td>An$_{50-70}$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Bytownite</td>
<td>An$_{70-90}$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Anorthite (An)</td>
<td>CaAl$_2$Si$_2$O$_8$</td>
<td>Triclinic</td>
</tr>
</tbody>
</table>
The Feldspars

General Formula:

\[ \text{XAlSi}_3\text{O}_8 \text{ or } \text{XAl}_2\text{Si}_2\text{O}_8 \]

\( \text{X}= \text{Ca}^{2+}, \text{Na}^+, \text{K}^+ \)

Two Varieties:
1) Alkali Feldspars  
   (incl Orthoclase Group)
2) Plagioclase Feldspars
Tektosilicate Minerals (Feldspars)

Feldspars are common igneous minerals.

http://depthome.brooklyn.cuny.edu/geology/core332/geofield.htm
Tektosilicate Minerals (Feldspars)

Feldspars are also common metamorphic minerals

http://depthome.brooklyn.cuny.edu/geology/core332/geofield.htm
The Feldspars

Alkali Feldspars

1) Orthoclase (incl. Adularia/Moonstone)
2) Microcline (incl. Amazonite)
3) Sanadine
4) Anorthoclase
5) Albite

We will group Albite in with the plagioclases
The Feldspars

Plagioclase Feldspars \((\text{NaAlSi}_3\text{O}_8-\text{CaAl}_2\text{Si}_2\text{O}_8)\)

1) Albite (Ab) = \(\text{NaAlSi}_3\text{O}_8\)  \(\Rightarrow\) Na-plagioclase (from GY 111)
2) 
3) 
4) 
5) 
6) Anorthite (An) = \(\text{CaAl}_2\text{Si}_2\text{O}_8\)  \(\Rightarrow\) Ca-plagioclase
The Feldspars

Plagioclase Feldspars \((\text{NaAlSi}_3\text{O}_8-\text{CaAl}_2\text{Si}_2\text{O}_8)\)

1) **Albite** (Ab) = \(\text{NaAlSi}_3\text{O}_8\)
2) **Oligoclase** \(\text{Na}_{0.9-0.7}\text{Ca}_{0.1-0.3}\text{AlSi}_3\text{O}_8\)
3) 
4) 
5) 
6) **Anorthite** (An) = \(\text{CaAl}_2\text{Si}_2\text{O}_8\)
The Feldspars

Plagioclase Feldspars \((\text{NaAlSi}_3\text{O}_8-\text{CaAl}_2\text{Si}_2\text{O}_8)\)

1) Albite (Ab) = \(\text{NaAlSi}_3\text{O}_8\)
2) Oligoclase \(\text{Na}_{0.9-0.7}\text{Ca}_{0.1-0.3}\text{AlSi}_3\text{O}_8=(\text{An}_{10-30})\)
3)
4)
5)
6) Anorthite (An) = \(\text{CaAl}_2\text{Si}_2\text{O}_8\)
The Feldspars

Plagioclase Feldspars \((\text{NaAlSi}_3\text{O}_8-\text{CaAl}_2\text{Si}_2\text{O}_8)\)

1) Albite (Ab) = \(\text{NaAlSi}_3\text{O}_8\) \((\text{An}_{0-10})\)
2) Oligoclase = \(\text{An}_{10-30}\)
3) Andesine = \(\text{An}_{30-50}\)
4) Labradorite = \(\text{An}_{50-70}\)
5) Bytownite = \(\text{An}_{70-90}\)
6) Anorthite (An) = \(\text{CaAl}_2\text{Si}_2\text{O}_8\)
The Feldspars

Plagioclase Feldspars (NaAlSi$_3$O$_8$-CaAl$_2$Si$_2$O$_8$)

Determination of plagioclase composition via twinning extinction angles
Tektosilicate Minerals (Feldspars)
Anorthoclase is an interesting mineral. It forms at temps above 600 °C followed by rapid cooling.
Tectosilicate Minerals (Feldspars)

Anorthoclase is an interesting mineral. It forms at temps above 600 ºC followed by rapid cooling.

If the rate of cooling is slow, exsolution (separation into 2 mineral phases occurs).

Diagram:

- Anorthoclase (600 ºC)
- Perthite
  - Albite “blebs” in orthoclase
- Antiperthite
  - Orthoclase “blebs” in albite
Anorthoclase is an interesting mineral. It forms at temps above 600 °C followed by rapid cooling.

If the rate of cooling is slow, **exsolution** (separation into 2 mineral phases occurs).
Tektosilicate Minerals (Feldspars)

Phase diagrams to the rescue!
Tektosilicate Minerals (Feldspars)

Phase diagrams to the rescue!

![Figure 4]
Tektosilicate Minerals (Feldspars)

Phase diagrams to the rescue!
Tektosilicate Minerals (Feldspars)

Phase diagrams to the rescue!
Tektosilicate Minerals (Feldspars)

Phase diagrams to the rescue!

![Phase diagram figure 4: Liquid, Alkali Feldspar Solid Solution + Liquid, Alkali Feldspar Solid Solution, 2 Feldspars.](image)
Orthoclase (Adularia/Moonstone)  
\[\text{KAlSi}_3\text{O}_8\]

Crystal: Monoclinic  
Pt. Group: 2/m  
Habit: prismatic, blocky  
SG: 2.56; H: 6  
L: vitreous; Str: colourless  
Col: pink, white, grey-green  
Clev: perfect [001], good [010]  
Optics: biaxial (-); \(\text{bir}=0.005-0.006\)  
\(n_\alpha=1.518; n_\beta=1.522, n_\gamma=1.523\)  
Occurrence: Felsic igneous rocks, metamorphic rocks (greenschist and above)
Tektosilicate Minerals (Orthoclase Group)

Sanidine

\[ \text{[KAlSi}_3\text{O}_8] \]

Crystal: Monoclinic
Pt. Group: 2/m
Habit: prismatic, blocky
SG: 2.52; H: 6
L: vitreous; Str: colourless
Col: colourless, white, grey (red)
Clev: perfect [001], good [010]
Optics: biaxial (-); \( \text{bir} = 0.006-0.007 \)
\( n_\alpha = 1.518; \ n_\beta = 1.523, \ n_\gamma = 1.525 \)

Occurrence: high temperature felsic igneous rocks

From the Greek sanis - "little plate" and idos - "to see."
Tektosilicate Minerals (Orthoclase Group)

Microcline (Amazonite)

\[ KAlSi_3O_8 \]

Crystal: Triclinic
Pt. Group: \( \overline{1} \)
Habit: prismatic, blocky
SG: 2.56; H: 6
L: vitreous/pearly; Str: colourless
Col: bluish-green, white, grey
Clev: perfect [001], good [010]
Optics: biaxial (-); \( \text{bir} = 0.007 \)
\( n_\alpha = 1.518; n_\beta = 1.522, n_\gamma = 1.525 \)
Occurrence: granite pegmatities

From the Greek *mikron* - "little" and *klinein* - "to stoop."
**Tektosilicate Minerals** (Plagioclase Group)

Albite (Clevelandite)

[NaAlSi$_3$O$_8$]

Crystal: Triclinic  
Pt. Group: 1  
Habit: prismatic, blocky  
SG: 2.62; H: 7  
L: vitreous; Str: colourless  
Col: white (greyish, greenish, bluish)  
Clev: perfect [001], good [010]  
Optics: biaxial (-); bir=0.007  
\[ n_\alpha = 1.518; \ n_\beta = 1.522, \ n_\gamma = 1.523 \]  
Occurrence: granite pegmatities etc.

From the Latin, *albus*, in allusion to the common color.
**Tektosilicate Minerals** (Plagioclase Group)

**Oligoclase** (Sunstone)  
[An$_{10-30}$]

Crystal: Triclinic  
Pt. Group: $\bar{1}$  
Habit: massive, blocky  
SG: 2.65; H: 7  
L: vitreous; Str: colourless  
Col: white (grey, brown, yellow)  
Clev: perfect [001], good [010]  
Optics: biaxial (+); bir=0.009  
  $n_\alpha=1.533; n_\beta=1.537, n_\gamma=1.542$  
Occurrence: granite pegmatities etc.

From the Greek, *oligos* and *kasein*, "little cleavage."
Tektosilicate Minerals (Plagioclase Group)

Labradorite (Spectrolite)
[An$_{50-70}$]

Crystal: Triclinic
Pt. Group: 1
Habit: granular, blocky striated
SG: 2.69; H: 7
L: vitreous; Str: colourless
Col: colourless, grey (irridescent)
Clev: perfect [001], good [010]
Optics: biaxial (+); bir=0.009-0.010
  $n_\alpha=1.554; \ n_\beta=1.559, \ n_\gamma=1.562$
Occurrence: Mafic igneous rocks, some metamorphic rocks

From the Greek, *oligos* and *kasein*, "little cleavage."
Anorthite (Indianite)  [An]

Crystal: Triclinic  
Pt. Group: \( \overline{1} \)  
Habit: euhedral-blocky striated)  
SG: 2.73; H: 6  
L: vitreous; Str: colourless  
Col: colourless, white, grey (reddish)  
Clev: perfect [001], good [010]  
Optics: biaxial (-); \( \text{bir} = 0.011-0.012 \)  
\( n_\alpha = 1.572; \ n_\beta = 1.579, \ n_\gamma = 1.583 \)  
Occurrence: Mafic igneous rocks, some metamorphic rocks

From the Greek, an + orthos, "not upright" in allusion to the oblique crystals.