GY 302: Crystallography & Mineralogy

Lecture 20: Class VIII-Silicates
Soro- and Cyclosilicates

Instructor: Dr. Douglas Haywick
Mineral Quiz 4 results

1: Witherite (21%)
2: Cerussite (86%)
3: Fluorite (93%)
4: Smithsonite (75%)
5: Siderite (100%)
6: Ulexite (50%)
7: Rhodochrosite (100%)

Bonus: Pyrrhotite (43%)

Average: ?%  Highest grade: 104%
Class VIII Minerals: Nesosilicates

1. Garnet Group
2. Aluminum Silicates
3. Other Nesosilicates

andradite
Nesosilicate Minerals

Garnet Group

Pyrope (Mg$_3$Al$_2$(SiO$_4$)$_3$)
Almandine (Fe$_3$Al$_2$(SiO$_4$)$_3$)
Grossular (Ca$_3$Al$_2$(SiO$_4$)$_3$)

Crystal: Isometric
Pt. Group: 4/m 3 2/m
Habit: dodecahedral
SG: 3.54-4.33; H: 6.5-7.5
L: vitreous/resinous; Str: white
Col: red, yellow, green, brown, black, smurf
Clev: none, parting on {110}
Optics: Isotropic (n=1.544)

http://webmineral.com/data  Pyrope

Pyrope: after the Greek term *pyropos* for “fiery eyed”
Silicate Classification

Grossular

Almandine
Silicate Classification

Phase relationships between garnet and other silicate minerals are varied and frequently complex (e.g., between kyanite)

http://eurjmin.geoscienceworld.org/content/23/4/609.abstract
Silicate Classification

And different rocks lead to different metamorphic assemblages
Silicate Classification

Metamorphic facies

http://studyblue.com
Nesosilicates

http://www.geol.lsu.edu/henry/Geology3041/lectures/21MetamorphicIntro/BarrovianBuchan.jpg
Today’s Agenda

Class VIII Minerals

1. Sorosilicates
2. Cyclosilicates (3, 4 and 6 fold coordination)
## Sorosilicates

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoisite</td>
<td>$\text{Ca}_2\text{Al}_3\text{O}(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})$</td>
<td>Orthorhombic</td>
</tr>
<tr>
<td>Clinozoisite</td>
<td>$\text{Ca}_2\text{Al}_3\text{O}(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})$</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Epidote</td>
<td>$\text{Ca}_2(\text{Al,Fe})\text{Al}_2\text{O}(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})$</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Allanite</td>
<td>$(\text{Ca,Ce})_2(\text{Fe,Fe})\text{Al}_2\text{O}(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})$</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Lawsonite</td>
<td>$\text{CaAl}_2\text{SiO}_7(\text{OH})_2\cdot\text{H}_2\text{O}$</td>
<td>Orthorhombic</td>
</tr>
<tr>
<td>Pumpellyite</td>
<td>$\text{Ca}_2\text{MgAl}_2(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})_2\cdot\text{H}_2\text{O}$</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Vesuvianite (Idocrase)</td>
<td>$\text{Ca}_{10}\text{Mg}_2\text{Al}_4(\text{SiO}_4)_5(\text{Si}_2\text{O}_7)_2(\text{OH})_4$</td>
<td>Tetragonal</td>
</tr>
<tr>
<td>Hemimorphite</td>
<td>$\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot(\text{H}_2\text{O})$</td>
<td>Orthorhombic</td>
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# Sorosilicates

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<tr>
<td>Epidote</td>
<td>Ca$_2$(Al,Fe)Al$_2$O(SiO$_4$)(Si$_2$O$_7$)(OH)</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Allanite</td>
<td>(Ca,Ce)$_2$(Fe,Fe)Al$_2$O(SiO$_4$)(Si$_2$O$_7$)(OH)</td>
<td>Monoclinic</td>
</tr>
<tr>
<td>Lawsonite</td>
<td>CaAl$_2$SiO$_7$(OH)$_2$·H$_2$O</td>
<td>Orthorhombic</td>
</tr>
<tr>
<td>Pumpellyite</td>
<td>Ca$_2$MgAl$_2$(SiO$_4$)(Si$_2$O$_7$)(OH)2·H$_2$O</td>
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</tr>
<tr>
<td>Vesuvianite (Idocrase)</td>
<td>Ca$_{10}$Mg$_2$Al$_4$(SiO$_4$)$_5$(Si$_2$O$_7$)$_2$(OH)$_4$</td>
<td>Tetragonal</td>
</tr>
<tr>
<td>Hemimorphite</td>
<td>Zn$_4$Si$_2$O$_7$(OH)$_2$·(H$_2$O)</td>
<td>Orthorhombic</td>
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Sorosilicate Minerals

**Epidote**

$$[\text{Ca}_2(\text{Al,Fe})\text{Al}_2\text{O}(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})]$$

Crystal: Monoclinic
Pt. Group: 2/m
Habit: fibrous, prismatic, massive
SG: 3.4-3.5; H: 7
L: vitreous to earthy; Str: white
Col: green to yellow
Clev: perfect (001), poor (100)
Optics: Biaxial (-); bir=0.013-0.046
\(n_\alpha=1.723; n_\beta=1.73, n_\gamma=1.736\)

Name Derivation: From the Greek *epidosis* - "addition."

[Image of Epidote crystal]
Sorosilicate Minerals

Zoisite

\[ \text{Ca}_2\text{Al}_3\text{O}_(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH}) \]

Crystal: Orthorhombic
Pt. Group: 2/m 2/m 2/m
Habit: prismatic, massive
SG: 3.1-3.4: H: 6.5
L: vitreous; Str: white
Col: blue-green
Clev: perfect (001)
Optics: Biaxial (+); bir=0.006
\( n_\alpha = 1.70; \ n_\beta = 1.69, \ n_\gamma = 1.70 \)

Named after the Austrian natural scientist, Siegmund Zois (1747-1819).
Pumpellyite

$[\text{Ca}_2\text{MgAl}_2(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})_2\cdot(\text{H}_2\text{O})]$  
Crystal: Monoclinic  
Pt. Group: 2/m  
Habit: fibrous  
SG: 3.2; H: 5.5  
L: vitreous; Str: white  
Col: blue-green, brown  
Str: white  
Clev: [001], [100]; good  
Optics: Biaxial (+); bir=0.014  
$n_\alpha=1.67; n_\beta=1.67, n_\gamma=1.684$  

Named after the American geologist, R. Pumpelly (1837-1923).
Hemimorphite

$[\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot\text{H}_2\text{O}]$  

Crystal: Orthorhombic  
Pt. Group: 2mm  
Habit: massive to mammillary  
SG: 3.45; H: 5  
L: vitreous; Str: white  
Col: colorless, brown, to grey  
Clev: perfect [001]  
Optics: Biaxial (+); bir=0.020  
$n_\alpha=1.61; n_\beta=1.62, n_\gamma=1.736$

http://webmineral.com/data/Hemimorphite.shtml

Named after the hemimorphic nature of the crystals.
Hemimorphite
\[\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot\text{H}_2\text{O}\]
Crystal: Orthorhombic
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Named after the hemimorphic nature of the crystals.
Sorosilicate Minerals

Hemimorphite

$[\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot\text{H}_2\text{O}]$
Sorosilicate Minerals

Hemimorphite
[Zn$_4$Si$_2$O$_7$(OH)$_2$·H$_2$O]

http://desertscope.com/collItem.php?itemId=16

http://www.mineral-forum.com
Hemimorphite

\[ \text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot\text{H}_2\text{O} \]

It has unique polar or hemimorphic crystals from where it gets its name. Specimens of hemimorphite tend to be of two different forms. One form produces very glossy, clear or white, thin, bladed crystals, often well formed showing many crystal faces. Many times these crystals are arranged in fan shaped aggregates. The other form produces a blue to blue-green botryoidal crust that resembles smithsonite or prenite.

In many cases, it is often confused with smithsonite. I found this really nice method of differentiate the two: “The carbonate (smithsonite) dissolves in warm acid with some effervescence, while the silicate (hemimorphite) dissolves slowly and quietly, leaving gelatinous silica. Smithsonite has a higher density as well a shimmering luster that causes a play of light across the rounded surfaces. The two species also show differences in the way they cleave. Smithsonite knobs break with a ready convex (rhombohedral) cleavage not characteristic of hemimorphite. Hemimorphite is slightly harder than smithsonite.”

http://desertscape.com/collItem.php?itemId=16
Hemimorphite
\[\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot\text{H}_2\text{O}\]

Hemimorphite (along with smithsonite) form in Zn-bearing gossans atop “alamine” deposits (named after Calamine, Belgium)
# Cyclosilicates

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<tr>
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<tr>
<td>Beryl</td>
<td>$\text{Be}_3\text{Al}_2\text{Si}<em>6\text{O}</em>{18}$</td>
<td>Hexagonal</td>
</tr>
<tr>
<td>Tourmaline</td>
<td>$(\text{Na},\text{Ca})(\text{Li,Mg,Al})(\text{Al,Fe,Mn})_6(\text{BO}_3)_3(\text{Si}<em>6\text{O}</em>{18})(\text{OH})_4$</td>
<td>Hexagonal</td>
</tr>
<tr>
<td>Cordierite</td>
<td>$\text{Al}_3(\text{Mg, Fe})_2(\text{AlSi}<em>3\text{O}</em>{18})$</td>
<td>Orthorhombic</td>
</tr>
<tr>
<td>Axinite</td>
<td>$(\text{Ca, Mn, Fe})_3\text{Al}_2(\text{BO}_3)\text{Si}<em>4\text{O}</em>{12}(\text{OH})$</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Dioptase</td>
<td>$\text{CuSiO}_2(\text{OH})_2$</td>
<td>Hexagonal (Trigonal)</td>
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<tr>
<td>“Tourmaline”</td>
<td>$(\text{Na, Ca})(\text{Li, Mg, Al})(\text{Al, Fe, Mn})_6(\text{BO}_3)_3(\text{Si}<em>6\text{O}</em>{18})(\text{OH})_4$</td>
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Silicate rings come in 3, 4 and 6 fold structures. 8-fold structures also occur in nature (e.g., sulfur)
Cyclosilicate Minerals

3 fold ring structure
Cyclosilicate Minerals

4 fold ring structure
Cyclosilicate Minerals

6 fold ring structure
Cyclosilicate Minerals (6-fold rings)

Tourmaline Group (14)

\[ \text{NaMg}_3\text{Al}_6(\text{BO}_3)_3\text{Si}_6\text{O}_{18}(\text{OH})_4 \]-Dravite

Crystal: Hexagonal (trigonal)
Pt. Group: 3m
Habit: columnar, curved sides
SG: 3.09; H: 7-7.5
L: vitreous; Str: colourless
Col: black, red, green; watermelon
Clev: indistinct
Optics: Uniaxial (-); bir=0.019-0.025
\( n_e = 1.612; \ n_w = 1.63 \)

Name Derivation: Drava River, Austria

http://webmineral.com
Cordierite

\[ \text{Mg}_2\text{Al}_4\text{Si}_5\text{O}_{18} \]

Crystal: Orthorhombic
Pt. Group: 2/m 2/m 2/m
Habit: prismatic, massive
SG: 2.65; H: 7
L: vitreous; Str: white
Col: colorless, pale blue, gray
Clev: poor [010]
Optics: Biaxial (-); bir=0.011-0.018
\( n_\alpha = 1.52; \ n_\beta = 1.53, \ n_\gamma = 1.54 \)

http://webmineral.com/specimens/picshow.php?id=123

From the French mining engineer and geologist P. L. A. Cordier (1777-1861)
Cyclosilicate Minerals (6-fold rings)

**Dioptase**

\[ \text{[CuSiO}_2\text{(OH)}_2 \text{]} \]

Crystal: Hexagonal (Trigonal)
Pt. Group: 3
Habit: massive
SG: 3.3; H: 5
L: vitreous; Str: green
Col: dark blur-green, turquoise
Clev: [1011]; poor
Optics: Uniaxial (+); bir=0.051-0.053
\[ n_e=1.644; \quad n_w=1.697 \]

From the Greek, *dia* - "through" and *optomai* - "vision."
Cyclosilicate Minerals (6-fold rings)

Beryl

\([\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}]\)

Crystal: Hexagonal
Pt. Group: 6/m 2/m 2/m
Habit: euhedral, columnar
SG: 2.76; H: 7.5-8
L: vitreous; Str: white
Col: blue, yellow, red, green
Clev: imperfect
Optics: Uniaxial (-); bir=0.004-0.007
\(n_e=1.564; n_w=1.568\)

From the ancient Greek, beryllos, signifying a "precious blue-green color of sea water" stone.
Cyclosilicate Minerals

Beryl
[single unit cell]

http://www.uwsp.edu/geo/projects/geoweb/participants/dutch/PETROLGY/Beryl-CordStruc.htm
Cyclosilicate Minerals

Beryl
[side view]

Solitary silica tetrahedra

rings

http://www.uwsp.edu/geo/projects/geoweb/participants/dutch/PETROLGY/Beryl-CordStruc.htm
Cyclosilicate Minerals

Beryl
[complete lattice]

Aluminum octahedra

http://www.uwsp.edu/geo/projects/geoweb/participants/dutch/PETROLGY/Beryl-CordStruc.htm
Benitoite
[\text{BaTiSi}_3\text{O}_9\ ]

Crystal: Hexagonal
Pt. Group: \text{\bar{6}m2}
Habit: tabular
SG: 3.6; \text{ H: 6-6.5}
L: vitreous; \text{ Str: white}
Col: blue, purple, colorless
Clev: poor [1011]
Optics: uniaxial (+); \text{bir}=0.0470
\text{n}_e=1.804; \text{n}_w=1.757

Name derivation: from Benitoite Gem Mine, Ca
Cyclosilicate Minerals

Benitoite

http://www.uwsp.edu/geo/projects/geoweb/participants/dutch/PETROLGY/
Axinite (Fe variety)
[Ca$_2$FeAl$_2$BO$_3$Si$_4$O$_{12}$(OH)]

Crystal: Triclinic
Pt. Group: $\overline{1}$
Habit: wedge-shaped, striated
SG: 3.18-3.37;  H: 6-7.5
L: vitreous; Str: white
Col: brown, purple, black
Clev: fair [100]
Optics: Biaxial (-); bir=0.011-0.018
$n_\alpha=1.67$; $n_\beta=1.68$, $n_\gamma=1.68$

Name derivation: From the Greek *acine* - "axe" because of the crystal shape
Today’s Stuff To Do

1. Poster “Draft” due Thursday

Today’s Lab

1. Quiz 7 (Sulfates and Phosphates 12:15-12:45 PM)

On Line Lecture

1. Lecture 21 (Inosilicates 1: pyroxenes)

Thursday

1. Group activity; discussion about posters