GY 302: Crystallography & Mineralogy

Lecture 13: Halides

Instructor: Dr. Douglas Haywick
Last Time (on line)

More Oxides

1. Chromite (and Chromium)
2. Uraninite (and Uranium)
3. Chromite formation (ultramafic intrusions)
4. Uraninite formation (sedimentary, placer)
5. Supergene enrichment (recap of hydrothermal emplacement)
Oxide Minerals

Chromite (FeCr$_2$O$_4$)

Crystal: Isometric
Pt. Group: 4/m 3 2/m
Habit: octahedral, sucrosic
SG: 5.10
H: 5.5
L: metallic
Col: black (brownish)
Str: black (brown)
Clev: none; twinning on {111}; concoidal fracture

Name derivation: From its elemental composition containing chromium

http://www.theodoregray.com/PeriodicTable/Samples/Chromite/s12s.JPG
Oxide Minerals

Uraninite (UO₂)

Crystal: Isometric
Pt. Group: 4/m 3 2/m
Habit: massive, botryoidal
SG: 7.0-9.5
H: 5.5
L: submetallic to dull
Col: black
Str: brown to black
Clev: none; concoidal fracture

Name derivation: From its elemental composition containing uranium

http://www.treasuremountainmining.com/eb56uran1M.jpg
Supergene enrichment

Hydrothermal: a process involving “hot” water (usually groundwater under confining pressure).

Epithermal: <200°C (50°C and above)
Mesothermal: 200-300°C
Hypothermal: >300°C

Supergene enrichment involves meteoric water (“cold”)

Today’s Agenda

Halides

1. Select minerals
2. Occurrences and Associations

Featured minerals: Evaporites
Halides

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>System</th>
<th>Specimen Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnallite</td>
<td>KMgCl₃·2H₂O</td>
<td>Orthorhombic</td>
<td>g, g, g</td>
</tr>
<tr>
<td>*Cryolite</td>
<td>Na₃AlF₆</td>
<td>Monoclinic</td>
<td>g, g</td>
</tr>
<tr>
<td>Fluorite</td>
<td>CaF₂</td>
<td>Isometric</td>
<td>g (x9)</td>
</tr>
<tr>
<td>Halite</td>
<td>NaCl</td>
<td>Isometric</td>
<td>g (x6)</td>
</tr>
<tr>
<td>*Sylvite</td>
<td>KCl</td>
<td>Isometric</td>
<td>g, g, g</td>
</tr>
</tbody>
</table>

This class also includes bromides (ABrₓ) and iodides (AIₓ); i.e., the halogens.
Halides

Iodides and bromides are rather rare, but you do get them in the **Cerargyrite** group of Ag-compounds

- AgCl: chlorargyrite
- AgBr: Bromyrite
- AgI: Iodryite
Halite (NaCl)

Crystal: Isometric
Pt. Group: $4/m\ 3\ 2/m$
Habit: cubic, hopper crystals
SG: 2.17; H: 2.5
L: vitreous; Str: white
Col: white (various shades)
Clev: perfect [100], [010], [001]
Optics: Isotropic (n=1.544)

Name derivation: From the Greek halos (salt)
Halite (NaCl)

Occurrence: the most common soluble evaporite mineral

Associated Mins: calcite (limestone), dolomite (dolostone), gypsum, anhydrite, sulfur (salt diapirs)

May be confused with: sylvite

Uses: Kentucky Fried Chicken, McDonald’s french fries
# Halide Minerals

## Salt (data in kilo tonnes)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production 2014</th>
<th>Production 2015*</th>
<th>Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States†</td>
<td>45,300</td>
<td>48,000</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>11,000</td>
<td>11,000</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>7,400</td>
<td>7,500</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>13,000</td>
<td>12,500</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>8,500</td>
<td>9,000</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>68,000</td>
<td>70,000</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>6,000</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>12,200</td>
<td>12,500</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>16,000</td>
<td>17,000</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>10,700</td>
<td>10,500</td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>4,300</td>
<td>4,200</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>4,380</td>
<td>4,300</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>5,400</td>
<td>5,500</td>
<td></td>
</tr>
<tr>
<td>Ukraine</td>
<td>6,100</td>
<td>6,100</td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6,700</td>
<td>6,700</td>
<td></td>
</tr>
<tr>
<td>Other countries</td>
<td>41,000</td>
<td>42,000</td>
<td></td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>266,000</td>
<td>273,000</td>
<td></td>
</tr>
</tbody>
</table>

**World Resources:** World continental resources of salt are vast, and the salt content in the oceans is virtually inexhaustible. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Source: USGS Mineral Commodity Summaries 2016
Halide Minerals

Salt (US data)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>45,000</td>
<td>37,200</td>
<td>39,900</td>
<td>45,300</td>
<td>48,000</td>
</tr>
<tr>
<td>Sold or used by producers</td>
<td>45,500</td>
<td>34,900</td>
<td>43,100</td>
<td>46,000</td>
<td>47,200</td>
</tr>
<tr>
<td>Imports for consumption</td>
<td>13,800</td>
<td>9,880</td>
<td>11,900</td>
<td>20,100</td>
<td>23,200</td>
</tr>
<tr>
<td>Exports</td>
<td>846</td>
<td>809</td>
<td>525</td>
<td>940</td>
<td>846</td>
</tr>
<tr>
<td>Consumption:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reported</td>
<td>48,000</td>
<td>36,900</td>
<td>47,600</td>
<td>56,500</td>
<td>57,000</td>
</tr>
<tr>
<td>Apparent²</td>
<td>58,500</td>
<td>44,000</td>
<td>54,500</td>
<td>65,200</td>
<td>69,500</td>
</tr>
<tr>
<td>Price, average value of bulk, pellets and packaged salt, dollars per ton, f.o.b. mine and plant:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum and open pan salt</td>
<td>174.00</td>
<td>169.93</td>
<td>172.09</td>
<td>180.61</td>
<td>182.00</td>
</tr>
<tr>
<td>Solar salt</td>
<td>51.19</td>
<td>71.87</td>
<td>78.04</td>
<td>83.90</td>
<td>89.00</td>
</tr>
<tr>
<td>Rock salt</td>
<td>38.29</td>
<td>36.89</td>
<td>47.22</td>
<td>48.11</td>
<td>50.00</td>
</tr>
<tr>
<td>Salt in brine</td>
<td>8.14</td>
<td>8.44</td>
<td>8.49</td>
<td>9.08</td>
<td>9.15</td>
</tr>
<tr>
<td>Employment, mine and plant, number³</td>
<td>4,100</td>
<td>4,100</td>
<td>4,100</td>
<td>4,200</td>
<td>4,200</td>
</tr>
<tr>
<td>Net import reliance³ as a percentage of apparent consumption</td>
<td>24</td>
<td>22</td>
<td>22</td>
<td>29</td>
<td>32</td>
</tr>
</tbody>
</table>

Recycling: None.

Import Sources (2011–14): Chile, 37%; Canada, 36%; Mexico, 12%; The Bahamas, 5%; and other, 10%.

Source: USGS Mineral Commodity Summaries 2016
Sylvite (KCl)

Crystal: Isometric
Pt. Group: 4/m 3 2/m
Habit: cubic, hopper crystals
SG: 1.99; H: 2.5
L: vitreous; Str: white
Col: white (various shades)
Clev: perfect [100], [010], [001]
Optics: Isotropic (n=1.4903)

Name derivation: named after Dutch chemist Sylvia de la Boe (1614-1672)
Sylvite (KCl)

Occurrence: potash deposits (evaporite basins); much less common than halite of which it is always mixed with.

Associated Mins: halite, gypsum

May be confused with: halite (distinguished because of its sectility)

Uses: fertilizer (potash)
Carnalite \((\text{KMgCl}_3 \cdot 6\text{H}_2\text{O})\)

Crystal: Orthorhombic  
Pt. Group: 2/m 2/m 2/m  
Habit: massive, fibrous, hexagonal  
SG: 1.6; H: 2.5  
L: greasy (deliquescent); Str: white  
Col: variable (white, grey, reddish)  
Clev: none/indistinct  
Optics: biaxial+  
\(n_\alpha = 1.467; n_\beta = 1.475; n_\gamma = 1.494\)

Name derivation: after a German mining engineer
Carnalite \((\text{KMgCl}_3 \cdot 6\text{H}_2\text{O})\)

**Occurrence:** evaporite deposits

**Associated Mins:** halite, sylvite

**May be confused with:** sylvite, halite

**Uses:** fertilizer/potash ore

http://www.dmr.go.th/images/info/mineral/carnallite_1.jpg
# Halide Minerals

## Potash (data in kilo tonnes)

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>Recoverable ore</th>
<th>K2O equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>United States</strong>¹</td>
<td>850</td>
<td>770</td>
<td>1,500,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Belarus</td>
<td>6,290</td>
<td>6,500</td>
<td>3,300,000</td>
<td>750,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>311</td>
<td>311</td>
<td>300,000</td>
<td>13,000</td>
</tr>
<tr>
<td>Canada</td>
<td>11,000</td>
<td>11,000</td>
<td>4,200,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Chile</td>
<td>1,200</td>
<td>1,200</td>
<td>NA</td>
<td>150,000</td>
</tr>
<tr>
<td>China</td>
<td>4,400</td>
<td>4,200</td>
<td>NA</td>
<td>210,000</td>
</tr>
<tr>
<td>Germany</td>
<td>3,000</td>
<td>3,000</td>
<td>NA</td>
<td>150,000</td>
</tr>
<tr>
<td>Israel</td>
<td>1,770</td>
<td>1,800</td>
<td>NA</td>
<td>270,000</td>
</tr>
<tr>
<td>Jordan</td>
<td>1,260</td>
<td>1,250</td>
<td>NA</td>
<td>270,000</td>
</tr>
<tr>
<td>Russia</td>
<td>7,380</td>
<td>7,400</td>
<td>2,800,000</td>
<td>600,000</td>
</tr>
<tr>
<td>Spain</td>
<td>715</td>
<td>700</td>
<td>NA</td>
<td>20,000</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>610</td>
<td>610</td>
<td>NA</td>
<td>70,000</td>
</tr>
<tr>
<td>Other countries</td>
<td>50</td>
<td>50</td>
<td>250,000</td>
<td>90,000</td>
</tr>
<tr>
<td><strong>World total (rounded)</strong></td>
<td><strong>38,800</strong></td>
<td><strong>38,800</strong></td>
<td><strong>NA</strong></td>
<td><strong>3,700,000</strong></td>
</tr>
</tbody>
</table>

¹ Source: USGS Mineral Commodity Summaries 2015
# Halide Minerals

## Potash (US data)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Production, marketable¹</td>
<td>1,000</td>
<td>900</td>
<td>960</td>
<td>850</td>
<td>770</td>
</tr>
<tr>
<td>Sales by producers, marketable¹</td>
<td>990</td>
<td>980</td>
<td>880</td>
<td>930</td>
<td>760</td>
</tr>
<tr>
<td>Imports for consumption</td>
<td>4,980</td>
<td>4,240</td>
<td>4,650</td>
<td>4,970</td>
<td>4,000</td>
</tr>
<tr>
<td>Exports</td>
<td>202</td>
<td>234</td>
<td>289</td>
<td>118</td>
<td>30</td>
</tr>
<tr>
<td>Consumption, apparent¹,²</td>
<td>5,800</td>
<td>5,000</td>
<td>5,200</td>
<td>5,800</td>
<td>4,700</td>
</tr>
<tr>
<td>Price, dollars per ton of K₂O,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average, muriate, f.o.b. mine³</td>
<td>730</td>
<td>710</td>
<td>640</td>
<td>580</td>
<td>635</td>
</tr>
<tr>
<td>Employment, number:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine</td>
<td>660</td>
<td>750</td>
<td>760</td>
<td>670</td>
<td>600</td>
</tr>
<tr>
<td>Mill</td>
<td>620</td>
<td>740</td>
<td>770</td>
<td>660</td>
<td>620</td>
</tr>
<tr>
<td>Net import reliance⁴ as a percentage of apparent consumption</td>
<td>83</td>
<td>82</td>
<td>82</td>
<td>85</td>
<td>84</td>
</tr>
</tbody>
</table>

Recycling: None.

Import Sources (2011–14): Canada, 84%; Russia, 9%; Israel, 3%; Chile, 2%; and other, 2%.

Source: USGS Mineral Commodity Summaries 2016
Halide Minerals

Rocanville Potash Mine, Saskatchewan, Canada

Location: Saskatchewan, Canada
Ownership: Potash Corporation of Saskatchewan (100%)
Geology type: Devonian evaporite sequences
Mineral type: Sylvite, carnallite, halite and clay
Reserve base: 372Mt mineable; 1,132Mt inferred resource
Annual production: 7.5Mt of ore and 2.57Mt of potash products (2005)
Mining method: Underground long room-and-pillar, using two- and four-rotor continuous miners
Processing method: Crushing, desliming, cyclones, flotation
Employment: 340

Key Equipment:
Underground: Marietta two- and four-rotor continuous miners
Concentrator: Allen Bradley central control system

http://www.mining-technology.com/projects/rocanville/
Halide Minerals

Subsurface potash deposits in Sask.

http://www.ags.gov.ab.ca/publications/wcsb_atlas/A_CH10/FG10_18.GIF
Fluorite (CaF₂)

Crystal: Isometric
Pt. Group: 4/m 3 2/m
Habit: cubic, octahedral crystals
SG: 3.0-3.25; H: 4
L: vitreous; Str: white
Col: variable
Clev: [111] perfect
Optics: Isotropic (n=1.434)

Name derivation: From its elemental composition containing fluorine
Fluorite (CaF$_2$)

Occurrence: epithermal veins (Mississippi Valley ore deposits).

Associated Mins: widespread; dolomite, calcite, sphalerite, galena

May be confused with: calcite

Uses: metal fluxes (Al and Fe); chemical industry

http://webmineral.com/specimens/Fluorite.jpg
Halide Minerals

Cryolite ($\text{Na}_3\text{AlF}_6$)

Crystal: Monoclinic
Pt. Group: 2/m
Habit: massive to prismatic
SG: 2.97
H: 2.5-3
L: vitreous to greasy
Optics: Anisotropic (biaxial)
Col: variable (white, grey, reddish)
Str: white
Clev: none

Name derivation: From the Greek kryos meaning “frost”
Cryolite \((\text{Na}_3\text{AlF}_6)\)

**Occurrence:** rare, pegmatite intrusion (Greenland); one other deposit in Russia

**Associated Mins:** Greenland: microcline, quartz, siderite, fluorite

**May be confused with:** just about everything

**Uses:** Al refining (electrolysis). Now artificially made from Fluorite
Evaporite Formation

Coastal sabkha near Abu Dhabi
Evaporite Formation

Coastal sabkha near Abu Dhabi

http://www.fsc.uaeu.ac.ae/Geology/c/sabkha%20trip/images/sabkha2.jpg
Evaporite Formation

Coastal sabkha near Abu Dhabi

http://www.fsc.uaeu.ac.ae/Geology/c/sabkha%20trip/images/sabkha2.jpg
Evaporite Formation

First
Aragonite (ooids) 

Dolomite
Gypsum
Anhydrite
Halite

Sylvite*

Evaporite Basin

Ca^{2+} + CO_3^{2-} \rightarrow \text{Calcite}
Ca^{2+} + Mg^{2+} + CO_3^{2-} \rightarrow \text{Dolomite}
Ca^{2+} + SO_4^{2-} \rightarrow \text{Anhydrite/Gypsum}
Na^+ + Cl^- \rightarrow \text{Halite}

↑↑↑↑ extreme evaporation.

Restricted flow
Today’s Stuff To Do

1) Choose a mineral for your poster!
2) Oxides/hydroxides mineral quiz (12:15 PM)
   (followed by Carbonate/halide minerals in lab)
3) Mineral notebook examination!

Next Time

1. Nothing……Fall break holiday….BUT
2. Lecture test 2 (in class) Thursday Oct 13th
GY 302: Crystallography and Mineralogy

Lecture 13: Halides

Instructor: Dr. Doug Haywick
dhaywick@southalabama.edu

This is a free open access lecture, but not for commercial purposes. For personal use only.