Last Time

1. Minerals properties under PPL (Plane polarized light)
2. Mineral properties under XN (crossed Nichols/polars)
Optical Properties

A: Plane-polarized Light (PPL)

1) **Colour**: Most minerals are colourless under PPL, but some minerals are intensely coloured. As a general rule, dark coloured minerals in hand specimen (e.g., pyroxene, amphibole, biotite etc.), are coloured in PPL. Light coloured minerals (quartz, fluorite, feldspars, muscovite etc.) are colourless.
Optical Properties

A: Plane-polarized Light (PPL)

2) **Pleochroism.** This is an interesting phenomenon where anisotropic minerals appear to change colour as they are rotated in PPL. It has to do with variable indices of refraction and is related to the crystal class of the minerals.

http://www.union.edu/PUBLIC/GEODEPT/COURSES/petrology/ig_minerals.htm
Optical Properties

A: Plane-polarized Light (PPL)

2) **Pleochroism.**

Orientation is important!
3) **Cleavage.** Same property as seen in hand specimen, but you are now looking at 2 dimensional slices.
Optical Properties

A: Plane-polarized Light (PPL)

4) **Relief**: the ratio of the index of refraction of a mineral to the index of refraction of the material immediately adjacent to it (usually glass).

http://www.uwgb.edu/DutchS/PETROLGY/Tsecplp.htm

http://www.brocku.ca/earthsciences/people/gfinn/optical/relief1.jpg
Optical Properties

A: Plane-polarized Light (PPL)

5) **Crystallinity**. A crystal with sharp, geometric edges is said to be **euhedral**. One that has rounded edges (e.g., water abraded) is said to be **anhedral**.

http://www.uwgb.edu/DutchS/PETROLGY/Tsecplp.htm
Optical Properties

B: Crossed Nichols (XN)

6) **Extinction**: occurs when the indicatrix aligns up with the polars and the entire crystal goes black (extinct).
7) **Birefringence.** This is the most important property of minerals under crossed polars. It is defined as the difference between the index of refraction of the minimum and maximum refractive indices of a mineral.

For uniaxial minerals: \( n_o - n_e \) or \( n_e - n_o \).
For biaxial crystals: \( n_a - n_c \) or \( n_c - n_a \).

As far as you are concerned, you see pretty colours under XN
Optical Properties

B: Crossed Nichols (XN)

7) Birefringence. This is the most important property of minerals under crossed polars. It is defined as the difference between the index of refraction of the minimum and maximum refractive indices of a mineral.
Optical Properties
Optical Properties

B: Crossed Nichols (XN)

8) **Optical Twinning.** Same thing as physical twins whereby two or more crystals of a single mineral grow together in a mathematically predicable pattern (involves twin planes, twin axes etc).

---

PPL  XN
Optical Properties

B: Crossed Nichols (XN)

Plagioclase feldspar exhibits **polysynthetic twinning** (resembles prison stripes). Microcline feldspar exhibits **tartan twinning** (resembles the plaid of a Scottish kilt). Orthoclase displays **Carlsbad twinning** (not as prominent as the other feldspars).
Optical Properties

B: Crossed Nichols (XN)

9) **Zonation.** Some minerals change their composition as they grow, particularly those that form continuous series through solid solution during igneous processes (e.g., olivine, plagioclase). This can result in optical zonation.
Today’s Agenda

Native elements

1. Chemistry and Crystallography (properties)
2. Occurrences and Associations
3. Economics (resources, reserves, extraction)

Featured Minerals: Gold
# Native Elements

<table>
<thead>
<tr>
<th>Metals</th>
<th>Copper</th>
<th>Cu</th>
<th>Isometric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>Au*</td>
<td>Isometric</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>Ag*</td>
<td>Isometric</td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>Pt*</td>
<td>Isometric</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semi-metals</th>
<th>Arsenic</th>
<th>As</th>
<th>Hexagonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>Sb</td>
<td>Hexagonal</td>
<td></td>
</tr>
<tr>
<td>Bismuth</td>
<td>Bi</td>
<td>Hexagonal</td>
<td></td>
</tr>
<tr>
<td>Tellurium</td>
<td>Te</td>
<td>Trigonal</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-metals</th>
<th>Sulfur</th>
<th>S</th>
<th>Orthorhombic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite</td>
<td>C*</td>
<td>Hexagonal</td>
<td></td>
</tr>
<tr>
<td>Diamond</td>
<td>C*</td>
<td>Isometric</td>
<td></td>
</tr>
</tbody>
</table>

* primary production from native elements
Metallic Native Elements

**Gold (Au)**

Crystal: Isometric  
Pt. Group: 4/m32/m  
Habit: octahedral, dendritic  
SG: 15.6-19.3 (depending on Ag content)  
H: 2.5-3*  
L: metallic  
Col: gold-yellow  
Str: gold-yellow  
Clev: none  
Optical: Opaque

Name Derivation: Anglo Saxon, of uncertain origin.

http://www.rocksandgems.info
Metallic Native Elements

**Gold (Au)**

Occurrence: quartz veins (igneous rocks, hydrothermal), placer deposits

Associated Mins: quartz, pyrite, chalcopyrite, galena, stibnite, sphalerite, arsenopyrite, tourmaline, molybdenite

Related Mins: Calaverite [AuTe$_2$], sylvanite [(Au,Ag)Te$_2$], maldonite [Au$_2$Bi], electrum [Au-Ag solid solution]
Metallic Native Elements

Gold (production, reserves in tonnes*)

Production: refined metal produced per year (metric tons)

*1 metric ton (tonne) = 1000 kg = 32,150.7 troy ounces

http://minerals.usgs.gov/minerals/pub
Metallic Native Elements

Resources: a concentration of a material useful to humanity (water, food, minerals)

Geological Resources: all materials (mineral and energy) including those only surmised to exist, that have present or anticipated future value and which can be extracted from the Earth via economically feasible methods ($$$) (i.e., gold, diamonds, coal, oil, natural gas, water)

Reserve Base: The in-place demonstrated (measured + indicated) amount of a resource that can be extracted via current mining and production techniques (currently economical + marginal +/- subeconomical). Equivalent to the old "geological reserve" definition.

Reserve (current): That part of the reserve base that could be economically extracted today

Production: refined metal produced per year (metric tons)

(see lecture supplements for additional resources jargon)
## Metallic Native Elements

### Gold (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></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine</td>
<td>234</td>
<td>235</td>
<td>230</td>
<td>210</td>
<td>200</td>
</tr>
<tr>
<td>Refinery:</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Primary</td>
<td>220</td>
<td>222</td>
<td>223</td>
<td>203</td>
<td>200</td>
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<tr>
<td>Secondary (new and old scrap)</td>
<td>263</td>
<td>215</td>
<td>210</td>
<td>161</td>
<td>140</td>
</tr>
<tr>
<td>Imports for consumption^2</td>
<td>550</td>
<td>326</td>
<td>315</td>
<td>308</td>
<td>265</td>
</tr>
<tr>
<td>Exports^2</td>
<td>664</td>
<td>695</td>
<td>691</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Consumption, reported</td>
<td>168</td>
<td>147</td>
<td>160</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Stocks, yearend, Treasury^3</td>
<td>8,140</td>
<td>8,140</td>
<td>8,140</td>
<td>8,140</td>
<td>8,140</td>
</tr>
<tr>
<td>Price, dollars per troy ounce^4</td>
<td>1,572</td>
<td>1,673</td>
<td>1,415</td>
<td>1,269</td>
<td>1,170</td>
</tr>
<tr>
<td>Employment, mine and mill, number^5</td>
<td>11,100</td>
<td>12,700</td>
<td>13,000</td>
<td>11,800</td>
<td>11,000</td>
</tr>
<tr>
<td>Net import reliance^6 as a percentage of apparent consumption</td>
<td>(‘)</td>
<td>(‘)</td>
<td>(‘)</td>
<td>(‘)</td>
<td>(‘)</td>
</tr>
</tbody>
</table>

**Government Stockpile:** The U.S. Department of the Treasury maintains stocks of gold (see salient statistics above), and the U.S. Department of Defense administers a Governmentwide secondary precious-metals recovery program.
Metallic Native Elements

Silver (Ag)

Crystal: Isometric
Pt. Group: 4/m32/m
Habit: massive, acicular
SG: 10.1-10.5
H: 2.5-3
L: metallic
Col: silver-white
Str: silver-white
Clev: none
Optical: Opaque

Name: Derivation: Anglo Saxon, of uncertain origin.

http://webmineral.com/specimens/picshow.php?id=1060
Metallic Native Elements

Silver (Ag)

Occurrence: hydrothermal deposits and in oxidized zones of ore deposits.

Associated Mins: arsenopyrite, Ni and As ores.

Related Mins: dyscrasite [Ag$_3$Sb], argentite [Ag$_2$S], proustite [Ag$_3$AsS$_3$], pyrargyrite [Ag$_3$SbS$_3$], amalgram [Hg-Ag solid solution]; electrum [Au-Ag solid solution]
Metallic Native Elements

Platinum Group (Pt, Ir, Pa, Rh, Ru, Os,)
Crystal: Isometric
Pt. Group: 4/m\(\overline{3}2/m\)
Habit: massive, acicular
SG: 21.47
H: 4-4.5
L: metallic
Col: gray-silver
Str: gray-silver
Clev: none
Optical: opaque

Name Derivation: Spanish, platina = "silver."
Metallic Native Elements

Platinum Group

Occurrence: ultramafic rocks and in placer deposits.

Associated Mins: chromite, spinel and olivine

Related Mins: none
## Metallic Native Elements

### Platinum Group (kilograms US data)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mine production:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>3,700</td>
<td>3,670</td>
<td>3,720</td>
<td>3,660</td>
<td>3,700</td>
</tr>
<tr>
<td>Palladium</td>
<td>12,400</td>
<td>12,300</td>
<td>12,600</td>
<td>12,400</td>
<td>12,500</td>
</tr>
<tr>
<td><strong>Imports for consumption:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>129,000</td>
<td>172,000</td>
<td>116,000</td>
<td>141,000</td>
<td>139,000</td>
</tr>
<tr>
<td>Palladium</td>
<td>98,900</td>
<td>80,100</td>
<td>83,100</td>
<td>92,400</td>
<td>89,000</td>
</tr>
<tr>
<td>Rhodium</td>
<td>13,100</td>
<td>12,800</td>
<td>11,100</td>
<td>11,100</td>
<td>11,000</td>
</tr>
<tr>
<td>Ruthenium</td>
<td>13,300</td>
<td>10,200</td>
<td>15,300</td>
<td>11,100</td>
<td>9,000</td>
</tr>
<tr>
<td>Iridium</td>
<td>2,790</td>
<td>1,230</td>
<td>1,720</td>
<td>1,990</td>
<td>730</td>
</tr>
<tr>
<td>Osmium</td>
<td>48</td>
<td>130</td>
<td>77</td>
<td>322</td>
<td>40</td>
</tr>
<tr>
<td><strong>Exports:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>11,300</td>
<td>8,630</td>
<td>11,200</td>
<td>14,800</td>
<td>11,000</td>
</tr>
<tr>
<td>Palladium</td>
<td>32,000</td>
<td>32,200</td>
<td>25,900</td>
<td>22,500</td>
<td>27,000</td>
</tr>
<tr>
<td>Rhodium</td>
<td>1,370</td>
<td>1,040</td>
<td>1,220</td>
<td>428</td>
<td>600</td>
</tr>
<tr>
<td>Other PGMs</td>
<td>1,150</td>
<td>1,640</td>
<td>1,320</td>
<td>901</td>
<td>800</td>
</tr>
<tr>
<td><strong>Price:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>1,724.51</td>
<td>1,555.39</td>
<td>1,489.57</td>
<td>1,387.89</td>
<td>1,080.00</td>
</tr>
<tr>
<td>Palladium</td>
<td>738.51</td>
<td>649.27</td>
<td>729.58</td>
<td>809.98</td>
<td>690.00</td>
</tr>
<tr>
<td>Rhodium</td>
<td>2,204.35</td>
<td>1,274.98</td>
<td>1,069.10</td>
<td>1,174.23</td>
<td>970.00</td>
</tr>
<tr>
<td>Ruthenium</td>
<td>165.85</td>
<td>112.26</td>
<td>75.63</td>
<td>65.13</td>
<td>48.00</td>
</tr>
<tr>
<td>Iridium</td>
<td>1,035.87</td>
<td>1,066.23</td>
<td>826.45</td>
<td>556.19</td>
<td>530.00</td>
</tr>
<tr>
<td><strong>Employment, mine, number:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>89</td>
<td>90</td>
<td>84</td>
<td>89</td>
<td>90</td>
</tr>
<tr>
<td>Palladium</td>
<td>64</td>
<td>57</td>
<td>60</td>
<td>65</td>
<td>58</td>
</tr>
</tbody>
</table>

Recycling: An estimated 125,000 kilograms of platinum, palladium, and rhodium was recovered globally from new and old scrap in 2015, including about 55,000 kilograms recovered from automobile catalytic converters in the United States.

**Import Sources (2011–14):** Platinum: South Africa, 18%; Germany, 16%; United Kingdom, 13%; Canada, 11%; and other, 42%. Palladium: Russia, 24%; South Africa, 24%; United Kingdom, 21%; Switzerland, 6%; and other, 25%.
Graphite (C)

Crystal: Hexagonal
Pt. Group: 6/m 2/m 2/m
Habit: platey, massive
SG: 2.1-2.2
H: 1-2
L: submetallic
Col: lead-gray, black
Str: black
Clev: perfect basal {001}
Optical: opaque

Name derivation: From the Greek, graphein, "to write"
Non-metallic Native Elements

Graphite (C)

Occurrence: metamorphic rocks (esp. schists, marbles and gneisses). Rare in igneous rocks.

Associated Mins: none to speak of

Related Mins: none
Non-metallic Native Elements

Diamond (C)
Crystal: Isometric
Pt. Group: 4/m\(\overline{3}2/m\)
Habit: octahedral, twinned
SG: 3.5
H: 10
L: adamantine
Col: colorless, rare blue, red, yellow
Str: n/a
Optical: isotropic, n=2.419
Clev: perfect \{111\}
Non-metallic Native Elements

Diamond (C)

Occurrence: altered ultramafic rocks and carbonated igneous rocks (Kimberlites)

Associated Mins: olivine, pyrope, zircon, kyanite

Related Mins: none
Metallic Native Elements

Diamond (production, reserves in 1000s of karats of gem quality stone)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>7,100</td>
<td>7,100</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>186</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>Botswana</td>
<td>17,300</td>
<td>17,300</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>57</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>12,000</td>
<td>12,000</td>
<td></td>
</tr>
<tr>
<td>Congo (Brazzaville)</td>
<td>53</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Congo (Kinshasa)</td>
<td>3,130</td>
<td>3,150</td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>242</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>Guinea</td>
<td>131</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Guyana</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Lesotho</td>
<td>346</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Namibia</td>
<td>1,920</td>
<td>1,920</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>21,500</td>
<td>21,500</td>
<td></td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>496</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>5,950</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>Tanzania</td>
<td>190</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>477</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Other countries</td>
<td>44</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>71,200</td>
<td>71,300</td>
<td></td>
</tr>
</tbody>
</table>

World reserves of diamond-bearing deposits are substantial. No reserve data are available for other gemstones.

2016 Mineral Commodity Summaries. USGS
Non-metallic Native Elements

Gemstones “Consumption” (not just diamonds-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></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural</td>
<td>11.0</td>
<td>11.3</td>
<td>9.6</td>
<td>9.5</td>
<td>9.6</td>
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<tr>
<td>Laboratory-created (synthetic)</td>
<td>31.9</td>
<td>31.2</td>
<td>56.9</td>
<td>51.0</td>
<td>52.4</td>
</tr>
<tr>
<td>Imports for consumption</td>
<td>23,500</td>
<td>21,500</td>
<td>24,700</td>
<td>26,400</td>
<td>25,700</td>
</tr>
<tr>
<td>Exports, including reexports</td>
<td>18,200</td>
<td>16,900</td>
<td>19,400</td>
<td>21,300</td>
<td>19,000</td>
</tr>
<tr>
<td>Consumption, apparent</td>
<td>5,360</td>
<td>4,570</td>
<td>5,400</td>
<td>5,120</td>
<td>6,770</td>
</tr>
<tr>
<td>Price</td>
<td>Variable, depending on size, type, and quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment, mine number</td>
<td>1,100</td>
<td>1,100</td>
<td>1,100</td>
<td>1,100</td>
<td>1,100</td>
</tr>
<tr>
<td>Net import reliance as a percentage of apparent consumption</td>
<td>99</td>
<td>99</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

Recycling: Gemstones are often recycled by being resold as estate jewelry, reset, or recut, but this report does not account for these stones.

Import Sources (2011–14 by value): Israel, 38%; India, 27%; Belgium, 19%; South Africa, 4%; and other, 12%. Diamond imports accounted for 93% of the total value of gem imports.

2016 Mineral Commodity Summaries. USGS
Emplacement and Extraction
Gold precipitation depends on:
- Temperature
- Pressure
- pH
- Cl\(^{-}\) concentration of hydrothermal solutions
- H\(_2\)S fugacity*

*pressure of an ideal gas which has the same chemical potential as the real gas.

http://www.mawsonresources.com
Gold

Gold is usually transported as [AuCl$_2^-$] in systems hotter than 400 C.
Gold is usually transported as \([\text{AuCl}_2^-]\) in systems hotter than 400 °C.

\([\text{Au(HS)}_2^-]\) is the dominant ion complex at lower temperatures.
Gold is usually transported as \([\text{AuCl}_2^-]\) in systems hotter than 400°C.

\([\text{Au(HS)}_2^-]\) is the dominant ion complex at lower temperatures.

Maximum solubility occurs near the \(\text{H}_2\text{S}-\text{HS}^-\text{-SO}_4^{2-}\) equilibrium point.
Gold is usually transported as [AuCl$_2^-$] in systems hotter than 400 C. [Au(HS)$_2^-$] is the dominant ion complex at lower temperatures.

AU dissolution

\[
\begin{align*}
\text{Au} + \text{HCl} + \text{NaCl} &= \text{NaAuCl}_2 + 0.5\text{H}_2 \\
\text{Au} + 2\text{Cl}^- + \text{H}^+ + 0.25\text{O}_2 &= \text{AuCl}_2^- + 0.5\text{H}_2\text{O} \\
\text{Au} + 4\text{Cl}^- + 3\text{H}^+ + 0.75\text{O}_2 &= \text{AuCl}_4^- + 1.5\text{H}_2\text{O}
\end{align*}
\]

(Zhu, An and Tan, 2011)
Gold

Precipitation of gold usually occurs following reduction in oxygen fugacity (Au-S complexes break down leading to precipitation of other sulfides like pyrite and precipitation of gold):

\[
\begin{align*}
2\text{Au(HS)}_2^- + \text{H}_2\text{O} &\rightarrow 2\text{Au} + 4\text{HS}^- + 2\text{H}^+ + 0.5\text{O}_2 \\
2\text{Au(HS)}_2^- + 8\text{H}_2\text{O} &\rightarrow 2\text{Au} + 4\text{SO}_4^{2-} + 4\text{H}^+ + 8\text{H}_2 \\
\text{FeCO}_3 + \text{Au(HS)}_2^- &\rightarrow \text{FeS}_2\text{pyrite} + \text{CO}_2 + \text{H}_2\text{O} + \text{Au}
\end{align*}
\]

(Zhu, An and Tan, 2011)
Gold

Gold is largely produced through hydrothermal precipitation
Gold

Gold is largely produced through hydrothermal precipitation

FIG. 2: Schematic illustration of geological setting and hydrothermal alteration associated with Au-rich high-sulphidation VMS hydrothermal systems (from Hannington et al., 1999).

Gold

Australian Gold Deposits
Gold

Hemlo Gold play
Gold
Gold

Golden Giant Mine (Newmont)
Gold

Golden Giant Mine
Gold Extraction

Golden Giant Mine

A typical underground mine
Gold Extraction

Waihi open pit gold mine (Newmont),
New Zealand
Gold Extraction

Summitville (Co) Gold Mine

An atypical open pit mine
Gold Extraction

Cyanide Leeching Method

\[ 4\text{Au}^0 + 8\text{CN}^- + \text{O}_2 + 2\text{H}_2\text{O} = 4\text{Au(CN)}^2^- + 4\text{OH}^- \]
Gold Extraction

Heap Cyanide Leaching Method

1. The ore is dug out of the pit by blasting and crane shovels. Some of these pits are so large that when fully excavated they are more than 300 metres across and 1.3 km deep.

2. Approximately 200 tons of rock will yield 1 ounce of gold. Huge piles of waste rock can leach toxic metals and acids.

3. The ore is driven to the top of the pit and dumped on open heaps, and flattened out by a bulldozer.

4. A weak cyanide solution is sprinkled on top of the heap and seeps through the pile, leaching the gold out of the ore.

5. The gold-bearing cyanide, called the 'pregnant solution' reaches a sloping rubber pad under the heap and runs into dams and from there runs into a rubber lined reservoir.

6. The pregnant solution is pumped into the processing plant.

7. Once the gold is extracted, the cyanide solution returns to the makeup tank to be reused.

8. After purification, the gold is poured into molds to make bars and traded. More than 80% of gold is used in jewellery, the rest is bought by investors or used in electronics.

Illustration by Christina Nicholas
Gold Extraction

Heap Cyanide Leeching Method

1. The ore is dug out of the pit by blasting and loaded onto a truck. Some of these pits are so large that when fully excavated they are more than 300 metres across and 1.3 km deep.

2. Approximately 200 tons of rock will yield 1 ounce of gold. Huge piles of waste rock can leach toxic metals and acids.

3. The ore is driven to the top of the pit and dumped on open heaps, and flattened out by a bulldozer.

4. A weak cyanide solution is sprinkled on the top of the heap and seeps through the pile, leaching the gold out of the ore.

5. The gold-bearing cyanide, called the 'pregnant solution', reaches a sloping rubber pad under the heap and runs into dams and from there runs into a rubber lined reservoir.

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Illustration by Christina Nicholas
Today’s Stuff To Do

1. Take home Lecture test 1 due now (email copies by 5:00 PM)

Today’s Lab

1. Quiz 3 (mono/triclinic models soon)
2. Lab Assignment 5 (Optical mineralogy)

On Line Lecture

1. Finish lecture (on diamonds*)

Thursday

1. Lab Assignment 5 continued
GY 302: Crystallography and Mineralogy

Lecture 8: Native Elements

Instructor: Dr. Doug Haywick
dhaywick@southalabama.edu

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