Flambeau Mine

Ore Analysis
Overview

- Locality
- Flambeau Mine Data
- Flambeau Geologic Information
- SEM
- SEM Results
- Ternary Diagram
Location

- Ladysmith, Wisconsin
- 2500x500 x220 feet in size
Flambeau Record

- Years of operation 1993–1997
- 181,000 tons copper
- 334,000 ounces gold
- 3.3 million ounces silver
- Old accumulation of ore possibly 1860–520MA

Jones et al., 1999
Flambeau Record

- Similar to at least 10 other ‘prospects’ in Wisconsin differing mainly in types of ore-chalcocite
- Flambeau– and in a higher grade of ore
- Cherty horizons indicating hot springs within ore
- Distinctive mine in that the Chalcocite has an brassy yellow bronze, purple or blue patina on the crystals determined to be Bornite $\text{Cu}_5\text{FeS}_4$ coating by microprobe studies

Jones et al., 1999
Flambeau Geologic Setting

- Mine in a broad belt of Precambrian volcanic and associated sedimentary rocks called the Wisconsin Magmatic Terranes on the South margin of the Canadian Shield
- Area was once tectonically active and beds were tilted up 90 degrees
- Rocks are remnants of a volcanic island arc that collided with ancient continent about 1860ma

Jones et al., 1999
Flambeau Primary Ore

- Pyrite – Fe $S_2$
- Chalcopyrite – Cu Fe $S_2$
- Chalcocite
- Sphalerite – Zn S
- Galena – Pb S
- Gold – Au
- Silver – Ag
Flambeau Ore Body

- Orebody is a volcanogenic massive sulfide (VMS) deposit
- One of the most concentrated ever mined
- Sulfides deposited on flanks of rhyolitic volcanic islands from hydrothermal brines containing Iron, Copper, Zinc, Lead, Silver and Gold
- At the Flambeau location these metal rich brines produced a layer of 50 foot layer thick sulfide mud with admixed volcanics

Jones et al., 1999
Flambeau Ore Body

- Flambeau is result of orebody extensively altered and enriched by chemical weathering
- Sulfide minerals were unstable in O rich ground waters
- Above water table sulfur went to sulfates by oxidation
- Fe in original pyrite, pyrrhotite and chalcopyrite oxidized into goethite or hematite
- These irons were insoluble and remained at surface and formed an iron rich cap with gold present

Jones et al., 1999
Flambeau Ore Body

- Near surface the acid rich ground water dissolved nearly all the Copper, Zinc and Silver and carried them deeper into the water table.
- Below the water table oxygen was less available; Copper replaced iron in the sulfide minerals:
  - Pyrite and pyrrhotite went to chalcopyrite, then bornite with iron going into the solution.
  - Zoning of chalcocite, bornite, and chalcopyrite.

DeMatties, T., 1996
Diagram of Mineralized Zones

- **Supergene Zone**
  - Gossan (Cassiterite, Quartz, Iron Oxides)
  - Zone of Copper Oxysalts, Oxides and Native Metal
  - Zone of Secondary Sulphides (Chalcocite, Etc)
  - Zone of Primary Sulphides (Chalcopyrite, Etc)
  - Zone of Mixed Sn/Cu Ores

- **Hypogene Zone**

Legend:
- Iron Oxides
- Oxysalts
- Secondary Sulphides
- Primary Sulphides
- Cassiterite
- Quartz

Present Surface
Present Water Table
So-called Copper Zone
Scanning Electron Microscope
Used to obtain morphology and surface features of materials
Electron Beams focused on a specific area of specimen
Radiation signals are recorded by detectors
Returned signals include secondary electrons, backscatter electrons, X Rays, emissions of ultraviolet, visible or infrared wavelengths during electron bombardment

Klein and Dutrow, 2008
SEM Ore Photos

Photo of Pyrite determined by Mineral Recalculation using weight percent

10521 Mine ore 2

Final Mineral Formula FeS$_2$
Mineral photo of **Chalcopyrite** by Recalculation of Mineral Weight Percent

\[ \text{Cu Fe S}_2 \]

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<tr>
<th>Element</th>
<th>Wt% SEM</th>
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<th>Atomic Proportion</th>
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SEM Ore Photos

Photo of Chalcopyrite by Recalculation of Mineral Weight Percent

Cu Fe S₂

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8 points with numerous counts on each 2500–7000 counts
Both dark and light ore have similar composition
Found 6 chalcopyrite CuFeS$_2$ and 2 Pyrite FeS$_2$
4 chalcopyrite points were almost exactly the correct formula
2 chalcopyrite points slightly different
Pyrite points were nearly exact formulas
Corners consist of native elements

Recalcs fell near actual compositions
References

- DeMatties, T., 1994, Economic Geology; v. 89; no. 5; p. 112
- Department of Natural Resources– Wisconsin; http://dnr.wi.gov/org/aw/wm/mining/metalllic/flambeau/ accessed 5/1/10
- www.poldark-mine.co.uk/images/geol_17
Questions?