# Yellow Pine Antimony—Largest Domestic Supply of a Critical Resource

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## Abstract

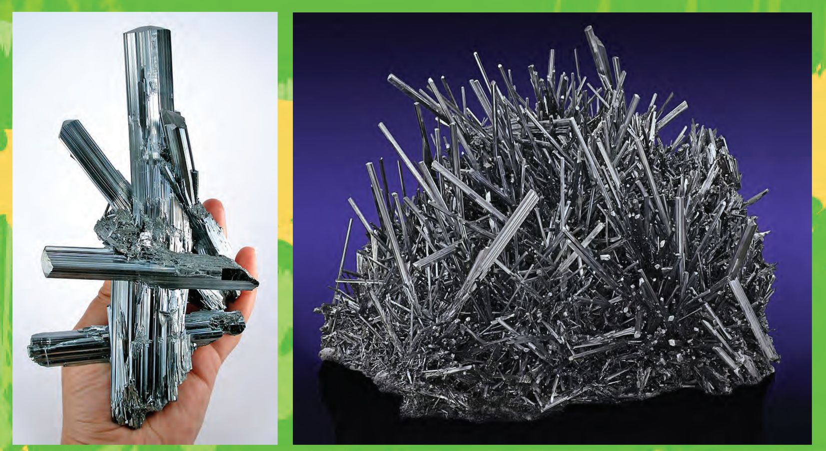
The United States defense, energy, and manufacturing industries are dependent on foreign antimony sources and could be affected if the global antimony supply declined. Although antimony substitutes are available, they are less effective and more expensive. Thus domestic antimony supplies are key. The Stibnite mining district (including the historic Yellow Pine deposit in central Idaho) contains an estimated 41,000 metric tons of antimony, making it the largest domestic antimony supply.

Many fundamental questions about the ore system that formed the ore deposits within the Yellow Pine\Stibnite mining district remain unanswered, but if addressed could provide unprecedented insight into fluid source, alteration patterns, ore-controlling fault geometry, key rock units ages, regional stratigraphic context, as well as relationship to the adjacent caldera complex.

Satellite image showing location of the historic Yellow Pine open pit mine within Idaho.

## Mineral Resources Program Context

This project addresses one of the five MRP science priorities for FY15—Characterization and Identification of Critical Mineral Resources. Likewise this project answers the call of the DOI Strategic plan for mineral resources that are imported from other countries.

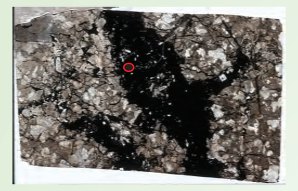


Stibnite specimens with well-developed crystals from Wuling Antimony Mine, Jiangxi Province, China. Photography courtesy of Robert Lavinsky (http://www.irocks.com).

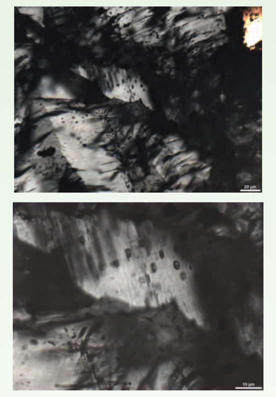
## Fluid Inclusions and Alteration

### Stibnite Fluid Inclusions

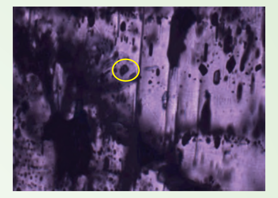
Photomicrograph of a thin section showing a stibnite-quartz vein from the Yellow Pine pit that was analyzed for fluid inclusions.



(1) Fluid inclusions in stibnite are dominantly what appears to be single phase inclusions or empty cavities.

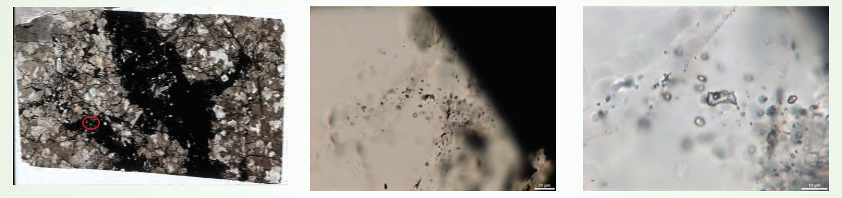


(2) A single two-phase inclusion in stibnite that is active at room temperature. This inclusion does not qualify as an FIA (fluid inclusion assemblage), so it is unmeasurable. Nonetheless, this was a likely a low temperature inclusion.



### Quartz Fluid Inclusions

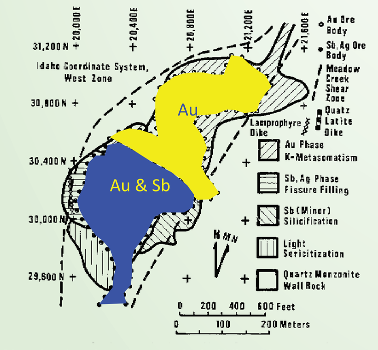
Fluid inclusions in quartz in stibnite vein: A fluid inclusion assemblage (FIA) of 8 inclusions has an ice melt temperature of -4.7 °C and homogenization (to liquid) temperature to 201-217 °C. The ice melt corresponds to a salinity of 7.4 NaCl wt% equiv. The temperature of homogenization provides a minimum temperature of formation and is not in conflict with the temperature indicated by the difference in the sulfur isotope signature between pyrite and stibnite (Delta 34S of 4.5 per mil = 232°C).



| FIA# | inclusions | $T_h$ | $T_{melt\ ice}$ | Wt% |
|---|---|---|---|---|
| 14-YP-7 FIA1 | 8 | 201-217 | -4.7 | 7.4 |

**Next Objectives:**
**Additional H, O ,C, and S analyses of paragentically controlled samples and dated samples will help distinguish Eocene from Cretaceous signatures. Radiogenic isotope analysis will help determine the souce of He, Pb, Sr, Nd, and Os in Eocene dikes, ore related minerals, and fluid inclusions.**

### Alteration Assemblage Mapping



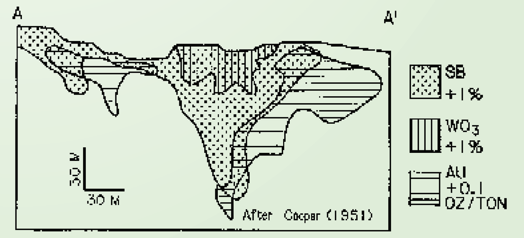


Map showing alteration types in the Yellow Pine pit (Modified from Cooper, 1951).

**Objectives:**
**(1) Characterization of modes, compositions, distribution, and ages of minerals that make up hydrothermal alteration assemblages**
**(2) Determine paragenetic relationship of alteration assemblages**

Relevance: characteristics of alteration minerals and time-spece relationships among alteration assemblages can be applied toward continuation of known deposits and exploration for new deposits

Background: Readily available alteration maps are dated, so a detailed alteration study is overdue at and around the Yellow Pine pit. Alteration assemblage mapping is a primary exploration tool.

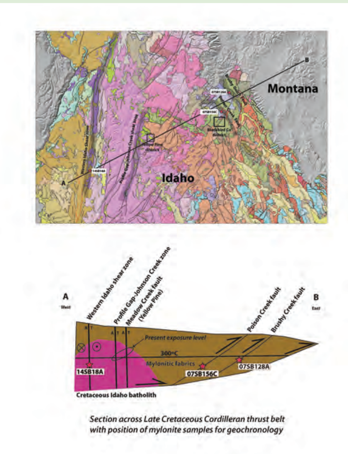




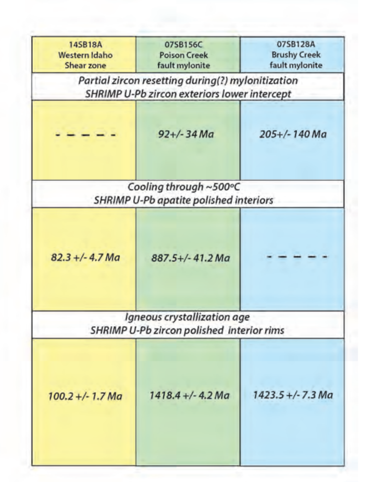
Cross section through Yellow Pine pit showing antimony, scheelite, and gold grades in ounces per ton (Modified from Cooper, 1951).

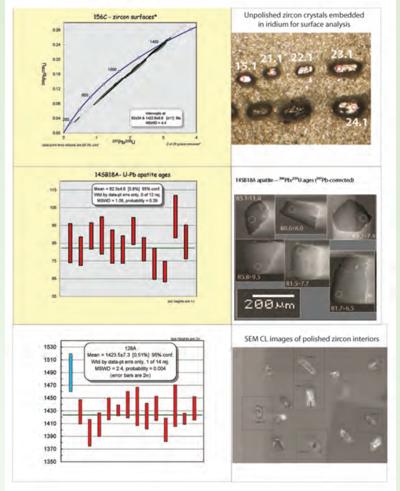
## Structural Controls and Timing

### Geochronology



Section across Late Cretaceous Cordilleran thrust belt with position of mylonite samples for geochronology





The geologic setting of mineralization in the Yellow Pine district of central Idaho is within the deep crustal hinterland of the Late Cretaceous Cordilleran thrust belt, which possibly formed during the last phases of Idaho batholith magmatism. The structures that appear to control mineralization in the district (Meadow Creek fault and associated structures) are part of a Late Cretaceous family of structures in the upper plate of the thrust belt allochthon. Many of the associated structures have ductile fabrics that are indicative of forming above 300ºC (~10 km depth), while the mineralized structures are brittle suggesting a shallower level during formation. We infer that mineralization occurred broadly during uplift of this region from middle to upper crustal depths.

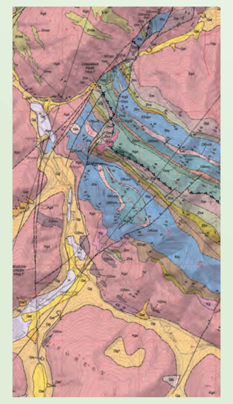
In an effort to constrain the timing and kinematics of this evolving structural setting, we undertook U-Pb dating of probable Late Cretaceous mylonites to the east and west of the Yellow Pine district using U-Pb dating methods on zircon and apatite at the USGS-Stanford SHRIMP in Menlo Park. U-Pb ages of apatite indicate when the sample cooled through 450-500ºC.

To the west, the subvertical right-slip West Idaho shear zone (WISZ) is subparallel to the brittle ore-controlling faults in the Yellow Pine district. The WISZ developed in granite that yielded a 100.2 Ma zircon age. Apatite from the same sample granite yielded an age of 82.3 Ma, indicating that crust was still in the ductile realm at that time.

Scheelite fluorescing light blue under shortwave UV light in a stibnite-bearing breccia. Photograph by Niki Wintzer; sample courtesy of Midas Gold Inc.

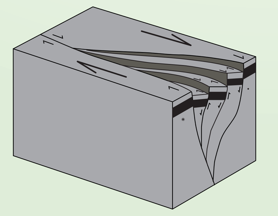
**Next Objectives:**
**(1) date the tungsten ore mineral (scheelite) using the U-Pb system with a laser ablation mass spectrometer (collaborating with Dr. Mark Schmitz at Boise State University)**
**(2) date any available molybdenite associated with scheelite using the Re-Os system**
**(3) date garnetiferous schist to constrain metamorphism of Stibnite roof pendant**

### Fault Controls

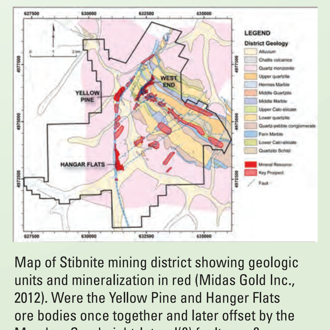


Yellow Pine pit and Stibnite roof pendant geology (Stewart and others, in press). Note the surface fault geometry that suggests a negative flower structure.

**Objectives:**
**(1) Characterize geometry of ore-controlling faults (negative flower structure?) to offer insight to ore geometry at depth**
**(2) Determine if the Meadow Creek fault offsets the Yellow Pine and Hanger Flat ore bodies**



Block model of a negative flower structure highlighting coallescing fault geometry at depth

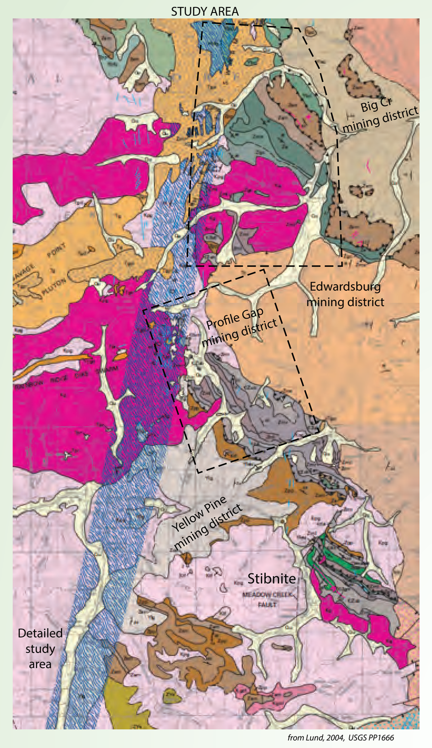




Map of Stibnite mining district showing geologic units and mineralization in red (Midas Gold Inc., 2012). Were the Yellow Pine and Hanger Flats ore bodies once together and later offset by the Meadow Creek right-lateral(?) fault zone?

## Regional Geologic Influences

### Stratigraphic Correlation and Ore Body Geometry Control





**Objectives:**
**(1) determine role of metamorphic roof pendants in sourcing or localizing ore deposits,**
**(2) determine role of roof pendant structures in controlling younger ore-related structures,**
**(3) discover regional trends of stratigraphic units, which could have implications for other roof pendants**

Premise:
Co-extensive belts of Cordilleran-miogeoclinal rocks, and a variety of sediment-hosted and magmatic ore deposits, are genetically linked. But in regions sigificantly altered by younger metamorphism and magmatism (British Columbia and central Idaho), their relationship to each other remains uncertain but implicated (Lund, 2004; Lund, 2008).
In the Yellow Pine district, granite- and meta-sedimentary rock hosted deposits are directly adjacent (<1 mi). so ore characteristics and sources can be readily studied and compared Results will impact understanding of many roof pendant-hosted districts across the region.

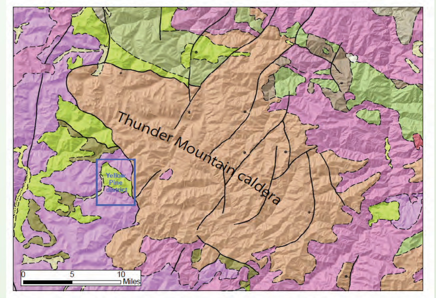
EXPLANATION

Background: Neoproterozoic and Early Paleozoic metasedimentary rocks occur as roof pendants in the Idaho Batholith (Lund and others, 2003, 2010; Lund, 2004). In the Yellow Pine and adjacent mining districts, these metasedimentary rocks also host ore (Lund, 2004, 2008). Ages of relevant rock units are being refined (IGS under contract to Midas Gold Inc.).

### Adjacent Thunder Mountain Volcanic Complex

**Objectives:**

**(1) determine if there is a genetic relationship betweeen Yellow Pine gold-antimony mineralization and nearby Eocene volcanic rocks most well manifested by the Thunder Mountain caldera, and**
**(2) determine the structure relations between Eocene volcanic rocks and pre-Tertiary host rocks at Yellow Pine and if there is possible post-mineralization eastward tilting of the Yellow Pine mineralizing system.**





Map of Thunder Mountain caldera with showing location of Yellow Pine mining district (modified from Lewis and others, 2012).

Relevance: Recently obtained (Gillerman, 2014) $^{40}Ar/^{39}Ar$ adularia dates indicate that gold mineralization at Yellow Pine formed at about 50 Ma and presumed Eocene porphyry dikes are altered in the Yellow Pine pit. Age and structural relations of nearby Eocene volcanic rocks (Thunder Mountain) are poorly understood, but these magmas may have been source of heat, metals, and/or volatiles that formed Yellow Pine deposits. Existing structural data for the Thunder Mountain caldera suggests eastward tilting that might extend into the Yellow Pine and could explain district-scale variations in hydrothermal

Methods: Field examination and sampling of select parts of the Eocene volcanic rocks and contained mineral deposits and of the Yellow Pine and other pits. Examination and sampling of select drill holes. Submittal of samples for geochemical analysis, thin sections, and $^{40}Ar/^{39}Ar$ dating.

## Questions Being Addressed:

What will numerous fluid inclusion analyses reveal about source(s) of the hydrothermal fluids, transported metals, brine, and sulfur?

What time-space relationships do patterns in alteration assemblages reveal?

What age dates will garnetiferous skarn, schist, aplite yield? What age date will scheelite (thus stibnite) reveal with U-Pb laser ablation methods?

What is the geometry and offset direction of ore-controlling faults?

What role did the metasedimentary host rocks play in ore-body geometry and ore source?

Is there a genetic relationship between the gold-antimony mineralization and Eocene volcanism?

Was the entire mineralizing system tilted to the east?

Was the ore deposited by one evolving hydrothermal system or by two unrelated age-staggered systems that overprinted the same area?

Did igneous activity, metamorphic activity, and/or circulation along deep faults drive the hydrothermal system?

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Midas Gold Inc., 2012, Gold rediscovered: Midas Gold, Inc., 67 p.



Time-lapse burn test comparing industrial suits with (left) and without (right) flame retardants that include antimony trioxide. Photograph courtesy of Thor, suppliers of AFLAMMIT® flame retardants for work wear.

http://geomaps.wr.usgs.gov/yellowpine/



Background illustration by Cassandra Hennings