Garnet Lu-Hf Geochronology and Geothermobarometry Constrain Pre-Ore Metamorphism in the Au-Sb-W Yellow Pine Mining District

Niki E. Wintzer\textsuperscript{1,2} & Dr. Jeffrey D. Vervoort\textsuperscript{2}

\textsuperscript{1} U.S. Geological Survey, 904 West Riverside Avenue, Spokane, WA 99201
\textsuperscript{2} School of the Environment, Washington State University, Webster Hall, Pullman, WA 99164

May 18\textsuperscript{th}, 2016
Stibnite is Critical

• The Yellow Pine ore deposit contains stibnite.

• Stibnite is the ore mineral for antimony (Sb$_2$S$_3$), and is a critical mineral.

• **Critical mineral**—mineral with a supply chain that is vulnerable to disruption, that serves an essential function in the manufacturing of a product, and the absence of which would cause significant economic or security consequences.
Import Reliance

[Bar chart showing import reliance for various minerals and materials, with Antimony highlighted in red.]
Importance of Yellow Pine Deposit

• Largest antimony-bearing deposit in the United States

• Important to understand our country’s resources as much as possible to mitigate any potential supply disruption

• Opportunity to gain a better overall understanding of antimony-bearing deposits
Geology of Mining Area

(Stewart et al., in prep., Geologic map of the Stibnite quadrangle)
Geologic Timeline Relevant to Yellow Pine Deposit

EXPLANATION
- Belt-Purcell Basin deposition \(<1576–\leq 1469\) Ma (Mesoproterozoic) Lydon (2007)
- Belt-Purcell Basin metamorphism \(~1.3\) and \(~1.1\) Ga (Mesoproterozoic) Zirakparvar and others (2010) & Nesheim and others (2012)
- Windermere deposition local to Stibnite, Idaho 1000–444 Ma (Neoproterozoic to Ordovician) Stewart and others (in prep.)
- Uncertain date of metamorphism local to Stibnite, Idaho
- Salmon River Suture Zone deformation 105–90 Ma (Cretaceous) Giorgis and others (2008)
- Idaho Batholith emplacement 98–54 Ma (Cretaceous) Gaschnig and others (2010)
- Regional uplift 85 to \(~40\) Ma (Late Cretaceous to Eocene) Giorgis and others (2008)
- Gold mineralization local to Stibnite, Idaho 77.9±0.3 Ma (Cretaceous) Gammons (1988) and/or 51 Ma (Eocene) (Gillerman, 2014)
- Uncertain date of scheelite and stibnite mineralization local to Stibnite, Idaho
- \(130\) Ma Start of metamorphism in Salmon River Suture Zone from Ar-Ar biotite, hornblende, and muscovite Lund and Sneé (1993)
- \(128\) Ma Peak metamorphism in Salmon River Suture Zone from Sm-Nd garnet Getty and others (1993)
- 122-90 Ma Age range for compression, crustal thickening, transpression, and end of thermal tectonism within Salmon River Suture Zone from Lu-Hf garnet Wilford (2012)
- 112.5 Ma Metamorphism of Rapid River Plate within Salmon River Suture Zone from Sm-Nd garnet McKay (2012)
Sample Location and Samples

Biotite-garnet schist; foliated and lineated

Garnetiferous aplite dike with minor biotite; not foliated or lineated

(Stewart et al., in prep.)
Each garnet fraction evolves to different $^{176}\text{Hf}/^{177}\text{Hf}$ isotopic compositions.

Bulk rock—evolves to Low $^{176}\text{Hf}/^{177}\text{Hf}$ ratios

Garnets—evolve to high $^{176}\text{Hf}/^{177}\text{Hf}$ ratios
Garnet Lu-Hf Date

Schist of Moore Station Formation
Sample NW8715SCB

112.8 ± 7.2 Ma
MSWD = 12

Initial $^{176}\text{Hf}/^{177}\text{Hf}$ = 0.28242
Garnet Lu-Hf Date

Garnetiferous Aplitic Dike
Sample 14SB32A

$\frac{^{176}\text{Hf}}{^{177}\text{Hf}}$ vs $\frac{^{176}\text{Lu}}{^{177}\text{Hf}}$

Initial $\frac{^{176}\text{Hf}}{^{177}\text{Hf}}=0.282488$

99.5±4.0 Ma
MSWD=3.4
Garnet Lu-Hf Dates

Schist of Moore Station Formation
Sample NW8715SCB

$\frac{^{176}Hf}{^{177}Hf}$

$112.8 \pm 7.2$ Ma
MSWD=12

Initial $\frac{^{176}Hf}{^{177}Hf}=0.28242$

Garnetiferous Aplitic Dike
Sample 14S832A

$\frac{^{176}Hf}{^{177}Hf}$

$99.5 \pm 4.0$ Ma
MSWD=3.4

Initial $\frac{^{176}Hf}{^{177}Hf}=0.282488$
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- Windermere deposition local to Stibnite, Idaho 1000–444 Ma (Neoproterozoic to Ordovician) Stewart and others (in prep.)
- Metamorphism local to Stibnite, Idaho 112.8±7.2–<99.5±4.0 Ma (Cretaceous) This Study
- Salmon River Suture Zone deformation 105–90 Ma (Cretaceous) Giorgis and others (2008)
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Ten pressures and ten temperatures were calculated and the mean of those pressure and temperature ranges is presented here. The GASP (garnet-aluminosilicate-silica-plagioclase) geothermobarometer was used with fibrous silimanite as the aluminosilicate. Pressures and temperatures were determined using the software GTB (available free at: http://ees2.geo.rpi.edu/metapetaren/software/gtb_prog/gtb.html).
Element Map of Analyzed Garnet

Schist of Moores Station Formation (112.8±7.2 Ma)
Geothermobarometry
Garnetiferous Aplite Dike (99.5±4.0 Ma)

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16.4 mi or 26.5 km deep
Element Map of Analyzed Garnet
Garnetiferous Aplite Dike (99.5±4.0 Ma)
Summary

• New Constraints:
  – Age of pre-ore metamorphism (112.7-99.5 Ma).
  – Pressures of 7.5 to 7.0 kbar indicates depth of formation between 17.6 and 16.4 miles deep (28.3 to 26.5 km).
  – Temperature of 775 °C indicates upper amphibolite-facies metamorphic temperature.

• Regional Context:
  – Timing fits with Salmon River Suture Zone metamorphism and deformation.
  – Timing also fits with the Sevier Orogeny (140-50 Ma).

• What to Remember:
The Cretaceous metamorphic age of the Stibnite roof pendant provides a long-overdue, first-order constraint and regional context for the comprehensive geologic story of the Yellow Pine Au-Sb-W ore deposit.
Acknowledgments

I whole-heartedly thank:

– Christopher Dail for his professional collaboration and Samuel Field for his assistance on the mine property.
– Diane Wilford and Charles Knaack for their expert leadership and assistance in the clean lab and with the Neptune.
– Dr. Owen Neill for use of the electron probe microanalyzer at Washington State University.
– Cassandra Hennings for this beautiful and thematically-appropriate background illustration.