Eocene U-Pb Scheelite LA-ICP-MS Dates of Stibnite-Scheelite Mineralization in the Yellow Pine Au-Sb-W Mining Area, Central Idaho, USA

This poster is version 2 so differs slightly from the originally submitted abstract and poster version presented at the 2016 annual GSA meeting. Wording in the abstract and poster are modified slightly for clarity and usage. The conclusions are unchanged.

By Niki E. Wintzer[1,2], Virginia S. Gillerman[3,4], and Mark D. Schmitz[4]

[1]U.S. Geological Survey, 904 W. Riverside Ave., Spokane, WA 99201; [2]School of the Environment, Washington State University, Webster Hall, Pullman, WA, 99164; [3]Idaho Geological Survey, 322 E. Front St., Ste. 201B, Boise, ID 83702; and [4]Department of Geosciences, Boise State University, 1910 University Drive, Boise, ID 83725

Abstract

Gold, antimony, and tungsten ore minerals are localized along the Meadow Creek fault zone that cuts Late Cretaceous granodiorite of the Idaho Batholith and Neoproterozoic to Ordovician strata of the Stibnite roof pendant in the Yellow Pine mining area, central Idaho. Paragenetic studies show the gold mineralization, as disseminated auriferous pyrite and arsenopyrite, is cut by stibnite-scheelite breccia and veins. Ar-Ar adularia geochronology constrained gold mineralization to circa 51 Ma.

Scheelite has relatively high and variable U concentrations (<1 to >10 ppm) and low initial Pb (<0.01 ppm), making it amenable to U-Pb geochronology. Coexisting stibnite was analyzed to confirm and measure initial Pb isotopic compositions. In situ laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was performed on scheelite from 4 polished thin sections. Spot measurements were taken in different textural scheelite types as seen on cathodoluminescent images of the blue-fluorescing scheelite. Three scheelite types are: (1) moderate brightness brecciated fragments, (2) brighter veins and disseminated grains replacing carbonate, and (3) oscillatory zoned subhedral grains in veins and vugs.

Analyses yielded reproducible U-Pb dates. Scheelite type 1 yielded mostly circa 45 Ma dates. Scheelite types 2 and 3 yielded mostly early 40s Ma dates with a relatively younger mid 30s Ma date. Scheelite grains of type 2 and 3 are intergrown with stibnite grains and in apparent isotopic equilibrium, so stibnite mineralization occurred in the late Eocene. Mid to late Eocene U-Pb scheelite dates prove that some of the stibnite-scheelite mineralization was coeval with Challis volcanism associated with the neighboring Thunder Mountain caldera complex (50-43 Ma).

Geologic Setting

The Yellow Pine mining area (dark gray box in fig. 1) in central Idaho is comprised of Neoproterozoic to Ordovician metamorphosed strata of the Windermere Supergroup (1000 to 444 Ma) and overlying Paleozoic strata (Lewis and others, 2016), Cretaceous Idaho Batholith granitoid rocks (locally 92 to 84 Ma; Gillerman and others, 2014; Stewart and others, in press), and Eocene Challis volcanic rocks associated with the Thunder Mountain caldera complex (50-43 Ma; Leonard and Marvin, 1982). Metamorphism of the Stibnite roof pendant started by at least 112.8 ± 7.2 Ma and continued through 99.5 ± 4.0 Ma (fig. 2) based on Lu-Hf garnet geochronology of a garnet-biotite schist and a garnet-bearing, cross-cutting, aplitic dike (Wintzer and Vervoort, 2016). These dates show that metamorphism of the Stibnite roof pendant was partially concurrent with deformation of the Salmon River suture zone 50 miles to the west.

Figure 1. Geologic map of the Stibnite Quadrangle showing ore (red polygons), Meadow Creek fault zone (blue lines), and a drillhole sampled for scheelite (light gray line) Modified from Stewart and others (in press).

Ore is hosted mainly within Idaho Batholith granitoids and metamorphosed strata along the Meadow Creek Fault zone (light blue lines in fig.1), but ore is also hosted between stratigraphic unit contacts within the metamorphosed sedimentary rocks of the Stibnite roof pendant (ore is represented by red polygons in fig. 1). The 3 main ore deposits are: (1) Yellow Pine, (2) Hangar Flats, and (3) West End where fault splays step right along the right-lateral, roughly north-south Meadow Creek fault zone. The stratigraphic unit contacts that were preferentially mineralized are along the Hermes marble (Ohm) and Middle quartzite (OCmq) and between the Fern marble (Zfm) and Lower calc-silicate (Zlcs).

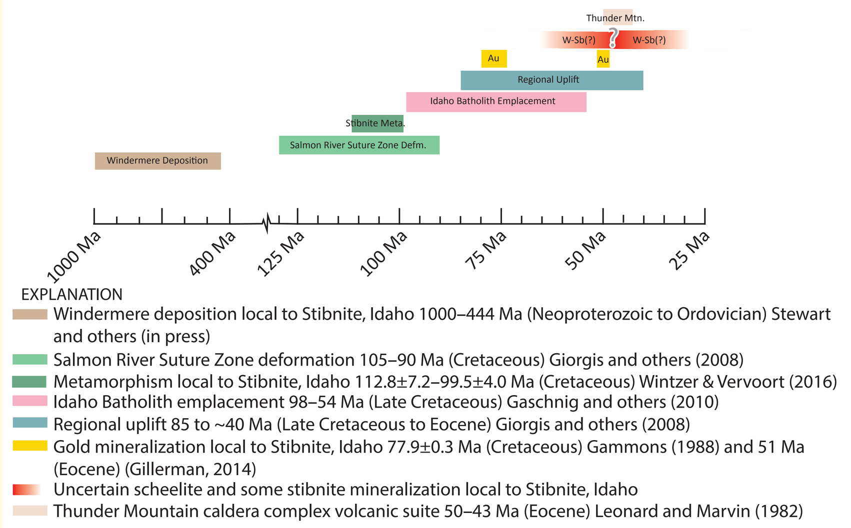

Figure 2. Timeline displaying absolute date ranges of events relevant to Stibnite, Idaho including the geologically plausible scheelite and stibnite mineralization time frame.

Mineralization occurred in two broad pulses within the Yellow Pine ore system: first, auriferous (gold) bearing pyrite and arsenopyrite, second, scheelite and stibnite (Lewis, 1984). Gammons (1988) reported an Ar/Ar sericite date of 77.9 ± 0.3 Ma that was interpreted as a date of gold (Au) mineralization in the mining area. Ar/Ar analyses of adularia associated with gold-bearing veins yielded dates of 51.7 ± 0.3 Ma, 51.0 ± 0.4 Ma, and 50.8 ± 0.3 Ma (fig. 2; Gillerman and others, 2014). The scheelite and stibnite mineralization remained undated but is essential for a complete timeline and deposit model.

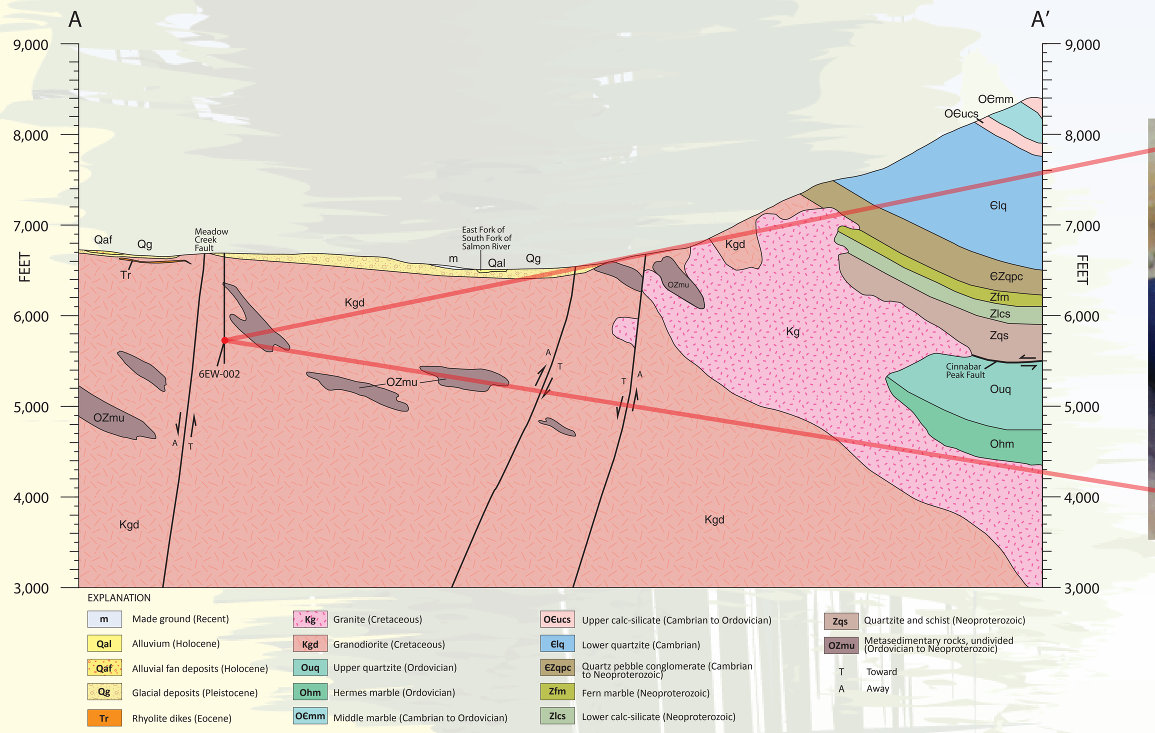

Figure 3. Cross section showing where the scheelite and stibnite bearing sample 6EW-002 was collected. Section line, A-A', shown on figure 1.

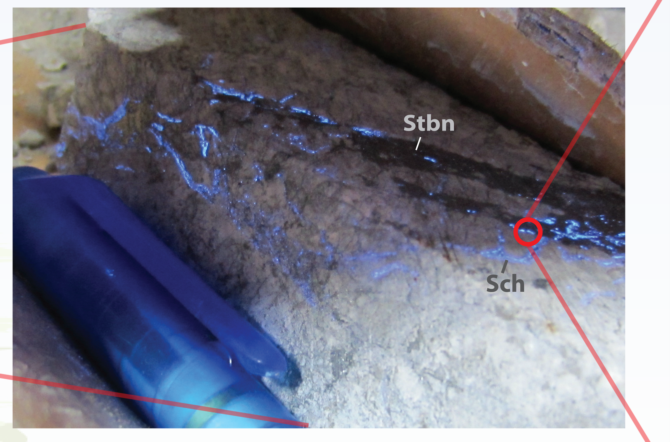

Figure 4. Drill core with scheelite (blue-fluorescent mineral; Sch) and stibnite (dark gray; Stbn) within granodiorite of the Atlanta Lobe of the Idaho Batholith in the Yellow Pine mining area. Mechanical pencil for scale and red circle showing representative thin section location.

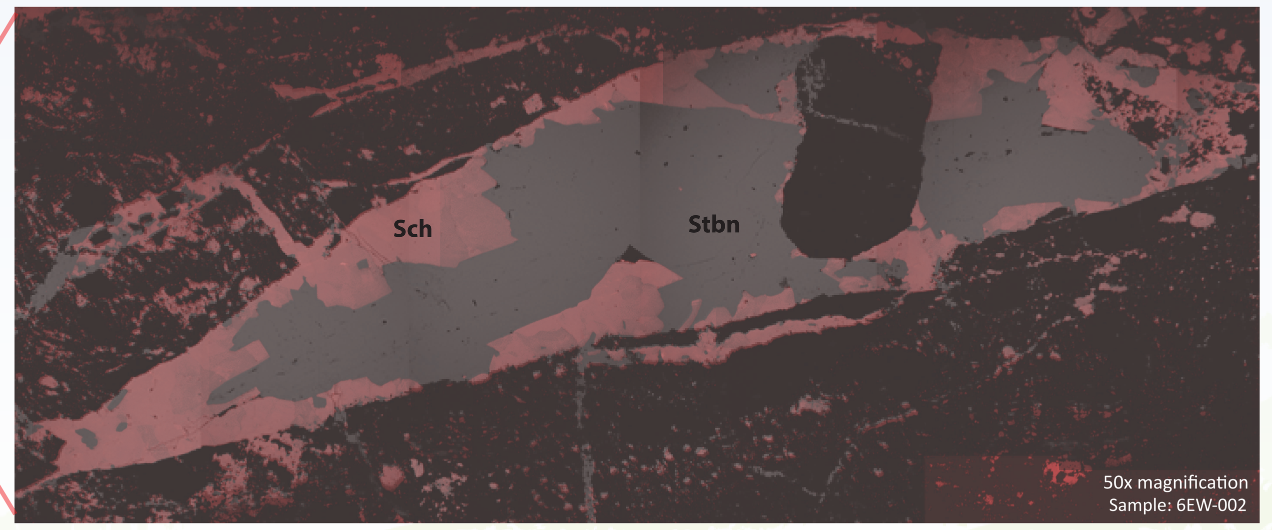

Figure 5. False-color cathodoluminescent image of a scheelite-stibnite vein showing intergrown texture of the two minerals. Scheelite (Sch) appears pink and stibnite (Stbn) dark gray. The scheelite shown here is categorized as type 2 brighter veins and yielded a U-Pb date of 35.83 ± 0.88 Ma.

Methods

Drill core rock samples were collected from the Hangar Flats deposit (figs. 1, 3, and 4). Scheelite-bearing thin sections made from the drill core rock samples were imaged with a scanning electron microscope under cathodoluminescent lighting to differentiate zoning or texture of the naturally blue-fluorescent scheelite (figs. 5 and 6). Three scheelite types are: (1) moderate brightness brecciated fragments, (2) brighter veins and disseminated grains replacing carbonate, and (3) oscillatory zoned subhedral grains in veins and vugs. To confirm and measure initial Pb isotopic compositions, coexisting stibnite was analyzed also.

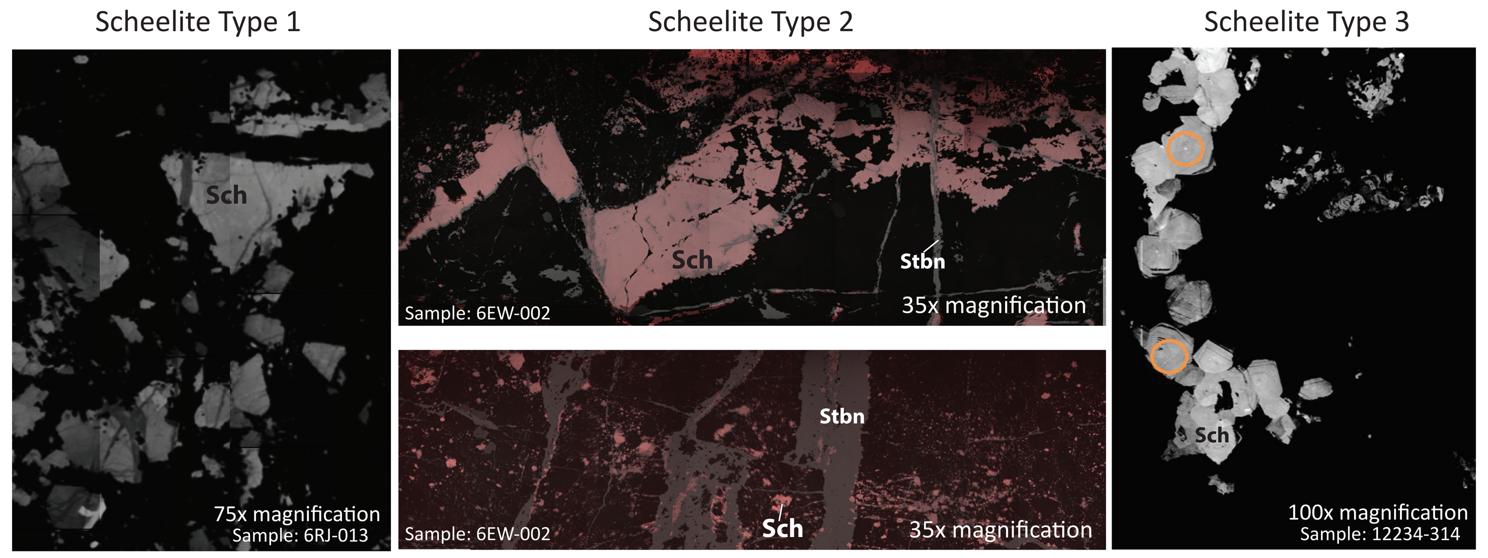

Figure 6. Cathodoluminescent images showing scheelite types. Center images are shown in false color and outer images are shown in grayscale. Scheelite (Sch) appears pink and light gray, and stibnite (Stbn) appears dark grey where visible. False color shows the intergrown scheelite and stibnite texture in greater contrast; see figure 5 also. Circles mark where spot analyses were taken for type 3.

Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was performed on numerous spots with diameters of 40, 80, and 100 microns for each scheelite type from 4 thin sections to determine the isotopic compositions of U (uranium) and Pb (lead). A ThermoElectron X-Series II quadrupole ICP-MS and New Wave Research UP-213 Nd:YAG UV (213 nm) laser ablation system were used to obtain the isotopic data. In addition to using NIST glass standards, multiple scheelite standard candidates were tested. The NIST standards 610 and 612 provided the most reliable reference points.

Results

Scheelite type 1 yielded older dates of 45.6 ± 1.6 Ma, 45.40 ± 0.94 Ma, and 43.48 ± 0.79 Ma (fig. 7; table 1), and scheelite types 2 and 3 yielded younger dates of 42.8 ± 1.4 Ma and 35.83 ± 0.88 Ma (fig. 8; table 1). Tera-Wasserburg diagrams were used to circumvent common lead (^{204}Pb) contamination errors. The lower discordia line intercepts are the reported dates. Scheelite has relatively high and variable radiogenic U concentrations (<1 to >10 ppm) and low initial non-radiogenic Pb concentrations (<0.01 ppm)—making the scheelite amenable to U-Pb geochronology. Stibnite spot analyses showed that stibnite Pb compositions are similar to scheelite Pb compositions.

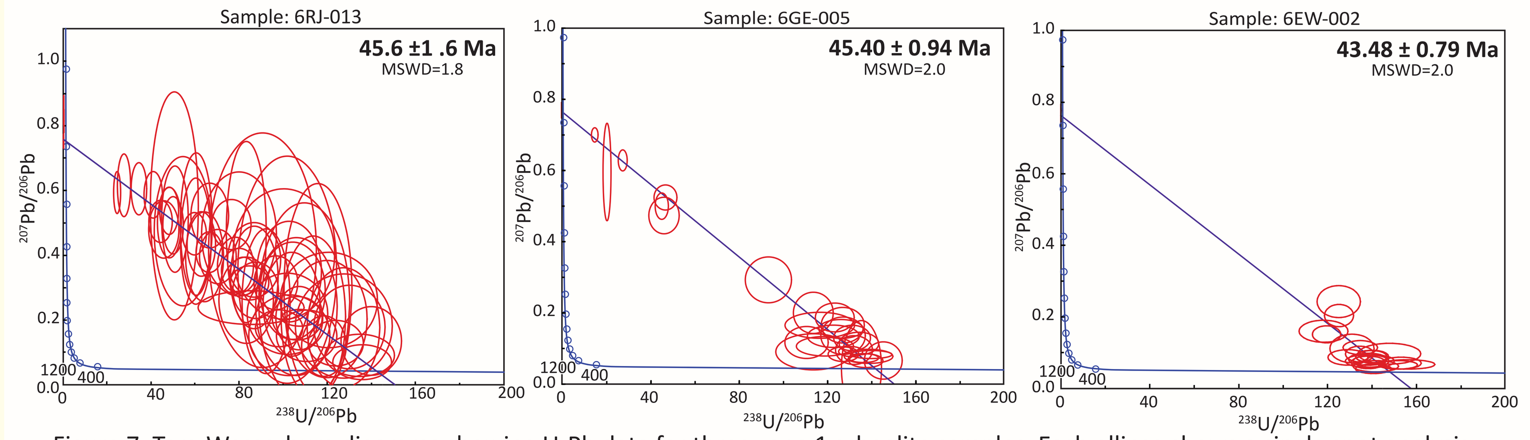

Figure 7. Tera-Wasserburg diagrams showing U-Pb data for three zone 1 scheelite samples. Each ellipse shows a single spot analysis and its 2σ standard error.

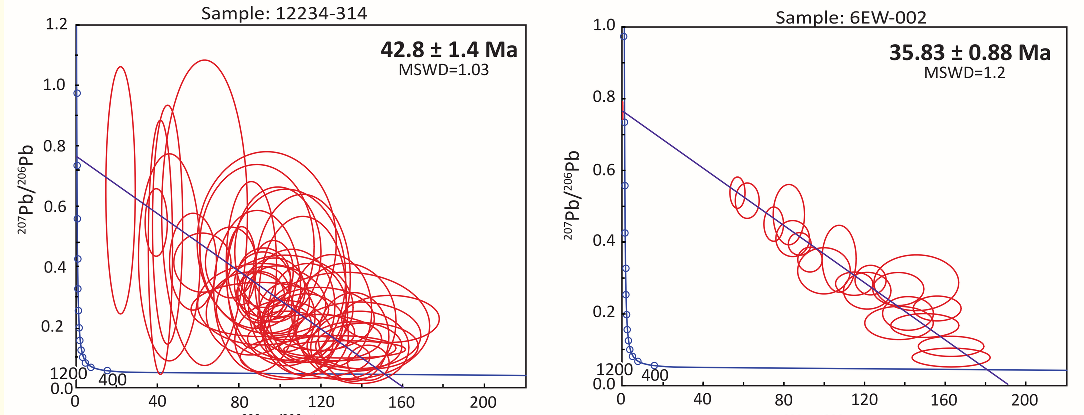

Figure 8. Tera-Wasserburg diagrams showing U-Pb data for two zone 2 and 3 scheelite samples. Each ellipse shows a single spot analysis and its 2σ standard error.

Table 1. Summary table of U-Pb scheelite dates by scheelite zone type in descending date order.

Scheelite Type 1
45.6 ± 1.6 Ma
45.40 ± 0.94 Ma
43.48 ± 0.79 Ma
Scheelite Types 2 and 3
42.8 ± 1.4 Ma
35.83 ± 0.88 Ma

Discussion

Mineralization age of the Yellow Pine ore system has been a long-standing controversy. Bailey (1934) interpreted the gold mineralization as Cretaceous and stibnite mineralization as Tertiary, whereas Currier (1935) concluded it was all Cretaceous. White (1940) and Cooper (1951) both interpreted mineralization as all Tertiary, the latter author based his interpretation on ore minerals that overprint Tertiary dikes. Cookro and others (1988) cited a Cretaceous age from one Ar/Ar sericite spectra (L.W. Snee, written commun., 1986) and K-Ar adularia dates that averaged to 57 ± 1 Ma (Lewis, 1984). The Cretaceous age was interpreted as more likely to date Au mineralization. Gammons (1988) reported a 77.9 ± 0.3 Ma Ar/Ar sericite date from a Yellow Pine pit sample and it was interpreted as a date of gold mineralization, which remains possible.

Gillerman and others (2014) report 3 precise circa 51 Ma Ar-Ar adularia dates that indicate some gold mineralization was Eocene. The U-Pb scheelite dates reported here further support that much of the mineralization W-Sb was Eocene. Some scheelite and stibnite grains are intergrown, as seen in the younger Type 2 for example (fig. 5), but interestingly Type 1 scheelite displayed no intergrown textures with stibnite (fig. 6). Stibnite grains intergrown with type 2 scheelite are likely the same age, so some stibnite mineralization occurred between 43 and 36 Ma. A significant portion of the Au-Sb-W mineralization was more likely related to the younger igneous activity of the Thunder Mountain caldera complex and not exclusively related to the Cretaceous emplacement of the Idaho Batholith. In particular, the W-Sb mineralization is perhaps related to the hypabyssal latite dikes emplaced 46.4 ± 1.5 Ma (Leonard and Marvin, 1982).

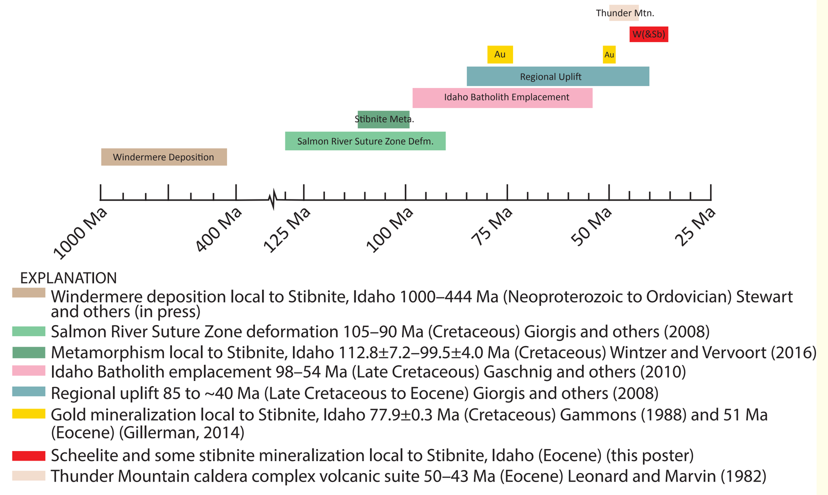

Figure 9. Timeline displaying absolute date ranges of events relevant to Stibnite, Idaho including newly-determined scheelite, and some stibnite, mineralization time frame of 45 to 36 Ma.

Au-Sb-W mineralization occurred over at least a 15-million-year period in the Eocene from ~51 Ma to ~36 Ma within the Yellow Pine ore system, thereby providing a more complete timeline for the ore deposit model. The Yellow Pine Au-Sb-W mining area holds the largest domestic resource of antimony—a critical commodity found in stibnite. In 2015, the U.S. imported 84 percent of domestically consumed antimony that came mostly from China (Guberman, 2015), leaving import supply vulnerable to disruption. A more complete ore deposit model can lead to new stibnite ore discoveries that could protect the U.S. against antimony supply disruption.

Conclusions

- Scheelite mineralization occurred between at least 45 Ma and 36 Ma in the Yellow Pine ore system.
- Stibnite mineralization occurred, in part, between 43 Ma and 36 Ma.
- Scheelite-stibnite mineralization was coeval with Challis hypabyssal latite dikes emplaced circa 45 Ma.

Future Research

The Yellow Pine pit—that held the largest U.S. tungsten resource in the early 1940s was mined and exhausted in July, 1945—has mostly fine-grained scheelite remaining. Given the initial success of U-Pb scheelite geochronology for the coarser Hangar-Flats scheelite, the Yellow Pine pit scheelite was sampled in late August 2016 for U-Pb dating. Resulting dates will offer context to the Hangar Flats U-Pb scheelite dates and perhaps provide insight into the timing of displacement within the ore-controlling Meadow Creek fault zone.

Acknowledgments

We thank Christopher Dail of Midas Gold Inc. for his professional collaboration and Perry Ponshock for his assistance collecting the valuable drillcore samples. Marion Lytle provided support for LA-ICP-MS operation that we greatly appreciate. Many thanks to the authors of Stewart and others (in press) for allowing us to use their high-quality geologic map of the Stibnite Quadrangle. The beautiful backdrop illustration is by Cassandra Hennings.

Scheelite ($CaWO_4$) specimen in daylight (left) and in shortwave ultraviolet light (right). Specimen is 6x4.8x4.7 cm and is from the Robert Lavinsky collection. (http://www.irocks.com)

Stibnite (Sb_2S_3) specimen from the Wuling antimony mine, Jiangxi Province, China from the Robert Lavinsky collection. (http://www.irocks.com)

References

Bailey, H.D., 1934, Ore genesis at Meadow Creek mine: Engineering and Mining Journal, v. 135, no. 4, p. 162–163.

Cookro, T.M., Silberman, M.L., and Berger, B.R., 1988, Gold-tungsten-bearing hydrothermal deposits in the Yellow Pine mining district, Idaho, *in* Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States: Reno, Nevada, Geological Society of Nevada, p. 577–624.

Cooper, J.R., 1951, Geology of the tungsten, antimony, and gold deposits near Stibnite, Idaho: U.S. Geological Survey Bulletin 969-F, p. 151–197.

Currier, L.W., 1935, A preliminary report on the geology and ore deposits of the eastern part of the Yellow Pine district, Idaho: Idaho Bureau of Mines and Geology, pamphlet no. 43, 27 p.

Gammons C.H., 1988, Studies in hydrothermal phenomena—(1) The solubility of silver sulfide in aqueous sulfide solutions to 300°C; (2) A paragenesis and fluid inclusion study of polymetallic vein mineralization in the Big Creek Mining District, central Idaho: State College, The Pennsylvania State University, Ph.D. dissertation, 337 p., 4 pls., 44 figs.

Gaschnig, R.M., Vervoort, J.D., Lewis, R.S., and McClelland, W.C., 2010, Migrating magmatism in the northern US Cordillera—In situ U-Pb geochronology of the Idaho batholith: Contributions to Mineralogy and Petrology, v. 159, p. 863–883.

Gillerman, V.S., Isakson, V.H., Schimitz, M.D., Benowitz, Jeff, and Layer, P.W., 2014, Geochronology of intrusive rocks and hydrothermal alteration at the structurally controlled Stibnite Au-Sb-W deposit, Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 46, no. 6, p. 165.

Giorgis, Scott, McClelland, William, Fayon, Annia, Singer, B.S., and Tikoff, Basil, 2008, Timing of deformation and exhumation in the western Idaho shear zone, McCall, Idaho: Geological Society of America Bulletin, v. 120, p. 1119–1133.

Guberman, D.E., 2015, Antimony mineral commodity summary 2016: U.S. Geological Survey, 2 p. Also available online at http://minerals.usgs.gov/minerals/pubs/commodity/antimony/mcs-2016-antim.pdf.

Leonard, B.F., and Marvin, R.F., 1982, Temporal evolution of the Thunder Mountain caldera and related features, central Idaho, *in* Bonnichsen, Bill, and Breckenridge, R.M., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 203–212.

Lewis, R.D., 1984, Geochemical investigations of the Yellow Pine, Idaho and Republic, Washington mining districts: West Lafayette, Purdue University, Ph.D. dissertation, 204 p., 40 figs.

Lewis, R.S., Isakson, V.H., Stewart, D.E., Schmitz, M.D., and Schwartz, Darin, 2016, Neoproterozoic and Paleozoic strata in the Stibnite-Edwardsburg area, central Idaho [abs.]: Geological Society of America Abstracts with Programs, v. 48, no. 6, p. 21.

Stewart, D.E., Stewart, E.D., Lewis, R.S., Weppner, K.N., and Isakson, V.H., in press, Geologic map of the Stibnite quadrangle, Valley county, Idaho: Idaho Geological Survey, Geologic Map 51, scale 1:24,000.

Wintzer, N.E., and Vervoort, J.D., 2016, Garnet Lu-Hf geochronology and geothermobarometry constrain pre-ore metamorphism in the Au-Sb-W Yellow Pine mining district [abs.]: Geological Society of America Abstracts with Programs, v. 48, no. 6, p. 16.