Study of an impressive yet under-studied mineralization in Philipsburg's polymetallic lode deposits, Granite County, Montana

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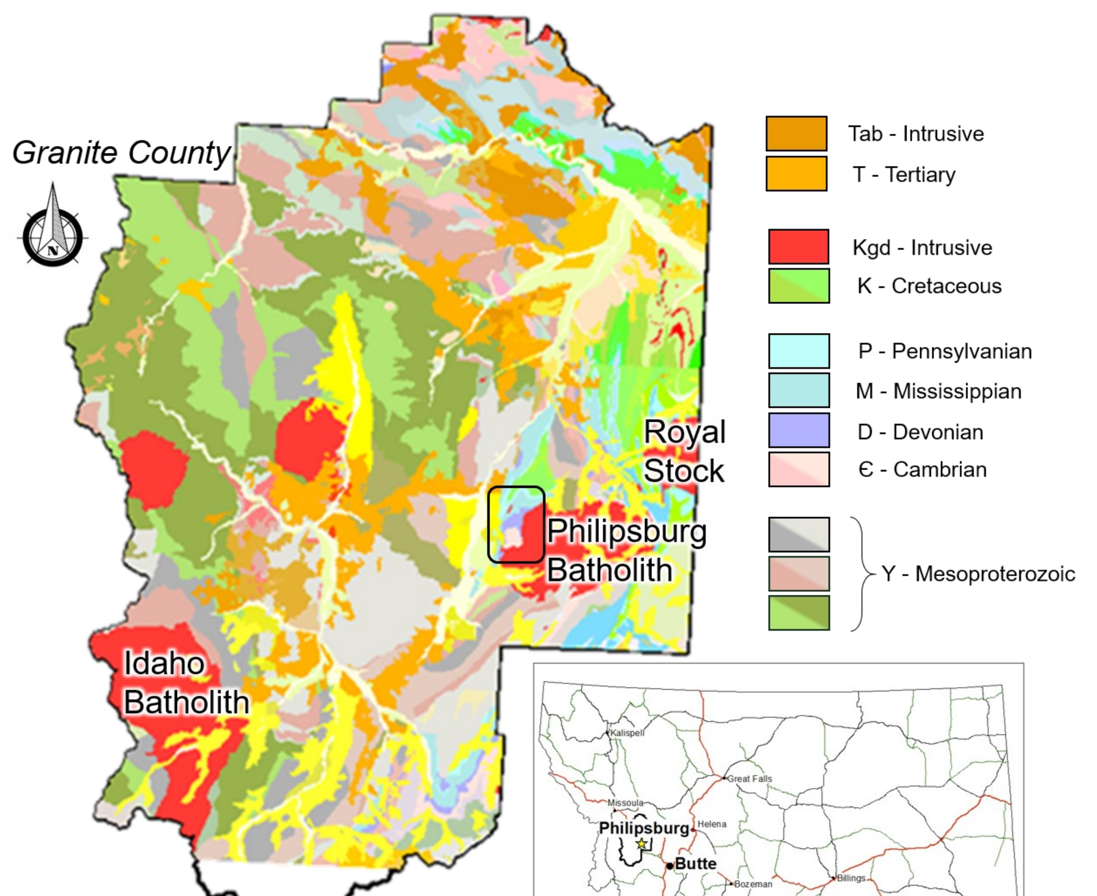
The Philipsburg mining district was one of Montana's most productive polymetallic-vein districts (24M oz Ag, 36M kg Zn, 1.8M kg Cu, 1M kg Pb, and 450M kg of battery-grade MnO_2), ranking second to Butte, to which it shares many characteristics. Early workers (Emmons and Calkins, 1913; Prinz 1967) described the geology of the district in detail. However, the source, timing, and composition of the mineralizing fluids have never been studied with modern methods.

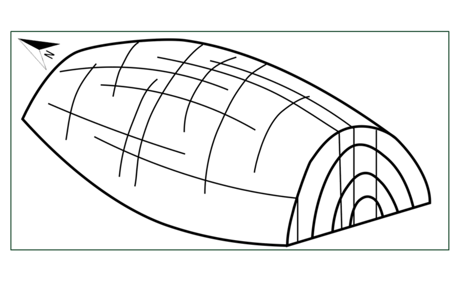
Geology and Structure

Compilation of detailed, historic mine maps is allowing a re-evaluation of the deposit's structural history in the context of modern plate tectonics. Mineralization occurs as quartz + rhodochrosite ± barite veins and replacements, hosted by Precambrian to Mesozoic metasedimentary rocks and the 75 Ma Philipsburg batholith. The dominant structural feature is an asymmetrical, N-plunging anticline. Dozens of nearly vertical quartz-fissure veins strike predominantly E-W, while less common, bedding-parallel veins and replacements follow the trace of the anticline. This structural pattern is similar to vein orientations in the Boulder Batholith and associated volcanic rocks, and is consistent with E-W shortening in the late Cretaceous. A 65Ma, Mo-bearing porphyry stock has been drilled at the north end of the district. The relationship of vein mineraliza-



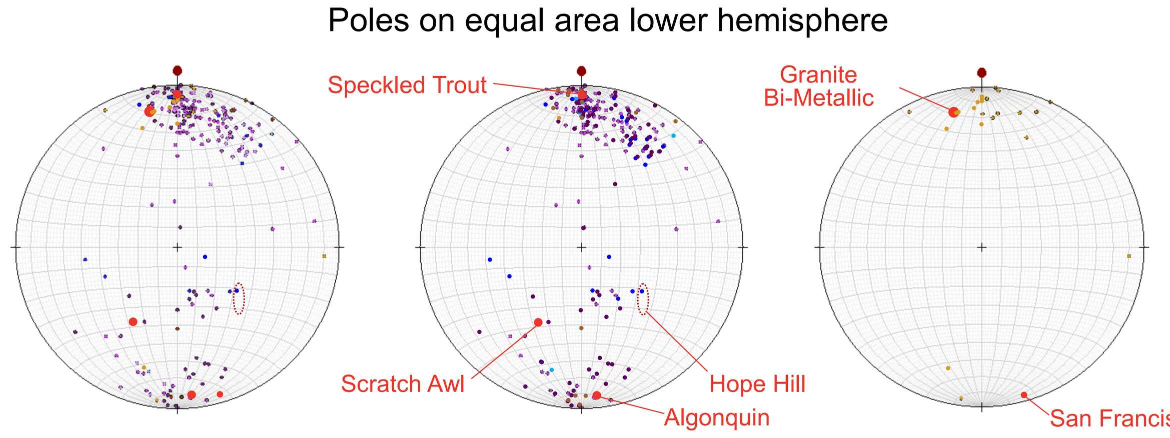
Geology: MBMG; Roads and county boundary: MDT; ArcGIS open files retrieved 2020

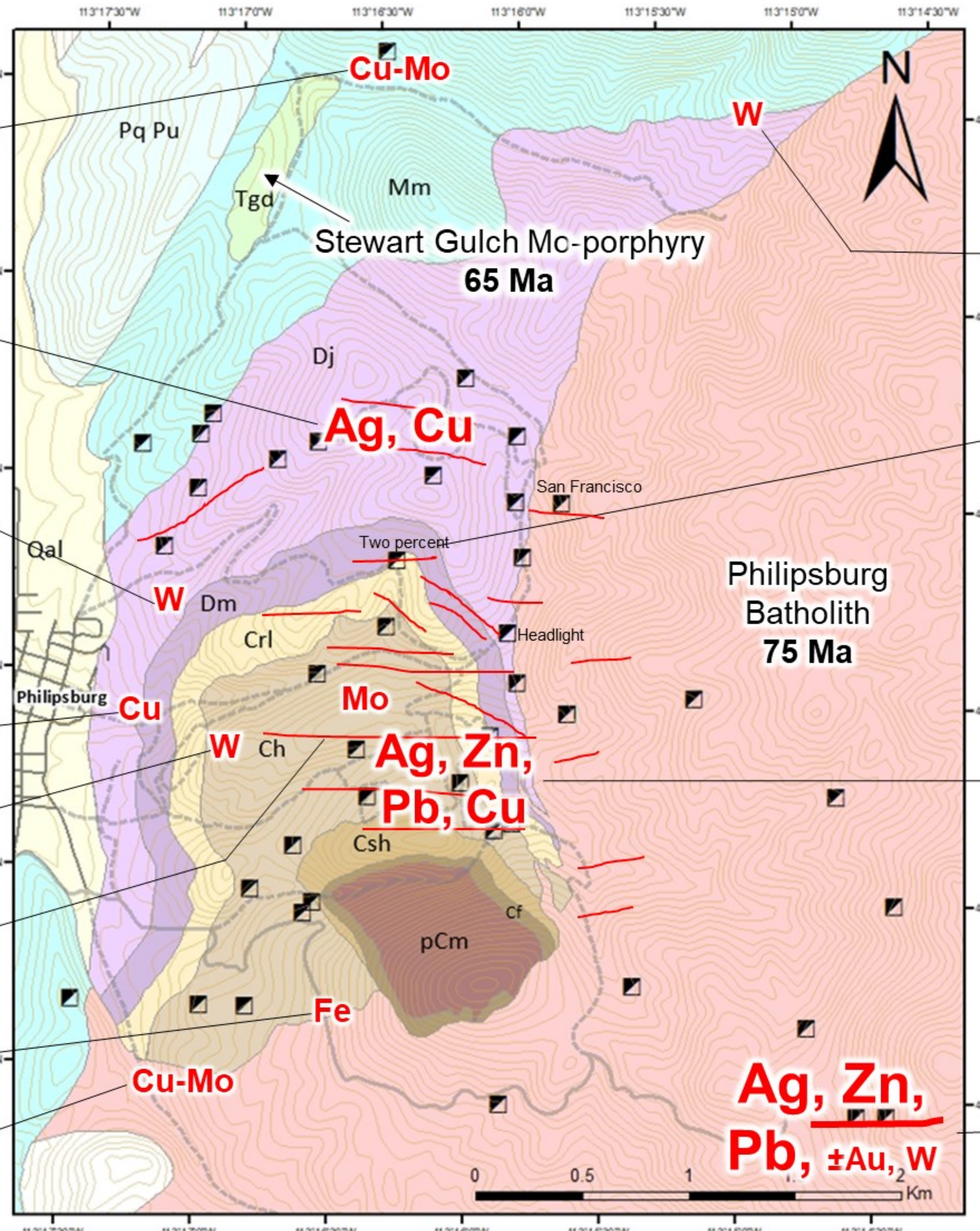
Age		Formation	Simplified lithology
Quaternary			Alluvium
Cretaceous		*Philipsburg Batholith*	Granodiorite
Permian		*Undifferentiated*	Sandstone/quartzite, shale, phosphate
Carboniferous	Pennsylvanian	*Quadrant quartzite*	Massive quartzite
	Mississippian	*Madison Limestone*	Limestone, chert
Devonian		*Jefferson Limestone*	Limestone
		Maywood Formation	Dolomitic limestone, siltstone, sandstone, shale
Cambrian	Upper	*Red Lion Formation*	Marble, limestone, shale
		Hasmark Formation	Dolomitic marble
	Middle	*Silver Hill Formation*	Limestone, shale
		Flathead Quartzite	Quartzite, shale
Precambrian		*Missoula Group*	Quartzite, shale



Vein orientations per formation

Poles on equal area lower hemisphere

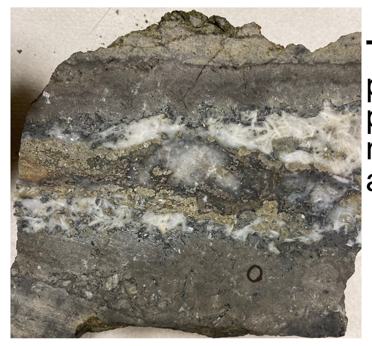




Geology: Modified from Prinz (1967) and Lonn et al. (2003)

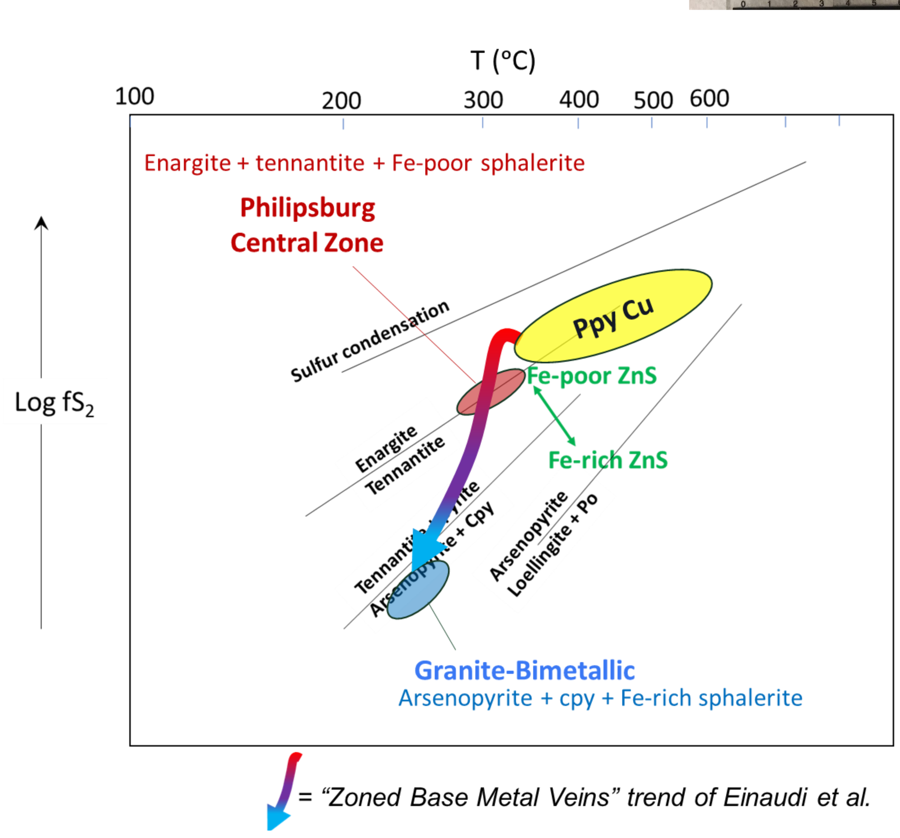
Zoned mineralogy

The north of the district (Hope Hill) contains a higher amount of copper-rich sulfides and barite, but little sphalerite.



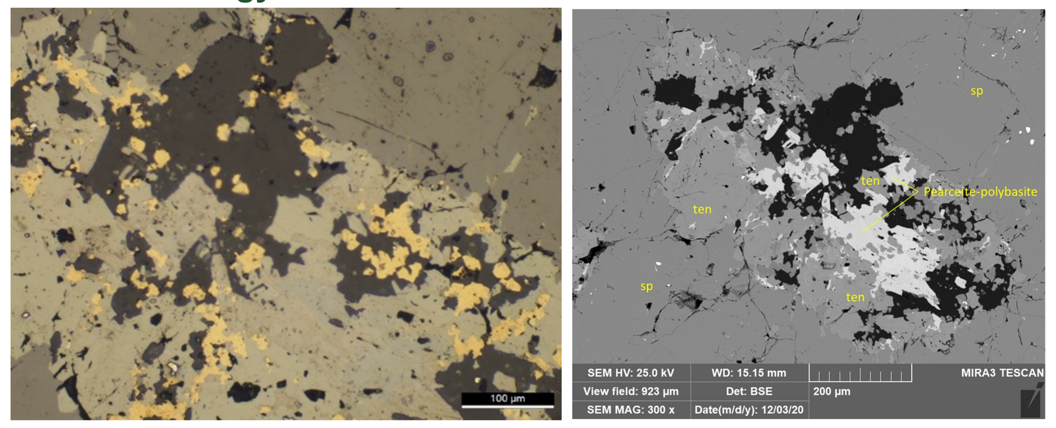
The center of the district contains Fe-poor, Zn-rich tennantite, enargite, Fe-poor sphalerite, barite, small amount of rhodochrosite, and silver minerals such as pearceite, jalpaite, and acanthite.

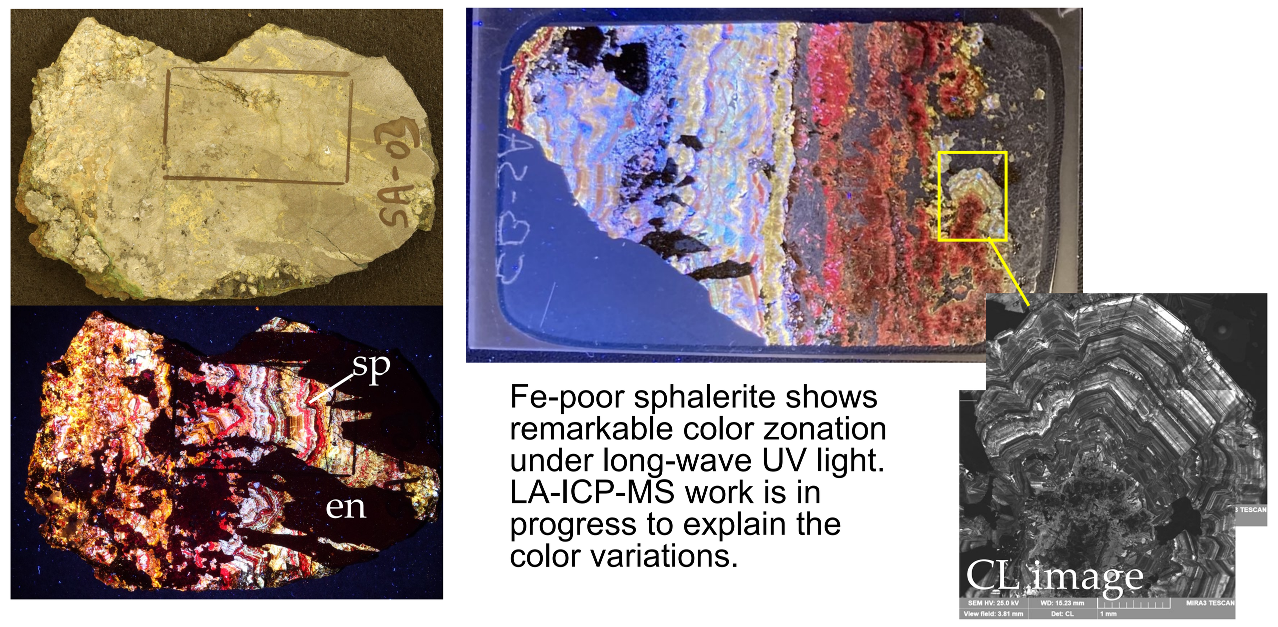
The south of the district (Granite Bi-metallic-Ruby) contains a lower sulfidation assemblage of Ag-rich tetrahedrite, Fe-rich sphalerite, arsenopyrite, chalcopyrite, and rhodochrosite. Silver minerals include pyrargyrite and miargyrite.



= "Zoned Base Metal Veins" trend of Einaudi et al.

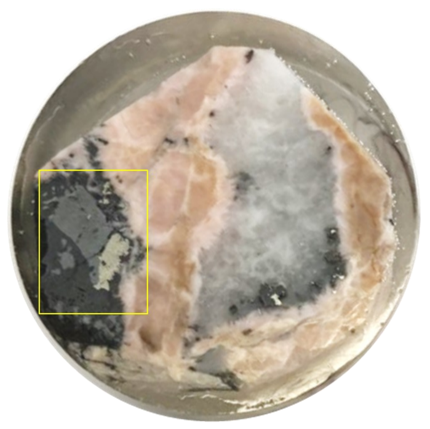
Examples of mineralogy in the center of the district:

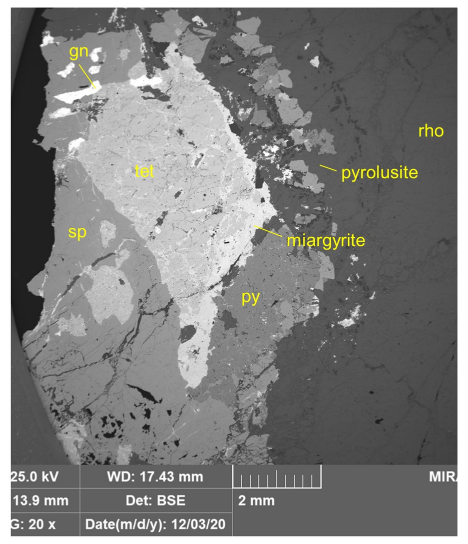




Fe-poor sphalerite shows remarkable color zonation under long-wave UV light. LA-ICP-MS work is in progress to explain the color variations.

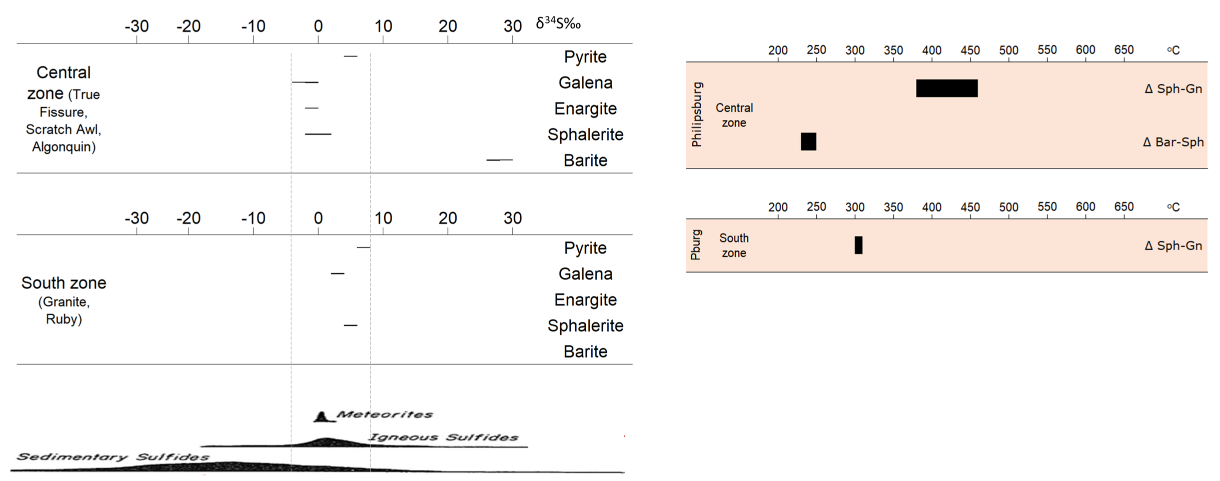
Example of mineralogy in the south of the district:





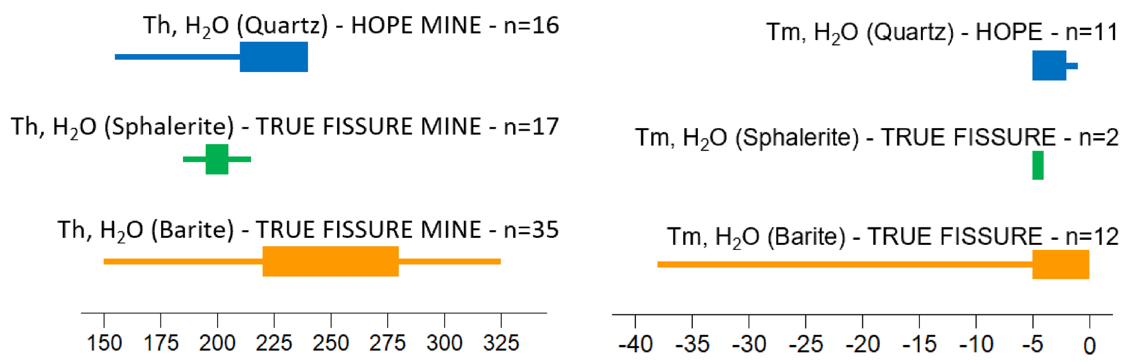
The Granite-Bimetallic mine was by far the largest producer of silver in the district, much of it as pyrargyrite/miargyrite and Ag-rich tetrahedrite.

Stable isotopes



Stable S-isotopes (n=20) show somewhat lighter $\delta^{34}S$ values in the district's center (-3.6 to 5.7‰) and heavier values to the south (3.7 to 6.5 ‰). S-isotope geothermometry on sphalerite-galena pairs gives higher temperatures (304-460°C) than sphalerite-barite pairs (221-246°C). Ongoing work will determine if this disparity reflects disequilibrium or separate mineralizing events.

Fluid inclusions



Preliminary results are summarized above. Fluid inclusions in veins from the center of the district homogenized around 244°C for barite (152-324°C, n=35) and around 202°C for sphalerite (190-215°C, n=7). Fluid inclusions in barite have a wide range in salinity, and at least one population is CO_2-rich (3-phase, with CO_2 homogenization to liquid at 23.4°C), suggesting a high pressure of trapping (> 1 kbar).

Butte vs Philipsburg

75 Ma Butte Granite	75 Ma Philipsburg Granodiorite
65 Ma Quartz porphyry dikes with porphyry Cu-Mo ± W	65 Ma Stewart Gulch porphyry with porphyry Mo-Cu ± W
Zoned, east-west (mostly) trending Cu-Ag-Pb-Zn lodes	Zoned, east-west (mostly) trending Ag-Zn-(Pb,Cu) lodes
Mined for Mn (rhodochrosite)	Mined for Mn (Mn-oxides)
Granite host rock	Granite and metasedimentary host rock
Cu-rich Main Stage Veins in center grade to Zn-Pb-Mn in outer zones.	Zn-rich veins with higher Cu in center of district (enargite-tennantite)
All zones are Ag-rich	All zones are Ag-rich
Range in $\delta^{34}S_{sulfides}$: -2.0 to 3.6‰	Range in $\delta^{34}S_{sulfides}$: -3.6 to 6.5‰

Acknowledgments

Grants

American Federation of Mineralogical Societies
Geological Society of America
Montana Geological Society
Tobacco Root Geological Society
Montana Tech

Ted Antonioli—Geologist
Dave Harris—Miner
Gary Wyss – Researcher CAMP
Simon Poulson – S isotopes, Reno, NV

References

Dr. Frank Dudas - Personal communication

Einaudi et al. (2003). Sulfidation state of fluids in active and extinct hydrothermal systems: transitions from porphyry to epithermal environments. SEG special publication.

Emmons, W.H. and Calkins, F.C. (1913) Geology and ore deposits of the Philipsburg Quadrangle Montana; USGS Professional Paper 78.

Lange, I., and Cheney, E., (1971). Sulfur isotope reconnaissance of Butte, Montana. Economic Geology 66, 63-74.

Prinz, W., (1967) Geology and ore deposits of the Philipsburg District, Granite County, Montana : A study of the silver-zinc and manganese deposits of the nation's only battery-grade manganese