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A Study of Philipsburg's Polymetallic Lode Deposits, Granite County, Montana

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From the late-1800s to the mid-1900s, the 10 km² mining district just east of Philipsburg, Montana, produced over 2.4×10^7 oz Ag, 3.6×10^7 kg Zn, 1×10^7 kg Pb, 1.8×10^6 kg Cu, 4.5×10^5 short tons of battery-grade MnO₂, and significant W. Although its silver production was surpassed in Montana only by the famous porphyry-lode deposits of Butte, the Philipsburg district has never been studied with modern methods of ore-deposit research. This study aims to re-evaluate the district's geochemistry, structural history, and economic potential, including critical metals. Mineralization occurs as quartz + rhodochrosite + barite veins and replacements, hosted by Precambrian to Mesozoic metasedimentary rocks and the 75 Ma Philipsburg granodiorite stock. A small 65 Ma Mo-porphyry outcrops on the district's northern edge, but its relationship to polymetallic vein mineralization is unclear. Mineral zonation in the district consists of a low-sulfidation suite (arsenopyrite + tetrahedrite + Fe-rich sphalerite) at the periphery, grading to a higher sulfidation suite (enargite + tennantite + Fe-poor sphalerite) in the center. Stable S-isotopes are lighter in the central area (near 0 per mil) than in the rest of the district (+2 to +6 per mil). Sphalerite from the central area fluoresces unusually bright colors under longwave UV (365 nm) light. LA-ICP-MS analysis reveals that the red fluorescence is correlated to a very low Fe-content, coupled with high concentrations of Cu, Ge, Ga, In, W, and Ag in the sphalerite lattice. Concentrations of Ga and W are particularly high (up to 4997 and 2834 ppm, respectively) and may be of economic importance. The Philipsburg district has many geological and geochemical similarities to the nearby Butte porphyry-lode district and likely belongs to the same clan of Cordilleran-style, zoned, polymetallic-lode deposits. Re-examination of historic mining districts such as Philipsburg may help address the rising need for domestic production of rare metals.