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District Scale Zonation of Sphalerite at Butte, Montana: Trace Elements, UV Fluorescence, and S Isotopes

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Ultraviolet (UV) fluorescence textures, hyperspectral cathodoluminescence imaging, LA-ICP-MS trace element analyses, and sulfur isotopes were used to investigate sphalerite-bearing Main Stage mineralization at mines across the porphyry-polymetallic lode district at Butte, Montana. Samples were selected from historic archives at the Montana Bureau of Mines and Geology and are representative of the high sulfidation state Cu-Ag-As Central Zone (Leonard Mine) and the intermediate sulfidation state Pb-Zn-Mn-Ag Peripheral Zone (Orphan Girl Mine), to test if sphalerite chemistry is correlated to formation in specific zones.

Central Zone sphalerite is Fe-poor (<100 ppm), commonly fluoresces red/orange/yellow, and is associated with covellite, enargite, and tennantite. UV micro-textures reveal sphalerite replacement of earlier minerals, including huebnerite. UV-red sphalerite in the Central and Intermediate Zones of the district contains highly elevated Ga, In, W, and Cu, with $\delta^{34}\text{S}(\text{VCDT})$ values ranging from -2.1 to +0.8 ‰. Incorporation of trivalent (Ga^{3+} , In^{3+} , As^{3+} , Sb^{3+} , Bi^{3+}), tetravalent (Ge^{4+}), or hexavalent (W^{6+}) metals into sphalerite requires coupled substitution mechanisms with monovalent Cu^{1+} and/or Ag^{1+} .

Peripheral Zone sphalerite is typically non-fluorescent or UV-yellow, and is associated with galena, rhodochrosite, and rhodonite. Non-fluorescent sphalerite is high Fe (>500 ppm), and Fe is known to quench fluorescence. Peripheral Zone UV-yellow sphalerite contains elevated Mn (>1000 ppm), and elevated but variable Fe, Cu, Hg, and Ag. Divalent metals such as Mn^{2+} , Fe^{2+} , Cd^{2+} , and Hg^{2+} directly substitute for Zn^{2+} . UV-yellow/non-fluorescent Peripheral Zone sphalerite returned $\delta^{34}\text{S}(\text{VCDT})$ values ranging from +2.0 to +6.2 ‰, notably heavier than UV-red sphalerite from the Central Zone. We will present additional data including in situ LA-MC-ICP-MS $\delta^{34}\text{S}$ analyses at high spatial resolution. These results provide additional context for understanding the mineralizing processes at Butte, and offer new exploration and characterization tools for assessing the critical minerals potential of porphyry-lode systems.