Holley, E.A., et al., 2023, Cobalt mineralogy at the Iron Creek deposit, Idaho cobalt belt, USA: Implications for domestic critical mineral production: Geology, https://doi.org/10.1130/G51160.1

Supplemental Material

Text.

Table S1. Volume % of phase [%]

Table S2. Letter citations

SUPPLEMENTAL MATERIAL

Sample Selection and Petrography Methods

From each ore zone, we selected pyrite-bearing samples from drill core displaying characteristic alteration and abundant sulfide mineralization. Initial petrography was conducted at 2.5, 5, 10, 20, 40 and 50x on polished 30 μm thin sections using a Carl Zeiss Axio Scope A1 polarizing microscope in the Mining Geology Research Laboratory at Colorado School of Mines. Scanning electron microscopy (SEM) was conducted in the Mineral and Materials Characterization Facility at the Colorado School of Mines using a TESCAN MIRA3 LHM Schottky field emission scanning electron microscope equipped with a Bruker XFlash® 6/30 silicon drift detector for energy-dispersive X-ray spectrometry (EDX) and a single-crystal YAG backscatter electron detector. Back-scattered electron (BSE) images were collected under an accelerating voltage of 8 or 15 kV, BI of 11, with a working distance of 10 mm. The EDX spot analyses provided semi-quantitative elemental concentrations, allowing for the identification of pyrite versus arsenian pyrite. Energy dispersive X-ray spectrometry was also used to create element maps to identify areas enriched in Cu, Co, and As.

μXRF Mapping

Element distribution maps of billets were acquired using a bench-top Bruker M4 Tornado μXRF (Bruker Nano GmbH, Berlin, Germany) equipped with dual 30 mm^2 silicon drift detectors in the Mineral and Materials Characterization Facility at the Colorado School of Mines, Golden, CO, USA. The instrument is equipped with a Rh X-ray tube with polycapillary optics achieving a spot size of ~25 μm. Measurements were made under vacuum (~20 mbar) at 50 kV and 600 μA, using a 12.5 μm thick Al filter. Element mapping was conducted at a line scan spacing of 25 μm (equivalent to final pixel size), and a data acquisition dwell time of 35 ms. Following data acquisition, X-ray peaks were checked manually prior to deconvolution. Element distribution maps were obtained showing normalized count rates.

Automated Mineralogy

Automated mineralogy analysis was conducted in the Mineral and Materials Characterization Facility at the Colorado School of Mines. The instrument used was a TESCAN-VEGA-3 Model LMU VP-SEM platform combined with the TIMA3 (Tescan Integrated Mineral Analyzer) control program. Element spectra were acquired using four energy dispersive X-ray (EDX) spectrometers with a stepping distance of 15 μm, an acceleration voltage of 25 kV and a beam intensity of 14. Identification of mineral phases was made at each acquisition point by comparison of measured EDX spectra with spectra held in a look-up table. Results are output by the TIMA software giving the area percent of each composition, which are used for generating compositional mineral maps. The modal abundances of each analysis are presented in Table S1.

Laser Ablation ICP-MS

Laser ablation ICP-MS point analyses and mapping were conducted at the Department of Geology and Geological Engineering at the Colorado School of Mines. Pyrite spot analyses and compositional maps were analyzed using a Resolution-SE 193 nm ArF excimer laser ablation system coupled with an Agilent 8900 triple quadrupole ICP-MS (Agilent 8900 ICP-QQQ). An Argon-Helium gas mixture was used at the ablation site to carry the sample aerosol into the mass spectrometer. The interface between the laser ablation system and mass spectrometer has a signal homogenizing device (squid) to reduce signal noise.

For pyrite spot analyses, a 20 second background was collected followed by a 5 Hz laser pulse at 2.7 J/cm^2 for 30 seconds of signal collection. The laser spot size was 30 μm for standards and pyrite analyses, and 60 μm for STDGL-3, which was analyzed using both spot sizes. A primary calibration for instrument drift and sensitivity was completed using STDGL-3 run at 60 μm. A secondary calibration for spot size and element fractionation was completed using STDGL-3 and GSD-1g analyzed at 30 μm. Masses analyzed for spot analyses include: ^{23}Na, ^{24}Mg, ^{27}Al, ^{29}Si, ^{34}S, ^{39}K, ^{43}Ca, ^{49}Ti, ^{51}V, ^{53}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{65}Cu, ^{66}Zn, ^{71}Ga, ^{72}Ge, ^{73}Ge, ^{75}As, ^{77}Se, ^{90}Zr, ^{93}Nb, ^{95}Mo, ^{107}Ag, ^{109}Ag, ^{111}Cd, ^{115}In, ^{118}Sn, ^{121}Sb, ^{125}Te, ^{157}Gd, ^{182}W, ^{195}Pt, ^{197}Au, ^{202}Hg, ^{205}Tl, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, and ^{238}U with dwell times per mass between 0.005 and 0.02 seconds. Spot analysis data was processed using the LADR software.

For compositional maps, a 10 μm laser square was rastered over the sample surface at 0.01 mm/s. A gas blank was collected prior to each image, and pre-ablation was done using a 10 μm laser beam with a 50% spot overlap before each line analysis. Similar to spot analyses, the laser energy was 2.7 J/cm^2, and STDGL-3 and GSD-1g standard materials were used for the quantification of pyrite. The mass list for pyrite mapping was ^{23}Na, ^{24}Mg, ^{27}Al, ^{29}Si, ^{31}P, ^{34}S, ^{39}K, ^{43}Ca, ^{49}Ti, ^{51}V, ^{53}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{65}Cu, ^{66}Zn, ^{75}As, ^{77}Se, ^{107}Ag, ^{118}Sn, ^{121}Sb, ^{125}Te, ^{137}Ba, ^{157}Gd, ^{182}W, ^{197}Au, ^{208}Pb, ^{209}Bi, and ^{238}U with dwell times for each mass between 0.001 and 0.01 seconds, and a total sampling period of 0.2 seconds. Data reduction was performed using the Iolite v. 4.0 program and the Cellspace module was used to construct the pyrite quantified compositional maps.

Mapping of Cobalt Mine Production and Processing

The locations, tonnages, deposit styles, and principal mineralogy of global cobalt resources were compiled from industry and government reports, shown in Table S2. Processing methods, infrastructure, and locations for cobalt ores were also compiled from published data and industry reports, and material flows were drawn to link the sites of mining to the primary sites of processing and refining (Table S2). With the exception of the Idaho Cobalt Belt and Minnesota, U.S.A., the map does not show unmined resources, hypothetical processing flows, or planned infrastructure.

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