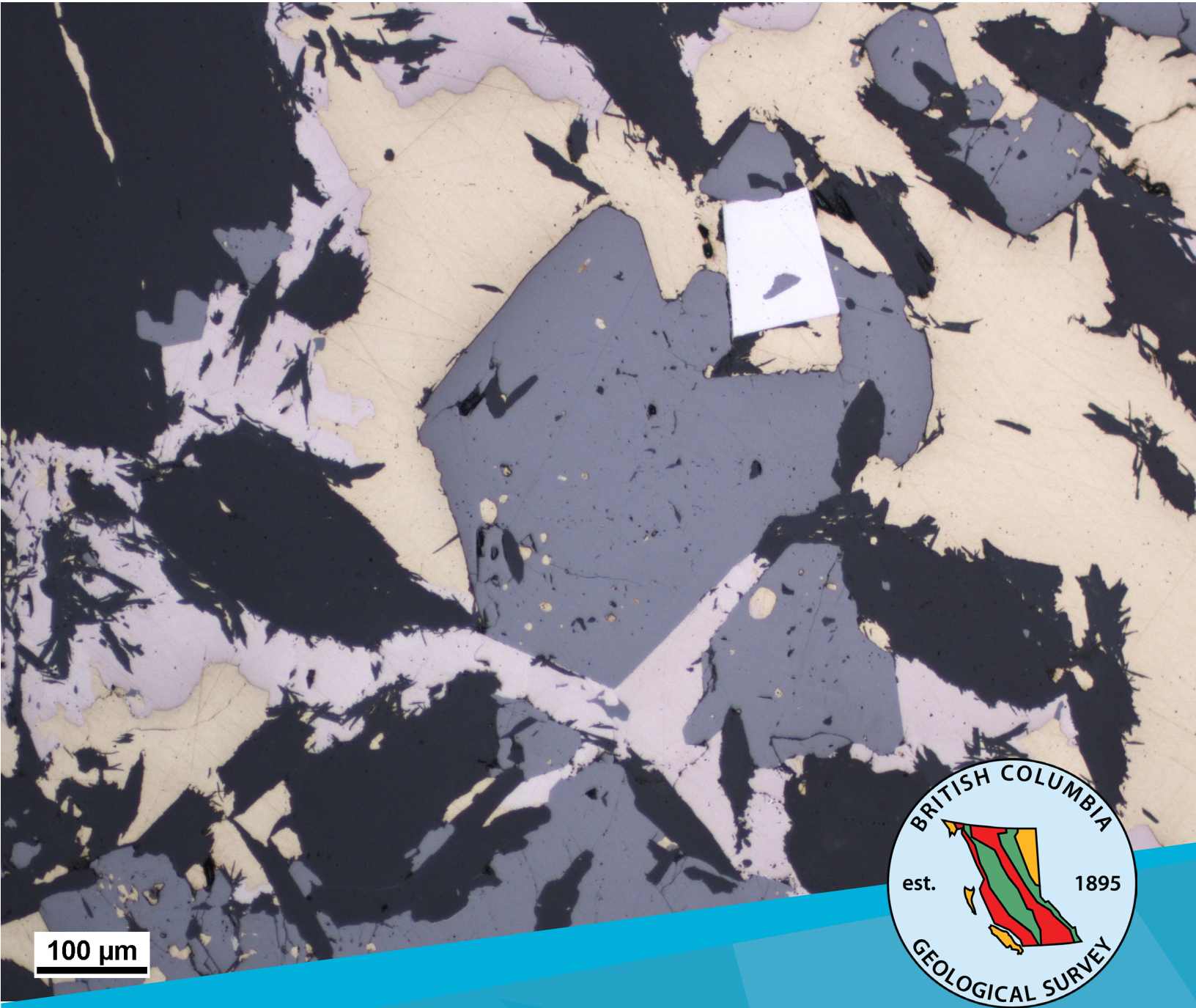

Supplementary data for 'Critical metal distributions in volcanogenic massive sulphide (VMS) deposits in British Columbia: A progress report'

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BRITISH COLUMBIA
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Front cover:
Reflected light microscope image of euhedral Co-bearing mineral cobaltite (white) with subhedral magnetite (grey) enclosed by pyrrhotite (pink) and chalcopyrite (yellow). Granduc deposit.

Back cover:
Reflected light microscope image of ablation pits in sphalerite (grey) after LA-ICP-MS analysis. Intergrown sphalerite and chalcopyrite (yellow) support anhedral to subhedral pyrite (white). Anyox/Hidden Creek deposit.

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Supplementary data for 'Critical metal distributions in volcanogenic massive sulphide (VMS) deposits in British Columbia: A progress report'

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Abstract

GeoFile 2026-01 provides supplementary data to support ongoing studies focussed on critical metals in volcanogenic massive sulphide deposits across British Columbia. The data are from three mafic-siliciclastic/Besshi deposits (Anyox/Hidden Creek, Goldstream, and Granduc) and include: 1) major and minor element concentrations in base metal sulphides and Fe-oxides obtained using electron probe microanalyzer (EPMA); and 2) trace element concentrations of spot analyses of sphalerite from laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS).

Keywords: critical metal abundance, volcanogenic massive sulphide deposit, EPMA, LA-ICP-MS

1. Introduction

Piercey et al. (2025) initiated a project to understand elements currently on the national critical minerals list (NRCan, 2024) such as Cu, Zn, Co, Sb, Bi, In, Ge, Ga, and Te, in volcanogenic massive sulphide deposits (VMS) across British Columbia. GeoFile 2026-01 supports the progress report of Wei et al. (2026), which expands on Piercey et al. (2025) by focussing on quantification of critical metal and other metal concentrations in minerals in three mafic-siliciclastic (or Besshi) deposits: Anyox/Hidden Creek, Goldstream, and Granduc (Fig. 1). This data release (BCGS_GF2026-01.zip) includes source data tables of: 1) major and minor elements concentrations obtained from pyrite, pyrrhotite, chalcopyrite, sphalerite, magnetite, cobaltite, and willyamite by electron probe microanalyzer (EPMA); and 2) trace elements concentrations in sphalerite measured by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Appendix 1 contains the results of EPMA analyses with atom per formula unit (APFU) calculations for each mineral phase separately. Appendix 2 consists of the EPMA analyses of secondary standards for different mineral phases. Appendix 3 shows EMPA detection limits for every analyses of unknown mineral and standard. Appendix 4 contains the results of LA-ICP-MS trace element analyses of sphalerite, uncertainties, and detection limits, and analyses of reference materials, NIST SRM 610 and MASS-1, used for calibration with %RSD and %RD calculations.

2. Analytical methods

2.1. Major and minor elements by EPMA

Nine polished thin sections (60 µm thick) from Anyox (n=3), Goldstream (n=2), and Granduc (n=4) were analyzed by JEOL JXA-8230 SuperProbe EPMA equipped with five wavelength-dispersive spectrometers and a tungsten filament electron gun at the Hibernia Project Electron Beam Laboratory within Core Research Equipment and Instrument Training (CREAIT) Network at the Department of Earth Sciences, Memorial University of Newfoundland. The instrument was calibrated using both natural and synthetic standards. Each run of unknown minerals consisted of an average 20-25 analyses with secondary standards analyzed at the beginning and the end of each run. The following elements were analyzed in minerals of interest: 1) Co, Cr, Cu, Fe, Ni, S, Sb, Sn, V, Zn in pyrite, and pyrrhotite; 2) Ag, As, Cd, Co, Cu, Fe, Pb, S, Sb, Sn, Zn in chalcopyrite; 3) Cd, Co, Cu, Fe, Hg, Pb, S, Sb, Sn, Zn in sphalerite; 4) As, Co, Fe, Ni, S, Sb, Se in cobaltite and willyamite; and v) Al_2O_3, CoO, Cr_2O_3, FeO, MnO, TiO_2, V_2O_3, WO_3, ZnO in magnetite. The minerals were analyzed using 20kV accelerating voltage, a 20-nA beam current with a 1 µm beam diameter, and counting times between 5 and 30 s. Ten to 15 data points were analyzed for each mineral phase per thin section to ensure results reflect the multiple paragenetic generations of a given mineral phase, its association with other minerals, and any in-grain zoning.

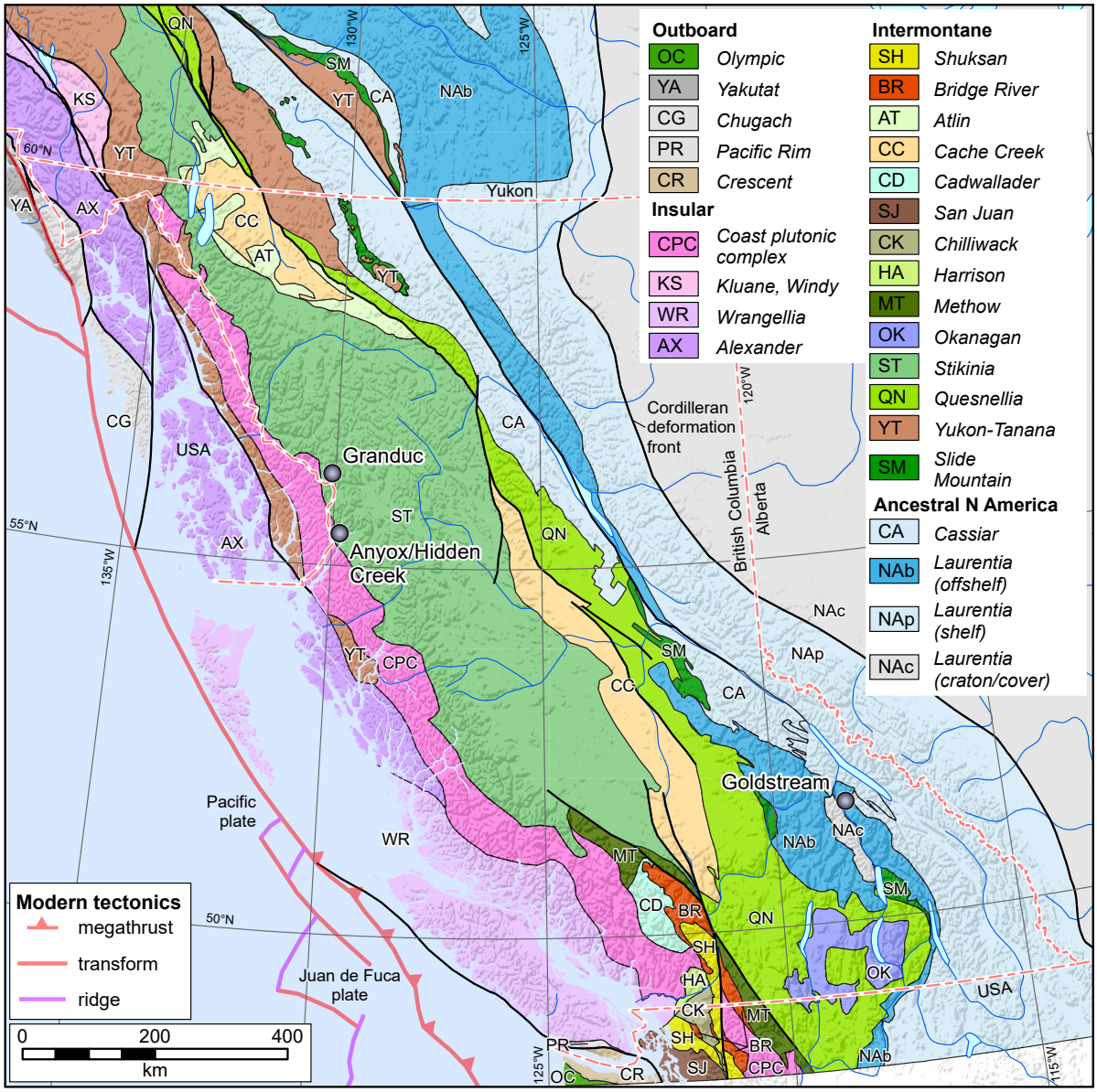

Fig. 1. Location of volcanogenic massive sulphide deposits discussed in this study. Terrane boundaries after Colpron (2020).

2.2 Quality assurance and quality control of EPMA data

Analyses of sulphides with totals outside the range of 100 ± 2 wt.% were excluded, as well as analyses that recorded a mixed signal from the mineral and its host or inclusions (Appendices 1, 2). We also performed atoms per formula unit (APFU) calculations (Appendix 1) to check data quality and test if the cation numbers and total sum of cations match the stoichiometric formula of a given mineral. Every individual run has an individual detection limit (DL) for every element analyzed (Appendix 3). The average DL for Co is 99 ppm (min=93 ppm; max=103 ppm) in pyrite, 102 ppm (min=98 ppm; max=108 ppm) in pyrrhotite, 106 ppm (min=101 ppm; max=116 ppm) in chalcopyrite, 108 ppm (min=104 ppm; max=113 ppm) in sphalerite, 125 ppm (min=108 ppm; max=134 ppm) in magnetite, 164 ppm (min=158 ppm; max=173 ppm) in cobaltite, and 188 ppm (min=181 ppm; max=197 ppm) in willyamite. Detection limits of the remaining elements in minerals are listed in Appendix 3. If the concentration of an element in an individual run was smaller than DL, then this element was marked as 'below detection limit' (BDL; Appendices 1, 2).

The secondary standards were monitored during the EPMA data acquisition. The basic statistics and percent relative standard deviation (%RSD) and percent relative difference (%RD) were calculated, where applicable, to determine precision and accuracy of the secondary standard analyses (Appendix 2). The precision and accuracy of most of the elements above the limit of quantification (LOQ) are good to excellent.

2.3. Trace elements in sphalerite by LA-ICP-MS

Analysis of minor and trace elements in sulphides was conducted using LA-ICP-MS. The system consists of a GeoLasPro 193 nm ArF Excimer laser ablation (Coherent) paired with an Element XR HR-ICP-MS (Thermo Scientific), operated at the Microanalysis Facility within the CREAIT Network at Memorial University of Newfoundland. Laser ablation took place in a pure He environment, with the aerosol mixed with argon before entering the ICP torch. The process used a 30 µm spot size, an energy density of 5 J/cm², and a pulse frequency of 5 Hz. Each analysis included 30 s of background measurement, 40 s of ablation, and 30 s of washout time. For certain mineral phases, such as high-Pb minerals, the washout time was extended. The ICP-MS was optimized for high sensitivity, ensuring a ThO/Th ratio of < 0.3%. All analyses were done in low resolution mode. The following isotopes were monitored with varying dwell times ^{24}Mg, ^{27}Al, ^{29}Si, ^{34}S, ^{43}Ca, ^{49}Ti, ^{232}Th and ^{238}U (5 ms); ^{51}V, ^{53}Cr, ^{90}Zr, ^{93}Nb, ^{157}Gd, ^{178}Hf, ^{181}Ta (10 ms); ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{65}Cu, ^{66}Zn, ^{69}Ga,^{71}Ga, ^{72}Ge, ^{74}Ge, ^{75}As, ^{77}Se, ^{95}Mo,^{107}Ag, ^{109}Ag, ^{111}Cd, ^{113}In,^{115}In, ^{118}Sn, ^{121}Sb, ^{125}Te, ^{182}W, ^{185}Re, ^{197}Au, ^{202}Hg, ^{205}Tl, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{209}Bi (20 ms). External calibration was performed using MASS-1 (Wilson et al., 2002) for chalcophile and siderophile elements, and NIST SRM 610 (Jochum et al., 2011) for lithophile elements. To ensure instrument stability and data quality, duplicate analyses of both reference materials were performed at the start of each session and after every 10-16 analyses.

2.4 Quality assurance and quality control of LA-ICP-MS data

Data reduction was carried out using the LADR software package (Norris and Danyushevsky, 2018). ^{57}Fe served as the internal standard for sphalerite. During data reduction, peaks for Cu, Pb, Si, Mg, Al and Ca, were closely monitored to exclude contamination from mineral inclusions or host mineral (e.g., chalcopyrite, galena, silicates, carbonates). All concentrations were normalized to 100 wt%, with corrections applied for elemental fractionation relative to Fe following the method described by Danyushevsky et al. (2011). Isobaric interferences of ^{74}Se on ^{74}Ge, ^{113}Cd on ^{113}In, and ^{115}Sn on ^{115}In, were corrected using known isotopic ratios of Cd, Sn, and Se. Interferences from ZrO and NbO on Ag were deemed negligible due to the low concentrations of Zr and Nb in the samples. Appendix 4 contains detection limits and uncertainties (ppm) for every individual run.

Both reference materials, NIST SRM 610 for lithophile elements and MASS-1 for chalcophile and siderophile elements, yield good to very good precision for the majority of the elements based on %RSD, and excellent accuracy based on %RD with the accepted values for MASS-1 (Wilson et al., 2002; Johum et al., 2005) and NIST SRM 610 (Jochum et al., 2011) (Appendix 4).

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References cited

Colpron, M., 2020. Yukon Terranes - A digital atlas of terranes for the northern Cordillera. Yukon Geological Survey. https://data.geology.gov.yk.ca/Compilation/2#InfoTab

Danyushevsky, L., Robinson, P., Gilbert, S., Norman, M., Large, R., McGoldrick, P. and Shelley, M., 2011. Routine quantitative multi-element analysis of sulphide minerals by laser ablation ICP-MS: Standard development and consideration of matrix effects. Geochemistry: Exploration, Environment, Analysis, 11, 51-60. https://doi.org/10.1144/1467-7873/09-244

Jochum K.P., Nohl U., Herwig K., Lammel E., Stoll B. and Hofmann A.W., 2005. GeoReM: A new geochemical database for reference materials and isotopic standards. Geostandards and Geoanalytical Research, 29, 333-338. https://doi.org/10.1111/j.1751-908X.2005.tb00904.x

Jochum, K.P., Weis, U., Stoll, B., Kuzmin, D., Yang, Q., Raczek, I., Jacob, D.E., Stracke, A., Birbaum, K., Frick, D.A. and Günther, D., 2011. Determination of reference values for NIST SRM 610–617 glasses following ISO guidelines. Geostandards and Geoanalytical Research, 35, 397-429. https://doi.org/10.1111/j.1751-908X.2011.00120.x

Norris, A., and Danyushevsky, L., 2018. Towards estimating the complete uncertainty budget of quantified results measured by LA-ICP-MS, Goldschmidt, Boston, 2018-08-12 1894. https://goldschmidt.info/2018/abstracts/abstractView?id=2018003403

NRCan (Natural Resources Canada), 2024. Critical minerals list. Government of Canada. https://www.canada.ca/en/campaign/critical-minerals-in-canada/critical-minerals-an-opportunity-for-canada.html

Piercey, S.J., Pietruszka, D.K., and Goudie, D., 2025. Critical metals in volcanogenic massive sulphide (VMS) deposits in British Columbia: A progress report. In: Geological Fieldwork 2024, British Columbia Ministry of Mining and Critical Minerals, British Columbia Geological Survey Paper 2025-01, pp. 189-201.

Wei, C. Pietruszka, D.K., Piercey, S.J., Aylward, W., Kommescher, S., Scanlan, E., and Layton-Matthews, D., 2026. Critical metal distributions in volcanogenic massive sulphide (VMS) deposits in British Columbia: A progress report. In: Geological Fieldwork 2025, British Columbia Ministry of Mining and Critical minerals, British Columbia Geological Survey Paper 2026-01, in press.

Wilson, S.A., Ridley, W.I. and Koenig, A.E., 2002. Development of sulfide calibration standards for the laser ablation inductively-coupled plasma mass spectrometry technique. Journal of Analytical Atomic Spectrometry, 17, 406-409.

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