British Columbia Geological Survey rock geochemical and geochronological data products: Examples of utility

Luke Ootes[1, a], Alexei S. Rukhlov[1], and Tian Han[1]

[1] British Columbia Geological Survey, Ministry of Energy, Mines and Low Carbon Innovation, Victoria, BC, V8W 9N3
[a] corresponding author: Luke.Ootes@gov.bc.ca

Recommended citation: Ootes, L., Rukhlov, A.S., and Han, T., 2024. British Columbia Geological Survey rock geochemical and geochronological data products: Examples of utility. In: Geological Fieldwork 2023, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2024-01, pp. 123-129.

Abstract

The British Columbia Geological Survey compiles, manages, and releases geochronology and geochemistry data updates. More than 8000 geochronological results from British Columbia are available from a data release in 2004 and an update in 2020, and this paper highlights one of the ways these datasets can be used to highlight episodes in the evolution of the Cordilleran orogen. Rock geochemical results are available from >12,000 samples across British Columbia and this paper also illustrates how these data can be used. Most of the data from Triassic to Early Jurassic intrusions overlap the field of rock compositions (Sr/Y vs. Sr/MnO) that are prospective for porphyry Cu, skarn, or epithermal mineralization. A plot of Cu concentrations from ~10,000 samples highlights elevated concentrations in western and eastern Stikine terrane and Quesnel terrane, areas with known porphyry Cu-Mo-Au deposits.

Keywords: BCGS data products, geochronology, geochemistry, data utility

---

1. Introduction

High-quality geochemical and geochronological data are fundamental to characterizing and understanding the geology and metallogeny of any region. In part because of continuous advances in analytical capabilities, the volume of rock geochemical and geochronological data has increased dramatically in recent years. The British Columbia Geological Survey (BCGS) provides systematic and consistent management of these data, which have been derived from province-wide collections. Current data compilations include previously published publicly available data and new data generated by ongoing projects (e.g., Han et al., 2019, 2020; Van der Vlugt et al., 2022; van Straaten et al., 2022). Data management includes compilation, metadata retrieval and verification, standardization and quality control, data query and extraction, and generation and release of data products. This paper highlights some general applications of the rock geochemical and geochronological data products from the British Columbia Geological Survey, showing a few of many potential applications of the data.

2. Rock geochemical and geochronological data products

The data products that the BCGS releases to the public are generated using data models (Figs. 1, 2) that define the structure of the database, specifying how data are organized and defined. Invisible in the data products, the models are the basis for capturing metadata using in-house dictionary guides; they work in the background to produce the simplified data products that the Survey releases (e.g., Han et al., 2020; Fig. 3). The geochemical and geochronological data products have a common sample code attribute that can be used to link both datasets and can be spatially enabled in GIS software and as a relational database where complex queries can be performed. The metadata structure has been designed to align with the international open data standards for geochemical data (van Straaten et al., 2022) and are identical to those in the BC Digital Geology (Cui et al., 2017). The most recent dataset of geochemical data (Han and Rukhlov, 2024) is populated with ~500,000 analytical values and metadata from 12,413 samples that were collected between 1973 and 2023. Han et al. (2020) updated Breitsprecher and Mortensen (2004) and the geochronological dataset now contains age determinations from 8292 samples that were collected between 1960 and 2020.

3. Application of the geochronological dataset

Geochronology refers to the age of rocks and minerals using the decay of radiogenic isotopes to measure time. Different mineral and isotope systematics have different temperatures at which the decay from parent to daughter isotopes becomes a closed system, or when the 'geological time clock' starts ticking. Because these ‘closure’ temperatures range from >900°C to <100°C, an array of isotopic systems is available to track episodes in the history of a rock. For example: 1) U-Pb zircon, monazite, and titanite can establish the crystallization age of igneous rocks, the provenance and age estimate of sedimentary rocks, and cooling age of high-grade metamorphic rocks; 2) Ar-Ar sanidine, hornblende, muscovite, and biotite geochronology can provide crystallization ages of fresh volcanic rocks, or mid-temperature (300 to 600°C) cooling ages of metamorphic or altered rocks; and 3) fission track or U-Th/He zircon and

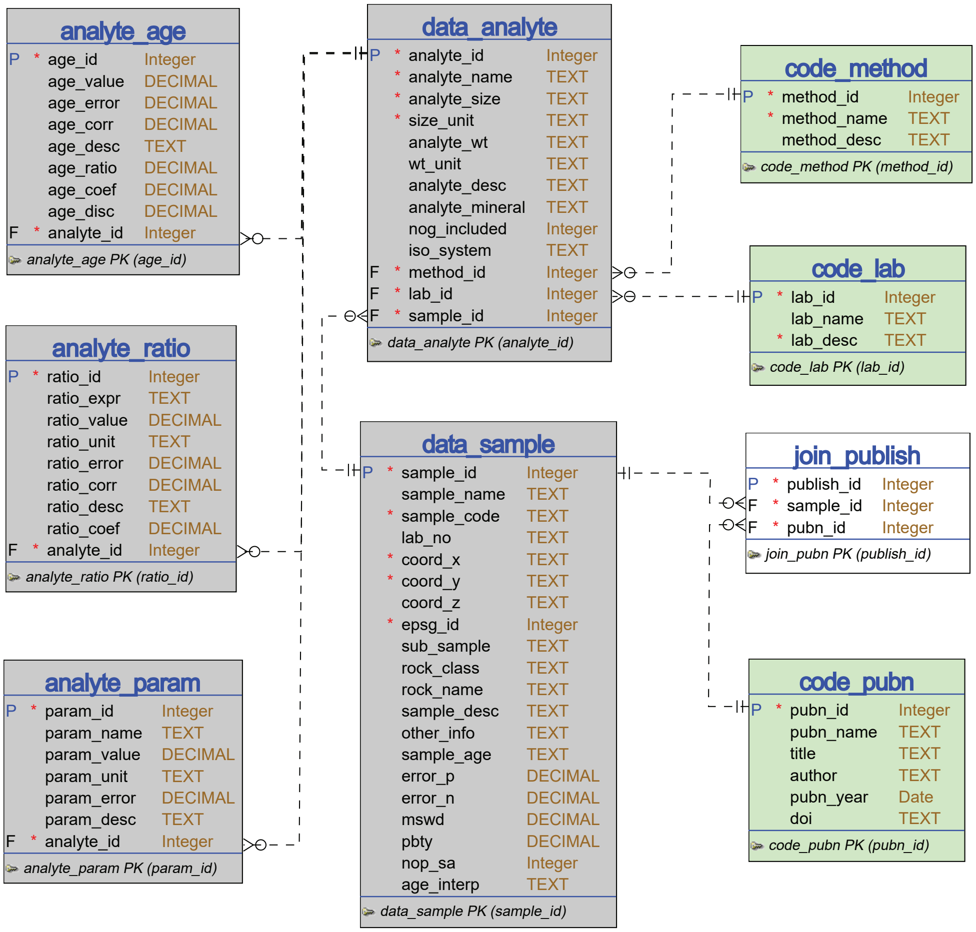

Fig. 1. Logical data model for the geochronological database. This data model is guided by an in-house data dictionary and used to produce simplified data products for release to the public (e.g., Han et al., 2020).

apatite data provide low-temperature results (<150°C), which can inform the time and pace of unroofing episodes.

The map of geochronological ages from across British Columbia (Fig. 3) was derived from 7759 age determinations from Breitsprecher and Mortensen (2004), which included results from a wide variety of isotopic systematics, including largely outdated methods (e.g., K/Ar), and 533 new results from data that were published between 2004 and 2020 (Han et al., 2020) and includes U-Pb, Ar-Ar, and Re-Os isotopic results. The age distribution of U-Pb and Ar-Ar results are plotted as Kernel density estimations (KDE; Figs. 4, 5; Vermeesch, 2018). Because U-Pb results are high-temperature (>600°C), these data record igneous crystallization or metamorphic resetting ages. The data show a background of continuous U-Pb results since ca. 400 Ma that is punctuated by peaks close to the Devonian-Carboniferous boundary, two peaks during the Jurassic, a subordinate Late Cretaceous peak (Fig. 4a), and a significant Paleocene to Eocene peak, specifically between the Thanetian to Lutetian (60-50 Ma; Figs. 4a, b). The Re-Os data mark the timing of molybdenite mineralization, typically from porphyry deposits, which formed in the Late Triassic to Early Jurassic, Early Cretaceous, and Eocene (Fig. 4a). The Ar-Ar data also show subordinate Late Jurassic and Late Cretaceous peaks, with the most significant between the Thanetian to Lutetian (Figs. 4c, d). The ‘other’ data show a similar pattern to the Ar-Ar data, with an additional peak in the Late Miocene to Pleistocene (Figs. 4e, f). Part of Cordilleran orogen of British Columbia is underlain by terranes with Late Triassic volcanic successions that are predominantly mafic (Quesnellia, Stikinia, Wrangellia). These terranes are not well-represented in the data set, in general because not many of these rocks contain zircon for U-Pb dating, and the rocks may have undergone post-emplacement metamorphism so that lower temperature techniques (Ar-Ar, fission track) record more recent overprints (Fig. 4). All of the data (Fig. 4) highlight a Paleocene to Eocene (Thanetian to Lutetian; 60-50 Ma) thermo-magmatic episode across the province, representing a significant tectonic event that affected the entire Cordilleran orogen.

Comparing the pre-2004 and the post-2004 U-Pb data (Fig. 5) highlights shifting research focus. The first observation is that there are no Precambrian dates for rocks in the post-2004 data compilation. Precambrian basement occurs within some of the metamorphic core complexes, and the Purcell Supergroup (Mesoproterozoic) is a sedimentary succession with predominantly mafic igneous rocks. This lack of new Precambrian results in the post-2004 compilation indicates

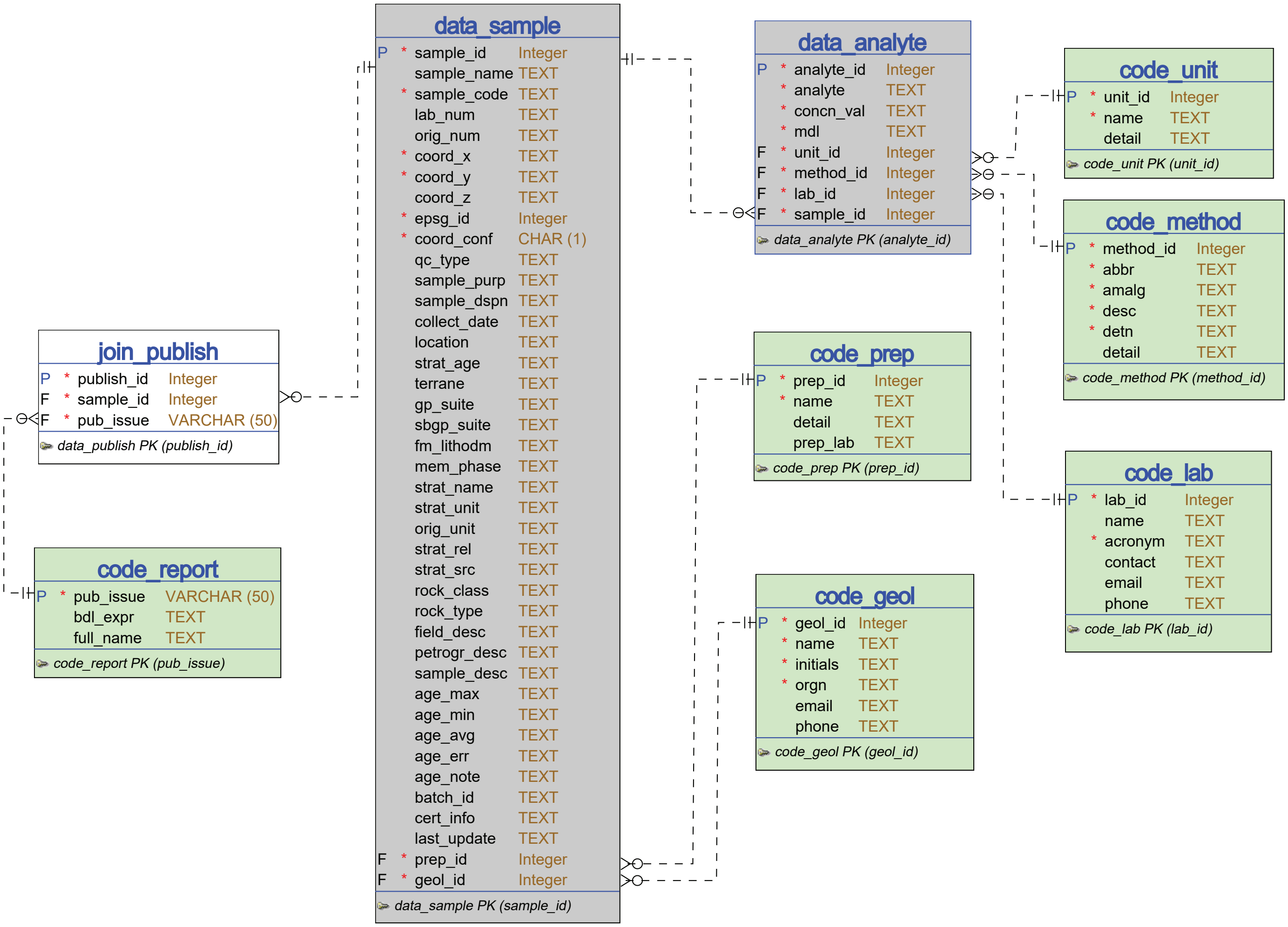

Fig. 2. Logical data model for the rock geochemical database. This data model is guided by an in-house data dictionary and used to produce simplified data products for release to the public (e.g., Van der Vlugt et al., 2022).

a shift away from research on these types of rocks and these geographic areas within British Columbia. The second is that the abundance of U-Pb results has shifted from predominantly Late Cretaceous-Paleocene/Eocene results toward Late Triassic-Early Jurassic. We speculate that this change may reflect a shift of research focus towards mineralized and barren plutons in porphyry environments (Quesnellia and Stikinia) in the last 20 years. This shift may also relate to advances in mineral separation and analytical techniques. For example, during the early to mid-2000s, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) became a mainstream geochronological tool, and this method is less expensive (both in cost and labour) than dating rocks by isotope dilution thermal ionization mass spectrometry (ID-TIMS).

4. Application of the rock geochemical dataset

British Columbia Geological Survey collects and maintains provincial lithogeochemical data from rocks, modern drainages, glacial sediments, and coal ash (Han et al., 2019). Modern whole-rock analysis determines up to 60 elements using partial (hot acid mixtures) or total (fusion at 1000°C) digestions and a combination of high-precision inductively coupled plasma atomic emission spectroscopy (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS). Non-destructive techniques such as instrumental neutron activation analysis (INAA) and X-ray fluorescence, and other methods (e.g., determination of Fe^{2+} concentration by digesting a sample in a hot, concentrated HF-H_2SO_4 mixture, followed by $KMnO_4$ titration of the H_3BO_3-neutralized solution; determination of F concentration using a Na_2CO_3-KNO_3 flux, followed by H_2O leaching of the fused sample and measuring fluoride ion concentration in the supernatant solution by ion selective electrode) extend the range of analytes and limits of detection. These determinations establish metal contents in altered and mineralized samples, whereas data on fresh igneous rocks help better understand the magmatic and geochemical evolution of the province and evaluate its large mineral endowment.

Data from fresh plutonic rocks that range from Mesoproterozoic to Neogene (n=943) overlap fields of barren, mixed-signal, and prospective rocks on a Sr/Y vs. Sr/MnO prospectivity diagram (Fig. 6; Ahmed et al., 2019). Data from the Cretaceous intrusions define the largest range of Sr/Y ratios,

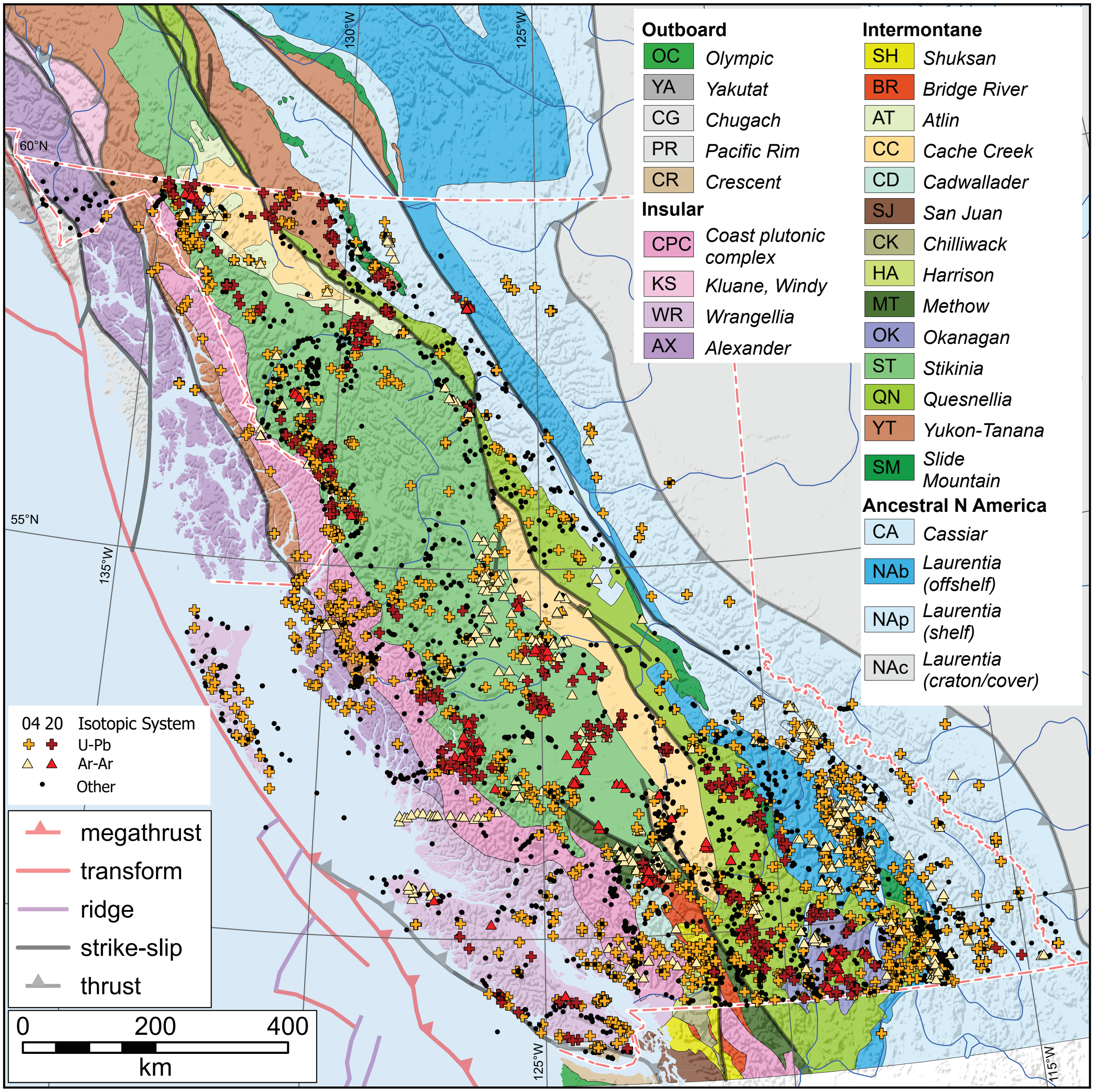

Fig. 3. Distribution of the geochronological samples in Han et al. (2020); '04' refers to 2004 compilation, '20' refers to 2020 compilation. Terranes modified from Colpron (2020).

and most of the data from Paleozoic and Jurassic plutons fall within the fields of barren and mixed-signal rocks. In contrast, most of data from the Triassic to Early Jurassic intrusions overlap the field of rock compositions that are prospective for porphyry Cu, skarn or epithermal mineralization. Elevated Cu concentrations (Fig. 7) highlight both the western and eastern flanks of Stikine terrane and the porphyry Cu-Mo-Au camps along the Quesnel terrane, as well as accreted crust of southern British Columbia.

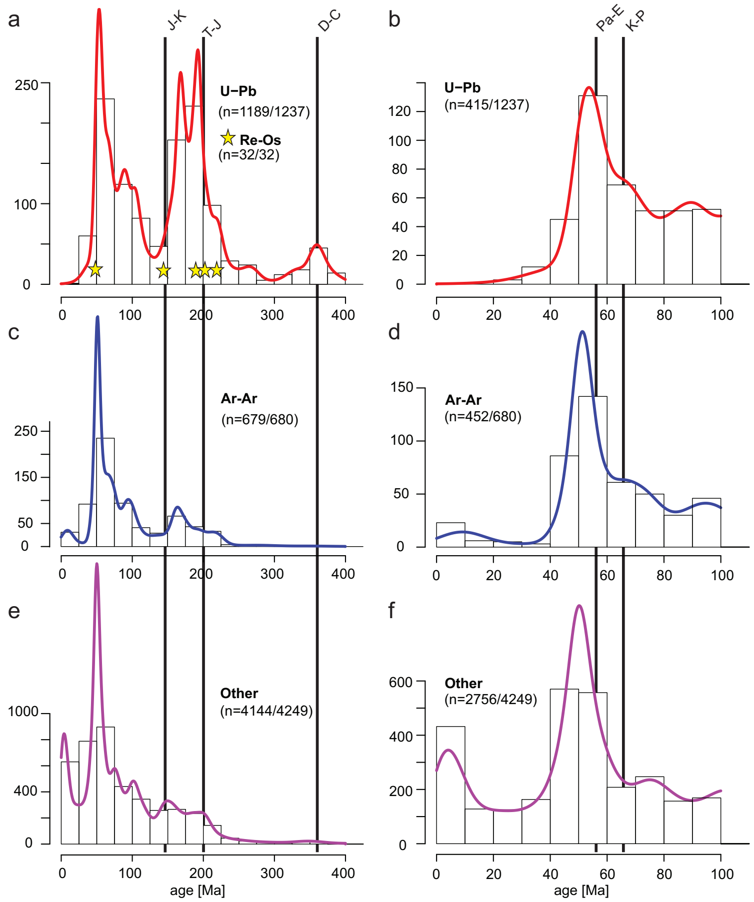

Fig. 4. Kernel density estimation (KDE; Vermeesch, 2018) plots of **a)** U-Pb and Re-Os results, **b)** U-Pb results, **c-d)** Ar-Ar results, and **e-f)** 'other' results. 'Other' refers to all isotope systematics that are not U-Pb or Ar-Ar results. Results within the data products that are listed as 'Detrital' are not plotted. Histogram bin widths are 25 Ma in a, c, e and 10 Ma in b, d, f. n=number used in plot/number available in dataset. Vertical black lines are stratigraphic time boundaries (Cohen et al., 2013): D-C=Devonian–Carboniferous; T-J=Jurassic–Triassic; J-K=Jurassic–Cretaceous; K-P=Cretaceous–Paleogene; Pa-E=Paleocene–Eocene.

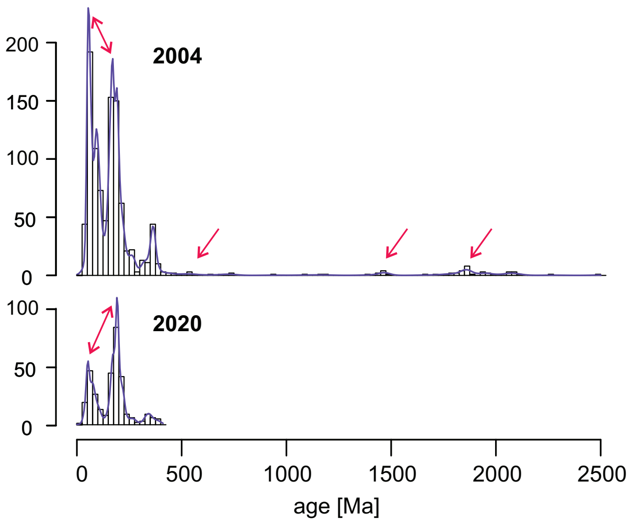

Fig. 5. Kernel density estimation (KDE) plots comparing U-Pb results from pre-2004 (Breitsprecher and Mortensen, 2004) and post-2004 to 2020 (Han et al., 2020). Red arrows point to Precambrian results in the pre-2004 data and the relative difference in the KDE peaks between the pre-2004 and post-2004 results.

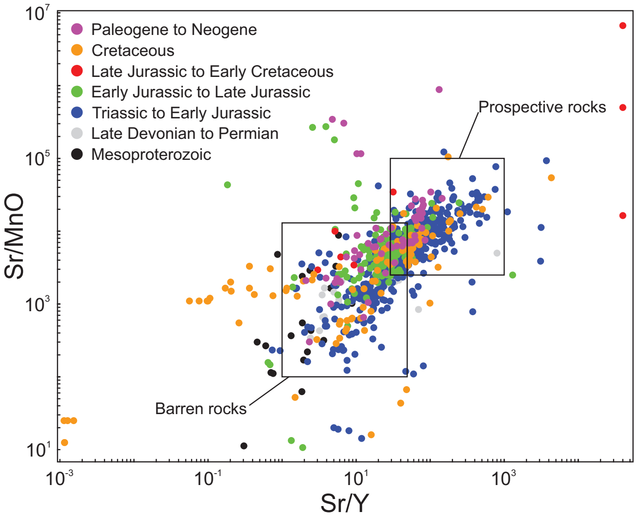

Fig. 6. Porphyry prospectivity diagram Sr/Y vs. Sr/MnO for plutonic rocks in British Columbia. Data from Han and Rukhlov (2024). Fields of prospective rocks for porphyry Cu, skarn or epithermal mineralization and barren rocks after Ahmed et al. (2019).

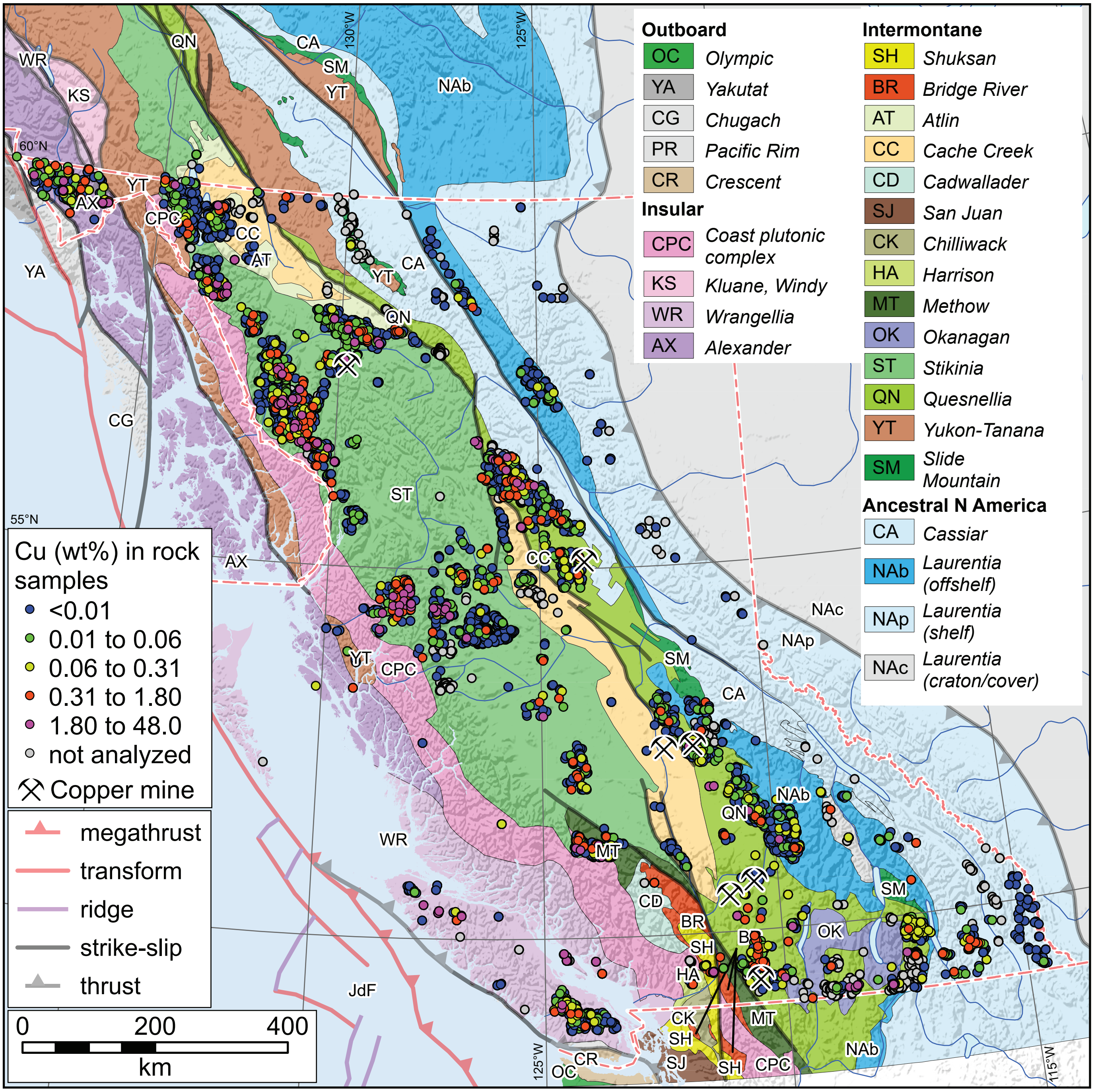

Fig. 7. Copper concentrations by different analytical methods (n=10057) in provincial rock samples; Han and Rukhlov, 2024. Current copper producers from MINFILE. Terranes modified from Colpron (2020).

5. Summary

The British Columbia Geological Survey continues to compile, manage, and release data products that include publicly available geochronological and geochemical results. These data have endless utility, and a few examples are shown in this paper.

Acknowledgments

We thank Ray Lett for a constructive review of the manuscript.

References cited

Ahmed, A., Crawford, A.J., Leslie, C., Phillips, J., Wells, T., Garay, A., Hood, S.B., and Cooke, D.R., 2019. Assessing copper fertility of intrusive rocks using field portable X-ray fluorescence (pXRF) data. Geochemistry: Exploration, Environment, Analysis, 20, 81-97.

Breitsprecher, K., and Mortensen, J.K., 2004. BC Age 2004A-1: A database of isotopic age determinations for rock Units from British Columbia. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Open File 2004-03.

Cohen, K.M., Finney, S.C., Gibbard, P.L., and Fan, J.-X., 2013. The

ICS International Chronostratigraphic Chart. Episodes, 36, 199-204 (updated version September, 2023). <https://stratigraphy.org/ICSchart/ChronostratChart2023-09.pdf>

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

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9 p.

Han, T., and Rukhlov, A.S., 2020. Update of the provincial Regional Geochemical Survey (RGS) database at the British Columbia Geological Survey. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey GeoFile 2020-08, 3 p.

Han, T., and Rukhlov, A.S., 2024. Update of rock geochemical database at the British Columbia Geological Survey. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile, in press.

Han, T., Rukhlov, A.S., Riddell, J.M., and Ferbey, T., 2019. A skeleton data model for geochemical databases at the British Columbia Geological Survey. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2019-01, pp. 125-135.

Han, T., Ootes, L., and Yun, K., 2020. The British Columbia Geological Survey geochronologic database: Preliminary release of ages. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile 2020-10, 4 p.

Van der Vlugt, J., Rukhlov, A.S., and van Straaten, B.I., 2022. Lithogeochemical reanalysis of British Columbia Geological Survey archived rock samples from northwestern British Columbia. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile 2022-14, 15 p.

van Straaten, B.I., Logan, J.M., Hunter, R.C., Nelson, J.L., and Miller, E.A., 2022. Igneous lithogeochemistry data for the Dease Lake, Kitsault River, Galore Creek, Telegraph Creek, Foremore, and other areas in northwestern British Columbia. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile 2022-12, 14 p.

Vermeesch, P., 2018. IsoplotR: A free and open toolbox for geochronology. Geoscience Frontiers, 9, 1479-1493. <https://doi.org/10.1016/j.gsf.2018.04.001>