



# Update of rock geochemical database at the British Columbia Geological Survey

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## Summary

Rock geochemical data are an integral part of provincial lithochemical data, which also include data from till, drainage sediments such as alluvium (including heavy mineral concentrates), moss-mat sediment, and lacustrine deposits. These lithochemical data characterize primary dispersion of elements in bedrock and secondary dispersion in weathered rocks, soil, and other surficial sediments, including mechanical dispersion by streams, gravity flows, and glaciers. The development and operation of the British Columbia Geological Survey rock geochemical database allows long-lasting storage and consistent update of rock geochemical data collected from across the province. For the current update, new rock geochemical data were compiled, format standardized, metadata validated, quality checked, and populated into the database, where they were integrated with existing data for permanent storage. The current release updates Han and Rukhlov (2020).

Twenty-eight new metadata attributes were added (Table 1). These new attributes include numerical age or age range, group or suite name, formation or lithodeme name, and member or phase name. Only the validated values of these attributes were populated into the database. Attributes that were not validated by BCGS geologists were left blank.

New analytical data from 1887 samples were added, including those previously published (van Straaten et al., 2022; Van der Vlugt et al., 2022). Some of these data are re-analysis of archived samples using modern analytical methods. The other sources are Ootes et al. (2020), Pearson and Zhang (2020), Milidragovic et al. (2021), and Stanley and Nelson (2022). The rock geochemical database now contains 435,567 analytical values, from 12,413 samples that were collected between 1973 and 2023.

Two data files derived from the rock geochemical database are included in this release ([BCGS\\_GF2024-09.zip](#)): *rock\_geochem\_dataset1.xlsx* and *rock\_geochem\_dataset2.xlsx*. Each of these data files contains two sheets for analytical data and attribute explanations. The analytical data in *rock\_geochem\_dataset1.xlsx* are grouped by analytical method

(Han and Rukhlov, 2020) and *rock\_geochem\_dataset2.xlsx* by total, near total, and partial determinations (van Straaten et al., 2022; Van der Vlugt et al., 2022). In *rock\_geochem\_dataset1.xlsx*, the first 39 columns are sample metadata. Column 40 and onwards are analytical data. Each of these columns is specified in the header by a triplet of analyte name, analytical method abbreviation, and unit, connected by two underscores. For example, Ag\_AAS\_ppm is for silver concentration in part per million determined by aqua regia digestion with atomic absorption spectroscopy (AAS).

In *rock\_geochem\_dataset2.xlsx*, the first 39 columns are identical to those in *rock\_geochem\_dataset1.xlsx*. Column 40 and onwards are also analytical determinations, but they are preferred values per element, grouped into three categories: a) 'total' determinations (TD); b) near-total determinations (NTD); and c) partial determinations (PD). Total determinations include those using non-destructive analytical techniques such as X-ray fluorescence (XRF) and instrumental neutron activation analysis (INAA) or combinations of total digestions involving flux (e.g., lithium borate and sodium peroxide) and inductively coupled plasma atomic emission spectroscopy (ICP-AES), inductively coupled plasma mass spectrometry (ICP-MS), and other techniques (Table 2). Near-total determinations involve multi-acid digestions and AAS, ICP-AES, and ICP-MS. They may have near-100% recovery of elements hosted by minerals that will not dissolve in hot aqua regia but using the same analytical instrumentation (Table 3). For example, Ag\_NTD\_ppm, is for silver concentration in part per million analyzed by one of the near total determination analytical methods listed in Table 3. Partial determinations (PD) analytical methods are summarized in Table 4.

Generating *rock\_geochem\_dataset2.xlsx* required merging multiple analytical data columns in *rock\_geochem\_dataset1.xlsx*. Each merging operation was conducted by selecting the preferred analytical value from the several available. The selection was based on the precision of the analytical methods and the analytes involved. For example, Ce\_LIP\_ppm, Ce\_INA\_ppm, and Ce\_XRF\_ppm in *rock\_geochem\_dataset1.xlsx*

Table 1. New metadata attributes

Name	Definition	Value	Example
1 qc_type	Type of quality control samples employed	Text	blank, duplicate, routine, or standard.
2 sample_purp	Purpose for sampling	Text	Petrogenesis, or alteration/mineralization
3 sample_dspn	Sample disposition	Text	drill core, float, outcrop, stratigraphic section, subcrop, surface, and trench
4 collect_date	Date of sample collection	Text	2006
5 location	Project area or general location for group of samples (using a formally named geographic feature)	Text	Forrest Kerr - Mess Creek
6 strat_age	Stratigraphic age or position range of unit at Epoch or Series level (using Lower, Middle, Upper for lithostratigraphic and Early, Middle, Late for lithodemic units)	Text	Upper Devonian to Mississippian
7 terrane	Geological terrane	Text	Stikinia
8 gp_suite	Group, plutonic suite name or others at equivalent rank	Text	Galore plutonic suite
9 sbgp_suite	Subgroup, subsuite name or others at equivalent rank	Text	lower
10 fm_lithodm	Formation, lithodeme name or others at equivalent rank	Text	Alkalic volcanic unit
11 mem_phase	Member, phase or others at equivalent rank	Text	Diorite phase
12 strat_name	Group/suite (subgroup/subsuite) - Formation/lithodeme - Member/phase	Text	Stikine assemblage - Division 2 - Felsic volcanic unit
13 strat_unit	Rock unit code (consisting of System/Period or Series/Epoch level code, Group or Suite code, Formation code and lithology code)	Text	uDMSvf
14 orig_unit	Original rock unit code	Text	CSmv
15 strat_rel	Reliability of strat_age to strat_unit fields	Text	H for high confidence, C for considerable confidence, M for moderate confidence, or L for inferred from enclosing bedrock map unit polygon, low confidence.
16 strat_src	Source for strat_age to strat_unit fields (e.g., using BCGS Publication Issue ID, and/or version number of BC Digital Geology)	Text	BCGS_P2023-01-06
17 rock_class	Rock class of sample	Text	Plutonic, subvolcanic, volcanic, volcanic (coherent), volcanic (fragmental), sedimentary, metamorphic, hydrothermal, or xenolith.
18 rock_name	Name or composition (felsic, intermediate, mafic, or ultramafic) based on sample description	Text	basalt, gabbro, limestone
19 field_desc	Field description of sample	Text	unaltered, medium green, white-weathering rhyolite dome complex, rhyolite S of SG
20 petrogr_desc	Petrographic description of sample	Text	Pl-bearing hornblende, cumulate-textured
21 sample_desc	Sample description. Derived from field_desc and/or petrogr_desc	Text	Lapilli-tuff to Pl-Aug coarse crystal tuff
22 age_max	Maximum numeric age of unit in million years	Numeric	298.9
23 age_min	Minimum numeric age of unit in million years	Numeric	251.9
24 age_avg	Average age, which is needed for some cases where average age can't be directly calculated using "age_min" and "age_max".	Numeric	275.4
25 age_err	Error of numeric age, ((age_max + age_min - (age_min - age_max)) / 2)	Numeric	29.75
26 age_note	Age constraint (e.g., U-Pb zircon) and reference(s) used for age_min and age_max fields. Conversions from stratigraphic to numerical age use the latest International Commission on Stratigraphy (ICS) International Chronostratigraphic Chart (Cohen et al., 2013).	Text	Permian using ICS chart v2021/10
27 last_update	When sample metadata were last updated by geologist. Empty/blank/or "none" means no update since release and the metadata were either from original publication or extracted from BC digital geology map.	Text	2022
28 cert_info	Laboratory name: lab_certificate number; Laboratory name 2: lab_certificate number 2	Text	Bureau Veritas: VAN21004256

Table 2. Analytical methods with total determinations (TD).

Abbreviation/Group	Description	Technical details
COL/COL	Colourimetric	Tungsten determined by $K_2SO_4$ fusion followed by HCl leach and complexed with toluene 3, 4 dithiol for colorimetric determination.
FAA/FA	Lead fire assay with flame AAS or ICP-AES	A 15 g or 30 g milled rock sample is mixed with a lead oxide flux and fused in a fire clay crucible at $>1000^\circ C$ . The lead is separated from the slag and cupelled in a bone ash cupell to recover the gold bead. The bead is digested in nitric acid and the gold content measured by flame atomic absorption spectroscopy (AAS) or inductively coupled plasma atomic emission spectroscopy (ICP-AES).
FAG/FA	Lead fire assay with graphite furnace AAS	A 15 g or 30 g milled rock sample is mixed with a lead oxide flux and fused in a fire clay crucible at $>1000^\circ C$ . The lead bead is separated from the slag and cupelled in a bone ash cupell to recover a gold bead. The bead is digested in nitric acid and the gold content measured by graphite furnace atomic absorption spectroscopy (AAS).
FAM/FA	Lead fire assay with ICP-MS	A 15 g or 30 g milled rock sample is mixed with a lead oxide flux and fused in a fire clay crucible at $>1000^\circ C$ . The lead is separated from the slag and cupelled in a bone ash cupell to recover the gold bead. The bead is digested in nitric acid and the gold content measured by inductively coupled plasma mass spectrometry (ICP-MS).
NFNA/FA	Nickel-sulphide fire assay with INAA or ICP-MS	A 30 g milled rock sample is fused with a nickel-sulphide flux, the bead dissolved in acid and concentrations of Pt, Pd, Os, Ir, Ru, Rh, Au, and Re determined by either instrumental neutron activation analysis (INAA) or inductively coupled plasma mass spectrometry (ICP-MS). Typical detection limits are in the 0.1 to 50 ppb range depending on the instrumental method.
GRAV/GRV	Gravimetric determination	Determination of loss on ignition (LOI) at a specific temperature, typically between 500 and 1100 $^\circ C$ and/or moisture ( $H_2O$ -) at a much lower temperature (typically about 100 $^\circ C$ ).
NA/INA	Instrumental neutron activation analysis (INAA)	A 2 g or 15 g or 30 g sample is sealed in a PVC vial, irradiated in a nuclear reactor and elements determined by counting gamma rays from the short-lived daughter isotope decay products. Up to 35 elements, including Au, can be determined. This is a "total" determination.
SE/ISE	Ion selective electrode	Fluorine concentration is determined using a $NaCO_3 + KNO_3$ fusion followed by $H_2O$ leach and ion selective electrode.
LE/LE	Leco combustion	Typically a 0.5 g or 1 g milled sample is mixed with a tin-copper conductor and heated in an oxygen stream in a closed system induction furnace. The $SO_2$ and $CO_2$ evolved are measured by an IR sensor or by volumetric/titrametric methods.
LIC/LIP	Lithium borate fusion with ICP-AES	Typically a 0.5 g or 1 g milled sample is mixed with lithium metaborate-tetraborate flux, fused and the residue leached with dilute hydrochloric or nitric acid. Major oxides, minor and trace elements are determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES). This is a "total" determination.
LICM/LIP	Lithium borate fusion with a combination of ICP-AES and ICP-MS	Typically a 0.5 g or 1 gram milled sample is mixed with lithium metaborate-tetraborate flux, fused and the residue leached with dilute hydrochloric or nitric acid. Major, minor and trace elements are determined by a combination of inductively coupled plasma atomic emission spectroscopy (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS).
NADNC/NAD	Neutron activation with delayed neutron counting (NADNC)	Uranium concentration is determined by neutron activation with delayed neutron counting.
PMS/SIP	Sodium peroxide fusion with ICP-MS	A 0.2 g sample is sintered with sodium peroxide, the sinter cake leached and the REE hydroxide-bearing precipitate separated from the sinter, dissolved and the solution analysed for Y, Zr, Nb, Nd, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta & Th by inductively coupled plasma mass spectrometry (ICP-MS) using the method of internal standardization to correct for matrix and drift effects. Y, Zr, Nb and Ba should be confirmed by XRF.
TI/TIT	Titration	A 1 g or 5 g milled rock sample is heated in a platinum crucible with concentrated HF and $H_2SO_4$ . The solution is neutralized with boric acid and the dissolved $Fe^{2+}$ measured by potassium permanganate titration. Detection limit for FeO is 0.01% - 0.10 %.
XRF1/XRF	XRF on fused glass	Typically a 1 to 2 g sample is mixed with a lithium metaborate-tetraborate flux, and fused in a platinum crucible. Major oxides are determined by X-ray fluorescence (XRF). Typical spectrometers used are Phillips (GSB lab) and Siemens (COM lab).
XRF2/XRF	XRF on pressed pellet	Typically rock pulp is milled with boric acid for 3 minutes. The milled samples are then pressed at high pressure to produce 40 mm pressed pellets. The pellets are analysed for minor and trace elements by X-ray fluorescence (XRF; see method code XRF1 for typical instrumentation).

Table 3. Analytical methods with near total determinations (NTD).

Abbreviation/Group	Description	Technical details
MAA/MAS	Digestion using mixed acid (including HF) with flame AAS	Typically a 0.5 g or 1 g sample is digested in hot, concentrated hydrofluoric=nitric=perchloric=hydrochloric acids and trace or minor elements (e.g., Ag, Cu, Pb, Zn, Co, Ni, Mo, Mn, Fe, Cd, Bi, As, Sb) determined by flame atomic absorption spectroscopy (AAS). Typical detection levels are in the 0.5 to 10 ppm range. This is a near total determination for most elements, while partial for some Cr and Ba minerals and oxides of Al, Fe, Hf, Mn, Sn, Ta and Zr. Some loss of As, S and Sb may be due to volatilization during fuming.
HAA/MAS	Digestion using mixed acids (including HF) with hydride generation AAS	Typically a 0.5 g or 1 g sample is digested in hot, concentrated hydrofluoric=nitric=perchloric=hydrochloric acids, followed by hydride generation atomic absorption spectroscopy (AAS) to determine As, Sb, Bi, Se, Ge, Tl. Some loss of As and Sb may be due to volatilization during fuming.
ICPM/MIP	Digestion using mixed acids (including HF) with ICP-AES	Typically a 0.25 g, 0.5 g or 1 g milled sample is digested with a hot hydrofluoric=nitric=hydrochloric=perchloric acids ( $\pm$ H <sub>2</sub> O) followed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) to determine up to 40 elements. This is a near total determination for most elements, while partial for some Cr and Ba minerals and oxides of Al, Fe, Hf, Mn, Sn, Ta and Zr. Some loss of As, S and Sb may be due to volatilization during fuming.
MSM/MIP	Digestion using mixed acids (including HF) with a combination of ICP-AES and ICP-MS	Typically a 0.25 g, 0.5 g or 1 g milled sample is digested with a hot HF+HCl+HNO <sub>3</sub> +HClO <sub>4</sub> =H <sub>2</sub> O mixture and up to 60 elements determined by a combination of inductively coupled plasma atomic emission spectroscopy (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS). Typical detection levels are in the 0.002 ppm to 0.1 % range. This is a near total determination for most elements, while partial for some Cr and Ba minerals and oxides of Al, Fe, Hf, Mn, Sn, Ta and Zr. Some loss of As, S and Sb may be due to volatilization during fuming.

Table 4. Analytical methods with partial determinations (PD).

Abbreviation/Group	Description	Technical details
CAA/AAS	Aqua regia digestion with cold vapour AAS (CV-AAS)	Used for the determination of mercury concentration only. After aqua regia digestion Hg is reduced with 10% stannous sulphate. Pyrolytically vapourized elemental Hg is measured in cold vapour using flameless atomic absorption spectroscopy (CV-AAS).
HAA/AAS	Aqua regia digestion with hydride generation AAS	HCl+KClO <sub>2</sub> digestion with potassium iodide (KI) iron reduction and methyl isobutyl ketone (MIBK) and trioctylphosphine oxide (TOPO) extraction (Bi and Sb), or aqua regia digestion followed by hydride generation atomic absorption spectroscopy (AAS) to determine As, Sb, Bi, Se, Ge, Tl. Typical minimum detection levels are in the 0.5 to 1 ppm range.
AAS/AAS	Aqua regia digestion with flame AAS	Typically a 1 g sample is digested in aqua regia or sintered with NH <sub>4</sub> I and leached with HCl and ascorbic acid (Sn only) and minor and trace elements (e.g. Ag, Cu, Pb, Zn, Mo) determined by flame atomic absorption spectroscopy (AAS). This is a "partial" determination for refractory elements (e.g. Cr, Ba).
ICP/AIP	Aqua regia digestion with ICP-AES	Typically a 0.5 g or 1 g milled sample is digested with modified aqua regia or a hot HNO <sub>3</sub> + HCl + H <sub>2</sub> O (v/v) mixture followed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) to determine up to 40 elements. This is a "partial" determination for refractory elements (e.g. Cr, Ba).
MS/AIP	Aqua regia digestion with a combination of ICP-AES and ICP-MS	Typically a 0.5 g, 1 g, 15 g, or 30 g milled sample is digested with modified aqua regia or a hot HCl + HNO <sub>3</sub> + H <sub>2</sub> O (v/v) mixture and up to 65 elements determined by a combination of inductively coupled plasma atomic emission spectroscopy (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS). This is a "partial" determination for refractory elements (e.g. Cr, Ba). Detection limits are in the order of 0.2 ppb to 0.01 %.

were merged into Ce\_TD\_ppm in *rock\_geochem\_dataset2.xlsx*. The analytical value that was taken for Ce\_TD\_ppm is from Ce\_LIP\_ppm. *rock\_geochem\_dataset2.xlsx* has fewer data columns and longer data series than *rock\_geochem\_dataset1.xlsx* due to combining available data by compatible methods. Both *rock\_geochem\_dataset1.xlsx* and *rock\_geochem\_dataset2.xlsx* are GIS-ready, so they can be enabled in GIS environment for visualization and statistical analysis.

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