2023

SCHEDULE OF FEES AND SERVICES

ISSUE 15: Effective April 1, 2023

GEO LABS

GEOSCIENCE LABORATORIES

Ontario

About the Geoscience Laboratories (Geo Labs)

History

The Geoscience Laboratories (Geo Labs) was established in 1898 and was housed in Toronto before moving to the Willet Green Miller Centre in 1991 as part of the Ministry of Northern Development and Mines' (MNDM) relocation to Sudbury.

Vision

To be a world-class, full service inorganic geoanalytical facility providing research quality analyses and services.

Mission Statement

To ensure that all clients are consistently provided with the highest level of service and quality of work by delivering, in a timely manner, high-quality, research-grade mineralogical and inorganic chemical analysis of rocks, minerals, and other materials, that meet method-specific precision and accuracy quality tolerances.

Quality Policy

It is the quality policy of the Geoscience Laboratories (Geo Labs) to consistently provide clients with the highest level of service and quality of work.

The management and employees at the Geo Labs accomplish this by:

- Delivering high-quality inorganic chemical and mineralogical analyses and services that meet method-specific precision and accuracy quality tolerances.
- Committing to good professional practice and to the quality of its testing.
- Meeting or surpassing client priority and turnaround time requirements.
- Ensuring that all information obtained or created during laboratory activities remains confidential.
- Continuously improving the quality system through client feedback, quality objectives, proficiency testing, annual internal and external audits, corrective actions, and management reviews.
- Maintaining a Management System registered to ISO 9001:2015.
- Complying with ISO/IEC 17025:2017 International Standard by the adoption and implementation of a documented system of policies and procedures while meeting technical requirements.
- Maintaining the culture that "at the Geoscience Laboratories, quality is the responsibility of all staff".

Contact Information

Geoscience Laboratories (Geo Labs)
Ontario Geological Survey
Ontario Ministry of Mines
Willet Green Miller Centre
933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5
Tel: (705) 670-5637
Toll Free: 1-866-436-5227
Fax: (705) 670-3047
E-mail: geolabs@ontario.ca

Certified System
SAI GLOBAL
ISO 9001
Quality

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Sample Submission

Sample Submission and Shipping Instructions

Every effort is made to ensure that data produced are accurate and representative of the sample submitted. The client is requested to provide as much information about their samples as possible, such as rock type, sulphide content, mineralogy, alteration, and any other unusual characteristics. If submitting mineralized samples, or samples likely to contain high concentrations of any analyte, please consult with the Geo Labs prior to sample submission. Clients may be subject to a decontamination charge to clean areas of the Geo Labs contaminated by submitted samples with undeclared mineralization or high analyte concentrations.

It is the client's responsibility to disclose all hazardous materials. The Geo Labs reserves the right to refuse such samples. The samples will be returned at the client's expense and their disposal will be the client's responsibility.

Samples can be shipped to:

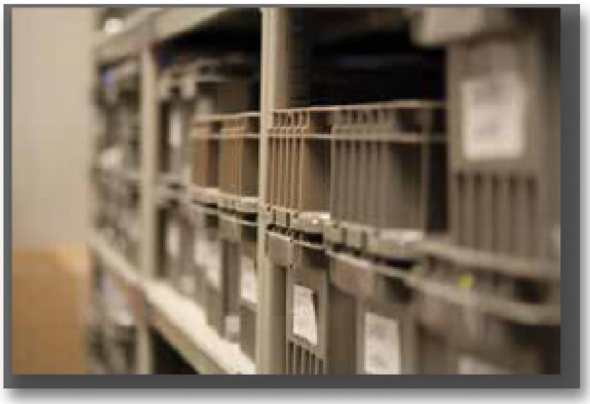
Sample Receiving
c/o Geoscience Laboratories
Ontario Ministry of Mines
Willet Green Miller Centre
933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5 CANADA

The client's name and address must be clearly marked on each shipment package. Individual samples should be properly numbered or identified and accompanied by a copy of the Geo Labs Sample Submission Form – Request for Analysis. Samples that are poorly labelled and/or unorganized will increase turnaround time and will be subject to a sample sorting charge. Samples will not be processed until adequate written instructions are received from the client. Optimal sample size for submission: 300 g.

All samples shipped from outside Canada should be labelled "GEOLOGICAL SAMPLES FOR ANALYSIS ONLY – NO COMMERCIAL VALUE".

Sample Storage

Samples are retained for a minimum of 30 days following the issue of the final Certificate of Analysis. After 30 days, samples may be discarded. If requested at the time of submission, samples can be returned at the client's cost.



Quality Assurance Program

The Geo Labs maintains a management system registered to ISO 9001:2015 and select test methods are accredited to ISO/IEC 17025:2017. A copy of the Geo Labs' Scope of Accreditation is available upon request.

The Geo Labs participates in proficiency testing (PT) programs organized by a range of national and international PT providers, including Proficiency Testing Canada, CANMET, Environment Canada, and the International Association of Geoanalysts (IAG).

The Quality Assurance (QA) program at the Geo Labs consists of adding a duplicate for at least every ten samples as a measure of precision. Additionally, one inter-laboratory reference material (RM) and one blank (if appropriate) are generally included with every twenty samples to help assess accuracy. Geo Labs offers a variety of RMs (both certified and in-house) for matrix matching. A specific RM may be available upon request. The Geo Labs QA program is applied to all sample submissions.

Summaries of the data obtained for Geo Labs' quality control materials can be found in the annual Summary of Field Work and Other Activities Open File Reports (http://www.geologyontario.mndm.gov.on.ca/index.html) or are available upon request.

Data Release (Certificate of Analysis)

Data will only be released to those who are designated on the Geo Labs' Sample Submission Form – Request for Analysis. Written authorization will be required from the primary contact person if data are to be released to a second or third party.

The Geo Labs will provide electronic and hard copies of data, upon request, for up to one year from the date of issue of the Certificate of Analysis. Retrieval of archived data after one year will be subject to a $50.00/hour charge.

Liability

The liability of the Government of Ontario and its ministries, boards, commissions, authorities, agents, corporations and unincorporated entities, their respective directors, officers, employees, advisors, agents servants and representatives, each of the members of the Province's Executive Counsel, past present and future and the respective heirs, assigns and successors of each of the foregoing (the "Province") for any liabilities, costs, damages and expenses (including legal, expert and consulting fees) ("Loss") resulting directly or indirectly from any default, negligence, error, or omission in the course of the performance of the analysis or otherwise in connection with the agreement shall be limited to the fees payable by the Client for the services in question.

The Province shall not be liable for any Loss:

- if inaccurate or any incomplete information is provided by the Client ; and/or
- for any matter which is beyond the control of the Government of Ontario.

Terms and Conditions

Results are for samples as received. Clients will be notified prior to performing any analytical work if non-routine analyses are required.

All prices are in Canadian funds and are subject to HST. Payment is due 30 days from the invoice date. Anything over 30 days is deemed overdue. All overdue accounts are subject to interest charges unless governed by legislation or approved exemption, or due from federal or provincial governments and agencies. The Ontario Ministry of Finance determines the interest rate. Contact the Geo Labs for payment options.

Sample Preparation

The preparation of samples represents the most important step in the analysis of geological materials. The Geo Labs uses a variety of sample preparation procedures on a routine basis for assay and geochemical analysis. While processing rock samples, the procedure uses a jaw-crusher with steel plates, a riffle to split the sample, and different grinding media to pulverize the sample.

Please contact the Geo Labs for more information about the levels of contamination contributed by the Sample Preparation techniques.

Assay Preparation

The assay preparation technique (**SAM-SPA**) uses high chrome steel mills. Minor amounts of chromium (Cr) and iron (Fe) may be added to the sample.

Geo Preparation

The geo preparation technique (**SAM-SPG**) is used whenever detailed whole-rock geochemical analysis is required. The samples are pulverized in a 99.8% pure aluminum oxide (Al_2O_3) planetary ball mill. A minor amount of aluminum (Al) may be added to the sample.

Agate Mill Preparation

The agate mill preparation technique (**SAM-AGM**) significantly reduces the amount of contamination (Cr, Fe, Al) compared to the assay and geo preparation methods.

Chittick Sample Preparation

The Chittick sample preparation technique (**SAM-CTK**) is used when a Chittick determination is required. Samples are disaggregated using a mortar and pestle. The minus 200 mesh (<75 μm) fraction is used for analysis.

Particle Size Sample Preparation

The particle size sample preparation technique (**SAM-PSA**) is used when particle size analysis (PSA) is required. Samples are sieved through a 10 mesh screen. The minus 10 mesh (<2000 μm) fraction is used for the analysis.

Sediment Sample Preparation

The sediment sample preparation technique (**SAM-SSP**) is used to prepare sediment samples for analysis. Samples are pulverised using a zirconium mill for 10-20 seconds and the material is sieved through a 60 mesh screen. The minus 60 mesh (<250 μm) fraction is used for the analysis.

Sample Drying

Wet samples received at the Geo Labs that require drying (**ADM-DRY**) will be subject to a drying charge.

Oversized Samples

The Geo Labs is equipped to handle samples up to 3 kg in size. Anything over that will be subject to an oversized sample charge (**ADM-OVER**).

Sample Preparation Costs Summary

Method Code	Sample Preparation Method	Minimum Sample Size	Mesh Size	Cost per Sample
SAM-SPA	Assay Preparation	150 g	80 mesh (177 µm)	$10.27
SAM-SPG	Geo Preparation	150 g	170 mesh (90 µm)	$16.34
SAM-AGM	Agate Mill Preparation	150 g	170 mesh (90 µm)	$21.19
SAM-CTK	Chittick Sample Preparation	100 g	200 mesh (75 µm)	$10.54
SAM-PSA	Particle Size Sample Preparation	100 g	10 mesh (2000 µm)	$9.33
SAM-SSP	Sediment Sample Preparation	100 g	60 mesh (250 µm)	$6.96
ADM-DRY	Sample Drying	n/a	n/a	$2.37
ADM-OVER	Oversized Samples	n/a	n/a	$1.27 per kg over

X-Ray Fluorescence Analyses

Major Element Analysis (ISO/IEC 17025 Accredited)

The major element XRF method (**XRF-M01**) is designed for the analysis of major elements in geological samples. The samples are run for loss on ignition (LOI: 105 °C under nitrogen atmosphere, 1000 °C under oxygen atmosphere). The calcined samples are then fused with a borate flux to produce a glass bead for analysis. The total content of each analyte is expressed as its oxide. This package is not suitable for ores and sulphide-rich samples.

Working Ranges for XRF-M01 Method

Analyte	Lower Limit (wt%)	Upper Limit (wt%)	Analyte	Lower Limit (wt%)	Upper Limit (wt%)
Al_2O_3*	0.02	100	MgO*	0.01	50
BaO	0.004	1	MnO*	0.002	5
CaO*	0.006	100	Na_2O*	0.02	15
Cr_2O_3	0.002	5	P_2O_5*	0.002	40
Fe_2O_3*	0.01	100	SiO_2*	0.04	100
K_2O*	0.01	20	TiO_2*	0.01	33
			Total Loss on Ignition (LOI) at 1000 °C*	±0.05	n/a
			Nitrogen Loss on Ignition (LOI) at 105 °C	0.05	n/a

** Accreditation to ISO/IEC 17025 temporarily removed while methods transfered to new instrumentation.*

Working Ranges for XRF-M02 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Cobalt	Co	12	5 000	Strontium	Sr	8	7 500
Copper	Cu	60	15 000	Vanadium	V	8	7 500
Lead	Pb	35	6 500	Zinc	Zn	40	5 000
Nickel	Ni	30	15 000	Zirconium	Zr	10	7 000

X-Ray Fluorescence Costs Summary

Method Code	Analytical Method Description	Minimum Sample Size	Cost per Sample
XRF-M01	XRF Major Oxides Analysis	10 g	$40.19
XRF-M02	XRF Trace Element Analysis *(Add-on to XRF-M01 only)*	-	$10.09
XRF-WAX	XRF Pressed Pellet Preparation	15 g	$10.35
XRF-T02	XRF Trace Element Analysis	-	$49.73
XRF-T03	XRF Trace Element Analysis	-	$27.54
XRF-T04	XRF Trace Element Analysis	-	$6.24
XRF-T05	XRF X-Ray Florescence Analyes	-	$78.82
XRF-W01	XRF Trace Element Analysis	-	$4.16

Trace Element Analysis (ISO/IEC 17025 Accredited)

The trace element XRF methods (**XRF-T02**, **XRF-T03, XRF-T04, XRF-T05,** and **XRF-W01**) are designed for the analysis of trace elements in geological samples. Samples are prepared as pressed pellets and analyzed using optimized parameters for each element. XRF method XRF-T05 combines methods XRF-T02 and XRF-T03 and presents data as a single report.

Working Ranges for XRF-T02 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Arsenic*	As	4	4 000	Rubidium*	Rb	0.6	3 000
Bromine	Br	0.8	240	Strontium*	Sr	1.0	4 000
Copper*	Cu	2	6 000	Thorium*	Th	1.9	220
Gallium*	Ga	1.2	125	Uranium	U	1.3	1 600
Lead*	Pb	2.0	4 000	Yttrium*	Y	0.9	800
Molybdenum*	Mo	0.9	2 000	Zinc*	Zn	1.1	6 000
Nickel*	Ni	1.6	6 000	Zirconium*	Zr	1.6	2 400
Niobium*	Nb	0.8	1 500				

** Accreditation to ISO/IEC 17025 temporarily removed while methods transfered to new instrumentation.*

Working Ranges for XRF-T03 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Barium*	Ba	12	2 700	Lanthanum	La	9	1 500
Cerium	Ce	18	2 500	Manganese	Mn	7	4 000
Cesium	Cs	8	700	Scandium*	Sc	4	100
Chromium	Cr	7	3 500	Titanium	Ti	9	4 500
Cobalt*	Co	1.8	3 500	Vanadium*	V	2	4 000

** Accreditation to ISO/IEC 17025 temporarily removed while methods transfered to new instrumentation.*

Working Ranges for XRF-T04 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Cadmium	Cd	4	300
Silver	Ag	1.5	1 700

Working Range for XRF-W01 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Chlorine	Cl	50	15 000

Loss On Ignition Analyses

Loss on Ignition (LOI)

The Loss on Ignition (LOI) method is a measure of the change in weight as a result of heating to drive off volatiles and/or remove components by thermal decomposition and/or burning in an oxygen-rich atmosphere. At any particular temperature, the LOI will be the sum of several processes and can express a net weight gain (negative value) or loss (positive value).

Samples submitted for major element analysis (XRF-M01, page 6) and for which the LOI at 500 °C are required should be submitted for the 3 Step LOI method (LOI-3ST).

Working Ranges for Loss on Ignition Programs

LOI Program	Program	Lower Limit (wt%)
2 Step LOI	• Nitrogen 105 °C • Oxygen 500 °C • Total LOI 500 °C	±0.05
3 Step LOI	• Nitrogen 105 °C • Oxygen 500 °C • Oxygen 1000 °C • Total LOI 1000 °C	±0.05
4 Step LOI	• Nitrogen 105 °C • Oxygen 371 °C • Oxygen 500 °C • Oxygen 1000 °C • Total LOI 1000 °C	±0.05

Dry weight LOI available upon request.

Loss on Ignition Costs Summary

Method Code	Analytical Method Description	Minimum Sample Size	Cost per Sample
LOI-2ST	2 Step LOI	2.0 g	$6.80
LOI-3ST	3 Step LOI	2.0 g	$8.93
LOI-4ST	4 Step LOI	2.0 g	$15.40

Carbon and Sulphur (ISO/IEC 17025 Accredited)

The carbon and sulphur methods (**IRC-100** and **IRC-101**) are designed for the determination of total carbon (C) (expressed as CO_2) and total sulphur (S) (expressed as either S or SO_3) in a variety of materials such as rocks, soils, cement, limestone, and coal. Combustion of a sample in an oxygen-rich environment oxidizes carbon and sulphur, which are then measured by infrared absorption.

Working Ranges for IRC-100 and IRC-101 Method

Method Code	Analyte	Reported As	Lower Limit (wt%)	Upper Limit (wt%)
IRC-100	Total Carbon*	CO_2	0.011	110
	Total Sulphur*	S	0.0012	54
IRC-101	Total Sulphur	SO_3	0.01	2.23

** Analyte accredited to ISO/IEC 17025*

Water Content

The water content method (**IRW-H2O**) is designed for the determination of moisture and crystalline water in rocks and other materials. Moisture (H_2O^-) is driven off at 105 °C and crystalline water (H_2O^+) at 1000 °C. The water is then measured by infrared absorption.

Working Ranges for IRW-H2O Method

Analyte	Reported As	Lower Limit (wt%)
Moisture	H_2O^-	0.01
Crystalline Water	H_2O^+	0.03

Ferrous Iron

The ferrous iron method (**FEO-ION**) dissolves samples in an aggressive, non-oxidizing acid mixture. The solubilized ferrous iron is quantified by potentiometric titration with a standardized permanganate solution. Samples rich in manganese (Mn) are not suitable for this method.

Working Range for FEO-ION Method

Analyte	Reported As	Lower Limit (wt%)	Upper Limit (wt%)
Ferrous Iron	FeO	0.13	35

Additional Major Element Analysis Costs Summary

Method Code	Analytical Method Description	Minimum Sample Size	Cost per Sample
IRC-100	Carbon-Sulphur Analysis (CO_2, S)	1 g	$37.21
IRC-101	Total Sulphur Analysis (SO_3)	1 g	$21.64
IRW-H2O	Water Content Analysis	1 g	$28.43
FEO-ION	Ferrous Iron Analysis	1 g	$19.77

Solution Preparation

Open Vessel Multi-Acid Digest

The open vessel multi-acid digest methods (**SOL-OAIO**, **SOL-OT3**, and **SOL-OT1**) are used for the preparation of samples to be analyzed by ICP-MS, ICP-AES, or Flame-AAS (page 12-15) and are designed to dissolve most silicate phases present in rock samples. Although the methods achieve a near total digestion of the sample, some resistant mineral phases may not be dissolved.

Closed Vessel Multi-Acid Digest

The closed vessel multi-acid digest method (**SOL-CAIO**) is used for the preparation of samples to be analyzed by ICP-MS and ICP-AES (page 12-15) and is designed for the complete dissolution of silicate rock samples. This method is preferred for the determination of the rare earth elements (REE: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), the high field strength elements (HFSE: Zr, Nb, Hf, Ta), and large ion lithophile elements (LILE: Rb, Sr, Cs, Ba) plus Y, Th, and U.

Sample Pre-Leach

Samples flagged high in carbonates are pre-leached using dilute nitric acid to remove excess calcium prior to acid-digestion (**SOL-PLN**). The leachate is combined with the digested sample prior to analysis for a complete determination.

Aqua Regia Digest

The aqua regia extraction method (**SOL-ARD**) is used for the preparation of samples being analyzed by ICP-MS and ICP-AES (page 18-20) and is designed to leach labile elements from silicate, sulphide, and oxide matrices, in particular base and precious metals. This method is most commonly applied to the analysis of soils, unconsolidated sediments, and humus samples.

Sodium Carbonate Fusion

The sodium carbonate fusion method (**SOL-FDI**) is used for the determination of fluoride (F^-) by ion selective electrode (page 24-25). This method is not suitable for the analysis of sulphide-rich samples (S >0.5 wt%).

Solution Preparation Costs Summary

Method Code	Solution Preparation Method	Analytical Method Code(s)	Minimum Sample Size	Cost per Sample
SOL-OAIO	Open Vessel Multi-Acid Digest	• IMO-100 • IAO-100	1 g	$17.55
SOL-OT3	Open Vessel Multi-Acid Digest	• AAF-101 • AAF-102 • AAF-103	2 g	$14.08
SOL-OT1	Open Vessel Multi-Acid Digest	• AAF-200	2 g	$14.08
SOL-CAIO	Closed Vessel Multi-Acid Digest	• IMC-100 • IAC-100	1 g	$23.52
SOL-PLN	Sample Pre-Leach	• IMC-100 • IAC-100	1 g	$11.70
SOL-ARD	Aqua Regia Extraction	• IML-100 • IML-101 • IAL-100	2 g	$11.70
SOL-FDI	Sodium Carbonate Fusion	• ISE-R01	3 g	$35.00

ICP-MS (ISO/IEC 17025 Accredited)

The ICP-MS (Inductively Coupled Plasma Mass Spectrometry) methods (**IMO-100** and **IMC-100**) are designed for the analysis of minor and trace elements in non-mineralized geological samples prepared using either a closed or open vessel multi-acid digestion (SOL-OAIO, SOL-CAIO, page 10-11). Due to the greater efficiency of the closed vessel digestion, data obtained from the IMC-100 method are considered more accurate for elements contained in acid-resistant phases (e.g., chromite, zircon, monazite, xenotime, and/or garnet).

Working Ranges for Methods IMO-100 and IMC-100

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Antimony†	Sb	0.025	560	Neodymium*	Nd	0.11	740
Barium*	Ba	1.3	8 200	Nickel*	Ni	0.6	14 000
Beryllium*	Be	0.024	330	Niobium*	Nb	0.05	1 900
Bismuth†	Bi	0.11	1 100	Praseodymium*	Pr	0.019	130
Cadmium‡	Cd	0.018	46	Rubidium*	Rb	0.15	8 500
Cerium*	Ce	0.17	1 100	Samarium*	Sm	0.05	130
Cesium*	Cs	0.018	1 600	Scandium*	Sc	0.17	61
Chromium*	Cr	2.9	9 500	Strontium*	Sr	1.3	1 900
Cobalt*	Co	0.09	520	Tantalum*	Ta	0.015	320
Copper*	Cu	0.9	3 200	Terbium*	Tb	0.009	30
Dysprosium*	Dy	0.04	130	Tellurium	Te	0.02	500
Erbium*	Er	0.04	30	Thorium*	Th	0.027	120
Europium*	Eu	0.008	30	Thallium*	Tl	0.004	140
Gadolinium*	Gd	0.04	120	Thulium*	Tm	0.005	30
Gallium*	Ga	0.04	70	Tin‡	Sn	0.17	140
Hafnium*	Hf	0.09	440	Titanium*	Ti	8	46 000
Holmium*	Ho	0.006	32	Tungsten*	W	0.05	3 700
Indium*	In	0.0017	13	Uranium*	U	0.01	720
Lanthanum*	La	0.09	480	Vanadium*	V	0.4	580
Lead	Pb	0.29	6 100	Ytterbium*	Yb	0.008	68
Lithium†	Li	0.24	25 000	Yttrium*	Y	0.09	1 200
Lutetium*	Lu	0.005	30	Zinc*	Zn	4	7 600
Molybdenum*	Mo	0.08	1 700	Zirconium*	Zr	4	17 000

** Analyte accredited to ISO/IEC 17025 (IMC-100 only).*
† Accuracy better than ± 10-20%.
‡ Accuracy better than ± 10-30%. Data for information purposes only.

ICP-AES

The ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometry) methods (**IAO-100** and **IAC-100**) are designed for the analysis of major and trace elements in non-mineralized geological samples prepared using either a closed or open vessel multi-acid digestion (SOL-OAIO and SOL-CAIO, page 10-11). This technique compliments the IMO-100 and IMC-100 packages (page 12).

Working Ranges for Methods IAO-100 and IAC-100

		IAO-100 Method		IAC-100 Method	
Element	**Analyte**	**Lower Limit (ppm)**	**Upper Limit (ppm)**	**Lower Limit (ppm)**	**Upper Limit (ppm)**
Aluminum	Al	260	120 000	260	120 000
Barium	Ba	2	1 900	2	1 900
Beryllium†	Be	0.1	300	0.1	300
Cadmium†	Cd	n/a	n/a	0.8	610
Calcium	Ca	46	300 000	46	300 000
Chromium	Cr	17	1 400	17	1 400
Cobalt	Co	1	450	1	450
Copper	Cu	3	280 000	3	280 000
Iron	Fe	110	320 000	110	320 000
Lead	Pb	n/a	n/a	8	48 000
Lithium	Li	2	220	2	220
Magnesium	Mg	140	330 000	140	330 000
Manganese	Mn	1	13 000	1	13 000
Molybdenum†	Mo	n/a	n/a	2	17 000
Nickel	Ni	4	14 000	4	14 000
Phosphorus	P	4	7 000	4	7 000
Potassium	K	98	49 000	98	49 000
Scandium	Sc	0.3	60	0.3	60
Sodium	Na	530	62 000	530	62 000
Strontium	Sr	3	1 500	3	1 500
Sulphur†	S	n/a	n/a	39	140 000
Titanium	Ti	6	25 000	6	25 000
Vanadium	V	3	580	3	580
Yttrium	Y	0.6	340	0.6	340
Zinc	Zn	3	210 000	3	210 000
Zirconium	Zr	n/a	n/a	7	610

† *Non-validated analyte: data for information purposes only.*

Digestion Analyses

Flame-AAS (ISO/IEC 17025 Accredited)

The atomic absorption methods (**AAF-101**, **AAF-102**, **AAF-103**, **AAF-104,** and **AAF-200**) are designed for the determination of base metals, lithium (Li), or silver (Ag) in mineralized geological samples digested using the open vessel digestion techniques (SOL-OT3, SOL-OT1, page 10-11) and can accommodate higher concentrations than the ICP-AES and ICP-MS techniques. Method AAF-104 combines methods AAF-101 and AAF-102 and presents data as a single report.

Working Ranges for AAF-101

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Cobalt	Co	8	20 000
Copper*	Cu	7	250 000
Nickel*	Ni	16	475 000

** Analyte accredited to ISO/IEC 17025.*

Working Ranges for AAF-102

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Copper*	Cu	7	250 000
Lead*	Pb	14	75 000
Zinc	Zn	4	450 000

** Analyte accredited to ISO/IEC 17025.*

Working Ranges for AAF-103

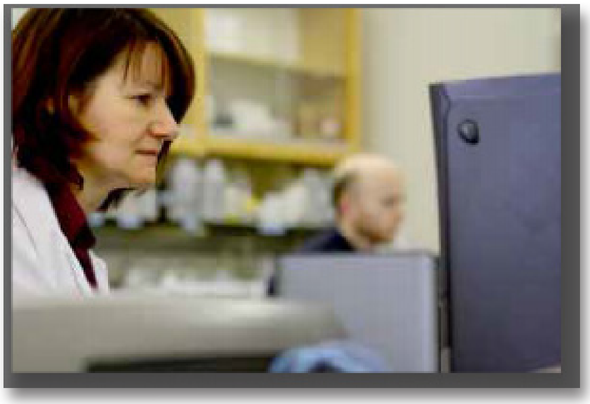
Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Lithium	Li	5	400

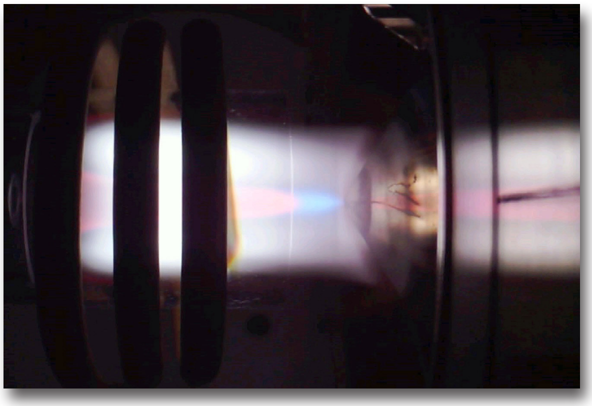
Working Ranges for AAF-200

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Silver	Ag	2	75

Rock Analysis Costs Summary

Method Code	Analytical Method	Solution Prep Code	Cost per Sample
IMO-100	ICP-MS Analysis after Open Vessel Multi-acid Digest	SOL-OAIO	$29.26
IMC-100	ICP-MS Analysis after Closed Vessel Multi-acid Digest	SOL-CAIO	$29.26
IAO-100	ICP-AES Analysis after Open Vessel Multi-acid Digest	SOL-OAIO	$16.23
IAC-100	ICP-AES Analysis after Closed Vessel Multi-acid Digest	SOL-CAIO	$16.23
AAF-101	Flame Atomic Absorption Analysis (Co, Cu, Ni)	SOL-OT3	$17.00
AAF-102	Flame Atomic Absorption Analysis (Cu, Pb, Zn)	SOL-OT3	$17.00
AAF-103	Flame Atomic Absorption Analysis (Li)	SOL-OT3	$11.15
AAF-104	Digestion Analysis (Co, Cu, Ni, Pb, Zn)	SOL-OT3	$26.01
AAF-200	Flame Atomic Absorption Absorption Analysis (Ag)	SOL-OT1	$11.15





Precious Metals Analyses

Lead Fire-Assay with Gravimetric Finish (ISO/IEC 17025 Accredited)

The lead fire-assay method (**GFA-PBG**) is used to determine gold (Au) in geological samples. The content of the precious metals collected in the fire-assay process is quantified gravimetrically.

Working Ranges for GFA-PBG Method

Element	Analyte	Lower Limit (oz/ton)
Gold*	Au	0.016

** Analyte accredited to ISO/IEC 17025.*

Lead Fire-Assay with ICP-MS Finish

The lead fire-assay method (**IMP-101**) is used to determine gold (Au), platinum (Pt), and palladium (Pd) in geological samples. The content of the precious metals collected in the fire-assay process is quantified by ICP-MS.

It is recommended that over range Au be followed-up with GFA-PBG analysis (above) for more accurate result.

Working Ranges for IMP-101 Method

Element	Analyte	Lower Limit (ppb)	Upper Limit (ppb)
Gold	Au	0.6	5 000
Platinum	Pt	0.06	11 000
Palladium	Pd	0.14	5 000

Nickel Sulphide Fire-Assay (ISO/IEC 17025 Accredited)

The nickel sulphide fire-assay method (**IMP-200**) is considered the foremost method for determination of low-level gold (Au) and platinum group elements (PGEs) in geological samples. To ensure efficiency and reduce the possibility of contamination, it is recommended that samples containing >1% base metal sulphides be submitted for base metal (method AAF-101, page 14-15) and total sulphur analysis (method IRC-100, page 9).

In order to maintain the low detection limits and high quality data offered by this technique, samples expected to contain >500 ppb of any individual precious metal (or 100 ppb rhodium, Rh) should be flagged at sample submission. In addition, samples expected to be elevated in organic carbon, chromite, or zinc should also be flagged.

Working Ranges for IMP-200 Method

Element	Analyte	Lower Limit (ppb)	Upper Limit (ppb)
Gold*	Au	0.3	2 000
Platinum*	Pt	0.19	4 200
Palladium*	Pd	0.20	2 700
Rhodium*	Rh	0.008	800
Ruthenium*	Ru	0.03	800
Iridium*	Ir	0.007	800
Osmium†	Os	0.09	165

** Analyte accredited to ISO/IEC 17025.*

† *Data for information only*

Precious Metals Analysis Costs Summary

Method Code	Precious Metal Analysis Method	Minimum Sample Size	Cost per Sample
GFA-PBG	Lead Fire Assay with Gravimetric Finish	30 g	$27.35
IMP-101	Lead Fire Assay with ICP-MS Finish	30 g	$27.33
IMP-200	Nickel Sulphide Fire Assay with ICP-MS Finish	Preferred: 30 g Minimum: 15 g	$205.08

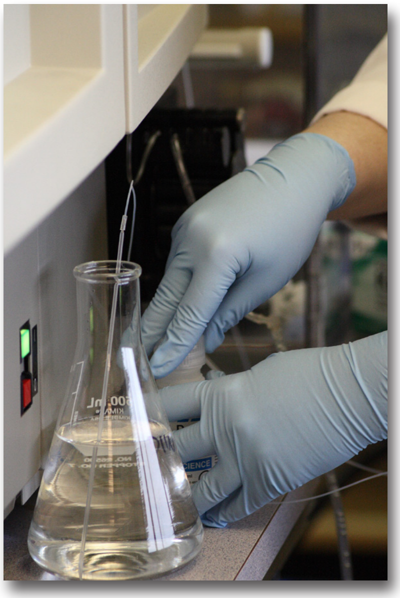
ICP-MS - Mineralized Rocks (ISO/IEC 17025 Accredited)

The ICP-MS method (**IML-101**) is designed for the analysis of minor and trace elements in mineralized rocks after a modified aqua regia extraction.

Working Ranges for IML-101 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Antimony	Sb	0.02	5 500	Molybdenum	Mo	0.2	17 000
Arsenic	As	0.4	10 000	Nickel*	Ni	2	22 000
Bismuth	Bi	0.02	3 000	Palladium	Pd	0.02	80
Cadmium	Cd	0.05	8 000	Platinum†	Pt	0.005	3
Cobalt*	Co	0.2	3 000	Selenium	Se	0.2	90
Copper*	Cu	0.6	12 000	Silver*	Ag	0.2	150
Gold	Au	0.003	100	Tellurium†	Te	0.04	500
Indium	In	0.005	600	Thallium	Tl	0.004	40
Iridium†	Ir	0.003	2	Tin†	Sn	0.06	90
Lead*	Pb	0.2	8 000	Zinc*	Zn	4	30 000
Mercury	Hg	0.08	700				

** Analyte accredited to ISO/IEC 17025.*
† Leachable component: data for information only.



ICP-MS (ISO/IEC 17025 Accredited)

The ICP-MS method (**IML-100**) is designed for the analysis of minor and trace elements in soils, humus, and unconsolidated sediments after a modified aqua regia extraction. Because the sample is incompletely digested during sample dissolution, the data produced by this package represent the composition of only the more easily acid-soluble components in the sample.

Working Ranges for IML-100 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Antimony*	Sb	0.007	100	Nickel*	Ni	0.4	2 400
Arsenic*	As	0.4	600	Niobium	Nb	0.014	20
Barium*	Ba	0.14	800	Palladium	Pd	0.004	2
Beryllium*	Be	0.002	20	Platinum	Pt	0.0013	2
Bismuth*	Bi	0.007	50	Praseodymium	Pr	0.03	60
Cadmium*	Cd	0.006	50	Rhodium	Rh	0.006	2
Cerium	Ce	0.04	560	Rubidium	Rb	0.01	140
Cesium	Cs	0.002	30	Samarium	Sm	0.05	60
Chromium*	Cr	0.4	720	Scandium	Sc	0.11	30
Cobalt*	Co	0.06	210	Selenium	Se	0.03	24
Copper*	Cu	0.4	3 500	Silver*	Ag	0.019	100
Dysprosium	Dy	0.017	30	Strontium*	Sr	0.6	600
Erbium	Er	0.004	30	Tantalum	Ta	0.0007	5
Europium	Eu	0.008	30	Tellurium	Te	0.003	40
Gadolinium	Gd	0.03	30	Terbium	Tb	0.006	30
Gallium*	Ga	0.02	20	Thallium	Tl	0.0013	11
Gold	Au	0.0011	100	Thorium	Th	0.02	60
Hafnium	Hf	0.008	8	Thulium	Tm	0.0011	30
Holmium	Ho	0.003	30	Tin	Sn	0.03	90
Indium	In	0.0011	15	Titanium*	Ti	16	2 300
Iridium	Ir	0.0006	2	Tungsten*	W	0.004	90
Lanthanum	La	0.2	300	Uranium*	U	0.004	30
Lead*	Pb	0.04	5 000	Vanadium*	V	1	210
Lithium*	Li	0.02	140	Ytterbium	Yb	0.012	30
Lutetium	Lu	0.002	30	Yttrium	Y	0.1	120
Mercury	Hg	0.006	35	Zinc*	Zn	0.9	6 000
Molybdenum*	Mo	0.013	110	Zirconium	Zr	0.1	20
Neodymium	Nd	0.16	240				

** Analyte accredited to ISO/IEC 17025*

Aqua Regia Extraction Analyses

ICP-AES

The ICP-AES method (**IAL-100**) is designed for the analysis of major and minor elements in soils, humus, and unconsolidated sediments after a modified aqua regia extraction and compliments the IML-100 and IML-101 methods (pages 18-19).

Working Ranges for IAL-100 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Aluminum	Al	9	42 000	Nickel	Ni	2	22 000
Antimony	Sb	5	120	Phosphorus	P	10	15 000
Arsenic	As	6	500	Potassium	K	30	25 000
Barium	Ba	1.3	5 000	Scandium	Sc	0.2	500
Beryllium	Be	0.09	500	Selenium	Se	9	500
Bismuth	Bi	11	48	Silicon	Si	23	5 000
Cadmium	Cd	0.5	52	Sodium	Na	17	15 000
Calcium	Ca	6	150 000	Strontium	Sr	0.05	2 500
Chromium	Cr	2	2 500	Sulphur	S	24	17 000
Cobalt	Co	1	2 500	Tin	Sn	3	500
Copper	Cu	3	20 000	Titanium	Ti	0.6	5 000
Iron	Fe	90	150 000	Tungsten	W	9	300
Lead	Pb	4	5 600	Vanadium	V	3	1 500
Lithium	Li	1	500	Yttrium	Y	0.4	1 500
Magnesium	Mg	70	50 000	Zinc	Zn	1	26 000
Manganese	Mn	0.3	25 000	Zirconium	Zr	0.9	500
Molybdenum	Mo	1	500				

Aqua Regia Extraction Analysis Costs Summary

Method Code	Analytical Method	Solution Prep Code(s)	Cost per Sample
IML-101	ICP-MS Analysis after Aqua Regia Digest (Mineralized Rock)	SOL-ARD	$29.26
IML-100	ICP-MS Analysis after Aqua Regia Digest (Soils, Humus, Sediments)	SOL-ARD	$29.26
IAL-100	ICP-AES Analysis after Aqua Regia Digest (Soils, Humus, Sediments)	SOL-ARD	$11.87

Water Filtration and Preservation

Sample filtration and preservation is the responsibility of the client prior to submitting samples. Unpreserved and unfiltered samples for the ICP-MS and ICP-AES will be treated without exception and where necessary at the client's cost (**SOL-ACID** and **SOL-FILT**).

For best results, samples should either be preserved by adding hydrochloric acid to a concentration of 2% v/v (HGW-100 analyses) or ultra-pure nitric acid to a concentration of 1% v/v (IAW-200 or IMW-100 analyses) or be submitted unpreserved (ICW-100 and TOC-100 analyses). All water samples should be kept refrigerated at 4 °C.

For submission of ground water samples, please contact the Geo Labs.

Mercury by Atomic Fluorescence Spectroscopy

Cold-vapour atomic fluorescence spectroscopy (**HGW-100**) determines parts-per-trillion (ppt) concentrations of total mercury in water samples after a bromochloride digestion for the release of organomercury and other mercury compounds into solution.

Working Range for HGW-100 Method

Element	Analyte	Lower Limit (ppt)	Upper Limit (ppt)
Mercury	Hg	1.5	100

ICP-AES

The ICP-AES method (**IAW-200**) determines major and trace element concentrations in fresh water samples. This method can tolerate up to 1 wt% total dissolved solids (TDS) without dilution. Samples with high TDS may be subject to a dilution charge.

Working Ranges for IAW-200 Method

Element	Analyte	Lower Limit (ppb)	Upper Limit (ppb)	Element	Analyte	Lower Limit (ppb)	Upper Limit (ppb)
Aluminum	Al	3	2 200	Magnesium	Mg	13	73 800
Boron	B	20	2 400	Manganese	Mn	0.4	1 800
Barium	Ba	6	1 900	Molybdenum	Mo	4	2000
Beryllium	Be	0.2	300	Nickel	Ni	8.4	2 200
Calcium	Ca	74	240 000	Phosphorus†	P	13	50 000
Cadmium	Cd	1	400	Potassium	K	160	80 000
Chloride	Cl	1100	320 000	Silicon	Si	20	11 000
Chromium	Cr	3	1 800	Sodium	Na	50	320 000
Cobalt	Co	3	2 200	Strontium	Sr	2	18 000
Copper	Cu	3	2 000	Sulphur	S	33	180 000
Iron	Fe	2	2 000	Titanium	Ti	1	300
Lead	Pb	20	2 200	Vanadium	V	4	2 200
Lithium	Li	6	220	Zinc	Zn	3	2 200

† *Non-validated analyte: data for information purposes only.*

ICP-MS (ISO / IEC 17025 Accredited)

The ICP-MS method (**IMW-100**) is designed to analyze a wide spectrum of elements. It is optimized for the determination of trace element concentrations in natural fresh water with low total dissolved solids contents (TDS <0.01 wt%). Samples with high TDS may be subject to a dilution charge. Owing to the high sensitivity of the ICP-MS instrument, it is recommended that major elements are determined by ICP-AES (IAW-100, page 21).

Working Ranges for IMW-100 Method

Element	Analyte	Lower Limit (ppb)	Upper Limit (ppb)	Element	Analyte	Lower Limit (ppb)	Upper Limit (ppb)
Aluminum*	Al	4	1 700	Manganese*	Mn	0.05	1 700
Antimony*	Sb	0.027	300	Molybdenum*	Mo	0.03	1 600
Arsenic*	As	0.029	300	Neodymium*	Nd	0.0013	650
Barium*	Ba	0.05	1 500	Nickel*	Ni	0.04	1 600
Beryllium	Be	0.008	250	Niobium†	Nb	0.0007	0.25
Bismuth	Bi	0.0025	140	Potassium	K	1.9	38 000
Boron†	B	19	640	Praseodymium*	Pr	0.00027	80
Cadmium	Cd	0.0028	300	Rubidium*	Rb	0.0017	980
Calcium	Ca	12	200 000	Samarium	Sm	0.0024	550
Cerium*	Ce	0.0007	100	Scandium	Sc	0.15	200
Cesium	Cs	0.0009	660	Selenium	Se	0.19	330
Chloride†	Cl	4 400	81 000	Silver	Ag	0.009	100
Chromium*	Cr	0.04	1 600	Sodium	Na	18	110 000
Cobalt*	Co	0.0026	1 600	Strontium*	Sr	0.11	1 400
Copper*	Cu	0.11	1 600	Tantalum†	Ta	0.00024	225
Dysprosium	Dy	0.0003	450	Terbium	Tb	0.00011	110
Erbium	Er	0.0005	600	Thallium*	Tl	0.0011	210
Europium	Eu	0.00022	200	Thorium	Th	0.00023	175
Gadolinium	Gd	0.0008	550	Thulium	Tm	0.00008	140
Gallium	Ga	0.0018	60	Tin	Sn	0.017	310
Gold†	Au	0.0012	2	Titanium	Ti	0.08	1 700
Hafnium†	Hf	0.0008	0.5	Tungsten	W	0.003	30
Holmium	Ho	0.0001	125	Uranium*	U	0.0025	450
Iron*	Fe	0.7	1 800	Vanadium*	V	0.004	1 700
Lanthanum*	La	0.0005	90	Ytterbium	Yb	0.00023	450
Lead*	Pb	0.03	1 500	Yttrium*	Y	0.0006	900
Lithium*	Li	0.07	200	Zinc*	Zn	0.5	1 500
Lutetium	Lu	0.00009	160	Zirconium†	Zr	0.007	130
Magnesium	Mg	7	36 000				

** Accreditation to ISO/IEC 17025 temporarily removed while methods are transferred to new instrumentation.*
† Data for information purposes only

Ion Chromatography (ISO/IEC 17025 Accredited)

The ion chromatography method (**ICW-100**) is used for the determination of several anions of geological and environmental importance in unacidified waters. Certain anions are stable for a limited time frame, even when properly preserved, and may reduce, oxidize, or decompose to a form undetectable by this method.

Working Ranges for ICW-100 Method

Anion	Analyte	Lower Limit (ppm)	Upper Limit (ppm)	Anion	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Bromide	Br^-	0.05	100	Nitrite*	NO_2^-	0.03	50
Chloride	Cl^-	0.04	100	Nitrate*	NO_3^-	0.03	100
Fluoride*	F^-	0.01	100	Phosphate	PO_4^{3-}	0.05	100
Total Nitrogen as NO_2^- + NO_3^-	N_{TOT}	0.02	40	Sulphate	SO_4^{2-}	0.05	150

** Accreditation to ISO/IEC 17025 temporarily removed while methods are transferred to new instrumentation.*

Total Organic Carbon

The total organic carbon (**TOC-100**) method determines non-purgeable organic carbon (NPOC) and total carbon (TC) in water samples by non-dispersive infrared detection following direct injection oxidative-combustion. Total inorganic carbon (TIC) is estimated by mathematical subtraction of NPOC from TC. This method is suitable for high TDS% water samples.

Working Ranges for TOC-100 Method

Analyte	Reported As	Lower Limit (ppm)	Upper Limit (ppm)
Total Carbon	TC	1.1	200
Total Organic Carbon (Non-Purgeable Organic Carbon)	TOC (NPOC)	0.46	200
Total Inorganic Carbon	TIC	0.46	150

Waters Analysis Costs Summary

Method Code	Analytical Method	Minimum Sample Size	Cost per Sample
SOL-FILT	Sample Filtration	100 mL	$9.33
SOL-ACID	Sample Preservation	100 mL	$9.33
HGW-100	Mercury Analysis by Atomic Fluorescence Spectroscopy	100 mL	$35.00
IAW-200	ICP-AES Water Analysis	100 mL	$10.53
IMW-100	ICP-MS Water Analysis	100 mL	$47.77
ICW-100	Ion Chromatography Water Analysis	20 mL	$93.63
TOC-100	Total Organic Carbon	100 mL	$47.76

Other Analytical Services

Total Suspended Solids

The total suspended solids method (**TSS-100**) uses an aliquot of well-mixed sample that is passed through a 0.45 µm filter paper to determine the total mass of suspended solids.

pH Determination

The pH determination methods (**PHP-100** and **PHS-200**) test solid or liquid samples for their acidity and/or alkalinity by direct measurement with an electronic pH meter.

Acid Base Accounting

The acid base accounting method (**ABA-200**) is designed to determine the balance between the acid producing and acid consuming components of samples. The samples are lightly digested and back-titrated using an automated titrator.

Particle Size Analysis

The particle size analysis method (**PSA-100**) is designed to analyze the physical characteristics and structural properties of soil. The Geo Labs can provide analysis of grain sizes between 0.025 to 2816 µm.

Specific Gravity

The specific gravity method (**SGT-R01**) is designed to measure the density of solid samples. Specific gravity of powders cannot be measured at the Geo Labs.

Calcite and Dolomite by Chittick Apparatus

The Chittick method (**CTK-100**) is designed to determine the calcite, dolomite, and total carbonate contents of sedimentary rock and till samples.

Working Ranges for CTK-100 Method

Analyte	Lower Limit (wt%)
% Dolomite	2.4
% Calcite	0.7
% Total Carbonate	0.6

Fluorine by Ion Selective Electrode

The ion selective electrode method (**ISE-R01**) is designed to determine the total fluorine (F) contents of non-mineralized geological samples. Samples are brought into solution following a sodium carbonate fusion (SOL-FDI, page 10-11) and analyzed using a direct-measure ion selective electrode.

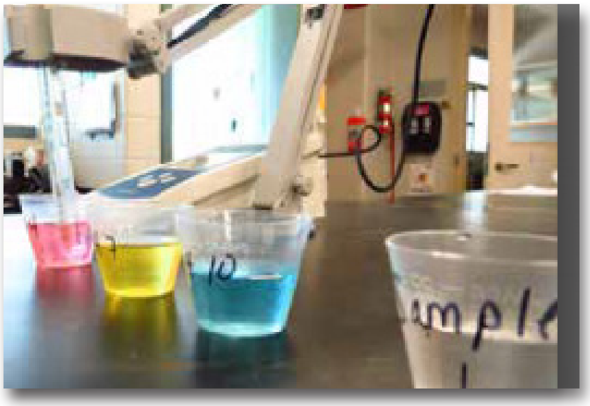
This technique is not suitable for the analysis of sulphide-rich samples (S >0.5 wt%).

Working Range for ISE-R01 Method

Element	Analyte	Lower Limit (ppm)	Upper Limit (ppm)
Fluorine	F	115	110 000

Other Services Costs Summary

Method Code	Method Description	Minimum Sample Size	Cost per Sample
TSS-100	Total Suspended Solids	100 mL	$20.48
PHP-100	pH Paste Determination	10 g	$17.55
PHS-200	pH Solution Determination	25 mL	$11.69
ABA-200	Acid Base Accounting	10 g	$66.77
PSA-100	Particle Size Analysis	10 g	$51.34
SGT-R01	Specific Gravity	>100 g to <2 kg	$17.55
CTK-100	Chittick Analysis	5 g	$29.26
ISE-R01	Fluorine by Ion Selective Electrode	3 g	$13.86



X-Ray Diffraction

XRD Analysis Without Interpretation

The **XRD-100** method is intended for clients that have an in-house capability to process raw XRD patterns. The Geo Labs will process samples as either whole powders or smears (on a low background substrate) depending on the amount of available material. A digital copy of the XRD pattern is supplied to the client as an ASCII file. Alternate file formats may be supplied upon request. Additional crushing/pulverising fees may apply.

Please note that the sample preparation method used for the XRD-100 method will produce preferred orientation for certain minerals. It is therefore not recommended that the data produced be used for quantitative applications unless the client has access to quantitative analysis software with the capability to properly model and correct for preferred orientation.

An additional fee will be charged for clients that require a list of peak positions and intensities. This fee will depend on the total number of samples and will be determined at the time of sample submission. If requested, the peak positions and intensities will be provided as a PDF document.

XRD Analysis With Interpretation

The **XRD-101** method provides a qualitative XRD analysis with the identification of major minerals (>5 wt%) present in the sample. The ability to properly identify all of the mineral phases may be limited by the complexity of the sample. Note that this type of routine XRD analysis is only intended to provide an identification based on general structural groups and cannot provide detailed compositional information.

XRD Rental Without Operator

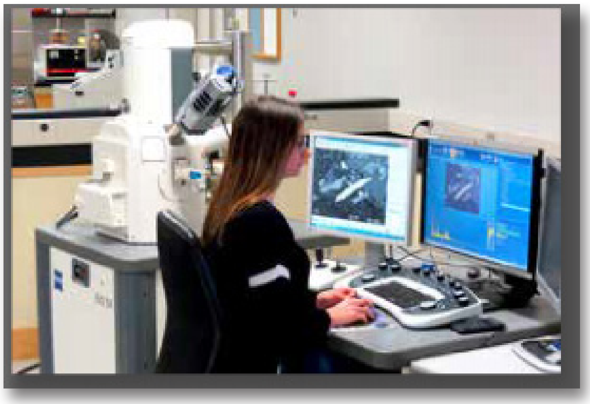
The XRD equipment is available for rent on an hourly basis. Clients should contact the Geo Labs for further information and scheduling. Charges for equipment training will be applicable.

X-Ray Diffraction Costs Summary

Method Code	Method Description	Cost
XRD-100	Mineral Identification Without Interpretation	$47.38/sample
XRD-101	Mineral Identification With Interpretation	$184.33/sample
XRD-102	X-Ray Diffraction Rental Without Operator	$54.76/hour

Scanning Electron Microscopy (SEM)

The Geo Labs currently operates a Zeiss EVO-50 Tungsten Scanning Electron Microscope (SEM) and a JEOL IT-500HR Field Emission Scanning Electron Microscope (FE-SEM). Routine capabilities of these instruments include qualitative mineral identification, quantitative mineral analysis (for specific mineral types), X-ray mapping, Feature analysis, cathodoluminescence (CL) imaging, secondary electron (SE) imaging, and fully integrated backscattered electron (BSE) imaging including montage generation. Except by prior agreement, only thin sections and polished mounts will be accepted for mineral identification.

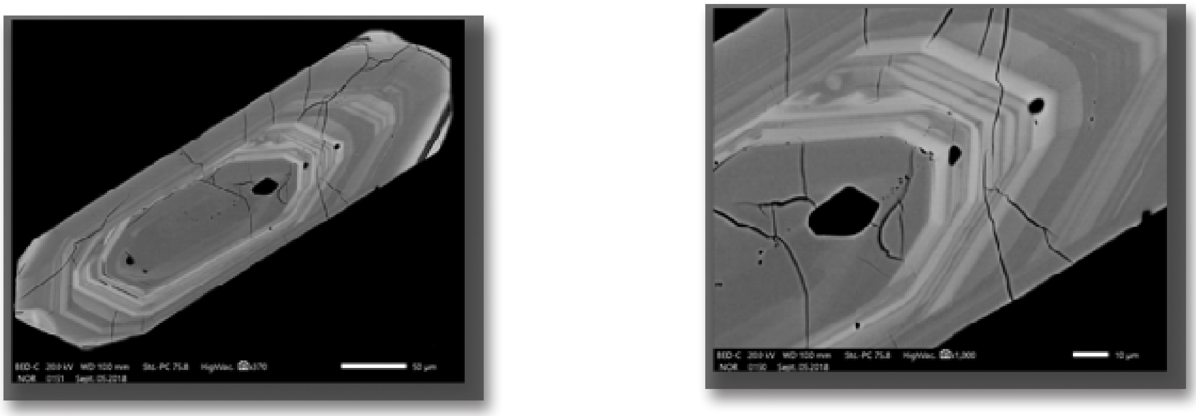


SEM Rental

The Zeiss EVO-50 SEM may be rented on an hourly basis with or without an operator. The client should contact the Geo Labs for further information regarding the scheduling of SEM rental time. Charges for equipment training will be applicable.

Scanning Electron Microscopy Costs Summary

Method Code	Method Description	Cost per Hour
SEM-101	SEM Rental With Operator	$191.00
SEM-102	SEM Rental Without Operator	$115.57



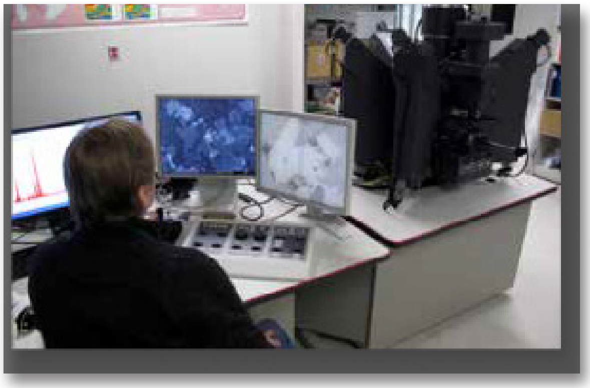
Backscattered electron images (JEOL IT-500HR FE-SEM)

Mineralogy Services

Electron Microprobe Analysis

The Geo Labs currently operates a Cameca SX-100 Electron Probe Micro Analyzer (EPMA) and a JEOL JXA-8530F Field Emission Electron Probe Micro Analyzer (FE-EPMA). These instruments are both equipped with five wavelength dispersive (WD) spectrometers that include large area diffraction crystals that are needed to produce the best possible sensitivity during quantitative mineral analysis.

The mineralogy section currently utilizes a number of different analytical packages that are optimized for various mineral species. Our strategy is to employ dual analytical conditions (low and high beam current settings) for minerals that are not susceptible to decomposition in order to produce the best possible sensitivity. Routines may be customized to suit the needs of the client to include any combination of elements, counting times, and analytical conditions.



Clients should contact the Geo Labs for further information regarding scheduling of jobs and access to the instrument. Charges for equipment training will be applicable.

Electron Microprobe Costs Summary

Method Code	Method Description	Cost
EMP-100	Microprobe Analysis per Grain • Minimum of 50 grains. • For KIMs, the price includes mounting and photography.	$15.90 per grain
EMP-101	Microprobe Rental With Operator • Minimum of ½ day (4 hours)	$238.52 per hour
EMP-102	Microprobe Rental Without Operator • Minimum of ½ day (4 hours)	$149.59 per hour

Note that for most instrument rentals, an operator is required to aid users with such tasks as instrument calibration, sample loading, and data processing. The number of operator hours required within a given rental period will depend to a large degree on the comfort level of the user. For more information please contact the Geo Labs for a quote.

Kimberlite Indicator Minerals (KIMs)

Mineral separates submitted to the Geo Labs are mounted in one inch epoxy plugs that are exposed, polished, and photographed prior to analysis on the Cameca SX-100 electron microprobe (**EMP-100** method). Please note that the Geo Labs does not perform either the heavy mineral separation or hand picking of indicator minerals.

The analytical routines have been optimized so that key elements associated with the various indicator mineral groups are analyzed in an appropriate fashion. This involves the use of dual analytical conditions (low and high beam current settings) in order to produce appropriate counting statistics for both major and minor elements thereby ensuring the best precision possible.

Sample Submission

KIMs should be submitted to the Geo Labs in clearly labelled vials that are mineral specific. Individual batches must contain a minimum of 50 grains. For high volume jobs (>2000 grains), please contact the Geo Labs for alternate sample submission protocols and scheduling information.

Curent Analytical Schemes and Associated Limits of Detection for the KIM suite

	Garnet	Pyroxene	Ilmenite	Chromite	Olivine
Oxide	**Lower Limit (wt%)**	**Lower Limit (wt%)**	**Lower Limit (wt%)**	**Lower Limit (wt%)**	**Lower Limit (wt%)**
SiO_2	0.025	0.025	0.005	0.006	0.026
TiO_2	0.007	0.008	0.025	0.007	0.007
Al_2O_3	0.021	0.019	0.025	0.030	0.004
V_2O_3	0.006	n/a	0.008	0.008	n/a
Cr_2O_3	0.012	0.013	0.017	0.036	0.006
Nb_2O_3	n/a	n/a	0.013	n/a	n/a
MgO	0.022	0.021	0.029	0.034	0.018
CaO	0.011	0.013	0.004	n/a	0.005
MnO	0.008	0.008	0.033	0.008	0.008
FeO^{TOT}	0.018	0.018	0.047	0.033	0.022
CoO	n/a	n/a	n/a	0.008	0.008
NiO	n/a	0.006	0.007	0.008	0.006
ZnO	n/a	n/a	0.011	0.014	n/a
Na_2O	0.006	0.006	n/a	n/a	n/a
K_2O	0.003	0.003	n/a	n/a	n/a

Note that the lower reporting limit may vary depending on the service status of the spectrometers.

Reference Materials (RMs)

The Geo Labs has a fully-equipped facility with specialized equipment to produce reference materials in batches from 1 kg up to 500 kg (depending on the specific gravity of the material).

The Geo Labs Reference Material Program focuses on three aspects:

- Production of reference materials for in-house use
- Production of reference materials to meet individual client requirements
- Production of reference materials for purchase

Production of Reference Materials for In-house Use

The Geo Labs has produced over 40 in-house reference materials for internal use, with a focus on material collected from various geological sites in Ontario, Canada. Materials are crushed, pulverized to -200 mesh, screened, blended, and bottled. The material then undergoes in-house homogeneity testing to determine the provisional composition and to ensure within-bottle and between-bottle consistency.

Production of Reference Materials for Client Requirements

The Geo Labs can produce reference materials based on individual client requirements. Contact the Geo Labs for further information and price quote.

Reference Materials Available for Purchase

- **LDI-1** is a low-grade Pt-group element (PGE) reference material collected from the Lac des Iles PGE deposit. The deposit is hosted by a gabbro located 85 km north of Thunder Bay, Ontario, Canada. See the chart opposite for provisional in-house data.
- **LK-NIP-1** is a diabase collected from a Nipigon diabase sill in Kitto Township, south of Beardmore, Ontario, Canada. See the chart opposite for provisional in-house data.
- **ORCA-1** is a calc-alkaline rhyolite collected from Pontiac Township, 35 km northeast of Kirkland Lake, Ontario, Canada. See the chart opposite for provisional data on the material's composition.
- **QS-1** is a hematitic shale collected from the Queenston Formation in the Niagara Region, Ontario. See chart opposite for provisional data on the material's composition.
- **PJV-1**, **PJV-2**, and **PJV-3** are three reference materials collected from the Porcupine Joint Venture gold project in Timmins, Ontario, Canada. See chart below for provisional in-house data.

Contact the Geo Labs for further information and pricing.

Provisional Composition of Porcupine Joint Venture In-House RMs

	Unit	PJV-1	PJV-2	PJV-3
Au	oz/ton	0.23	0.28	0.95
Ag	ppm	1.12	1.28	3.98
Cu	ppm	180	210	150
Ni	ppm	83	81	108
S	wt %	1.15	1.29	0.76
CO_2	wt %	3.52	4.04	9.61

Provisional Composition of LDI-1, LK-NIP-1, ORCA-1, and QS-1 In-House RMs

	Unit	LDI-1	LK-NIP-1	ORCA-1	QS-1		Unit	LDI-1	LK-NIP-1	ORCA-1	QS-1
Al_2O_3	wt %	17.36	15.35	12.55	14.28	**Ho**	ppm	0.09	0.83	2.53	1.08
CaO	wt %	10.16	10.21	1.14	8.07	**In**	ppm	n/a	0.066	n/a	n/a
$Fe_2O_3^T$	wt %	7.69	13.54	2.91	6.49	**Ir***	ppb	0.08	0.179	0.034	n/a
K_2O	wt %	0.21	0.474	2.14	4.41	**La**	ppm	1.2	8.5	27.0	39.4
MgO	wt %	10.87	7.25	0.47	3.63	**Li**	ppm	18	10.2	6.1	61
MnO	wt %	0.13	0.1899	0.060	0.1	**Lu**	ppm	0.05	0.32	1.21	0.430
Na_2O	wt %	1.89	2.42	4.59	0.11	**Mo**	ppm	<1.0	1.08	4.4	1.10
P_2O_5	wt %	<0.01	0.112	0.057	0.151	**Nb**	ppm	0.22	4.2	11.6	14.5
SiO_2	wt %	48.77	49.2	74.84	50.91	**Nd**	ppm	1.2	11.6	34.8	36.6
TiO_2	wt %	0.12	1.148	0.298	0.758	**Ni**	ppm	656	142.4	6.0	38.4
LOI	wt %	2.74	0.119	0.77	10.77	**Pb**	ppm	2.6	2.99	5.0	9.3
S	wt %	0.12	0.024	0.01	<0.01	**Pd**	ppb	834*	16.9	<0.2*	n/a
CO_2	wt %	n/a	0.049	0.048	7.19	**Pr**	ppm	0.3	2.55	8.20	9.6
FeO	wt %	5.46	10.03	2.07	2.06	**Pt**	ppb	98.2*	12.4	<0.19*	n/a
H_2O^+	wt %	3.25	0.61	0.71	3.68	**Rb**	ppm	7.8	13.0	52.1	135.5
H_2O^-	wt %	0.15	0.157	0.02	0.52	**Rh***	ppb	0.7	0.87	0.019	n/a
Ag	ppm	n/a	<0.2	<0.2	n/a	**Ru***	ppb	0.32	0.46	0.053	n/a
As	ppm	n/a	0.79	n/a	n/a	**Sb**	ppm	n/a	0.068	n/a	n/a
Au	ppb	83.9*	4.4	1.3	n/a	**Sc**	ppm	24.5	31.3	7.3	14.2
Ba	ppm	55	142	374	362	**Sm**	ppm	0.28	3.13	8.95	7.08
Be	ppm	n/a	0.51	n/a	n/a	**Sn**	ppm	n/a	0.82	n/a	n/a
Bi	ppm	n/a	<0.5	n/a	n/a	**Sr**	ppm	183	162.4	71.6	113.0
Cd	ppm	n/a	0.122	n/a	n/a	**Ta**	ppm	<0.3	0.288	0.99	0.98
Ce	ppm	2.5	18.7	62.1	81.1	**Tb**	ppm	0.06	0.63	1.8	0.91
Co	ppm	52	54	3.0	16.0	**Te**	ppm	n/a	<0.04	<0.04	n/a
Cr	ppm	n/a	159	65	71	**Th**	ppm	0.12	1.55	4.91	11.0
Cs	ppm	1.07	0.59	0.60	6.20	**Tl**	ppm	<0.03	0.087	0.199	0.66
Cu	ppm	413	161	12.0	11.4	**Tm**	ppm	0.05	0.34	1.19	0.45
Dy	ppm	0.39	4.0	11.7	5.4	**U**	ppm	0.04	0.45	1.29	2.62
Er	ppm	0.28	2.38	7.60	3.05	**V**	ppm	93	285.1	10.2	112
Eu	ppm	0.18	1.10	1.32	1.42	**Y**	ppm	2.4	22.2	70.8	29.2
Ga	ppm	10	20.1	16.0	19.7	**W**	ppm	n/a	0.33	n/a	n/a
Gd	ppm	0.32	3.8	9.87	6.1	**Yb**	ppm	0.31	2.16	7.85	2.86
Hf	ppm	0.2	2.32	7.5	4.2	**Zn**	ppm	n/a	101	51.2	75
Hg	ppm	n/a	<0.08	<0.08	n/a	**Zr**	ppm	n/a	82	246	159

** Analysis by Nickel Sulphide Fire-Assay with ICP-MS Finish*

Note: results for S, CO_2, FeO, H_2O^+, and H_2O^- in ORCA-1 and QS-1 and Na_2O in QS-1 are based on the average of triplicate analyses on 12 randomly selected bottles. Other data for ORCA-1 and QS-1 are based on the results of a 2015 and 2017 International Association of Geoanalysts (IAG) round-robin proficiency tests.

Periodic Table of the Elements

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8B	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminium 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulphur 32.065	17 Cl Chlorine 35.45	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.63	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.96	43 Tc Technetium [98]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.293
55 Cs Caesium 132.905	56 Ba Barium 137.327	57-71 Lanthanides See Below	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.984	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	89-103 Antinides See Below	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [272]	108 Hs Hassium [277]	109 Mt Meitnerium [276]	110 Ds Darnstadtium [281]	111 Rg Roentgenium (280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.5	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium [277]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium (247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [100]	101 Md Mendelevium [258]	102 No Nobelium [259]	103 Lr Lawrencium [262]

KEY

Lanthanides | Noble gases | Halogens | Alkaline earth metals | Alkalai metals | Actinides | Other metals | Other nonmetals | Transition metals

Symbol State: Gas, Liquid, Solid, Synthetic

0 — Atomic Number
J — Symbol
Geo Labs — Name
3.14159 — Atomic Weight

An atomic weight in brackets indicates that isotopes of the element are unstable/radioactive.

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Ontario

GEOSCIENCE LABORATORIES SAMPLE SUBMISSION FORM - REQUEST FOR ANALYSIS

Ministry of Mines, Ontario Geological Survey, GeoServices Section
Willet Green Miller Centre, 933 Ramsey Lake Road, Sudbury, Ontario, P3E 6B5, Canada

FOR LAB USE:

Received date (initial):		**Job No:**	
Condition upon receipt:		**Log-in date (initial):**	
Management approval, if applicable (or attach record):			

A. CLIENT INFORMATION

Send Report to:		**Send Invoice to:**	
Name:		Name:	
Company:		Company:	
Mailing Address:		Mailing Address:	
E-mail:		E-mail:	
Phone:		Phone:	
Fax:		Fax:	
Project No:		CRA BN No (if applicable):	
Client Order/PO No:		Geo Labs Quote No:	
Additional Report to:		**Authorization:**	
Name:		**Questions?** Contact Geo Labs at 705-670-5637 (toll free: 1-866-436-5227) or at geolabs@ontario.ca.	
E-mail:			

B. SAMPLE INFORMATION

Comments/Special Instructions (Please indicate hazards):

Sample Management:		**Solutions**	**Pulps**	**Rejects**
Pulps, rejects, and solutions will be disposed after 30 days holding period unless otherwise requested.	**Discard**	☐	☐	☐
	Return (client's expense)	☐	☐	☐

DISCLAIMER: Values are reported as achieved on each instrument. If values are above or below the reporting limit, it is the client's responsibility to request an appropriate alternative method of analysis, if desired, at their expense.

C. SAMPLE IDENTIFICATION AND ANALYTICAL REQUEST

Qty	Sample ID's or Sequence	Sample Description	Sample Prep	Method Codes / Elements of Interest				

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The Geo Labs supports all people being able to access our services; for a more accessible version of this form please contact us at geolabs@ontario.ca.

PRECISE ANALYSIS

ACCURATE RESULTS

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Ontario

Ontario Ministry of Mines
Ontario Geological Survey, GeoServices Section