A compilation of soil and till geochemical data from surveys at the Ace and Getty South mineral properties, British Columbia

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Front cover: Looking southwest across the Little River valley, Ace property area. **Photo by P. Bobrowsky**

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Summary

Glacial deposits are a challenge to mineral exploration, especially in British Columbia where repeated glaciations produced sediments that conceal prospective bedrock. Geochemical anomalies in soil and till are commonly displaced several kilometers down-ice from a bedrock source. An additional challenge to interpreting soil and till geochemical anomalies is the fact that their surface expression can be located some distance down-ice from the bedrock source as defined by an ascending dispersal plume through the till profile in the direction of ice flow. An analysis of the geochemical composition of soil, glacial sediment (till) and bedrock can define the shape and dimensions of glacial dispersal patterns (e.g., Paulen, 2001).

Several surficial geochemical surveys, supervised by Dr. Peter Bobrowsky (now Emeritus Scientist, Geological Survey of Canada), were completed by the British Columbia Geological Survey in 1998 and 2000. These surveys included studies of the soil and till geochemistry in the region of massive sulphide and gold-quartz vein mineralization at the Ace mineral property (MINFILE 93A 046) near Likely, and disseminated copper sulphides in quartz diorite at the Getty South property (MINFILE 092INE043) in the Highland Valley (Fig. 1). Detailed geochemical soil and till surveys over these properties generated trace element, minor element, and major oxide data for 57 elements from 112 sites where up to three samples were collected in a profile: C-horizon (till), B-C transitional horizon and B-horizon. Presented herein is a compilation of these data (BCGS_GF2021-11.zip), including analyses of field duplicate and laboratory duplicate samples and standard reference materials as part of the quality control measures.

At the Ace property (Fig. 2), subglacial till deposited by northwestward ice movement, ablation till, and colluvium conceals early to middle Paleozoic graphitic phyllite of the Downey Formation and mafic volcanic bedrock (Lett and Paulen, 2021). These rocks are suspected as the host for copper-zinc massive sulphide and gold-quartz vein mineralization based on evidence from sampling scattered outcrops and a boulder train. Following a sampling survey completed in 2000, Lett and Paulen (2021) reported that the concentrations of commodity and pathfinder metals Au, As, Bi, Co, Cu, Pb, Se, and Zn at the Ace property are higher in the <0.063 mm silt-clay fraction of the subglacial till compared to those in the B-horizon soil. However, Ag and Hg are higher in the B-horizon soil. The analysis of six different size fractions prepared by dry sieving till and soil samples revealed that Au and Pb could be present as discrete mineral grains. A multi-element anomaly (Co, Cu, Pb, Se, and Zn) in till and soil defines a ribbon-shaped dispersal train along the northern edge of the survey area.

At the Getty South property, about 5 km north of the former Bethlehem copper mine, porphyry sulphide mineralization contains pyrite, chalcopyrite, bornite, native copper, malachite, chrysocolla, azurite, tenorite, and molybdenite in fractures and disseminated in a brecciated quartz diorite phase of the Guichon Creek batholith (Late Triassic-Early Jurassic; McMillan et al., 2009). The mineralized quartz diorite is oxidized to a depth of 100 m below the bedrock surface and is partially covered by Eocene volcanic and sedimentary rocks (Parkinson and Fayman, 2010). Since the Getty South mineral claims were staked in 1903, the property has been explored by a number of companies including Trojan Consolidated Mines, Rio Tinto, Phelps Dodge Corporation and, most recently, Getty Copper Corporation. Diamond drilling programs by these companies and underground development of the Trojan Mine has established an initial deposit of 36 million tonnes of oxide and sulphide mineralization grading 0.47% Cu.

Samples of bedrock and unconsolidated sediment were collected systematically at the Getty South property. Up to 8 m of till deposited by a north to south ice advance covers the oxidized bedrock (Bobrowsky et al., 2002; Plouffe et al., 2016). The sampling design was to provide a three-dimensional glacial dispersal model in this type of terrain. A horizon soil, B horizon soil, till, and bedrock samples were collected in 1998 and 2000 from profiles along trenches excavated into bedrock

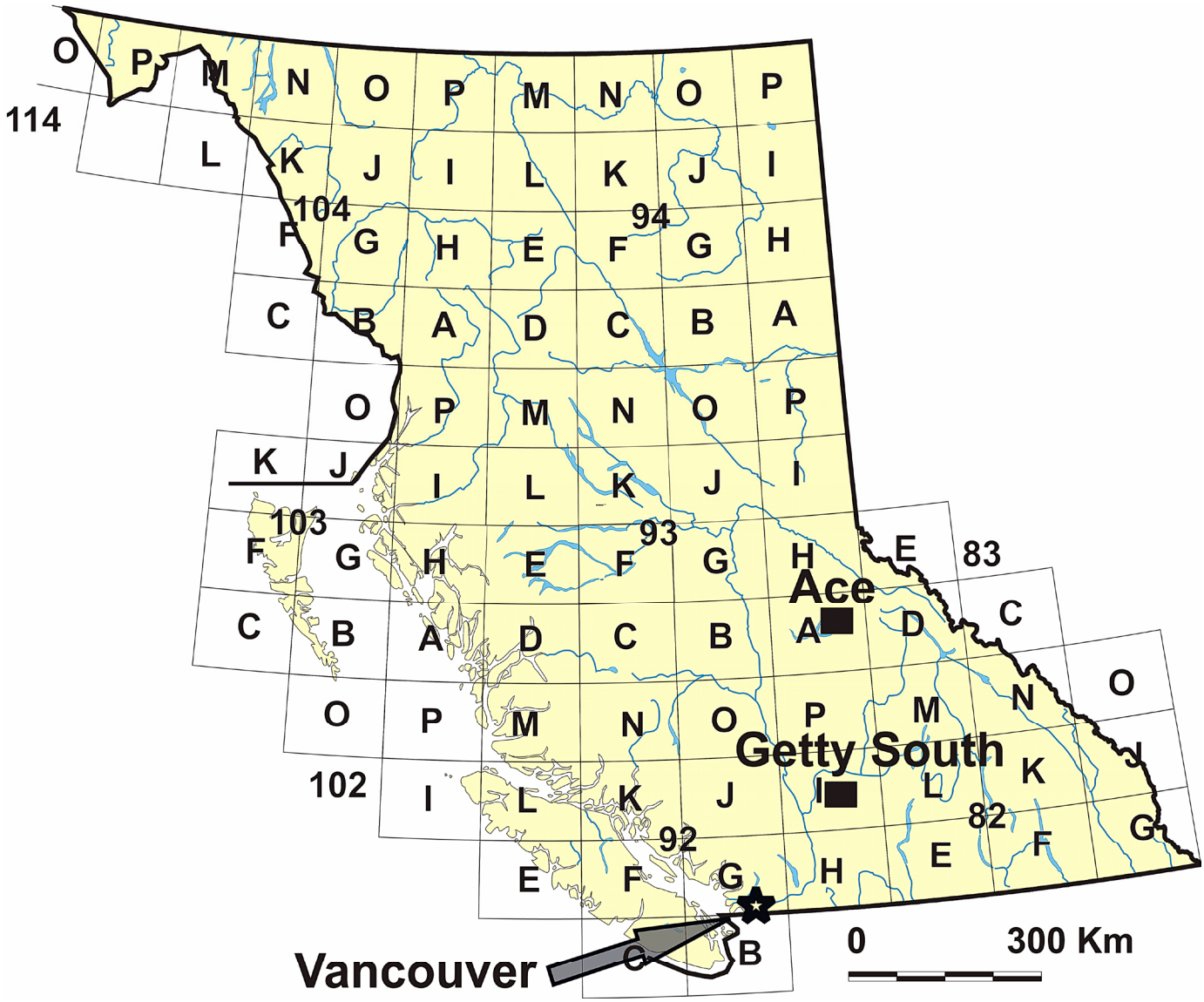

Fig. 1. Ace and Getty South property locations.

and from dug pits (Fig. 3). Elemental distributions differ significantly amongst the major pathfinder elements (Mo, As, Ag, Pb, Bi); although concentrations and spatial patterns of Cu distribution are the primary focus for this type of deposit, variations of the pathfinder elements provide a useful contrast for understanding the behaviour of subglacial comminution and dilution during the erosion of the source mineralization, sediment transport, and deposition (Bobrowsky et al., 2000). Soil and the parent glacial sediment samples (i.e., till) collected on the Ace property in 2000 (Lett and Paulen, 2021) and on the Getty property in 1998 and 2000 were dried and sieved to <0.063 mm (silt-clay fraction). A number of rock samples from trenches on the Getty property were jaw crushed and milled to < 0.050 mm. The <0.063 mm fraction of the B-horizon soil horizon, the transitional B-C horizon, and the C horizon from the Ace and Getty property was analyzed for more than 50 minor and trace elements and major oxides by a combination of two methods: modified aqua regia dissolution (1:1:1 solution of HNO_3-HCl-H_2O) followed by inductively coupled plasma mass spectrometry (ICP-MS) analyses on 0.5 g aliquots and a lithium metaborate/tetraborate fusion and dilute nitric acid digestion (HNO_3) followed by inductively coupled plasma emission spectroscopy (ICP-ES) on 0.2 g aliquots. All analyses were completed at Acme Analytical Laboratories Ltd. (now Bureau Veritas) in Vancouver, BC.

The samples were also analyzed at Acme Analytical Laboratories Ltd. for total carbon (TOT C), total sulphur (TOT-S), and loss on ignition (LOI) and for Au and 32 elements by instrumental thermal neutron activation at Activation Laboratories Ltd, Ancaster, Ontario. Five size fractions from selected Ace soil and till samples ranging from 1-2 mm to 0.125-0.063 mm and the Getty milled rock samples were analyzed for 35 trace elements by modified aqua regia dissolution followed by ICP-MS at Acme Analytical Laboratories Ltd. The Getty soil and till samples collected in 1998 were analyzed at Acme Analytical for 35 elements by a modified aqua regia dissolution

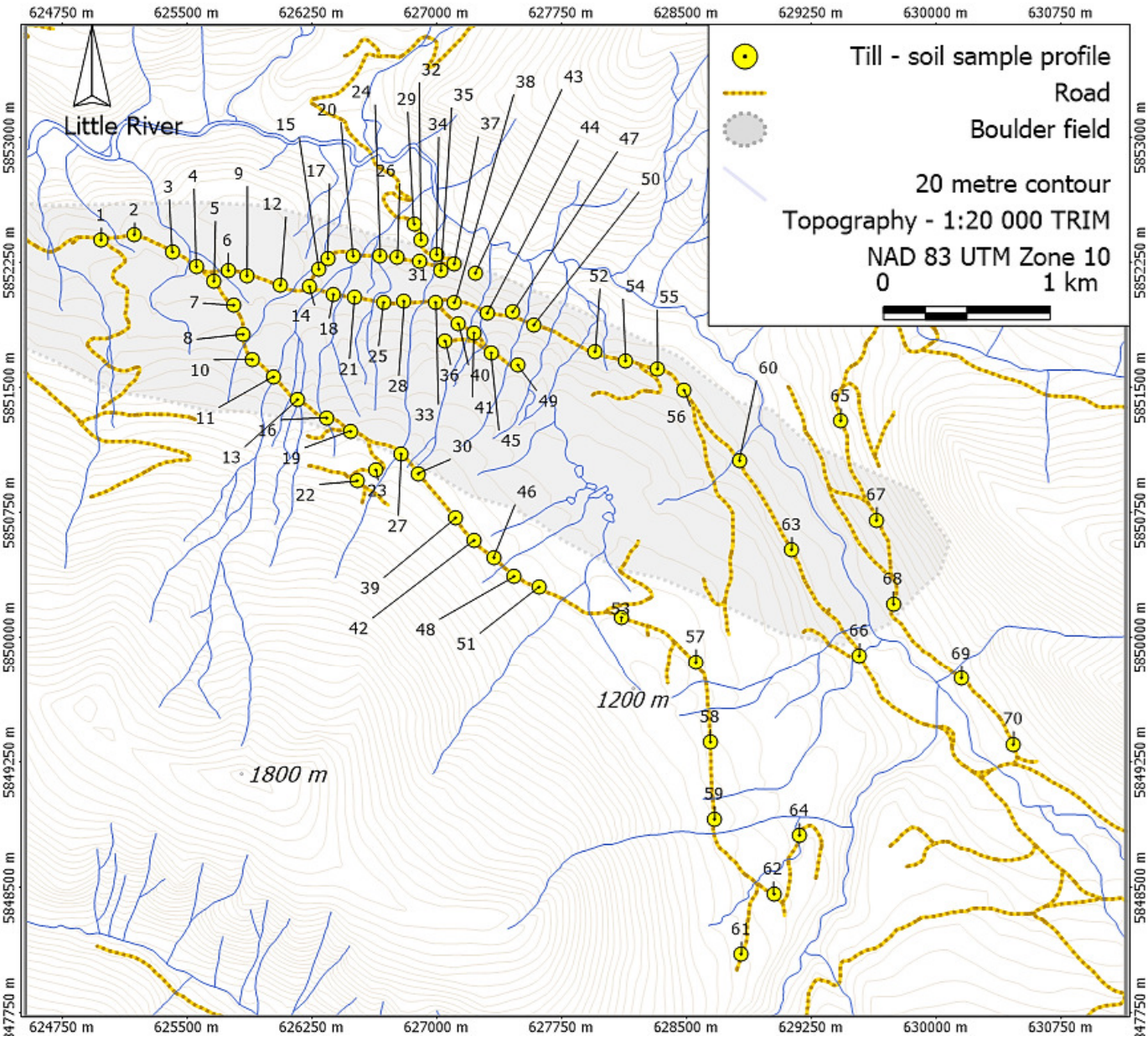

Fig. 2. Ace property soil and till sample profile locations. Sample numbers for the profiles are listed in Appendices 1 (Ace) and 2 (Ace).

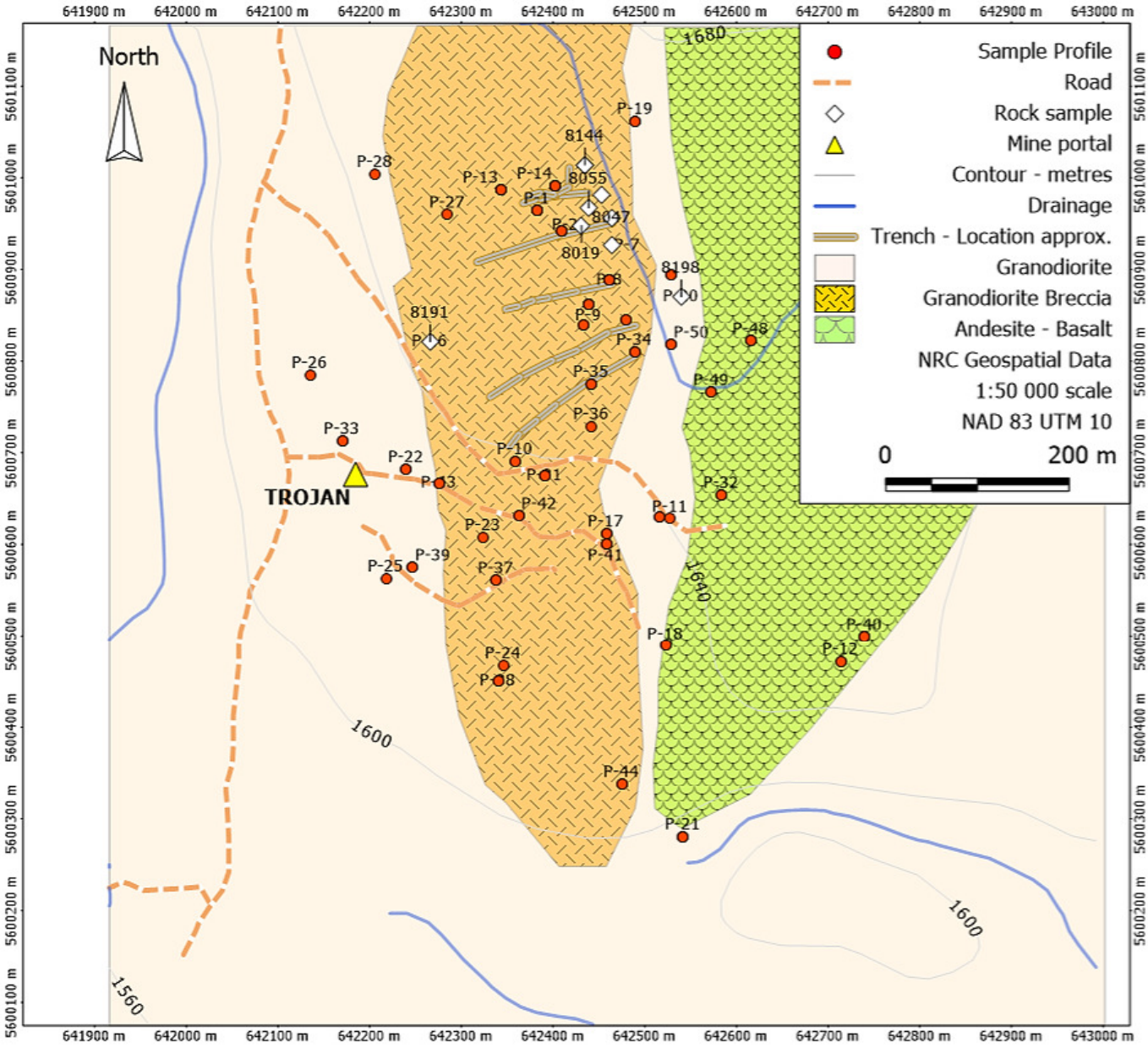

Fig. 3. Getty South property sample profile and rock sample locations. Samples for the profiles and rocks are listed in Appendices 3 (Getty South), 4 (Getty South) and 5 (Getty South).

followed by ultrasonic nebulizer inductively coupled plasma emission spectroscopy (ICP-UNES). Detection limits for both ICP-MS and ICP-UNES methods, the lithium metaborate fusion-inductively coupled plasma emission spectroscopy (LMB-ICP), carbon, sulphur, LOI and the INAA analysis are listed in Table 1.

Table 1. Detection limits (DL) in parts per billion (ppb), parts per million (ppm) and percent (pct) determined by modified aqua regia digestion - inductively coupled plasma mass spectrometry (ICP-MS), ultrasonic nebulizer inductively coupled plasma emission spectroscopy (ICP-UNES), lithium metaborate fusion-inductively coupled plasma emission spectroscopy (LMB-ICP), instrumental neutron activation (INAA) total carbon and total sulphur by Leco combustion (C-LECO; S-LECO) and loss on ignition (LOI).

Element	DL	Element	DL	Element	DL	Element	DL
Ag ppb ICP-UNES	30	Ag ppb ICP-MS	2	Au ppb INAA	2	SiO2 pct LMB-ICP	0.04
Al pct ICP-UNES	0.01	Al pct ICP-MS	0.01	As ppm INAA	0.1	Al2O3 pct LMB-ICP	0.03
As ppm ICP-UNES	2	As ppm ICP-MS	0.1	Ba ppm INAA	50	Fe2O3 pct LMB-ICP	0.04
Au ppb ICP-UNES	2000	Au ppb ICP-MS	0.2	Co ppm INAA	1	MgO pct LMB-ICP	0.01
B ppm ICP-UNES	3	B ppm ICP-MS	1	Cr ppm INAA	5	CaO pct LMB-ICP	0.01
Ba ppm ICP-UNES	2	Ba ppm ICP-MS	0.5	Cs ppm INAA	1	Na2O pct LMB-ICP	0.01
Bi ppm ICP-UNES	2	Bi ppm ICP-MS	0.02	Fe ppm INAA	0.01	K2O pct LMB-ICP	0.01
Ca pct ICP-UNES	0.01	Ca pct ICP-MS	0.01	Hf ppm INAA	1	TiO2 pct LMB-ICP	0.01
Cd ppm ICP-UNES	0.2	Cd ppm ICP-MS	0.01	Mo ppm INAA	1	P2O5 pct LMB-ICP	0.01
Co ppm ICP-UNES	1	Co ppm ICP-MS	0.1	Na pct INAA	0.01	MnO pct LMB-ICP	0.01
Cr ppm ICP-UNES	1	Cr ppm ICP-MS	0.5	Ni ppm INAA	100	Cr2O3 pct LMB-ICP	0.001
Cu ppm ICP-UNES	1	Cu ppm ICP-MS	0.01	Rb ppm INAA	15	Ba ppm LMB-ICP	5
Fe pct ICP-UNES	0.01	Fe pct ICP-MS	0.01	Sb ppm INAA	0.1	Ni ppm LMB-ICP	20
Ga ppm ICP-UNES		Ga ppm ICP-MS	0.02	Sc ppm INAA	0.1	Sr ppm LMB-ICP	10
Hg ppb ICP-UNES		Hg ppb ICP-MS	5	Ta ppm INAA	0.5	Zr ppm LMB-ICP	10
K pct ICP-UNES	0.01	K pct ICP-MS	0.01	Th ppm INAA	0.2	Y ppm LMB-ICP	10
La ppm ICP-UNES	1	La ppm ICP-MS	0.5	U ppm INAA	0.5	Nb ppm LMB-ICP	20
Mg pct ICP-UNES	0.01	Mg pct ICP-MS	0.01	Zn ppm INAA	50	Sc ppm LMB-ICP	1
Mn ppm ICP-UNES	1	Mn ppm ICP-MS	1	La ppm INAA	0.5	LOI pct FUS	0.1
Mo ppm ICP-UNES	1	Mo ppm ICP-MS	0.01	Ce ppm INAA	3	TOT C pct LECO	0.01
Na pct ICP-UNES	0.01	Na pct ICP-MS	0.001	Nd ppm INAA	5	TOT S pct LECO	0.01
Ni ppm ICP-UNES	1	Ni ppm ICP-MS	0.1	Sm ppm INAA	0.1	SUM	
P pct ICP-UNES	0.001	P pct ICP-MS	0.001	Eu ppm INAA	0.2		
Pb ppm ICP-UNES	2	Pb ppm ICP-MS	0.01	Tb ppm INAA	0.5		
S pct ICP-UNES		S pct ICP-MS	0.02	Yb ppm INAA	0.2		
Sb ppm ICP-UNES	0.2	Sb ppm ICP-MS	0.02	Lu ppm INAA	0.05		
Sc ppm ICP-UNES		Sc ppm ICP-MS	0.1				
Se ppm ICP-UNES		Se ppm ICP-MS	0.1				
Sr ppm ICP-UNES	1	Sr ppm ICP-MS	0.5				
Te ppm ICP-UNES		Te ppm ICP-MS	0.02				
Th ppm ICP-UNES	1	Th ppm ICP-MS	0.1				
Ti pct ICP-UNES	0.01	Ti pct ICP-MS	0.001				
Tl ppm ICP-UNES	0.2	Tl ppm ICP-MS	0.02				
U ppm ICP-UNES	5	U ppm ICP-MS	0.1				
V ppm ICP-UNES	2	V ppm ICP-MS	2				
W ppm ICP-UNES	2	W ppm ICP-MS	0.2				
Zn ppm ICP-UNES	1	Zn ppm ICP-MS	0.1				

The geochemical data, sample locations, and sample descriptions are detailed in Appendices 1 and 2 (Ace property) and 3,4 and 5 (Getty property). The Appendices, provided as Microsoft Excel files, contain two tabs: one with the data and a second one with a legend for the column headers and variable descriptions. The Appendix Column headers and the

Table 2. Appendix 1(Ace) column headers and description for soil and till samples analyzed by modified aqua regia -ICP-MS, lithium metaborate-ICP-ES, INAA, C, S and LOI.

Column Header	Description
Year	Project year (2000)
Sample	Project number, sample number e.g. 08010.
Profile Number	Profile number on Figure 2.
Sample Type	Analytical duplicate sample; Field duplicate; Standard reference material, Routine sample.
NTS	National topographic system (NTS) 1: 50,000 scale Map Number
UTM Zone	Universal Transverse Mercator Zone
UTM Easting	Universal Transverse Mercator (UTM) East coordinate.
UTM Northing	Universal Transverse Mercator (UTM) North coordinate.
Elevation (m)	Elevation above sea level in metres.
Sample Depth (m)	Depth from surface to sample collection point.
Parent material	Surficial material at profile site.
Sample material	Material sampled.
M-ppm-ICP-MS	Element in parts per million by a modified aqua regia - inductively coupled plasma mass spectrometry.
M-ppb-ICP-MS	Element in parts per billion by a modified aqua regia - inductively coupled plasma mass spectrometry.
M-pct-ICP-MS	Element in percent by a modified aqua regia - inductively coupled plasma mass spectrometry.
M-ppm-INA	Element in parts per million by instrumental neutron activation.
M-ppb-INA	Element in parts per billion by instrumental neutron activation.
M-pct-INA	Element in percent by instrumental neutron activation.
Mass-gr-BAL	Weight of sample used for instrumental neutron activation analysis.
M-pct-LMB-ICP	Element in percent by lithium metaborate fusion - Inductively coupled plasma emission spectroscopy.
M-ppm-LMB-ICP	Element in ppm by lithium metaborate fusion - Inductively coupled plasma emission spectroscopy.
LOI-pct-FUS	Loss on ignition at 1100^{o}C.
C-pct-LECO	Toal carbon in percent by Leco combustion.
S-pct-LECO	Total sulphur in percent by Leco combustion.
SUM	Sum of oxides by lithium metaborate fusion - Inductively coupled emission plasma spectroscopy in percent.
-	Value below detection limit.

Table 3. Appendix 2 (Ace) column headers and description for soil and till sample size fractions analyzed by modified aqua regia -ICP-MS.

Column Header	Description
Year	Sample collection and analysis year.
Sample - Size fraction	Sample number and mesh size of fraction analysed.
Sample type	Acme laboratory (analytical) duplicate; Field duplicate; Standard reference material; Routine sample.
Sample No.	Sample number.
Profile Number	Profile number on Figure 2.
NTS Map	National topographic system (NTS) 1: 50,000 scale Map Number.
UTM Zone	Universal Transverse Mercator Zone.
UTM Easting	Universal Transverse Mercator (UTM) East coordinate.
UTM Northing	Universal Transverse Mercator (UTM) North coordinate.
Elevation	Elevation above sea level in metres.
Depth-m	Depth to sample collection point.
Parent Material	Surficial material.
Sample Material	Material sampled.
M-ppm-ICP-MS	Element in parts per million by a modified aqua regia - inductively coupled mass spectrometry.
M-ppb-ICP-MS	Element in parts per billion by a modified aqua regia - inductively coupled mass spectrometry.
M-pct-ICP-MS	Element in percent by a modified aqua regia - inductively coupled mass spectrometry.
Sample Wt Gr	Weight of material recovered from fraction in grams.
Plus 10 mesh weight gr	Weight of plus 10 mesh fraction in grams.
-0.1	Values below detection limit.

Table 4. Appendix 3 (Getty South) column headers and description for soil and till samples analyzed by modified aqua regia -ICP-MS, lithium metaborate-ICP-ES, INAA, C, S and LOI.

Column Header	Description
Year	Sample collection and analysis year (1998)
Sample	Project number (8) and sample number e.g. 010.
Sample Type	Analytical duplicate sample; Field duplicate; Standard reference material, Routine sample.
Map Number	Profile number on Figure 3.
NTS	National topographic system (NTS) 1: 50,000 scale Map Number
UTM Zone	Universal Transverse Mercator Zone
UTM Easting	Universal Transverse Mercator (UTM) East coordinate.
UTM Northing	Universal Transverse Mercator (UTM) North coordinate.
Elevation (m)	Elevation above sea level in metres.
Profile Depth (m)	Depth to base on profile sampled.
Sample depth (M)	Depth to sample.
Sample type	Surficial material e.g. till, soil.
Sample description	Material description notes.
M-ppm-ICP-UNES	Element in parts per million by a modified aqua regia - ultrasonic nebulizer inductively coupled plasma emission spectroscopy.
M-ppb-ICP-UNES	Element in parts per billion by a modified aqua regia - ultrasonic nebulizer inductively coupled plasma emission spectroscopy.
M-pct-ICP-UNES	Element in percent by a modified aqua regia - ultrasonic nebulizer inductively coupled plasma emission spectroscopy.
M-ppm-INA	Element in parts per million by instrumental neutron activation.
M-ppb-INA	Element in parts per billion by instrumental neutron activation.
M-pct-INA	Element in percent by instrumental neutron activation.
Mass-gr-BAL	Weight of sample used for instrumental neutron activation analysis.
M-pct-LMB-ICP	Element in percent by lithium metaborate fusion - Inductively coupled emission spectroscopy.
M-ppm-LMB-ICP	Element in ppm by lithium metaborate fusion - Inductively coupled emission spectroscopy.
LOI-pct-FUS	Loss on ignition at 1100^{o}C.
C-pct-LECO	Total carbon in percent by Leco combustion.
S-pct-LECO	Total sulphur in percent by Leco combustion.
SUM	Sum of oxides by lithium metaborate fusion - Inductively coupled emission spectroscopy in percent.
-	Value below detection limit.
9999	No data.

Table 5. Appendix 4 (Getty South) column headers and description for soil and till samples analyzed by modified aqua regia -ICP-UNES, lithium metaborate-ICP-ES, INAA, C, S and LOI.

Column Header	Description
Year	Sample collection and analysis year.
Sample	Project number (8) and sample number e.g. 300.
Sample Type	Analytical duplicate sample; Field duplicate; Standard reference material, Routine sample.
Map Number	Profile number on Figure 3.
NTS	National topographic system (NTS) 1: 50,000 scale Map Number
UTM Zone	Universal Transverse Mercator Zone
UTM Easting	Universal Transverse Mercator (UTM) East coordinate.
UTM Northing	Universal Transverse Mercator (UTM) North coordinate.
Elevation (m)	Elevation above sea level in metres.
Profile Depth (m)	Depth to base on profile sampled. (9999 - not recorded)
Sample depth (M)	Depth to sample.
Sample type	Surficial material e.g. till, soil.
Material (soil horizon)	Material description.
M-ppm-ICP-MS	Element in parts per million by a modified aqua regia - inductively coupled mass spectrometry.
M-ppb-ICP-MS	Element in parts per billion by a modified aqua regia - inductively coupled mass spectrometry.
M-pct-ICP-MS	Element in percent by a modified aqua regia - inductively coupled mass spectrometry.
M-ppm-INA	Element in parts per million by instrumental neutron activation.
M-ppb-INA	Element in parts per billion by instrumental neutron activation.
M-pct-INA	Element in percent by instrumental neutron activation.
Mass-gr-BAL	Weight of sample used for instrumental neutron activation analysis.
M-pct-LMB-ICP	Element in percent by lithium metaborate fusion - Inductively coupled emission spectroscopy.
M-ppm-LMB-ICP	Element in ppm by lithium metaborate fusion - Inductively coupled emission spectroscopy.
LOI-pct-FUS	Loss on ignition at 1100^{o}C.
C-pct-LECO	Carbon in percent by Leco combustion.
S-pct-LECO	Sulphur in percent by Leco combustion.
SUM	Sum of oxides by lithium metaborate fusion - Inductively coupled emission spectroscopy in percent.
-	Value below detection limit.

Table 6. Appendix 5 (Getty South) column headers and description for rock samples analyzed by modified aqua regia -ICP-MS and S.

Column Header	Description
Year	Sample collection and analysis year (1998)
Sample	Project number (8) and sample number e.g. 010.
Sample Type	Rock
Profile number	Profile number on Figure 3.
NTS	National topographic system (NTS) 1: 50,000 scale Map Number
UTM Zone	Universal Transverse Mercator Zone
UTM Easting	Universal Transverse Mercator (UTM) East coordinate.
UTM Northing	Universal Transverse Mercator (UTM) North coordinate.
Profile Depth (m)	Depth to base on profile sampled.
Figure 3 Map Unit	Geological unit shown on Figure 3.
Sample description	Rock type description from field notes.
M-ppm-ICP-MS	Element in parts per million by a modified aqua regia - inductively coupled plasma mass spectrometry.
M-ppb-ICP-MS	Element in parts per billion by a modified aqua regia - inductively coupled plasma mass spectrometry.
M-pct-ICP-MS	Element in percent by a modified aqua regia - inductively coupled plasma mass spectrometry.
S-pct-LECO	Sulphur in percent by Leco combustion.
-	Less than detection limit.
9999	No data.

variable descriptions are summarized in Tables 2 to 5.The list of elements in each Appendix follow the same order with some discrepancies because the analytical methods were different in 1998 and 2000. Quality control data in the Appendices include the following.

- Field duplicate samples. Typically, a field duplicate was collected within a batch of twenty routine soil and till samples to estimate overall sampling and analytical variability. For the Ace survey, three field duplicate samples were collected at a number of sites. Field duplicate samples were collected from the same site and the same depth as the routine sample.
- Laboratory duplicate samples. After sample drying and sieving, one of the field duplicate sample was split into two samples representing a field and laboratory duplicate pair. These were inserted into the batch of twenty routine samples for analysis.
- Standard reference materials. Each batch of twenty routine samples includes a standard reference material. In addition to CANMET Till 4 from Natural Resources Canada, we used three internal British Columbia Geological Survey standards: GSB till 99, a bulk till from near Adams Lake; Red Dog 97, a bulk stream sediment from Northern Vancouver Island; and Clisbako 99, a bulk lake sediment from central British Columbia.

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