Evidence of Westward Glacial Dispersal Along a Till Geochemical Transect of the Copper Star Cu±Mo±Au Occurrence, West-central British Columbia

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ABSTRACT

An 2.5 km east-west geochemical sampling transect over the Copper Star porphyry Cu±Mo±Au mineral occurrence in an area of a known ice-flow reversal reveals evidence for dominantly westward (locally 290°) glacial dispersal. The highest Cu (686 ppm) and Mo (5 ppm) values in the till transect occur directly west of the occurrence and generally decrease westward. The second highest Cu value (195 ppm), however, occurs in till directly east of the occurrence suggesting that a component of eastward dispersal also occurred. These observations are consistent with the ice-flow model for the area that predicts both eastward and westward dispersal. Dispersal distance from the mineral occurrence to the highest Cu concentration in till is short, probably reflecting the shallow till depth (<1 m) at the occurrence. In addition elevated Au and Ag at two sites at the east end of the transect suggests potential precious metal mineralization in that area.

INTRODUCTION

During the summer 2000 field season, a till geochemical study was initiated in the vicinity of the Copper Star porphyry Cu±Mo±Au mineral occurrence (MINFILE 093L 326), within the Chisholm Lake claim group. Located approximately 45 km southwest of Houston, BC (Figure 1), this is an area with extensive Quaternary sediment cover and relatively little bedrock outcrop.

The discovery of angular mineralized granodiorite boulders in a new roadcut led to the staking of the original CL claims which became known as the Chisholm Lake claim group. When the till geochemical samples were collected the claim group was under option by Imperial Metals Incorporated. Although the claim name and ownership has since changed (now West and Thompson claim group owned by Lowprofile Ventures Ltd.), the name Chisholm Lake claim group will be used in this report.

The objectives of this study are to:

- determine if till geochemistry can detect mineralization associated with the Copper Star porphyry Cu±Mo±Au mineral occurrence;
- evaluate dominant detrital dispersal direction of mineralization in till; and
- assess if till geochemistry can enlarge the area of interest by identifying new geochemical exploration targets.

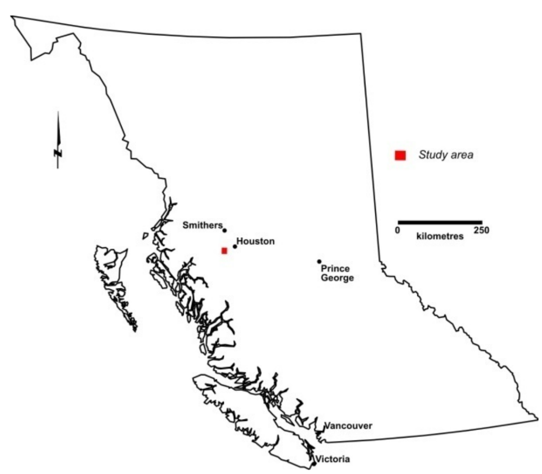

Figure 1. Location of study area.

The primary goal of this study is to document major, minor and trace element concentrations in tills adjacent to a known porphyry Cu±Mo±Au mineral occurrence. These geochemical data will enable meaningful assessments of new regional-scale till geochemical data being collected in the region and provide a means of comparison for other explorationists working in the area, who are using surface geochemical datsets (e.g., stream sediments, till, etc.).

LOCATION AND PHYSIOGRAPHY

The study area is located approximately 45 km southwest of Houston, BC, on the north side of Morice River (Figures 1 and 2), near the border between NTS mapsheets 093L/03 and 06. Including the Copper Star porphyry Cu±Mo±Au mineral occurrence, and associated Chisholm Lake claim group, the study area is accessible by forest service roads and a single lane bridge that crosses Morice River.

The study area is situated in the Nechako Plateau, a subdivision of the Interior Plateau, which can be described as an area of low relief with flat or gently rolling topography (Holland, 1976). The majority of the Nechako Plateau is mantled by a thick package of glacial sediments. Within the study area the dominant Quaternary sediment is till. Although bedrock outcrop is relatively uncommon, some exposures can be found at the stoss (i.e., up-ice) end of crag-and-tail forms, along lake shorelines and stream or river courses, and in upland areas.

BEDROCK GEOLOGY

The Chisholm Lake area, located within Stikine Terrane, is included in regional 1:250 000-scale bedrock mapping completed by Tipper (1976; Figure 2), and the bedrock mapping compilation of Massey et al. (2005). To date, prospecting, geologic mapping, percussion drill program, induced polarization lines, and soil sampling have been conducted on the property and have been used to build upon this original, regional-scale mapping. Much of this more detailed work is presented by Robertson (1999) and is, in part, summarized here.

The west half of the study area is underlain by maroon, green, and purple andesites to dacites that belong to the Telkwa Formation of the Lower Jurassic Hazelton Group. A north-trending fault located just east of the Copper Star mineral occurrence separates these volcanic rocks from sedimentary rocks of the Lower Cretaceous Skeena Group. Located near the contact of these two units is a previously unmapped quartz monzonite stock that appears to be lithologically similar to rocks of the Late Cretaceous Bulkley plutonic suite. In the region, these Late Cretaceous intrusives are associated with many porphyry Cu±Mo±Au occurrences, including mineralization in the Main and East zone orebodies at Huckleberry Mine (Carter, 1981; MacIntyre, 1985; Jackson and Illerbrun, 1995). A line of shallow percussion drill holes (3.6 to 16.6 m below surface), completed at 20 m spacing, suggests this stock is at least 1 km in diameter in the east-west direction.

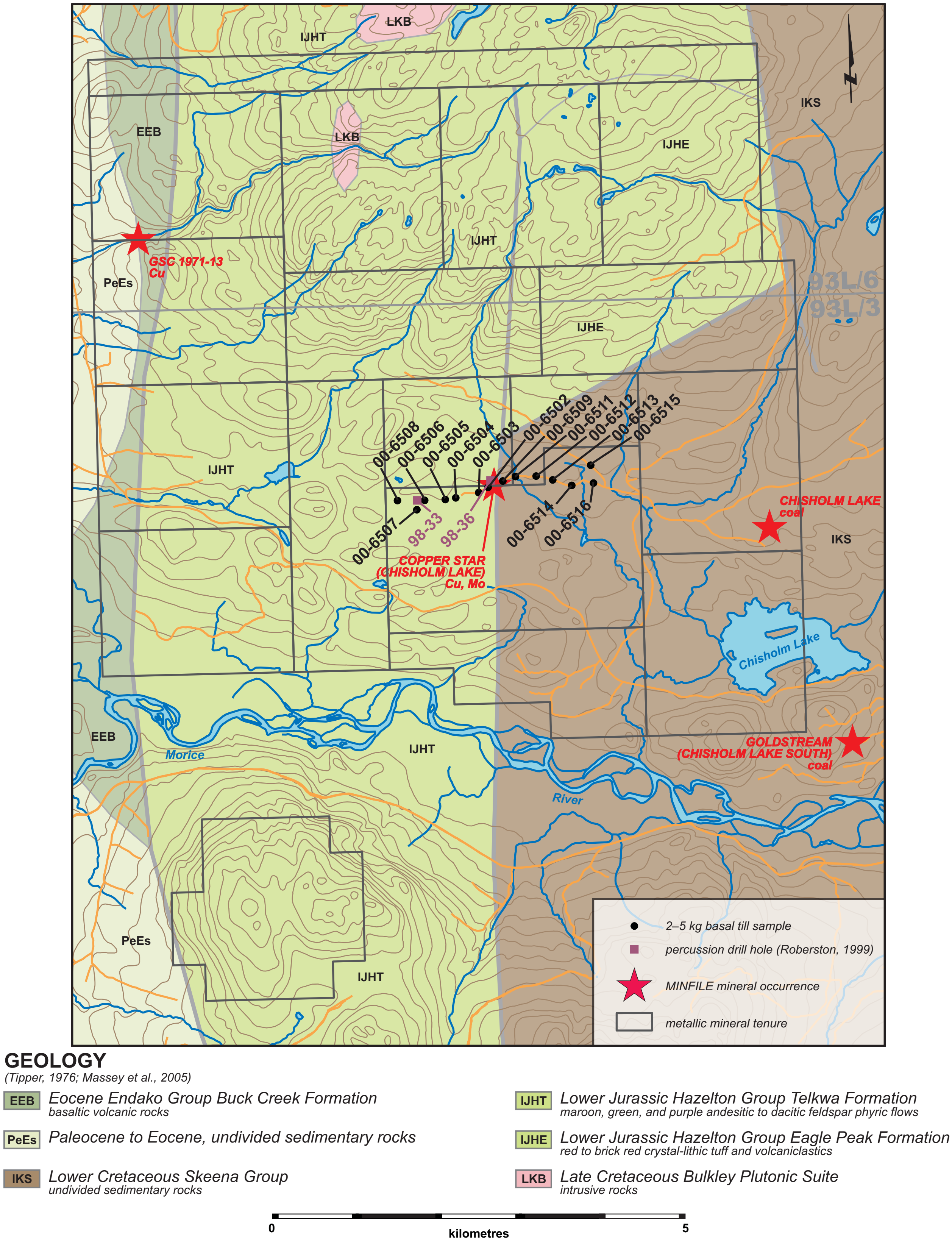

Figure 2. Bedrock geology of study area. Included here are locations of all till samples and percussion drill holes with the two highest Cu values (Robertson, 1999).

Based on percussion drill hole results and bedrock sampling at surface, mineralization observed so far appears to be hosted within the stock itself, not the adjacent country rocks. The best intersection in this drill program was 1.8 m of 0.494% Cu in a quartz-rich intrusive (likely a quartz-rich phase of the quartz monzonite stock). As indicated in percussion drill logs, depth to bedrock (or Quaternary sediment thickness) averages 2.7 m, although locally it can be >7 m (Robertson, 1999).

GLACIAL AND ICE-FLOW HISTORY

The glacial and ice-flow history of the study area and surrounding region was described by Stumpf et al. (2000), Ferbey and Levson (2001a, b), Ferbey and Levson (2002), and Ferbey (2004, 2010). Results from these studies indicate there was an ice-flow reversal in west-central British Columbia during the Late Wisconsinan Fraser Glaciation maximum. During the onset of glaciation, ice flowed radially from accumulation centres, such as the Coast Mountains, towards central BC. Sometime during the glacial maximum, however, the ice-divide over the Coast Mountains migrated east into central British Columbia resulting in an ice-flow reversal. Glaciers then flowed west across some parts of the western Nechako Plateau, over the Coast Mountains and towards the Pacific Ocean. Eastward ice-flow resumed once the ice divide migrated back over the axis of the Coast Mountains and continued until the close of the Late Wisconsinan glaciation.

It is the presence of west-directed ice-flow indicators in both high elevation (>1500 m) and low elevation valley settings that enabled Stumpf et al. (2000), Ferbey and Levson (2001a, b), Ferbey and Levson (2002), and Ferbey (2004) to assign this ice-flow reversal event to the Fraser Glaciation maximum. A review of 1:70 000-scale black and white aerial photographs of the study area shows the presence of landform-scale features such as crag-and-tail ridges, in a lower elevation setting, that indicate ice-flow towards the west-northwest (approximately 290°).

An ice-flow reversal was also identified by Tipper (1994) in his investigation into the glacial and ice-flow history of NTS 093L. Glacial and geomorphic features in high ground located 58 km east of the study area, in the vicinity of the former producing Equity Silver Cu-Ag-Au mine, were highlighted as evidence for this ice-flow reversal. In Tipper's investigation, however, this reversal was attributed to an earlier glaciation or perhaps earlier phase of the Late Wisconsinan Fraser Glaciation, not the Late Wisconsinan glacial maximum as has been described above. Timing aside, evidence for an ice-flow reversal in the Equity Mine area indicates that an ice-divide migrated east at least this far at some point during later Pleistocene time. Data presented by Tipper (1994) show glacial grooves or lineations in the Chisholm Lake area oriented towards 112-122° (or east-southeast).

Given the location of these studies, and the steamlined glacial features identified in aerial photographs of the study area, it is likely that the Chisholm Lake area experienced a similar ice-flow reversal, which would have influenced net transport direction of basal till.

TILL SAMPLE COLLECTION

Fourteen till samples, each weighing 2-5 kg, were collected for this study from roadcuts along an east/west oriented forestry road (Figure 2). The sampled transect is 2.5 km long. The Copper Star Cu±Mo±Au mineral occurrence is located near the mid-point of the transect (Figure 2). Till exposures along this road are good which enabled efficient sample collection and confident interpretation of sample medium.

At each till sample site, sedimentological data were collected such as: matrix texture, colour, and density; primary and secondary structures; and clast size and abrasion characteristics (e.g., striae). Notes were also made on type of exposure, terrain map unit, geomorphology (e.g., topographic position, aspect, slope, drainage), local stratigraphy, clast lithology, and any evidence of mineralization. The proximity of sample sites to bedrock outcrops and the lithologies at these outcrops were also noted. Average sample depth was 99 cm.

Laboratory Methods

Samples collected for this study were air dried, disaggregated, and sieved to the silt plus clay-sized fraction (<0.063 mm) at Bondar Clegg Canada Limited (Vancouver, BC). For each sample, a 1.0 g split was analyzed for a total of 37 trace elements by inductively coupled plasma mass spectrometry (ICP-MS), following an aqua-regia digestion, at Acme Analytical Laboratories Limited (Vancouver, BC). The elements determined for using this analytical method, and detection limits, are summarized in Table 1. Aqua regia ICP-MS determinations for all 14 till samples are provided in Appendix A.

A 25-30 g sample-split was also analyzed for 35 elements by instrumental neutron activation analysis (INAA) at Activation Laboratories, Limited (Ancaster, ON). The elements determined for using this analytical method, and detection limits, are summarized in Table 2. Instrumental neutron activation determinations for all 14 till samples are provided in Appendix B.

Quality Control

Quality control measures implemented as part of this study included one analytical duplicate (a sample split after sample preparation but before analysis), and one in-house BCGS reference standard. Analytical determinations for select elements by aqua regia ICP-MS and INAA, for these quality control measures, are presented in Tables 3 and 4, respectively.

RESULTS

Summary statistics for aqua regia ICP-MS and INAA determinations of select elements are presented in Tables 5 and 6, respectively. Figure 3 presents Cu, Mo, Au, and Ag values in tills of the study area and shows the relative position of till sample locations, the Copper Star porphyry Cu±Mo±Au mineral occurrence, and percussion drill holes presented by Robertson (1999), including the locations of the two holes with the highest Cu values (hole 98-33 with 4940 ppm Cu and hole 98-36 with 2120 ppm Cu). The Cu values indicated in Figure 3 for the percussion holes is the top most assay for a given hole, which is assumed to occur at or near the

ELEMENT		DETECTION LIMIT	UNIT
Aluminum	**Al**	0.01	%
Antimony	**Sb**	0.02	ppm
Arsenic	**As**	0.1	ppm
Barium	**Ba**	0.5	ppm
Bismuth	**Bi**	0.02	ppm
Boron	**B**	1	ppm
Cadmium	**Cd**	0.01	ppm
Calcium	**Ca**	0.01	%
Chromium	**Cr**	0.5	ppm
Cobalt	**Co**	0.1	ppm
Copper	**Cu**	0.01	ppm
Gallium	**Ga**	0.02	ppm
Gold	**Au**	1	ppb
Iron	**Fe**	0.01	%
Lanthanum	**La**	0.5	ppm
Lead	**Pb**	0.01	ppm
Magnesium	**Mg**	0.01	%
Manganese	**Mn**	1	ppm
Mercury	**Hg**	5	ppb
Molybdenum	**Mo**	0.01	ppm
Nickel	**Ni**	0.1	ppm
Phosphorus	**P**	0.001	%
Potassium	**K**	0.01	%
Scandium	**Sc**	0.1	ppm
Selenium	**Se**	0.1	ppm
Silver	**Ag**	2	ppb
Sodium	**Na**	0.001	%
Strontium	**Sr**	0.5	ppm
Sulphur	**S**	0.02	%
Tellurium	**Te**	0.02	ppm
Thallium	**Tl**	0.02	ppm
Thorium	**Th**	0.1	ppm
Titanium	**Ti**	0.001	%
Tungsten	**W**	0.2	ppm
Uranium	**U**	0.1	ppm
Vanadium	**V**	2	ppm
Zinc	**Zn**	0.1	ppm

Table 1. Elements analzyed for, and detection limits, by aqua regia ICP-MS.

ELEMENT		DETECTION LIMIT	UNIT
Antimony	**Sb**	0.1	ppm
Arsenic	**As**	0.5	ppm
Barium	**Ba**	50	ppm
Bromine	**Br**	0.5	ppm
Calcium	**Ca**	1	%
Cerium	**Ce**	3	ppm
Cesium	**Cs**	1	ppm
Chromium	**Cr**	5	ppm
Cobalt	**Co**	1	ppm
Europium	**Eu**	0.2	ppm
Gold	**Au**	2	ppb
Hafnium	**Hf**	1	ppm
Iridium	**Ir**	5	ppb
Iron	**Fe**	0.02	%
Lanthanum	**La**	0.1	ppm
Lutetium	**Lu**	0.05	ppm
Mercury	**Hg**	1	ppm
Molybdenum	**Mo**	1	ppm
Neodymium	**Nd**	5	ppm
Nickel	**Ni**	20	ppm
Rubidium	**Rb**	15	ppm
Samarium	**Sm**	0.1	ppm
Scandium	**Sc**	0.1	ppm
Selenium	**Se**	3	ppm
Silver	**Ag**	5	ppm
Sodium	**Na**	0.01	%
Strontium	**Sr**	500	ppm
Tantalum	**Ta**	0.5	ppm
Terbium	**Tb**	0.5	ppm
Thorium	**Th**	0.5	ppm
Tin	**Sn**	100	ppm
Tungsten	**W**	1	ppm
Uranium	**U**	0.5	ppm
Ytterbium	**Yb**	0.2	ppm
Zinc	**Zn**	50	ppm

Table 2. Elements analzyed for, and detection limits, by INAA.

	Cu (ppm) ICP-MS	Mo (ppm) ICP-MS	Pb (ppb) ICP-MS	Zn (ppm) ICP-MS	Ag (ppb) ICP-MS	Ni (ppm) ICP-MS	Hg (ppb) ICP-MS
Analytical duplicate							
first determination	28.71	0.46	10.32	54.5	19	20.9	23
second determination	27.62	0.46	9.81	53.4	15	20.1	26
Reference Standard							
this study	182.32	0.82	235.87	341.8	1478	224.1	411
reference value	179.13	0.80	221.21	348.4	1473	212.7	373

Table 3. Determinations for select elements by aqua regia ICP-MS for quality control measures.

	Au (ppb) INAA	As (ppm) INAA	Sb (ppm) INAA	Cr (ppm) INAA
Analytical duplicate				
first determination	-2	14.4	1.1	81
second determination	-2	13	1	76
Reference Standard				
this study	30	67.3	15	380
reference value	34	67.9	15.5	390

Table 4. Determinations for select elements by INAA for quality control measures.

	Cu (ppm) ICP-MS	Mo (ppm) ICP-MS	Pb (ppm) ICP-MS	Zn (ppm) ICP-MS	Ag (ppb) ICP-MS	Ni (ppm) ICP-MS	Hg (ppb) ICP-MS
detection limit	0.01	0.01	0.01	0.1	2	0.1	5
maximum	686.10	4.98	14.34	99.3	101	40.3	59
minimum	27.62	0.39	6.95	52.4	15	19.1	24
mean	105.40	1.14	9.41	74.4	46	28.3	44
median	50.79	0.81	8.85	77.2	41	29.3	47
n=	14	14	14	14	14	14	14

Table 5. Summary statistics for select elements by aqua regia ICP-MS analysis.

	As (ppm) INAA	Sb (ppm) INAA	Cr (ppm) INAA
detection limit	0.5	0.1	5
maximum	90	1.6	120
minimum	2	0.8	62
mean	30	1.0	95
median	19	1.0	99
n=	14	14	14

Table 6. Summary statistics for select elements by INAA.

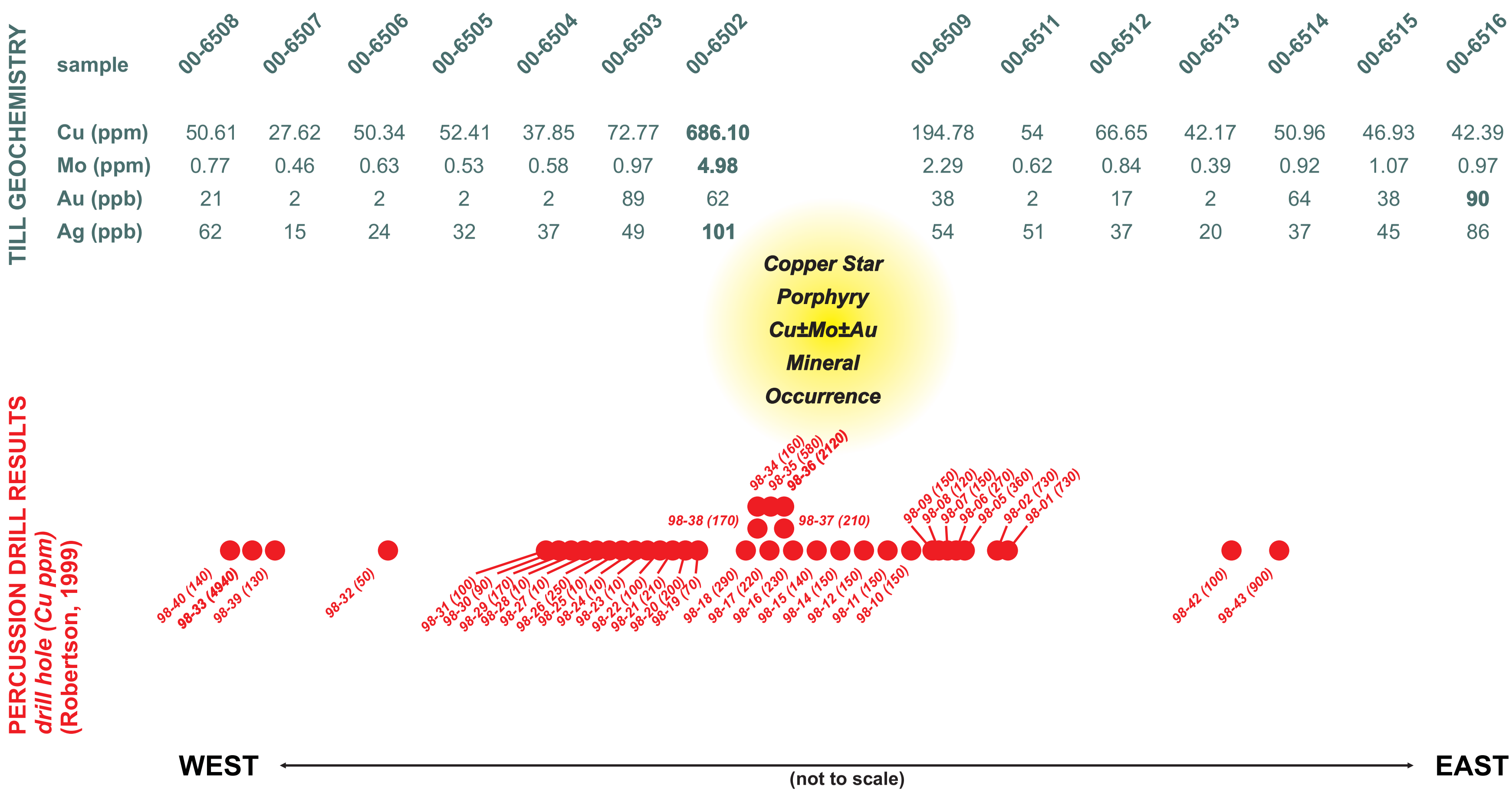

Figure 3. Determinations for Cu, Mo, Au, and Ag in till samples (in green). Copper values in bedrock at the bedrock/till interface are also presented (in red). Note that the locations of till samples, the Copper Star mineral occurrence and percussion drill holes are relative and not to scale.

Quaternary sediment/bedrock interface. In this study, the background value in till is considered to be the median value for a given element (see Tables 5 and 6).

Maximum Cu for the study area is 686.10 ppm (sample 00-6502) while the median Cu value is 50.79 ppm. The maximum Mo and Ag values (4.98 ppm Mo and 101 ppb Ag) occurs within the same sample. This sample is located immediately west of the Copper Star porphyry Cu±Mo±Au mineral occurrence and percussion hole 98-36 (2120 ppm Cu; Figures 3 and 4). Percussion drill logs indicate bedrock in the vicinity of sample 00-6502 is approximately 1.5 to 2.1 m below surface. Depth to bedrock at percussion hole 98-36 is 0.3 m.

The second highest Cu and Mo values (194.78 ppm and 2.29 ppm, respectively) occur in sample 00-6509, which is located immediately east of the Copper Star occurrence. The third highest Cu and Mo, and second highest Au values (72.77 ppm Cu, 0.97 ppm Mo, and 89 ppb Au) occur in sample 00-6503 which is located 145 m west of sample 00-6502. These data suggest both eastward and westward dispersal from the second highest Cu value in bedrock (percussion drill hole 98-36).

It is interesting to note that in the vicinity of percussion hole 98-33, which has the highest Cu value of the percussion drill program (4940 ppm Cu; Robertson, 1999), till samples only contain median values or less of Cu and Mo concentrations. Percussion hole 98-33 is located approximately 900 m west of percussion drill hole 98-36. Till sample 00-6508 may have low Cu and Mo concentrations because it is over 300 m west of, and is not directly in the down-ice direction from, percussion drill hole 98-33. Alternatively, depth to bedrock increases significantly in this direction which may result in lower Cu and Mo at surface.

The maximum Au value and second highest Ag (90 ppb Au and 86 ppb Ag; sample 00-6516) occurs at the very eastern end of the sample transect, approximately 1.3 km east of the Copper Star mineral occurrence (Figures 3 and 4). The second highest Au value (89 ppb Au; sample 00-6503) occurs approximately 250 m west of the Copper Star mineral occurrence, and also contains the third highest Cu value (72.77 ppm Cu).

DISCUSSION

Till geochemistry is able to detect Cu, Mo, and Au mineralization within the Chisholm Lake claim group. As seen in Table 7, Cu, As, and Sb values in tills of the study area are similar to determinations from other regional till geochemical surveys, including those from the Babine porphyry copper belt. Samples 00-6502 and 00-6509 contain Cu, Mo, and As values that are above background values for all other surveys listed, and would be included in the >98th percentile for the same surveys. Gold values from the data presented in this study are also in the >98th percentile for the surveys listed in Table 7.

Levson and Giles (1995), Paulen (2001), and Levson (2002) suggest that there is a general relationship between till thickness and detrital transport distance, with an increase in till thickness resulting in an increase in transport distance. Drill logs presented by

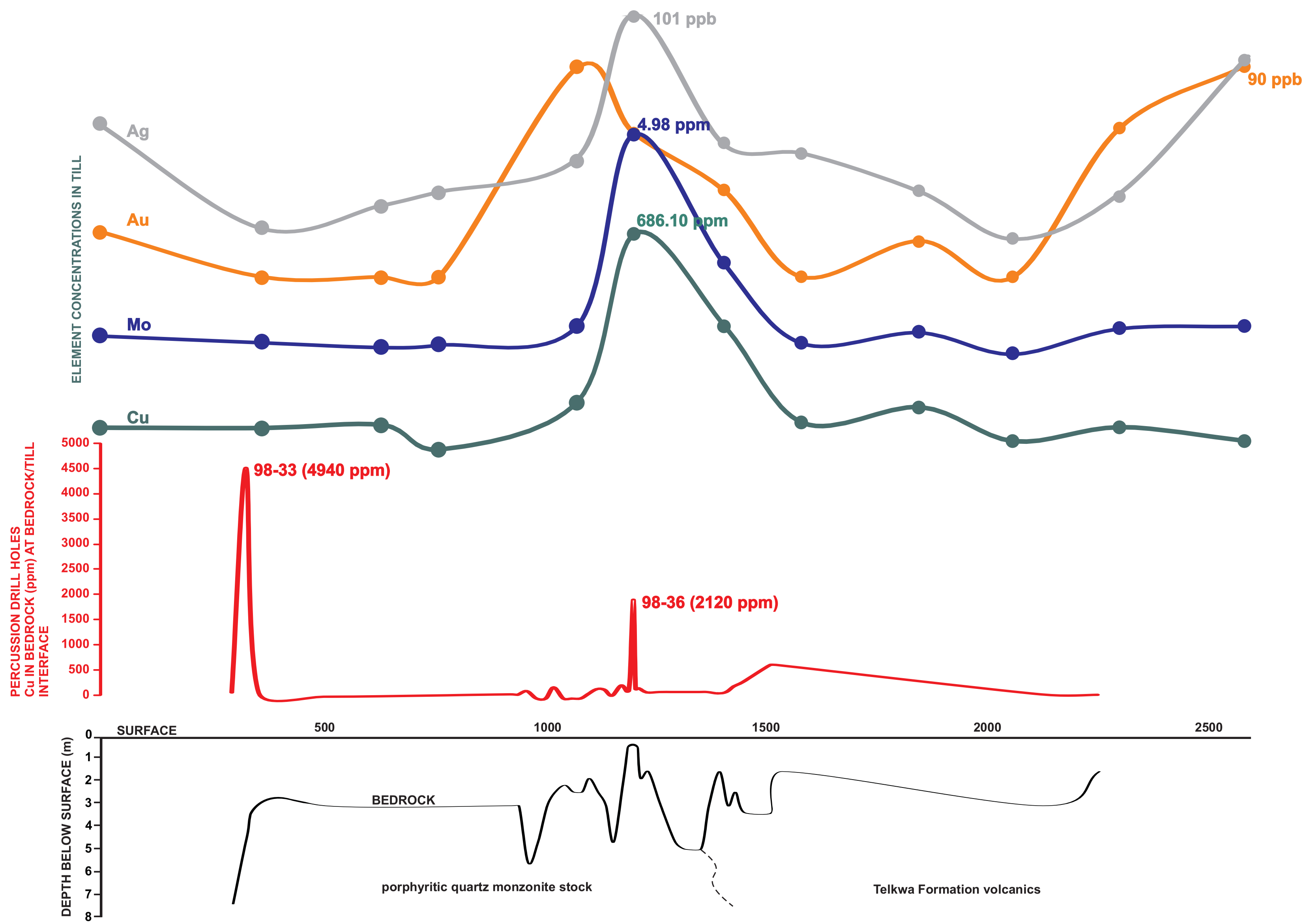

Figure 4. Determinations for Cu, Mo, Au, and Ag in till samples for the 2.5 km transect (upper diagram). Copper values in bedrock at the bedrock/till interface are also presented (in red; Robertson, 1999). Presented in lower diagram is till thickness (or depth to bedrock) across the study area transect (Robertson, 1999). Units are not given for element concentrations in till but locations of maximum values are. All data are plotted to scale across the transect.

TILL GEOCHEMICAL SURVEY	Cu (ppm) median	Cu (ppm) max	As (ppm) median	As (ppm) max	Sb (ppm) median	Sb (ppm) max
[1]NTS 93C/01, 08, 09, 16	23	58	2.1	43	0.4	4.6
[2]NTS 93L/09, 16, 93M/01, 02, 07, 08	41	1550	15	130	1.4	30
[3]NTS 93F/05, 12	24	145	10.4	51	1.4	5.4
[4]NTS 92O/05, 12	43	3113	7	30	1.1	11
[5]NTS 93K, N	63	409	13	69.8	1.9	10.4
[6]NTS 93B/04, 05	25.34	46.45	3.5	20	0.6	1.0
[7]Chisholm Lake claim block	50.79	686.10	22.2	15.1	1.6	1.0

[1] Lett et al. (2006).
[2] Levson (2001, 2002).
[3] Levson and Mate (2002).
[4] Plouffe and Ballantyne (1994).
[5] Plouffe and Ballantyne (1993).
[6] Ferbey (2009).
[7] This study.

Table 7. A comparison of median and maximum values for select elements from five different regional-scale till geochemical surveys, conducted in central British Columbia, to those of this study.

Robertson (1999) indicate that till occurring in the study area is relatively thin, and in the vicinity of percussion drill hole 98-36, it is <1 m thick. When considering this and what is known about a Late Wisconsinan ice-flow reversal in the region, the occurrence of elevated Cu values in till immediately adjacent to and west of percussion drill hole 98-36, and the near background Cu values in till east of percussion drill hole 98-33 (the highest Cu value in bedrock; Figures 3 and 4), it appears that mineralization within the study area has been transported towards the west. That is to say, the bedrock source of Cu in till sample 00-6502 is more likely in the area of percussion drill hole 98-36 than 98-33. With the exception of till sample 00-6509 which is located immediately east of the Copper Star occurrence, this idea of westward transport is further supported by the occurrence of at or near background values of Cu in tills east of percussion drill hole 98-36. If elevated Cu in till sample 00-6502 was related to transport from a bedrock source near percussion drill hole 98-33, then similarly high Cu values in till would be expected a similar distance east of percussion drill hole 98-36. A review of Cu values in till here shows that this is not the case (Figures 3 and 4).

This idea of westward detrital transport in tills is in agreement with work presented by Ferbey and Levson (2007) that shows that the region's ice-flow reversal has influenced the dispersal direction of mineralization from ore bodies of Huckleberry Mine, resulting in westward transport of Cu in till. Follow-up till sampling within the Chisholm Lake claim group, in particular west of percussion drill hole 98-33, is required to further test this idea of westward detrital dispersal. It should be noted that the till sample transect presented here is oblique to ice-flow direction in the study area. Till sampling north and south of the Copper Star occurrence would also be required to confirm the relationship between till sample 00-6502 and bedrock near this occurrence.

SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

Analytical results from 14 basal till samples collected in the vicinity of the Copper Star Cu±Mo±Au porphyry mineral occurrence, show that till geochemistry is able to detect Cu, Mo, and Au mineralization within the Chisholm Lake claim group. Locations of till samples elevated in Cu, Mo, Au, and Ag (686.10 and 194.78 ppm Cu; 4.98 and 2.29 ppm Mo; 90 ppb Au; 101 ppb Ag) suggest there is a relationship between these till samples and known locations of mineralized bedrock within the claim group. These data also document major, minor, and trace element concentrations in tills adjacent to a known porphyry Cu±Mo±Au mineral occurrence. These geochemical data will be useful in the interpretation of new regional-scale till geochemical data being collected in the region and provide a means of comparison for other explorationists working in the area who are using surface geochemical datsets (e.g, stream sediments, till, etc.).

The Chisholm Lake area almost certainly experienced an ice-flow reversal during the Late Wisconsinan Fraser Glaciation maximum. Elevated Cu values in till are most likely related to Cu mineralization near Copper Star mineral occurrence itself and suggest that mineralization within the study area has been transported towards the west (in addition to eastward transport as suggested by early workers). This is in agreement with work that has been conducted at Huckleberry Mine, 60 km to the south, which documents westward dispersal of Cu in tills (Ferbey and Levson, 2001, 2007).

The following is a list of recommended next steps to follow up the till geochemical data presented in this report.

- Conduct a more detailed glacial and ice-flow history study for the Chisholm Lake area to assess the dominant ice-flow direction during the last glaciation with the goal of estimating net transport direction of basal till in the Chisholm Lake area.

- Using percussion drill hole logs, characterize Quaternary sediment thickness with the goal of estimating potential transport distance.

- Collect till samples west of percussion hole 98-33, and north and south of the Copper Star Cu±Mo±Au mineral occurrence, to test for westward dispersal. Additional sampling to investigate the source of high Au and Ag is recommended in the vicinity of till sample 00-6516.

- Integrate till geochemistry and bedrock geochemistry with recently acquired airborne electromagnetic data. These data have been acquired for the QUEST-West Project area and may help characterize the potential areal extent of mineralized bedrock and the source of mineralization for locally occurring tills, and may help with estimating net transport direction. A review of these data show a low conductivity response over the known extent of the intrusion, surrounded by conductivity highs. These conductivity highs are located beyond the east and west ends of the till geochemical transect where elevated Au and Ag values occur in tills.

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