BRITISH COLUMBIA

TILL GEOCHEMICAL EXPLORATION TARGETS, BABINE PORPHYRY COPPER BELT, CENTRAL BRITISH COLUMBIA

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BRITISH COLUMBIA GEOLOGICAL SURVEY

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INTRODUCTION

In 1995, the Nechako National Mapping Program (NATMAP) was initiated to improve the geologic understanding of the Nechako Plateau area of central British Columbia and to figure_4provide some guidance for mineral exploration companies working in the region (McMillan and Struik, 1996). Coordinated and funded by the Geological Survey of Canada (GSC) and British Columbia Geological Survey (BCGS), this focused five year, multi-agency, multi-disciplinary geoscientific study successfully delivered new bedrock, surficial and combined bedrock and surficial, biogeochemistry and geophysical data for the region, and added insight into its tectonic and metallogenic history (McMillan and Struik, 1996; Struik and MacIntyre, 1997, 1998, 1999, 2000). As part of this program, Levson (2001a, 2002) mapped the surficial geology of the Babine porphyry copper belt (NTS map areas 93L/9, 16, and 93M/1, 2, 7, 8) and collected 937 basal tills samples for trace element geochemical analyses on the silt plus clay-sized fraction (<0.063 mm). As a result of this work, 66 multi-site, multi-element geochemical exploration targets were identified in the region. These targets were identified by assessing the magnitude of elevated metal concentrations in till within the context of glacial dispersal patterns and transport direction, other geochemical data sets, and surficial and bedrock geology data (Levson, 2002).

This study is designed to build on the identification of these multi-site, multi-element geochemical exploration targets by analyzing the clay-sized fraction (<0.002 mm) of archived till samples originally collected and discussed by Levson (2002).

Specifically, the objectives of this study are to:

- conduct trace element geochemical analyses on the clay-sized fraction (<0.002 mm) of archived till samples collected in the Babine porphyry copper belt; and
- use these new geochemical data to further constrain and better define previously identified geochemical targets within the Babine porphyry copper belt and possibly identify new ones.

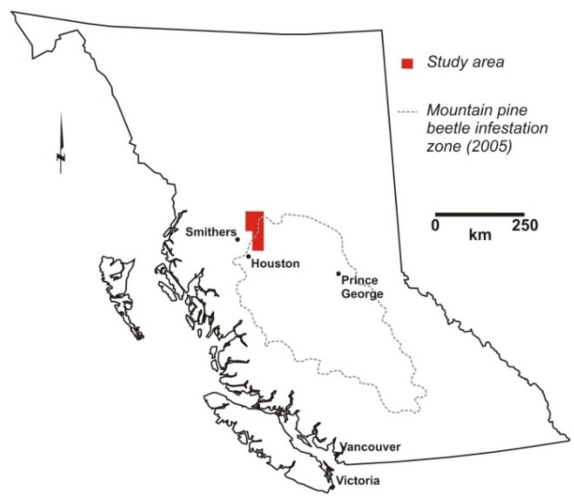

Figure 1. Location of study area.

The goal of this study is to provide to the mineral exploration community a new, high-quality, regional-scale, geochemical dataset that will help guide exploration efforts in the Babine porphyry copper belt. This study will also serve as an extension of the original surficial geology and till geochemistry work completed by Levson (2001a, 2002), and the other geological and geochemical data collected as part of the Nechako NATMAP project (Struik and MacIntyre, 2000). It is hoped that the new geochemical data generated as part of this study will contribute towards longer-term benefits from increased mineral exploration activity in an area adversely affected by the mountain pine beetle infestation.

Although the study presented here does stand alone, the reader is encouraged to review Levson (2002) as a more in-depth understanding of till geochemistry of the Babine porphyry copper belt, and the drift prospecting method, will be had.

STUDY AREA

The Babine porphyry copper belt is located in west-central British Columbia in NTS map areas 93L/9, 16, 93M/1, 2, 7, and 8 (Figure 1). It falls within the Nechako Plateau physiographic region and can be characterized as having low relief and gently rolling topography (Holland, 1976). Large, elongate, northwest-trending lakes are common in lower valley settings (e.g., Babine, Takla, Morrison, Nakinilerak, and Fulton lakes; Figure 2). Although the study area does become more mountainous in the north, as the Skeena Mountains are approached, bedrock outcrop in this region is limited as a ubiquitous cover of Late Wisconsin drift dominates the landscape.

BEDROCK GEOLOGY

The bedrock geology of the study area is described in detail by MacIntyre (1998, 2001) and MacIntyre et al. (1996, 1997, 1998, 2001). Only a brief summary of the bedrock units occurring within the study area is provided here.

The study area falls within the Stikine Terrane of the Intermontane tectonic belt. Limestones of the Lower Permian Asitka Group are the oldest to occur in the study area (Figure 3). Overlying these rocks are Upper Triassic Takla Group basalts, andesites and marine sedimentary rocks, likely deposited in an island arc setting. The most areally extensive units to occur in the study area are the Early to Middle Jurassic Telkwa, Nilkitkwa, Smithers and Saddle Hill formations, of the Hazelton Group, which define a broad calcalkaline volcanic arc. Granitic rocks belonging to the Late Triassic to Early Jurassic Topley Suite, and the more mafic rocks of the Early to Middle Jurassic Spike Peak Suite, can be found intruding these Late Paleozoic to Mid Mesozoic-age units.

Mainly limited to the northern half of the study area are Middle to Late Jurassic Ashman and Trout Creek sediments, of the Bowser Lake Group. These sediments were deposited in the Bowser Basin during uplift and erosion of the Skeena Arch. Along the southern margins of the Bowser Basin, Early Cretaceous Skeena Group sediments were deposited. Other Cretaceous-age rocks in the study area include clastics of the Sustut Group and submarine volcanics and felsic volcanic centres of the Rocky Ridge Formation.

Subduction-related arc volcanism resumed within Stikine Terrane from Late Cretaceous to Eocene time, as recorded by volcanic rocks of the Kasalka and Nechako Plateau groups. Late Cretaceous Bulkley and the Eocene Babine intrusions are associated with this volcanic arc setting. It is these intrusions, and surrounding country rocks, that host economically significant porphyry Cu±Mo±Au±Ag mineralization within the study area.

Known Sources of Mineralization

There are 47 metallic mineral occurrences within the study area (Figure 2). Thirty-seven of these

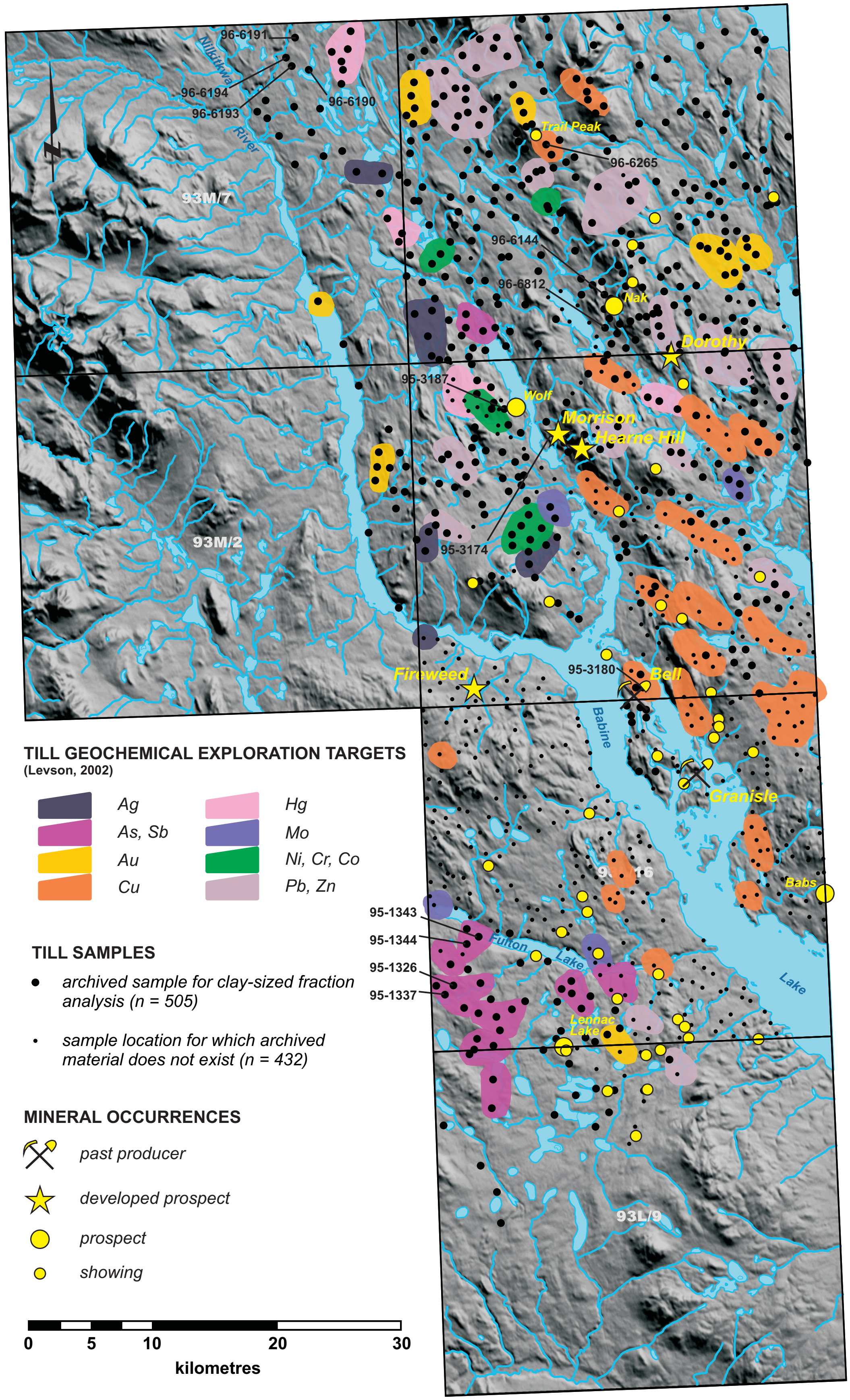

Figure 2. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) of the study area. Included are till sample locations (labelled samples are discussed in text) and locations of mineral occurrences. Also included are the 66 till geochemical exploration targets presented by Levson (2002).

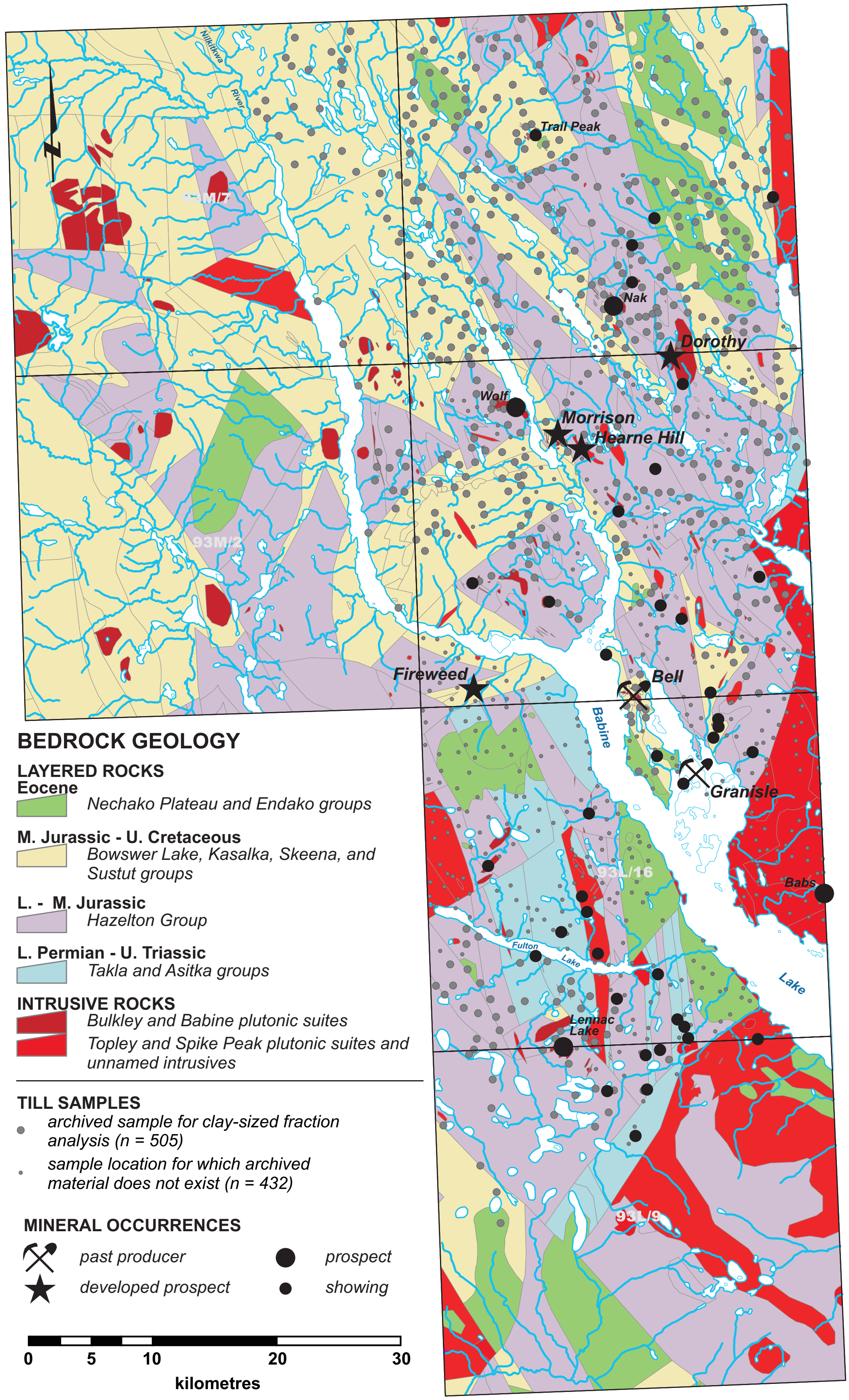

Figure 3. Bedrock geology of study area (after Massey et al., 2005).

occurrences are classified as showings and are summarized in Table 1. The remaining 10 occurrences can be divided into prospects, developed prospects, and past producing mines. The four prospects Lennac Lake (MINFILE 093L190), Babs (MINFILE 093L325), Wolf (MINFILE 093M008), and Nak (MINFILE 093M010), and the three developed prospects Hearne Hill (MINFILE 093M006), Morrison (MINFILE 093M007), and Dorothy (MINFILE 093M009), all host porphyry-style Cu±Mo±Au±Ag mineralization. The remaining developed prospect Fireweed (MINFILE 093M151) hosts SEDEX-style Ag-Zn-Cu-Pb mineralization. Of historic significance are the two past producing mines of the Babine porphyry copper belt - Bell porphyry Cu-Mo-Au mine (MINFILE 093L146) and Granisle porphyry Cu-Mo-Au-Ag mine (MINFILE 093M001).

Descriptions of these occurrences are beyond the scope of this study. They are mentioned here to familiarize the reader with their location and the styles of mineralization they host. A summary of the geological and geochemical characteristics of these past producers and prospects and developed prospects, in the context of till geochemistry, is provided by Levson (2002) while more detailed descriptions are presented by Carter et al. (1995), Ogryzlo et al. (1995) and MacIntyre et al. (1996, 1997, 1998). Summaries of these metallic mineral occurrences can also be found within the British Columbia Ministry of Energy, Mines, and Petroleum Resource’s mineral inventory database (MINFILE).

SURFICIAL GEOLOGY

Till deposits are the dominant surficial material type in the study area. These deposits vary in thickness from <1 m to several metres and can be ridged or rolling, hummocky, or a subdued representation of underlying bedrock topography. On steeper slopes, in the northern part of the study area especially, tills begin to thin and are closely associated with colluvial deposits and discontinuous bedrock outcrop. Continuous bedrock outcrop is limited to some of the higher peaks in the study area such Frypan and Trail. Streamlined glacial features, produced by moving ice (e.g., flutes and drumlins) can be found in the study area and are typically oriented sub-parallel to major valleys. Hindering mineral exploration are thick glaciolacustrine units that can be associated with the larger, modern lake-basins, in particular Babine Lake. Glaciofluvial sediments also occur in the study area and are typically interpreted to be associated with areas of stagnant ice along with ice-proximal and subglacial fluvial systems (Levson, 2002).

PREVIOUS WORK

Levson (2002) presents high-quality, regional-scale, till geochemical data for the Babine porphyry copper belt; still the largest single regional till geochemical data base collected in British Columbia (n = 937). These original basal till samples (each weighing 3 to 5 kg) were collected during the summers of 1995 and 1996 from natural and anthropogenic exposures (e.g., roadcuts, river and lake shores, borrow pits, trenches, and hand-dug soil pits), at average sample depth of 1 m below surface. After being air dried, split for archival purposes, and sieved to the silt plus clay-sized fraction (<0.063 mm), these samples were analyzed for 30 elements by inductively

MINFILE Number	Name	Map Sheet	Commodities	Deposit Type
093L 144	Tachi	93L16E	Cu, Mo	Porphyry
093L 145	Newman	93L16E	Pb, Zn, Ag, Au, Cu	Polymetallic vein
093L 163	O	93L16W	Cu	Volcanic redbed
093L 164	Mine	93L16W	Cu	Volcanic redbed
093L 167	Alp	93L16W	Cu	Volcanic redbed
093L 191	Lennac Lake	93L09W	Cu	Porphyry
093L 192	Cortina	93L16W	Cu	Porphyry
093L 193	Cougar	93L09W	Cu	Porphyry
093L 199	Topley	93L09E	Cu	Porphyry
093L 207	Hag	93L16E	Cu, Pb, Zn	Polymetallic vein
093L 208	Trek	93L16E	Cu, Pb, Zn	Besshi massive sulphide
093L 209	Mag	93L16E	Cu, Pb, Zn	Polymetallic vein
093L 212	Donna	93L16E	Cu	Porphyry
093L 213	Fg	93L09E	Cu	Porphyry
093L 215	Badge	93L16W	Fe, Ma	n/a
093L 219	Ketza	93L16E	Cu	Porphyry
093L 220	Kare	93L16E	Cu	Porphyry
093L 224	Sat	93L16W	Cu	Porphyry
093L 225	Pro	93L16E	Cu, Mo	Porphyry
093L 242	Jill	93L09E	Cu	Porphyry
093L 243	Jacob	93L09W	Cu, Mo	Porphyry
093L 315	Gold Dust	93L16E	Cu, Mo, Au, Ag	Intrusion related vein
093M 002	Mag	93M01E	Pb, Zn, Cu	Polymetallic vein
093M 003	Snoopy	93M01E	Cu	n/a
093M 004	Old Fort	93M01W	Cu, Mo	Porphyry
093M 005	Jake	93M01E	Cu	Porphyry
093M 011	Trail Peak	93M08W	Ag, Zn, Cu, Pb	Porphyry
093M 121	Mast	93M01E	Cu	Porphyry
093M 127	Bab	93M01E	Cu	Porphyry
093M 137	Bear Hill	93M08E	Cu, Ag, Ba, Zn, Pb	Volcanic redbed
093M 142	Lynn	93M08E	Cu	Porphyry
093M 144	Fort	93M01W	Cu	Porphyry
093M 159	Newman North	93M01W	Cu	Porphyry
093M 160	Sparrowhawk	93M01E	Cu	Porphyry
093M 162	Copper 1-4	93M01E	Ag, Pb, Zn, Cu	Polymetallic vein
093M 163	Friday Green	93M08E	Cu	Porphyry
093M 164	Friday Red	93M08E	Cu	Volcanic redbed

Table 1. A summary of metallic mineral showings of the study area.

coupled plasma emission spectrometry (ICP-ES) after an aqua regia digestion, 35 elements by instrumental neutron activation analysis (INAA), and 11 major oxides and 7 elements by ICP-ES after a lithium metaborate fusion. It is the archived splits of these original samples that were reprocessed and analyzed to produce the data that are presented in this study.

During sample collection, care was taken to ensure that basal till, the sample medium of choice for a till geochemistry survey, was consistently sampled. Basal till (considered a first derivative of bedrock) can be ideal for mineral potential assessments as it: 1) has a relatively simple transport history; 2) is deposited directly down-ice of its source; and 3) produces a geochemical signature that is aerially more extensive than its bedrock source and therefore at a regional-scale can be more easily detected (Levson, 2001b). Basal till can appear similar to other Quaternary deposits such as glacigenic debris flows, colluviated till, or other facies of till. These different material types are differentiated in the field based on various physical properties (e.g., texture, sorting, internal structure, compaction) and position in the local stratigraphy. Each of these material types has a different erosion, transport, and deposition history and therefore their geochemical signatures can be unrelated. As with any geochemical survey, it is imperative that analytical determinations are being compared for the same sample media.

Ice-flow History

The ice-flow history of the study area is described in detail by Levson (2002) and is summarized here. Leading up to the Late Wisconsinan glacial maximum, ice flowed from the Skeena Mountains southeast to east-southeast into the study area (Figure 4). Abundant, well developed and preserved landform-scale, valley parallel ice-flow indicators in the Babine Valley (e.g., drumlins, crag-and-tails, flutings) clearly show this southeast to east-southeastward ice flow. Although their abundance and degree of preservation suggest this was the dominant ice-flow direction through the study area, there are also data that indicate an ice-flow reversal occurred here, likely during the Late Wisconsinan glacial maximum.

A westerly ice-flow event in central British Columbia was recognized by Tipper (1971, 1994) in aerial photographs but was attributed to an earlier, pre-Late Wisconsinan, glaciation. More recent data presented by Stumpf *et al*. (2000), Ferbey and Levson (2001a, b), and Levson (2002), and in particular outcrop-scale data collected on the ground, show that this westerly ice-flow event did occur during the Late Wisconsinan glacial maximum. It is thought this event was the result of the establishment of ice domes/divides in central British Columbia, somewhere east of the study area. These ice-centres must have migrated east from Coast Mountains, where snow accumulation would have been initiated during the onset and build up of Late Wisconsinan glacial conditions.

In the most southern portion of the study area, ice-flow appears to have been almost east. This deflection from the dominant southeast to east-southeast flow is likely the product of Skeen Mountain ice meeting ice that was moving east out of the Hazelton Mountains. The contact between these two ice masses would have been somewhere southwest of the study area.

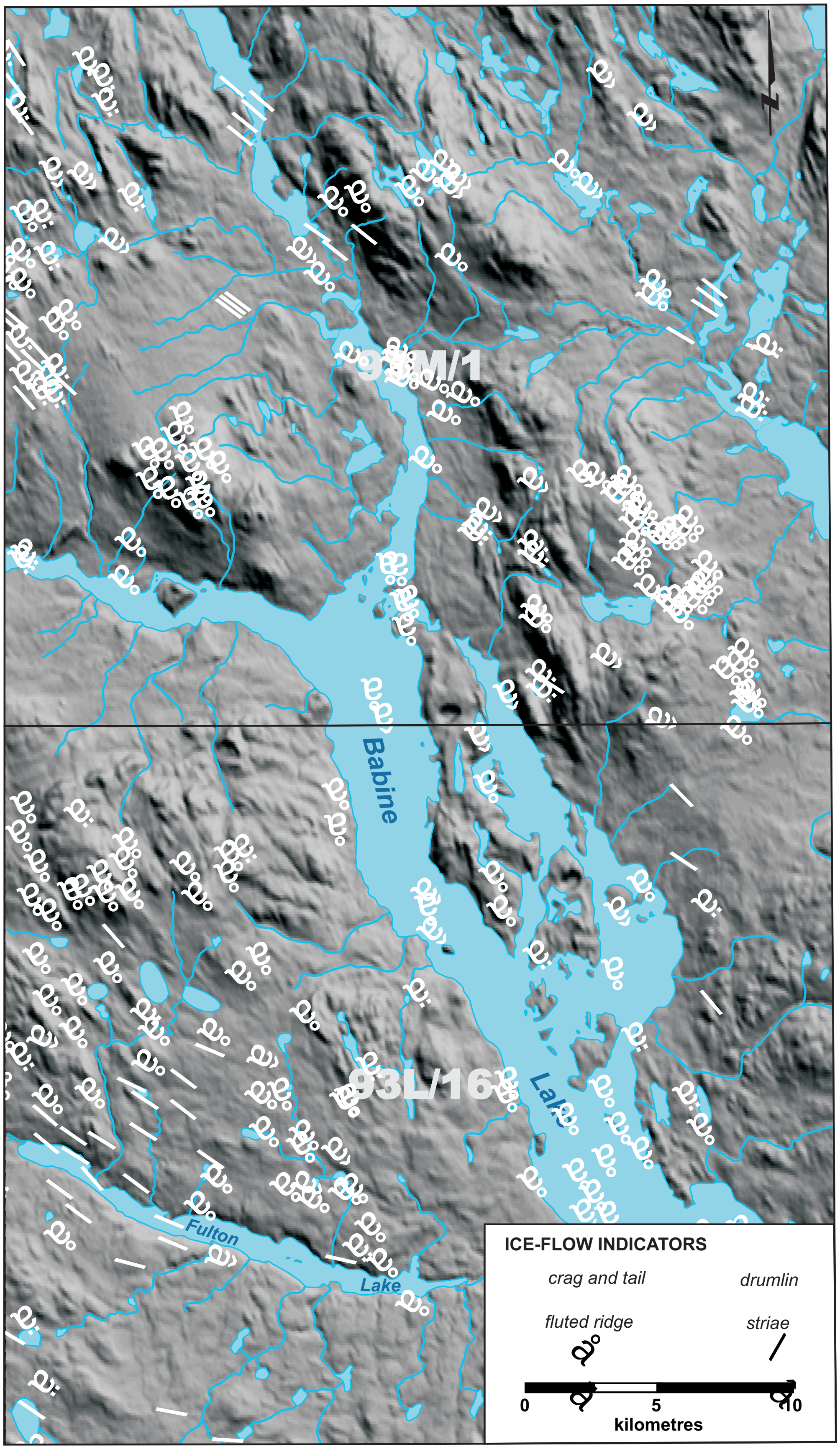

Figure 4. Ice-flow indicators for the central portion of the study area (modified from Huntley et al., 1996, and Stumpf et al., 1996).

Glacial Dispersal Patterns

To assess what influence, if any, this ice-flow reversal had on the detrital dispersal of mineralized bedrock in the study area, detailed basal till sampling was conducted at the past producing Bell porphyry Cu-Mo-Au mine and the Nak porphyry Cu-Au prospect (Levson, 2002). At the Bell Mine, a multi-element dispersal plume (Cu, Mo, Zn, Hg) was identified that extends for up to 5 km southeast (down-ice) of the mine. A plot of Cu concentration versus distance down-ice of the mine shows an exponential decay curve (highest values occur proximal to the mine and decrease exponentially down-ice from it) indicating this dispersal plume is a detrital signature and that material within it was transported and deposited in the basal portions of a glacier.

Similar observations were made at the Nak. The detailed sampling conducted here also included subsurface samples, originally collected during a previous diamond drill program. In general, samples with <105 ppm Cu occur northwest of the prospect while samples with >105 ppm Cu occur southeast of prospect. Data from these detailed sampling programs show that the dominant dispersal direction in basal till samples collected at these sites is southeast and that the westerly ice-flow reversal had only a minimal effect, if any, on the detrital dispersal of mineralization. It is thought that dispersal direction in the Babine porphyry copper belt is closely approximated by the orientation of landform-scale ice-flow indicators.

Dispersal Plume Characteristics

From the detailed sampling mentioned above, and from other sampling conducted near known mineral occurrences, Levson (2002) made some general comments on the characteristics of dispersal trains in basal tills of the Babine porphyry copper belt:

- Dispersal plumes are typically elongate parallel to ice-flow (i.e., southeast);
- The highest metal values in a dispersal plume occur nearest to the mineralized source with mineralized source rocks sometimes occurring at or near its up-ice end;
- Dispersal plumes can be up to a few kilometres long and several hundreds of metres or more wide. Isolated anomalies and erratics associated with the same bedrock source can increase the size of these dispersal plumes to several kilometres in length; and
- The bedrock source of a dispersal plume is always in the up-ice direction and the offset between a dispersal plume head and bedrock source can be 0.5 km or more. The bedrock source of a dispersal plume is never located directly below the head of the plume.

These comments were made based on geochemical analysis of the silt plus clay-sized fraction (<0.063 mm) of basal tills collected within the Babine porphyry copper belt. The comments here are relevant to this study as dispersal plume characteristics are expected to be the same in the clay-sized fraction (<0.002 mm) of the same basal till samples (i.e., the size fraction analyzed as part of this study).

Detection of Known Mineral Occurrences

Trace element geochemistry of basal till samples collected in the Babine porphyry copper belt reliably detects known mineral occurrences. Nearly all till samples collected in the vicinity of existing mineral properties have >95th percentile metal concentrations. For example, >95th percentile concentrations of Cu, Pb, Zn, Au, Cr, and Co occur in samples collected at Bell Mine and the Nak prospect. Also at these properties are >98th percentile concentrations of As and Sb in till samples. Till samples collected in the vicinity of Morrison and Hearne Hill developed prospects have >98th percentile concentrations of Cu, Pb, Au, Ag, and Sb. Additionally, till samples collected near Morrison contain >98th percentile concentrations of As and Hg while those collected near Hearne Hill have >95th percentile concentrations of Co and Cr. Till samples collected near most other known mineral occurrences have at least 95th percentile concentrations of at least one element of interest. Maximum concentrations for the elements Cu, Mo, Zn, Pb, Ag, As, and Cr are associated with existing mineral properties (Levson, 2002).

Multi-site, Multi-element Geochemical Exploration Targets

Elevated metal values in till samples collected within the Babine porphyry copper belt also occur in areas where there are no known mineral occurrences. It is these samples that form the basis of the 66 multi-site, multi-element geochemical exploration targets identified by Levson (2002) (Figure 2). These exploration targets have element concentrations and dispersal characteristics similar to those observed near existing properties and known mineral occurrences. These areas have been highlighted based on not only the magnitude of elevated metal concentrations in till, but also by assessing these values within the context of glacial dispersal patterns and transport direction, other geochemical data sets, and existing surficial and bedrock geology data. These geochemical exploration targets form the starting point of this study.

METHODOLOGY

Clay separations have been routinely used for geochemical interpretations by the Geological Survey of Canada (GSC) (Shilts, 1995; Girard et al., 2004). Analysis of the clay-sized fraction in basal tills can be ideal for exploration targets such as porphyry Cu deposits as it has been shown that base metals (more specifically, chalcophile elements such as Cu and Zn) tend to concentrate in this fraction due to a clay-sized particle's (dominated by phyllosilicates) high cation exchange capacity (Nikkarinen et al., 1984; DiLabio, 1995; Shilts, 1984, 1995). In the context of base metal exploration, trace element analyses of the clay-sized fraction of tills (<0.002 mm) can increase geochemical anomaly contrast, as compared to the contrast with same analyses of the silt plus clay-sized fraction (<0.063 mm). This is due to the fact that the abundance of quartz and feldspars are reduced in clay-sized fraction and therefore do not dilute the geochemical signature of the sample. Using these data, it may be possible for elevated geochemical values to be identified with more certainty and detail.

Sample Preparation and Analysis

For this study, clay separations for 533 archived till samples were produced following the procedures outlined by Girard et al. (2004). Closely following such procedures is imperative, in particular the length of time samples are centrifuged and the velocity at which the centrifuge operates, for a clay-sized separation (<0.002 mm) to be consistently produced. De-ionized water was used throughout the centrifuge and decanting process, instead of the sodium hexametaphosphate solution suggested by Girard et al. (2004). Clay separations were conducted at Acme Analytical Laboratories Limited, Vancouver, British Columbia.

For each reprocessed sample, a 0.5 g split of clay-sized material was analyzed for a total of 37 elements by inductively coupled plasma mass spectrometry (ICP-MS) following an aqua regia digestion (a 0.5 g sample is leached with 6 ml of hydrochloric acid, nitric acid, and distilled, deionized water (2:2:2 v/v) at 95°C for one hour and then diluted to 20 ml). Elements analyzed for, and detection limits, are presented in Table 2. These analyses were conducted at Acme Analytical Laboratories Limited, Vancouver, British Columbia. Geochemical determinations are presented in Appendix A.

QUALITY CONTROL

Quality control measures were implemented during the initial collection till samples in the Babine porphyry copper belt. Included in each block of 20 samples submitted for analysis was one field duplicate (taken at a randomly selected sample site), one analytical duplicate (a random sample split after sample preparation but before analysis), and one reference standard (Levson, 2002). As part of this study of archived till samples, similar quality control measures were implemented. The original field duplicates collected by Levson (2002) were utilized and new reference standards were inserted. Reference standards used here are certified Canada Centre for Mineral and Energy Technology (CANMET) Till 1 and Till 2. Field duplicate samples are used here to measure the combined sampling and analytical variability. Reference standards are used to measure analytical precision. For this study, 28 field duplicate (FDUP) samples (i.e., 14 duplicate pairs) and six reference standards were analyzed. Field duplicate (FDUP) 10 identifies the first sample collected at a field duplicate sample site while FDUP 20 is the second sample collected at the same sample site.

Before an analysis of precision is carried out, clay separation quality must first be assessed as low quality or inconsistent separations would likely have a negative impact on data precision. As previously mentioned, it is expected that for a given element the clay and silt plus clay-sized fractions of the same sample will contain different element abundances. It is therefore important that comparisons and interpretations are being made with geochemical determinations from the same size-fraction. To assess the quality of clay separations a comparative analysis of Al values in the new clay-sized (<0.002 mm) ICP-MS data and previously published slit plus clay-sized (<0.063 mm) ICP-ES data was conducted on the same sample subset (n = 533; Figure 6) (cf., Shilts, 1995).

Due to the natural concentration of phyllosilicate minerals in the clay-sized

Element	Detection Limit
Mo	0.01 ppm
Cu	0.01 ppm
Pb	0.01 ppm
Zn	0.1 ppm
Ag	2 ppb
Ni	0.1 ppm
Co	0.1 ppm
Mn	1 ppm
Fe	0.01 %
As	0.1 ppm
U	0.1 ppm
Au	0.2 ppb
Th	0.1 ppm
Sr	0.5 ppm
Cd	0.01 ppm
Sb	0.02 ppm
Bi	0.02 ppm
V	2 ppm
Ca	0.01 %
P	0.001 %
La	0.5 ppm
Cr	0.5 ppm
Mg	0.01 %
Ba	0.5 ppm
Ti	0.001 %
B	20 ppm
Al	0.01 %
Na	0.001 %
K	0.01 %
W	0.1 ppm
Sc	0.1 ppm
Tl	0.02 ppm
S	0.02 %
Hg	5 ppb
Se	0.1 ppm
Te	0.02 ppm
Ga	0.1 ppm

Table 2. Elements analyzed for by aqua regia ICP-MS, on the clay-sized fraction (<0.002 mm) of archived till samples, and associated detection limits.

fraction, Al concentrations should be greater in this fraction than in the silt plus clay-sized fraction. The mean percent-difference of Al concentrations between these two data sets is 44.4, with Al values being greater in the clay-sized fraction 96.4% of the time (i.e., in 531 of the 533 samples) (Figure 5). The exception to this is sample 96-6005 (where Al concentrations in the clay and silt plus clay-sized fractions are 2.58 and 3.55%, respectively) and sample 96-6025 (where Al concentrations are the same in both size-fractions). This comparative analysis indicates that clay separations conducted for this study are of high quality.

Copper, Pb, Zn, Ag, As, and Hg were selected for analyses of precision (and in the data presentations that follow) as from a mineral exploration perspective, in the Babine porphyry copper belt, they are chalcophile elements of interest. Although not a chalcophile element, Mo is also included in this analysis as it too is an element of interest. Figure 6 presents scatterplots of trace element concentrations measured in field duplicates. High correlation coefficients ($R^2 > 0.8$) indicate good reproducibility, and suggest a relatively high sampling and analytical precision. In the case of Cu, Pb, As, and Hg correlation coefficients of $R^2 > 0.9$ indicate an even higher degree of precision and suggest there is a more homogeneous distribution of these elements in the clay-sized fraction.

Percent relative standard deviation (%RSD) values for repeat determinations on certified CANMET standards have been calculated for the same seven elements. By dividing the standard deviation for each element population by the absolute value of the mean, and multiplying by 100, a measure of data dispersion around the mean can be generated. As seen in Tables 3 and 4, the majority of %RSD values vary between 0.6 and 11.2. In exploration geochemistry, %RSD values in the range of 15 to 20 are considered applicable and therefore these values also indicate that there is high analytical precision in these clay-sized fraction geochemical data.

The maximum and minimum %RSD values of 0 and 20 are for determinations of Hg. It is not known if this variability is related to analytical error or if it is to do with the distribution of Hg within the certified CANMET standards (in particular CANMET Till 2). This variability is in contrast to the high precision for Hg determinations shown in field duplicate scatterplots (Figure 6). In this analysis of precision Hg has the second highest R^2 value of the seven elements analyzed ($R^2 = 0.973$).

CLAY-SIZED FRACTION TILL GEOCHEMICAL DATA

Summary statistics for Cu, Mo, Pb, Zn, As, Ag, and Hg are presented in Table 5. Proportional symbol plots for the same elements are shown in Figures 7 to 13. Percentile class breaks used in these plots (<50, 50-70, 70-90, 90-95, 95-98, >98) are commonly used to categorize till geochemical data as they do not bias data classification. For these statistics and proportional symbol plots, the second sample collected at a field duplicate sample site (i.e., FDUP 20; see Appendix A) has been removed from the data set. Therefore, for the remainder of this report, presentations and discussions will focus on samples with unique locations (n=505).

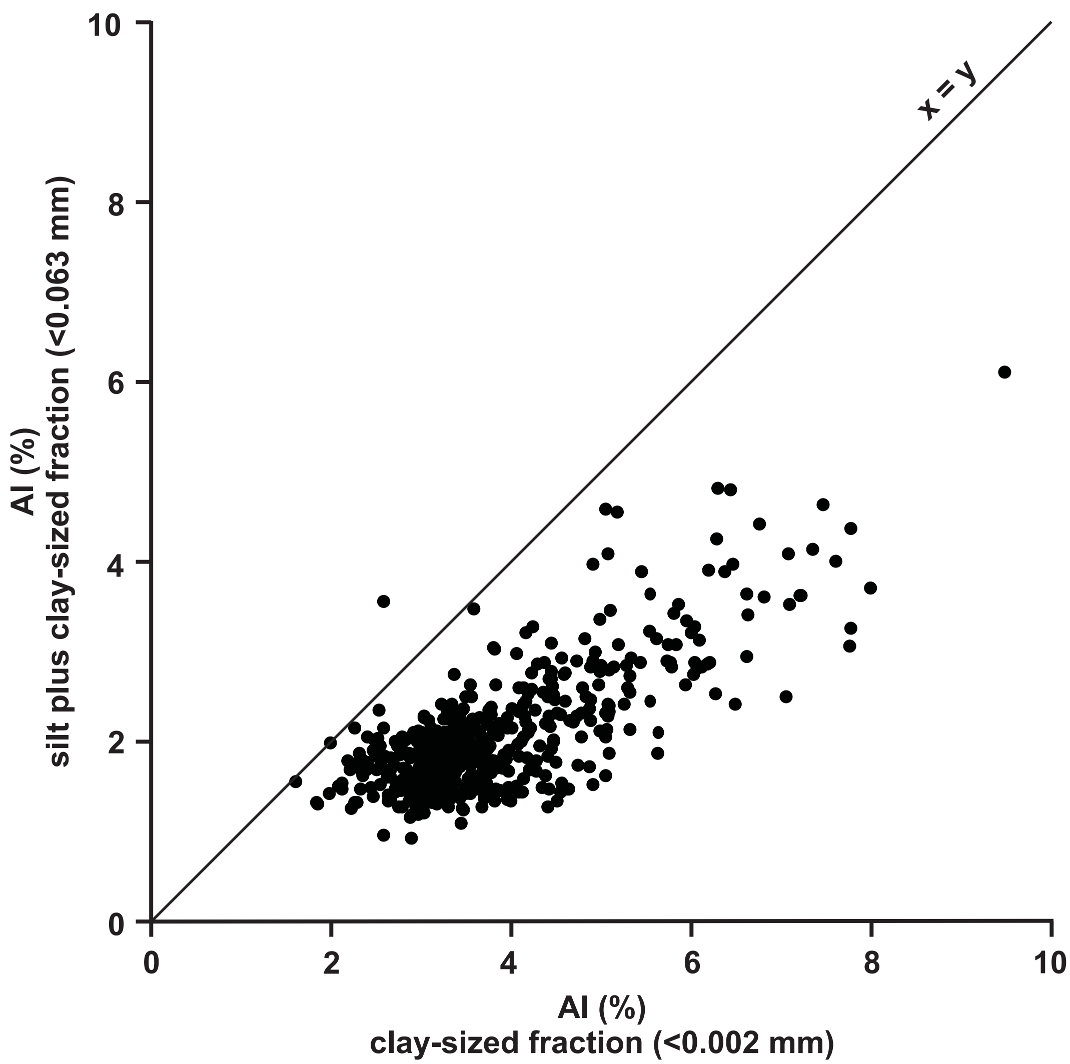

Figure 5. Scatter plot of Al values for clay (<0.002 mm) and silt plus clay (<0.063 mm) sized fractions. Clay-sized data were analyzed by ICP-MS, and silt plus clay-sized by ICP-ES, after an aqua regia digestion.

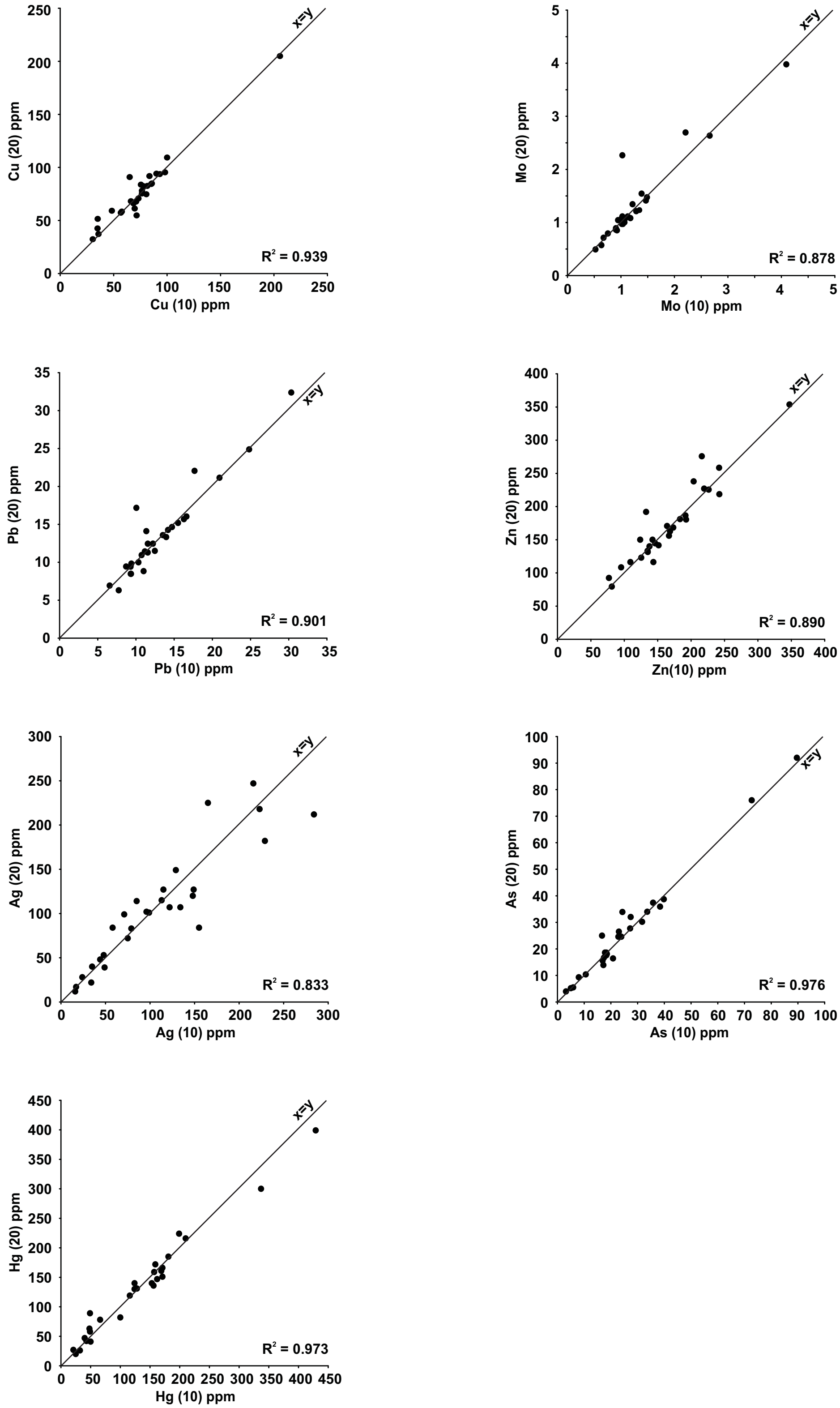

Figure 6. Field duplicate scatter plots for the elements Cu, Mo, Pb, Zn, As, Ag, and Hg.

Determination CANMET Till 1	Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppb)	As (ppm)	Hg (ppb)
1	0.68	50.76	15.52	67.9	189	17.5	74
2	0.65	47.56	15.64	62.0	195	15.9	74
3	0.67	52.28	15.71	68.6	198	17.8	74
mean	0.67	50.20	15.62	66.2	194	17.1	74
recommended	2.00	48.00	12.00	70.0	200	13.0	92
standard deviation	0.02	2.41	0.10	3.6	5	1.0	0
% RSD	***2.30***	***4.80***	***0.60***	***5.5***	***2***	***6.0***	***0***

Table 3. Percent relative standard deviation (%RSD) values for CANMET Till 1.

Determination CANMET Till 2	Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppb)	As (ppm)	Hg (ppb)
1	11.32	154.40	23.56	111.6	213	22.1	48
2	10.85	144.40	23.42	109.9	215	22.0	57
3	10.17	136.10	21.19	105.2	175	20.8	38
mean	10.78	144.90	22.72	108.9	201	21.6	48
recommended	11.00	149.00	21.00	116.0	200	22.0	74
standard deviation	0.58	9.16	1.33	3.3	23	0.7	10
% RSD	***5.04***	***6.30***	***5.90***	***3.0***	***11***	***3.3***	***20***

Table 4. Percent relative standard deviation (%RSD) values for CANMET Till 2.

	Mo (ppm) ICP-MS	Cu (ppm) ICP-MS	Pb (ppm) ICP-MS	Zn (ppm) ICP-MS	Ag (ppb) ICP-MS	As (ppm) ICP-MS	Hg (ppb) ICP-MS
detection limit	0.01	0.01	0.01	0.1	2	0.1	5
minimum	0.06	10.53	3.62	49.2	8	1.5	7
maximum	49.74	2127.11	68.94	8314.3	1087	203.4	755
mean	1.64	80.28	15.33	188.7	121	24.5	131
median	1.26	71.25	13.6	158	91	20.6	95
98^{th} percentile	4.09	159.18	34.68	343.2	431	78.9	439
n=	505	505	505	505	505	505	505

Table 5. Summary statistics for aqua regia ICP-MS data (n=505), for the clay-sized fraction (<0.002 mm), including the 98^{th} percentile element concentration.

In till geochemical data median element concentrations are often considered to represent geochemical background levels of that element. Figures 7 to 13 show there is a clear relationship between till samples elevated in Cu, Mo, Pb, Zn, As, Ag, and (or) Hg and the locations of known mineral occurrences. In most cases, till samples in the vicinity of known mineral occurrences have >95th percentile concentrations. There are some instances where samples with >90th percentile concentrations occur where there is no known mineralized bedrock source. The following is a brief discussion of maximum and >98th percentile element concentrations.

Copper

Mean and median Cu values are 80.28 and 71.25 ppm, respectively (Table 5). The maximum Cu value of 2127.11 ppm (sample 95-3180) occurs directly northeast of Bell Mine (MINFILE 093M001) (Figure 7). This same sample also has the maximum Cu value in the silt plus clay fraction (<0.063 mm) ICP-ES data presented by Levson (2002). Greater than 98th percentile concentrations of Cu also occur in the vicinity of Trail Peak, Nak, Wolf, and Morrison properties.

Molybdenum

Mean and median Mo values are 1.64 and 1.26 ppm, respectively (Table 5). The maximum Mo value of 49.74 ppm (sample 95-3187) occurs approximately 1 km west of the Wolf Cu-Mo prospect (MINFILE 093M008) on the southern margin of a quartz diorite to granodiorite belonging to the Babine Plutonic Suite (Figure 8). This same sample also has the maximum Mo value in the silt plus clay fraction (<0.063 mm) ICP-ES data presented by Levson (2002). Greater than 98th percentile concentrations of Mo also occur in the vicinity of Trail Peak and Wolf properties. There are three samples with >98th percentile concentrations near the Nak prospect.

Lead

Mean and median Pb values are 15.33 and 13.60 ppm, respectively (Table 5). The maximum Pb value of 68.94 ppm (sample 96-6265) occurs approximately 1.1 km southeast (down-ice) of the Trail Peak Ag-Zn-Cu-Pb showing (MINFILE 093M11) (Figure 9). Greater than 98th percentile concentrations of Pb also occur in the vicinity of Trail Peak, Nak, and Morrison properties.

Zinc

Mean and median Zn values are 188.7 and 158.0 ppm, respectively (Table 5). The maximum Zn value of 8314.3 ppm also occurs at sample 96-6265, approximately 1.1 km southeast (down-ice) of the Trail Peak Ag-Zn-Cu-Pb showing (MINFILE 093M11) (Figure 10). This same sample also has the maximum Zn value in the silt plus clay fraction (<0.063 mm) ICP-ES data presented by Levson (2002). At Trail Peak there three other samples with >98th percentile concentrations of Zn. Similar concentrations occur in the vicinity of Hearne Hill developed propect and the past producing Bell Mine.

Arsenic

Mean and median As values are 24.5 and 20.6 ppm, respectively (Table 5). The maximum As value of 203.4 ppm (sample 96-6144) occurs approximately 1.1 km northwest (up-ice) of the Nak Cu-Au prospect (MINFILE 093M010), adjacent to mapped granodiorites of the Babine Plutonic suite (Figure 11). Two other samples with >98th percentile values for As occur near the Nak prospect. Greater than 98th percentile concentrations also occur in the vicinity of Trail Peak and Morrison properties.

Silver

Mean and median Ag values are 121 and 91 ppb, respectively (Table 5). The maximum Ag value of 1087 ppb (sample 96-6812) occurs approximately 2.0 km southwest of the Nak Cu-Au prospect (MINFILE 093M010) (Figure 12). Greater than 98th percentile concentrations also occur in the vicinity of Trail Peak and Morrison properties, and the past producing Bell Mine.

Mercury

Mean and median Hg values are 131 and 95 ppb, respectively (Table 5). The maximum Hg value of 755 ppm (sample 95-3174) occurs approximately 3.8 km down-ice of the Wolf Cu-Mo prospect (MINFILE 093M008) (Figure 13). Within a few hundred metres of the sample are mapped biotite-feldspar porphyrytic granodiorites of the Babine Plutonic Suite and the Morrison Cu±Au±Mo developed prospect. A northwest-trending line three samples, located south of the Dorothy developed prospect, also have >than 98th percentile concentrations of Hg.

NEW TILL GEOCHEMICAL EXPLORATION TARGETS

Trace element determinations on the clay-sized fraction (<0.002 mm) highlight two new till geochemical exploration targets. These are multi-element, multi-site targets that have element concentrations similar to those of samples located in the vicinity of known mineralization. Most of the samples that define these new exploration targets have >90th percentile concentrations of more than one element, in some cases >95th percentile concentrations and up to >98th percentile concentrations. There are no documented mineral occurrences in the vicinity of these targets and therefore their bedrock source remains unknown. These new till geochemical exploration targets are not included in the 66 geochemical exploration targets identified by Levson (2002). In the silt plus clay-sized fraction (<0.063 mm) ICP-ES determinations presented by Levson (2002) most of the samples that define these new exploration targets have <90th percentile element concentrations, in many cases <70th percentile concentrations.

A recalculation of percentile class breaks for the silt plus clay-sized fraction (<0.063 mm) ICP-ES determinations was completed for the same sample subset analyzed as part of this study (n=505). Table 6 presents summary statistics and 98th percentile values for this recalculated data set which can be compared to the original 98th percentile values and summary statistics presented by Levson (2002) for the complete data set (n=937; Table 7). As can be seen in this comparison, summary statistics are similar and there are only minor departures in the recalculated values for the sample subset (n=505) from the original 98th percentile values calculated for all 937 till samples. This demonstrates that data distributions of the full ICP-ES data set (n=937) and

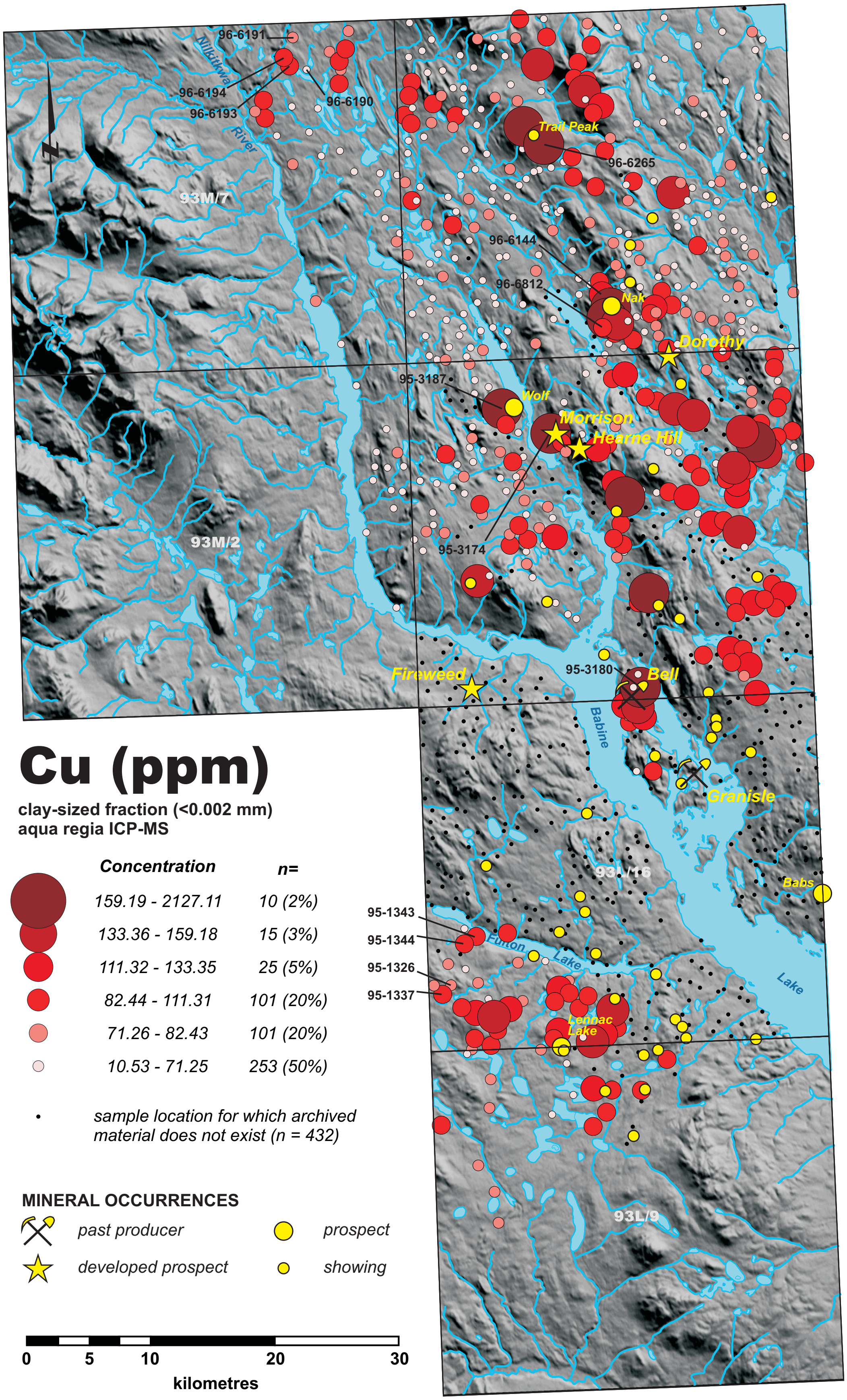

Figure 7. Proportional symbol plot for Cu values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

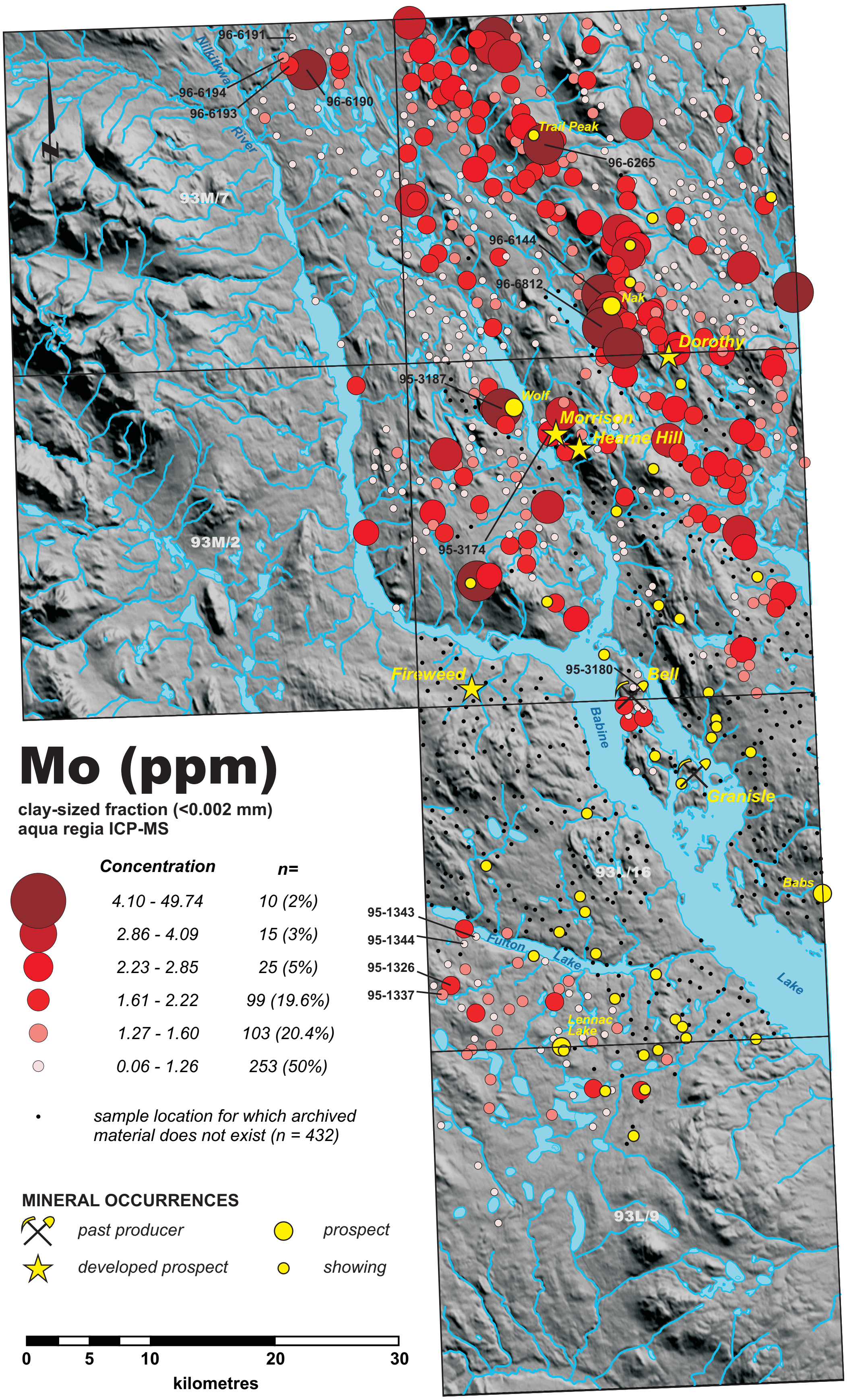

Figure 8. Proportional symbol plot for Mo values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

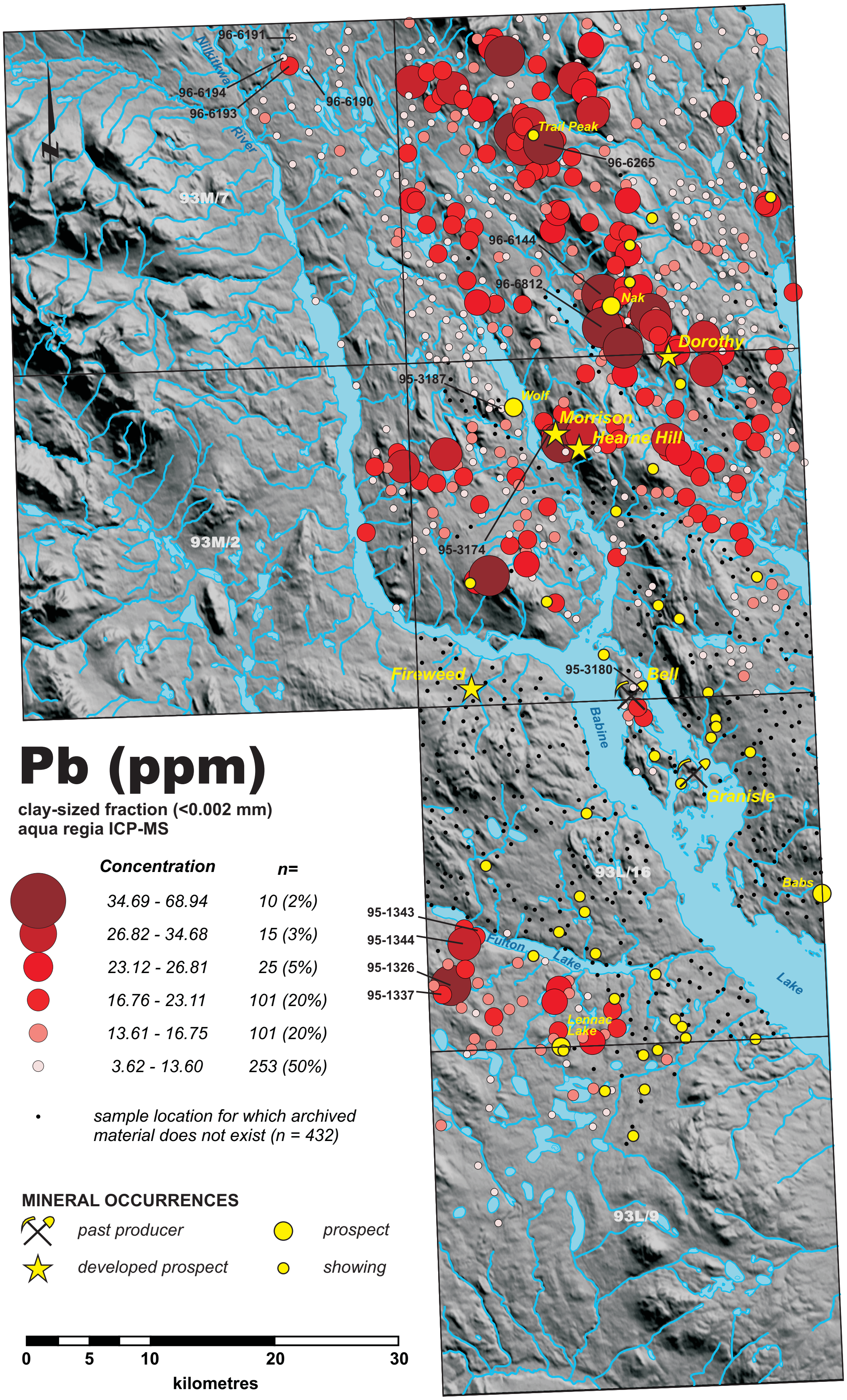

Figure 9. Proportional symbol plot for Pb values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

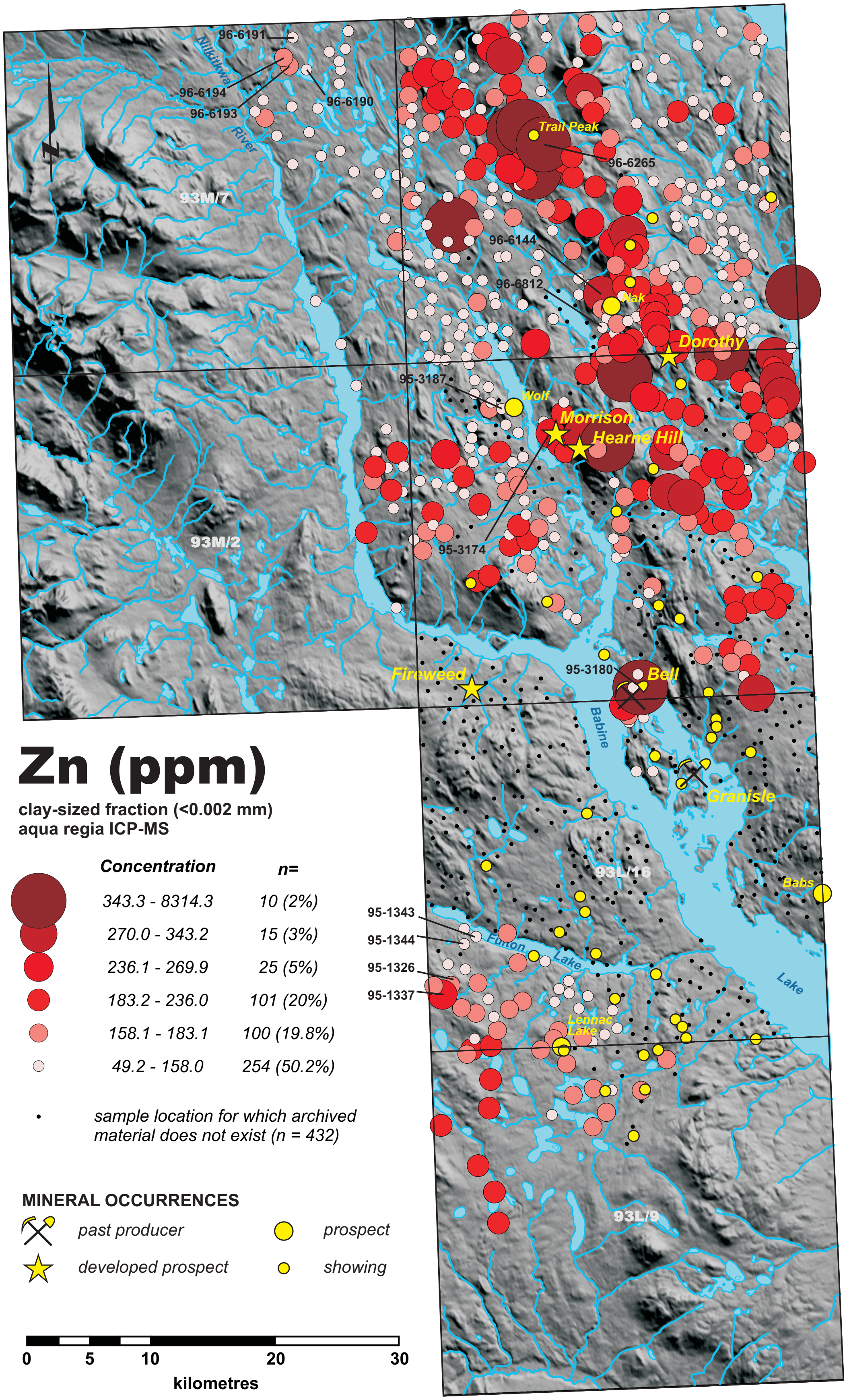

Figure 10. Proportional symbol plot for Zn values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

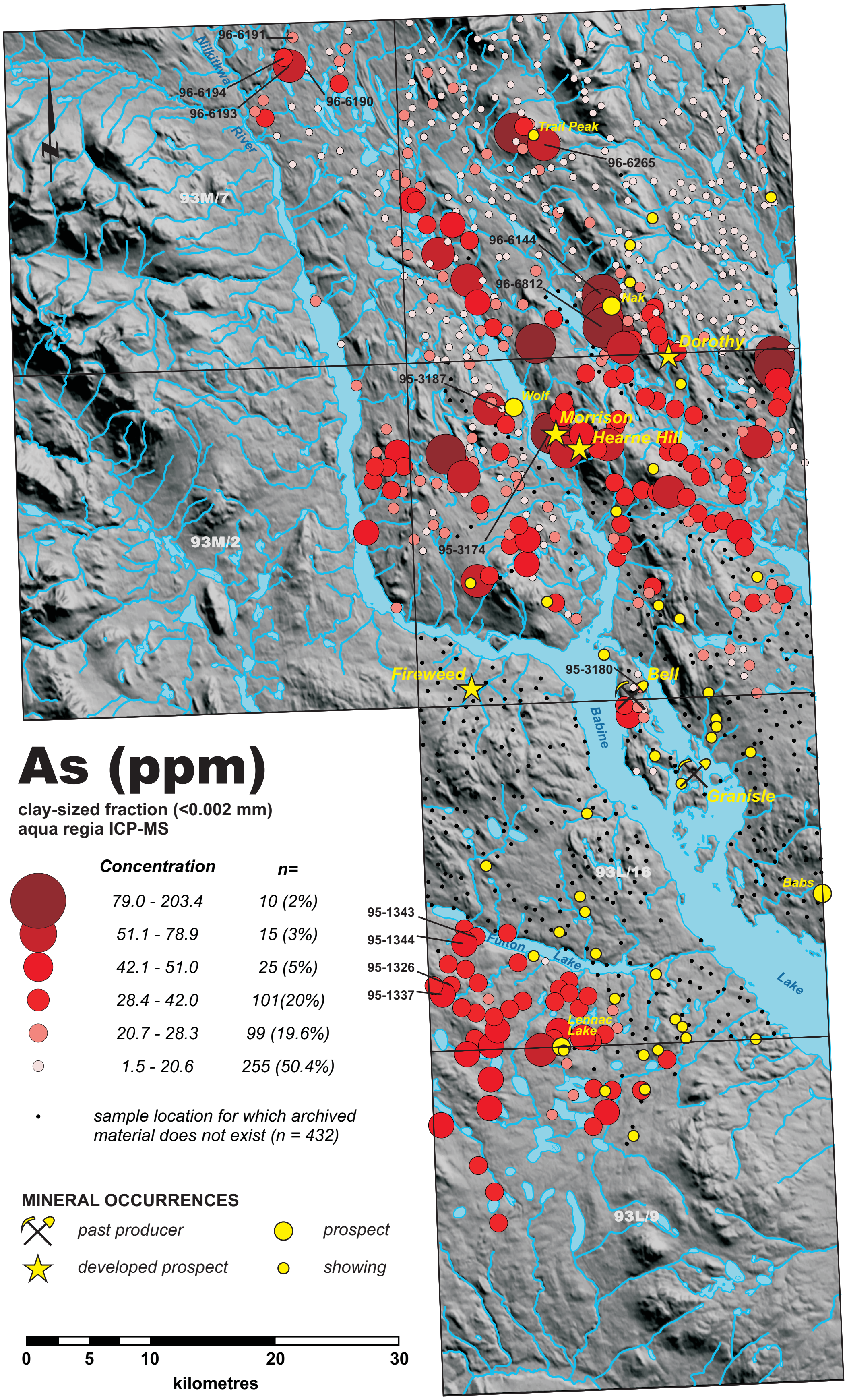

Figure 11. Proportional symbol plot for As values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

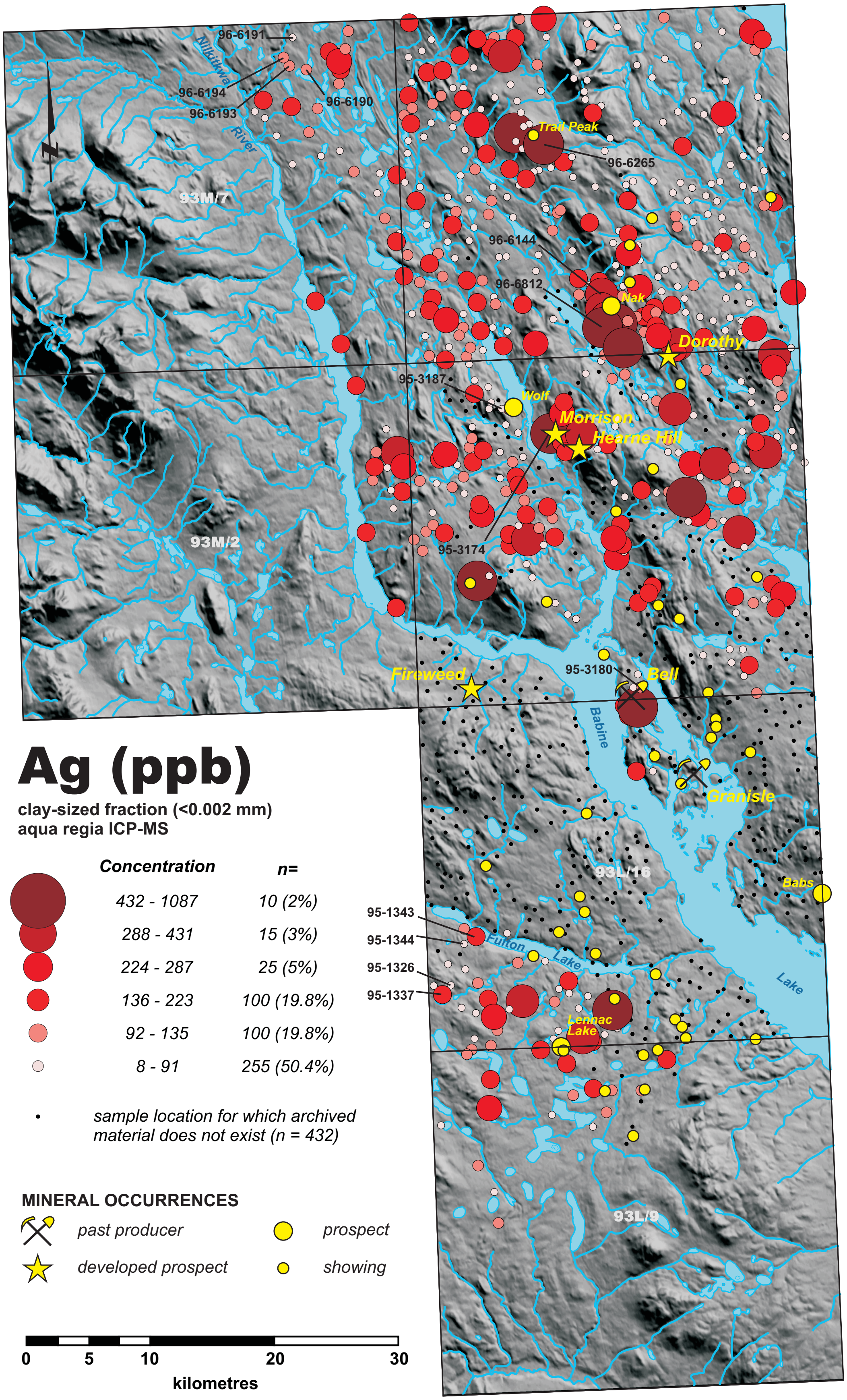

Figure 12. Proportional symbol plot for Ag values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

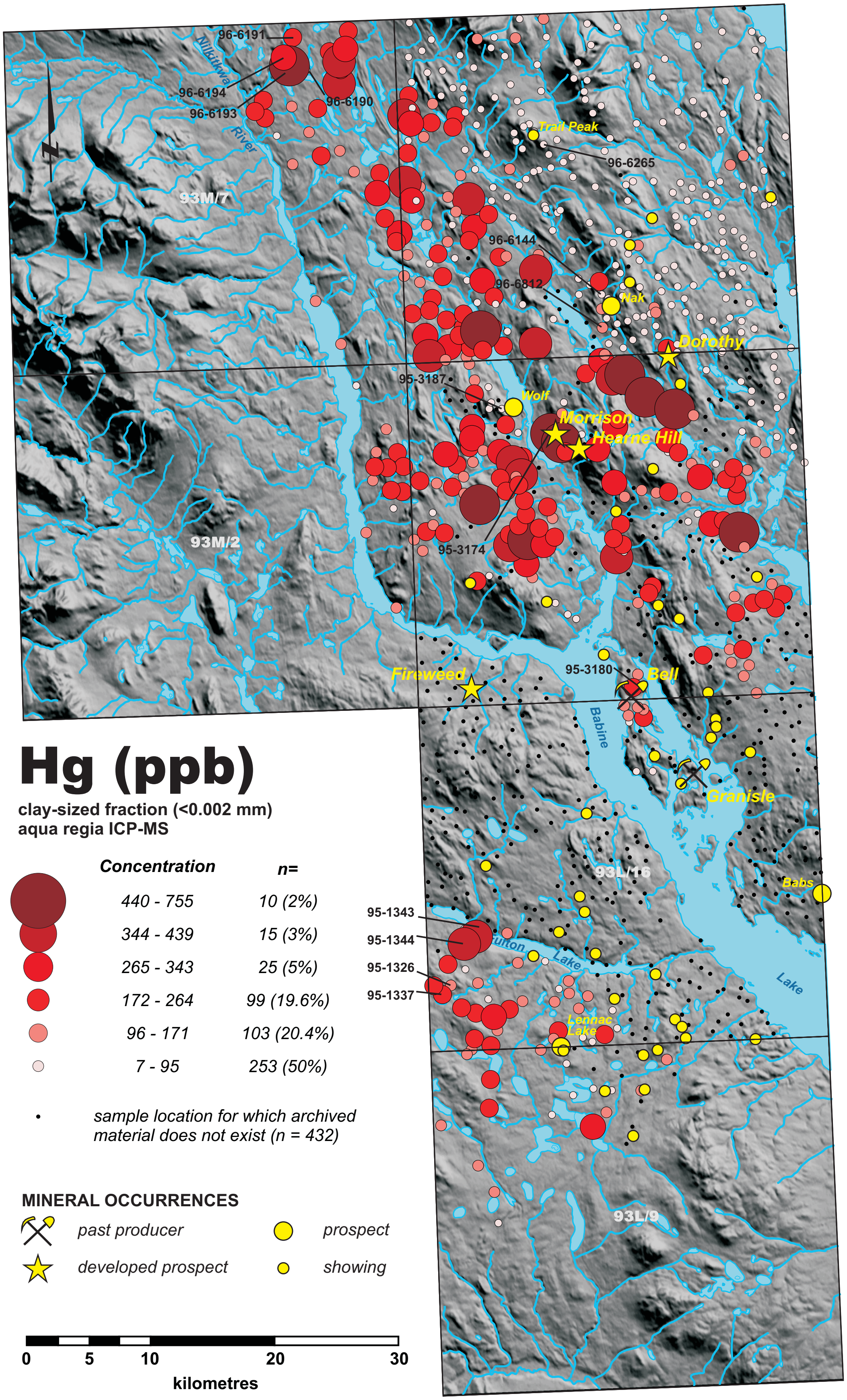

Figure 13. Proportional symbol plot for Hg values in the clay-sized fraction (<0.002 mm) of archived till samples for the Babine porphyry copper belt.

the sample subset (n=505) are very similar. This suggests that the differences in percentile ranking for an element of a given sample in the clay-sized fraction (<0.002 mm; n=505) and the silt plus clay-sized fraction (<0.063 mm; n=937) is not a statistical artefact resulting from the percentile classification of a smaller data set but rather it is due to detrital transport taking place predominantly in the clay-sized fraction. The following is a discussion of these two new till geochemical exploration targets.

Fulton Lake, NTS map area 93L/16

Located southwest of Fulton Lake, in the southwest corner is NTS map area 93L/16, is a group of samples with elevated metal values. Defined by samples 95-1326 (82.27 ppm Cu; 39.01 ppm Pb), 95-1337 (100.52 ppm Cu; 51 ppm As), 95-1343 (83.04 ppm Cu; 345 ppb Hg), and 95-1344 (97.32 ppm Cu; 27.73 ppm Pb; 49.5 ppm As; 356 ppb Hg), up to $>98^{th}$ percentile concentrations of Pb, $95\text{-}98^{th}$ percentile concentrations of Hg and Pb, $90\text{-}95^{th}$ percentile concentrations of As, and $70\text{-}90^{th}$ percentile concentrations of Cu occur here (Figures 7, 9, 11, and 13). Although this area is included as a Sb exploration target by Levson (2002), it is discussed here as a new till geochemical exploration target as Cu, Pb, As, and Hg concentrations are all higher in the clay-sized fraction of these samples and these concentrations are statistically different as they fall within a higher percentile class.

This area is underlain by Early to Mid Jurassic Saddle Hill Formation volcanics, of the Hazelton Group. A small Late Cretaceous to Eocene-age diorite body has been mapped approximately 1 km west-northwest of sample 95-1344. Approximately 5 km west of samples 95-1326 and 95-1337, a Late Cretaceous Bulkley Plutonic Suite intrusive has been mapped. These intrusions are in general located up-ice of these till sample sites. There is no documented mineralization associated with these intrusions.

Nilkitkwa River, NTS map area 93M/7

Located east of Nilkitkwa River, near the northern border of NTS map area 93M/7, is a group of samples with elevated metal values. Defined by samples 96-6190 (4.47 ppm Mo), 96-6191 (199 ppb Hg), 96-6193 (96.18 ppm Cu; 2.22 ppm Mo; 20.25 ppm Pb; 51.8 ppm As; 455 ppb Hg), and 96-6194 (87.54 ppm Cu; 29.1 ppm As; 326 ppb Hg), up to $>98^{th}$ percentile concentrations of Mo and Hg, $95\text{-}98^{th}$ percentile concentrations of As, $90\text{-}95^{th}$ percentile concentrations of Hg, and $70\text{-}90^{th}$ percentile concentrations of Cu, Mo, Pb, As, and Hg occur here (Figures 7, 8, 9, 11, 13).

This area is underlain by clastic rocks of the Lower Cretaceous Red Rose Formation, of the Skeena Group. The closest mineral occurrence to this area, in the up-ice direction (i.e., northwest), is the Mount Horetzky porphyry Cu-Mo showing (MINFILE 093M093). Located approximately 22 km away (and outside the study area), this showing is located on the flank of an Eocene-age Babine Plutonic Suite intrusive, the next-closest mapped intrusion in the up-ice direction.

SUMMARY

The clay-sized fraction (<0.002 mm) of 533 archived basal till samples collected within the Babine porphyry copper belt was analyzed for 37

	Mo (ppm) ICP-ES	Cu (ppm) ICP-ES	Pb (ppm) ICP-ES	Zn (ppm) ICP-ES	Ag (ppm) ICP-ES	As (ppm) INAA	Hg (ppb) CAA
detection limit	1	1	3	1	0.3	0.5	10
minimum	1	11	3	44	0.1	0.5	10
maximum	38	1550	56	5067	1.4	130.0	950
mean	1	45	12	122	0.2	16.1	101
median	1	40	11	104	0.1	14.0	85
98th percentile	3	105	26	218	0.6	42.0	305
n=	505	505	505	505	505	505	500

Table 6. Summary statistics for aqua regia ICP-ES data (n=505), for the silt plus clay-sized fraction (<0.063 mm), including the 98th percentile element concentration.

	Mo (ppm) ICP-ES	Cu (ppm) ICP-ES	Pb (ppm) ICP-ES	Zn (ppm) ICP-ES	Ag (ppm) ICP-ES	As (ppm) INAA	Hg (ppb) CAA
detection limit	1	1	3	1	0.3	0.5	10
minimum	1	9	3	37	0.1	0.5	10
maximum	38	1550	78	5067	1.4	130	950
mean	1	45	11	108	0.2	15.8	105
median	1	41	10	97	0.1	15	90
98^{th} percentile	4	105	24	201	0.6	39	310
n=	937	937	937	937	937	937	932

Table 7. Summary statistics for aqua regia ICP-ES data (n=937), for the silt plus clay-sized fraction (<0.063 mm), including the 98^{th} percentile element concentration.

elements by aqua regia digestion followed by inductively coupled plasma mass spectrometry (ICP-MS). The spatial distribution of samples elevated in Cu, Mo, Pb, Zn, Ag, As, and Hg, was analyzed and compared to element concentrations that occur in the vicinity of known mineral occurrences. These data highlight two new multi-element, multi-site till geochemical exploration targets. Further work is required to assess the significance of these new targets and to locate their bedrock source(s). To maximize effectiveness, this work should be multi-disciplinary in approach and include till sampling and bedrock geological mapping in the vicinity, and up-ice, of the samples that define these new till geochemical exploration targets.

Additionally, with these new aqua regia, ICP-MS determinations a detailed reinterpretation of Mo and Ag values in till samples may be warranted. Advances in analytical instrumentation since the initial till geochemical data sets were produced for the Babine porphyry copper belt have resulted in lower detection levels for such elements as Mo and Ag.

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