TILL GEOCHEMICAL STUDIES IN THE BABINE PORPHYRY BELT: REGIONAL SURVEYS AND DEPOSIT-SCALE STUDIES (NTS 93 L/16, M/1, M/2, M/7, M/8)

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INTRODUCTION

Two approaches to till geochemical studies in the Babine porphyry belt have been employed by the British Columbia Geological Survey: 1) regional geochemical surveys to identify geochemically anomalous sites for follow-up by the mineral exploration industry and 2) detailed investigations around areas of known mineralization to evaluate the effects of surficial processes on geochemical distribution patterns, refine models of glacial dispersal in montane and plateau areas and develop methods of drift exploration applicable to the Interior Plateau. This paper provides an overview of these two components of the Babine till geochemistry program.

The study area is centered on northern Babine Lake and covers the entirety of the Babine porphyry belt (Figure 1). Copper porphyry mineralization in the study area is hosted in the Eocene Babine intrusives. Major deposits include the former Bell and Granisle copper mines. Porphyry copper deposits remain the primary exploration target in this region and several active porphyry properties, including the Hearne Hill, Nak and Trail Peak prospects, are within the bounds of the study area.

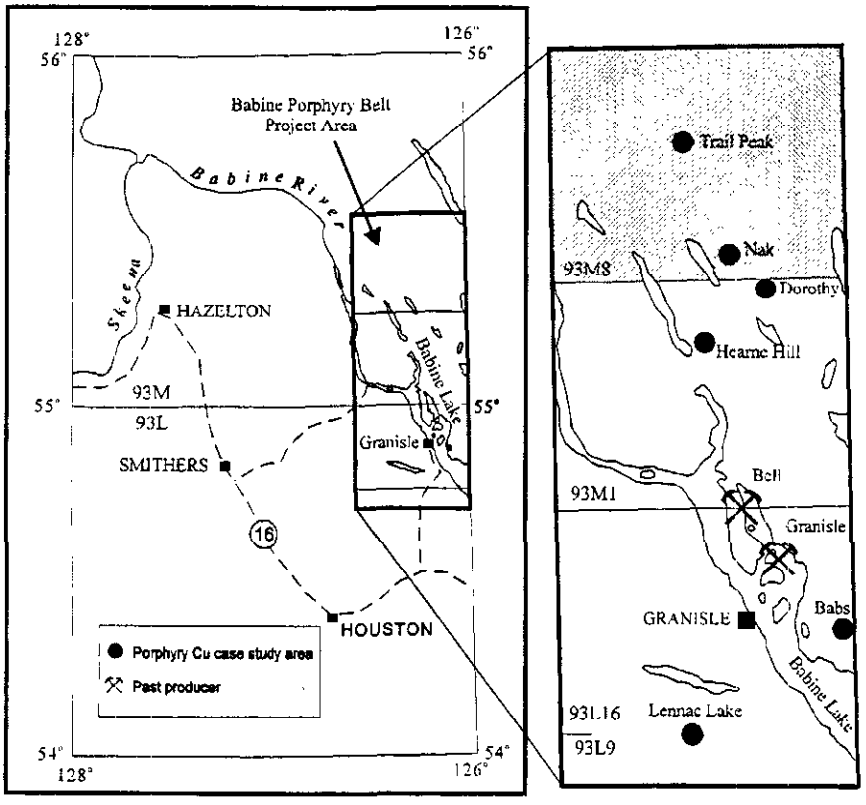

Figure 1. Location map of the study region and case study areas.

The purpose of the regional till geochemistry program is to improve the existing geochemical database of the Nechako Plateau area. This information will help to better assess the mineral potential of the region and thus increase the possibility of new discoveries. The Nechako Plateau is characterized by subdued topography, an extensive drift cover and poor bedrock exposure. For these reasons, mineral exploration in the Babine porphyry belt has been hindered. Results of the till geochemical surveys are expected to provide useful new data to stimulate further exploration.

The purpose of the detailed case studies in the Babine porphyry belt is to determine the most effective geochemical exploration methods for discovering, in till, the dispersed remnants of buried Babine porphyry Cu-Au deposits and their associated hydrothermal systems. These case study investigations include lithologic studies used to determine regional dispersal patterns in different types of sample media, needed for appropriate design of exploration programs. Stratigraphic and sedimentologic studies of Quaternary deposits are also included in order to define the glacial history and aid in interpreting till geochemical data.

Complementary regional geochemical surveys (till and lake sediments) and bedrock mapping surveys have proven highly effective in stimulating mineral exploration in low-lying drift-covered regions of the northern Interior Plateau. For example, prior till and lake sediment geochemistry surveys in the Nechako River map area (NTS 93F) to the south were successful in delineating several areas of known mineralization (Cook *et al.*, 1995) and in revealing locations of new mineralized zones. For this reason, till geochemical studies in the Babine porphyry belt have been conducted in conjunction with ongoing bedrock geology mapping (MacIntyre *et al.*, 1997), surficial geology mapping (Levson *et al.*, 1997) and regional lake sediment geochemistry (Cook *et al.*, 1997) components. These studies are part of the Nechako National Mapping (NATMAP) Project, a joint project of the British Columbia Geological Survey Branch, the Geological Survey of Canada, and university researchers.

PREVIOUS WORK

The bedrock geology of the Babine porphyry belt has been described by Carter (1973) and MacIntyre *et al.* (1996, 1997). The surficial geology of the region was discussed by Huntley *et al.* (1996) and Levson *et al.* (in press, 1997). Tipper (1971) and Plouffe (1994a, b) completed reconnaissance mapping of Quaternary deposits in the Nechako Plateau. Recent till geochemical studies in the plateau were discussed by Levson and Giles (in press). Several case study investigations have been conducted to date, as part of the NATMAP and Interior Plateau programs (Levson and Giles, 1995, in press; O'Brien *et al.*, 1995; O'Brien, 1996; Stumpf *et al.*, 1996, 1997). Kerr and Levson (1995) provided an annotated bibliography of published studies dealing with glacial dispersal processes in British Columbia. An overview of drift prospecting methods and research of particular relevance to the Interior Plateau region was completed by Kerr and Levson (in press). A discussion of current methods of exploration in the southern Nechako Plateau area, typical problems encountered and information that can be used to develop and refine drift exploration methods, was provided by Levson and Giles (in press). Reconnaissance till geochemical sampling programs in the Interior Plateau have been conducted in the Manson River - Fort Fraser area (93K, N) by Plouffe and Ballantyne (1993) and Plouffe (1995).

LABORATORY METHODS AND QUALITY CONTROL

Till samples collected during the regional geochemical surveys (each 3-5 kg in weight) are air dried, split and sieved to -230 mesh (<62.5 μm). This fraction is analyzed by instrumental neutron activation analysis (INA) and inductively coupled plasma analysis - atomic emission spectroscopy (ICP-AES). Half of each sample split is reserved for grain size or other follow-up analyses. For the detailed case study investigations, heavy mineral concentrates and magnetic separates of selected samples are also analyzed in the laboratory.

A number of quality control measures are included in both the field and laboratory analysis components of the program in order to discriminate geochemical trends, related to geological factors, from those that result from spurious sampling or analytical errors. These measures include the use of field duplicates, analytical or blind duplicates and control standards, one of each being randomly inserted into each set of 17 routine field samples to make a block of 20 samples that are submitted for analysis. Field duplicates are taken from randomly selected field locations and are subjected to the identical laboratory preparation procedures as their replicate pairs. Analytical duplicates consist of sample splits taken after laboratory preparation procedures but prior to analysis. Control reference standards include several British Columbia Geological Survey (Analytical Sciences Unit) geochemical reference materials comprising the -180 micron size fraction of a variety of bulk samples.

1) REGIONAL TILL GEOCHEMISTRY PROGRAM

OBJECTIVES

The primary objectives of regional till geochemical studies conducted in the Babine region were to identify geochemically anomalous sites that reflect areas of buried mineralization and to investigate patterns of glacial dispersal. Till geochemical anomalies identify areas where glaciers eroded mineralized bedrock and redeposited the mineral debris in down-ice dispersal trains. As glacial

dispersal trains may be hundreds to thousands of times larger in area than their original bedrock source, they provide a cost effective target for mineral exploration programs in drift-covered terrains (Shilts, 1976; DiLabio, 1990; Levson and Giles, 1995, in press). In addition, tills are 'first-derivative' products of bedrock and, having been transported to their present location mainly by the relatively linear flow of glaciers during one or more glacial episodes, they are more readily traced to source than higher order derivatives such as glaciofluvial or glaciolacustrine sediments (Shilts, 1993).

SAMPLING MEDIUM

Basal till was selected as the preferred sampling medium for this program rather than other types of surficial materials because mineral anomalies in basal till tend to be large, relatively easily detected and more readily traced to their origin than other sediment types (Levson and Giles, in press). In addition, the dominance of one main regional ice-flow direction throughout much of the last glacial period in the survey area (Levson *et al.*, 1997), resulted in a simple linear, down-ice transport of material. This makes tracing of basal till anomalies to source relatively easy compared to regions with a more complex ice-flow history.

Basal tills typically consist of compact, fissile, matrix-supported, sandy-silt diamicton (Photo 1). They are typically over-consolidated and often exhibit moderate to strong subhorizontal fissility. Vertical jointing and blocky structure are also common, especially in dry exposures. Oxidation of the till, characterized by reddish brown staining, is common and may occur pervasively or along vertical joint planes and horizontal partings. Subhorizontal slickensided surfaces are sometimes present, especially in clay-rich parts of the till. Clasts are mainly medium to large pebbles but they range in size from granules to large boulders. Total gravel content generally is between 10 and 30% but locally may be up to 50%. Subangular to subrounded clasts are most common and typically up to about 20% and are glacially abraded. Striated clasts are commonly bullet shaped, faceted or lodged; the a-axes of elongate clasts are often aligned parallel to ice-flow direction. Lower contacts of basal till units are usually sharp and planar. All of these characteristics are consistent with a basal melt-out or lodgement till origin (Levson and Rutter, 1988; Dreimanis, 1990).

Photo 1. Massive, matrix-supported diamicton interpreted as basal till; note the variety of clast sizes, fine-grained matrix and presence of subrounded to subangular clasts.

Basal till deposits can be confused with other facies of morainal sediments such as glacigenic debris-flow deposits or with other poorly sorted sediments such as colluvial deposits. These sediments have different processes of transportation and deposition which must be recognized in order to understand associated mineral anomaly patterns. For example, local variations will be reflected in some sediments while regional trends may be observed in others. Basal tills are first order derivative products whereas glacigenic debris-flow deposits and colluvial deposits have undergone a second depositional phase, related either to the paleo-ice surface or the present topography, and they are therefore more difficult to trace to their source. Glacigenic debris-flow deposits include some supraglacial tills and basal tills reworked by gravity or water. They typically consist of loose, massive to stratified, sandy or gravelly diamicton often with lenses and beds of sorted silt, sand and gravel. They often gradationally overlie basal till. Colluvial diamictons are differentiated from basal tills by their loose unconsolidated character, the presence of coarse, angular clasts of local bedrock, crude stratification and lenses of sorted sand and gravel.

1996 REGIONAL TILL GEOCHEMICAL SAMPLING PROGRAM

Regional till geochemical sampling in 1996 focused on the Nakinilerak map sheet (NTS 93 M/8) where 321 samples were collected. The 1996 regional program was combined with surficial geology mapping and, together with the 1995 program on NTS map sheets 93 L/16 and M/1, completes coverage of the Babine porphyry belt. Sample density on 93 M/8, M/1 and L/16, is one sample per 2.75, 2.0 and 3.0 square kilometres, respectively. An additional 42 samples were taken on adjoining parts of the Harold Price Creek and Netalzul Mountain (NTS 93 M/2 and M/7, respectively) map sheets. The western limit of sampling in the latter two map areas was the west arm of Babine Lake and the Babine River. Sample sites were selected to provide complete coverage of the map areas, with the greatest density of samples along transects perpendicular to established ice-flow direction. Along transects parallel to ice flow, where samples repeatedly represent the same terrain directly up-ice and therefore duplicate each other, wide spaced sampling was used. An intermediate sample spacing was used on transects oblique to flow. Sample sites included natural river cuts, wave-cut benches on lake shorelines and man-made exposures (roadcuts, borrow pits, soil pits and trenches). Average sample depth was 0.96 metre but ranged from 0.2 to 7.0 metres. Locations were plotted on a 1:50 000 topographic base maps.

Logging road access to the 1996 map area was limited to the westernmost and easternmost sides of the map sheet. All terrain vehicles, boats and helicopters were used to access other parts of the map area.

Sedimentologic data were collected at all sample sites in order to distinguish basal till from other sediment types. Data collected at each sample site included descriptions of sediment type, primary and secondary structures, matrix texture, presence of fissility, compactness, total percentage and modal size of clasts, rounding of clasts, presence of striated clasts, and sediment genesis and thickness. Further information was noted on soil horizons, local slope, bedrock striae, bedrock lithology, clast provenance and abundance and type of mineralized clasts.

The till sampling program included an evaluation of clasts in the till at each sample site. The objectives were to look for mineralized clasts, decipher patterns of glacial dispersal, determine the distances of glacial transport and rates of clast abrasion and rounding, and relate till-clast lithology to the bedrock lithology to aid in bedrock mapping. The procedure involved field identification of lithology, angularity and abrasion characteristics of each of five categories of clasts: 1) subangular to angular clasts in the basal tills with little or no evidence of glacial transport (*i.e.* clasts of very local origin); 2) distally derived surface erratics (*i.e.* clasts of probable supraglacial origin; often cobble to boulder sized); 3) clasts showing abundant evidence of glacial abrasion such as striae and faceting (*i.e.* basally transported clasts of probable local to intermediate provenance); 4) clasts of any size or shape showing evidence of potential mineralization (*e.g.*, sulphides, heavy iron oxidation, drusy quartz); and 5) other rock types. A visual survey of a wide area around the sample sites was conducted to locate rocks of category 4, the main focus of the sampling program; these clasts were described and collected for assay.

REGIONAL GEOCHEMICAL RESULTS

Geochemical analyses of till samples from the Nakinilerak map sheet (93 M/8) were not available at the time of writing but results from the 1995 sampling program on the adjoining Old Fort Mountain map sheet (93 M/1) were available. Median concentrations (in ppm) of copper, molybdenum, lead, zinc, nickel, arsenic and antimony in the regional data set were 44, 1, 11, 103, 30, 18 and 1.6, respectively. In nearly every case these median concentrations are higher than was encountered in the Fawnie Creek map area (NTS 93 F/3) in the southern Nechako Plateau where median concentrations of the same elements (in ppm) are 24, 1, 8, 65, 12, 9.2 and 1.2, respectively (Levson *et al.*, 1994 and Cook *et al.*, 1995). The only exception to this is gold which had a median concentration of 4 ppb in the southern Nechako Plateau rather than 2 ppb in the Babine study area.

Maximum concentrations of the same elements are also generally higher in the Babine area. These concentrations are (in ppm, with southern Nechako concentrations in parentheses): 1550 (66) for copper, 38 (7) for molybdenum, 97 (58) for lead, 626 (168) for zinc, 39 (35) for nickel, 130 (170) for arsenic and 4.2 (4.3) for antimony. The higher median and maximum concentrations of these elements in the regional till samples in the Babine area compared to the southern Nechako probably reflects the higher base metal potential of the former. This is especially apparent for copper,

where background (median) concentrations in till, as expected, are nearly twice as high in the Babine area as in the Fawnie area (44 ppm vs 24 ppm) and maximum copper concentrations are an order of magnitude higher (1550 ppm vs 66 ppm).

2) TILL GEOCHEMISTRY CASE STUDIES

OBJECTIVES

The Babine porphyry belt has excellent potential for hosting additional Cu-Au porphyry deposits, but geochemical exploration in the region is difficult due to an extensive drift cover and the widespread distribution of post-glacial lake sediments. Surficial mapping conducted during the first year of the Nechako NATMAP Project has demonstrated the usefulness of glacial till as a geochemical sampling medium, but sedimentological studies of till must be complemented with detailed investigations into the till geochemical expression of the hydrothermal alteration zones associated with the deposits.

The main objectives of the detailed geochemical investigations are two fold:

a) identify geochemical dispersal patterns in till, and the most effective pathfinder elements associated with Babine porphyry deposits,

b) identify, in the field and laboratory, the most effective methods of identifying the geochemical signatures of dispersed remnants of hydrothermal alteration zones in till around Babine deposits.

1996 GEOCHEMICAL CASE STUDIES

Alteration zones associated with Babine porphyry deposits are typically more extensive than the mineralized zones themselves, offering potentially larger exploration targets, provided that the geochemical and mineralogical expressions of the alteration mineralogy can be recognized in till. The porphyry deposits typically have potassic and propylitic alteration zones around a smaller central ore zone of Cu-sulphide minerals, as well as extensive pyrite halos with marginal polymetallic veins. The main purpose of the study was to identify, in till, the geochemical response of the dispersed remnants of hydrothermal alteration zones associated with the porphyry mineralization. The project will identify those geochemical exploration methods which most reliably reflect the alteration signatures, thus increasing the likelihood of future mineral deposit discoveries.

Case study investigations were conducted at five porphyry copper prospects in the Babine porphyry belt in 1996: Lennac (MINFILE 93L 190, 191), Hearne Hill (MINFILE 93M 006), Trail Peak (MINFILE 93M 011), Nak (MINFILE 93M 010) and Dorothy (MINFILE 93M 008) properties (Figure 1). A total of 321 till samples were obtained at these sites. Samples were collected along linear or fan-shaped traverses down-ice of the prospects to provide a clearer understanding of glacial dispersal processes and transport distances. Numerous profile samples (Photo 2) were also taken from trenches and soil pits on the properties and, at the Nak prospect, from diamond drill holes (Photo 3). Till samples from the latter were recovered by Hera Resources Ltd. during their drilling program. The drill core samples were analyzed before the regional till geochemical samples so that the preliminary results could be discussed here (see below).

A collaborative detailed till and biogeochemical study was also undertaken at the Lennac prospect with Colin Dunn (Geological Survey of Canada). In this study the principal biogeochemical sample medium was lodgepole pine outer bark, supplemented with samples of alder. Lodgepole pine bark samples were obtained from more than 120 sites over the general vicinity of the Lennac prospect.

NAK CASE STUDY RESULTS

The preliminary results of geochemical analyses of unique till samples recovered from diamond drill core at the Nak property are presented here. A total of 58 till samples were recovered from 19 of the 57 cores investigated (Figure 2). Wherever possible, more than one sample was taken at any one drill hole at varying depths. Nine of the 19 sampled cores yielded two or more samples, for total of 48. The largest number of samples obtained in any one hole was 17. These came from between 31 and 61 metres depth at hole 57. Copper concentrations in these nine holes in relation to depth are shown in Figure 3.

The median concentration of copper in all till samples recovered from core on the Nak property is 56 ppm. This value is elevated relative to the regional background (median) value of 44 ppm copper in tills on the Old Fort Mountain map sheet (93 M/1; see above), just south of the Nak property (Figure 1). Every till sample analyzed yielded copper values higher than the 75 percentile value (53 ppm) for the regional data set on 93 M/1, except two samples. These were both taken from cores on the northwest side of the property (holes 42 and 45; Figure 2) up-glacier of the main porphyry target. The lowest copper concentration (26 ppm) was obtained from the farthest up-ice location sampled (hole 42, located on the northern most side of the drill zone; Figure 2). Likewise, the highest copper concentrations obtained on the property came from two sites located on the southeastern most or down-glacier side of the main porphyry target zone (holes 13 and 35; Figure 2).

Seven holes yielded at least one till sample with copper concentrations above 100 ppm. These are all located on the down-ice side of the property except hole 50 which occurs at a much lower elevation (70 to 200 m lower) than the other six sites. High copper (404 ppm) in till at hole 50 probably reflects a greater depth of sampling within the till sheet at that location as well as a possible copper source to the northeast of that site. In

Photo 2. Vertical sampling profile at the Trail Peak property in colluvial sediments overlying till.

Photo 3. Indurated basal till in drill core at the Nak property.

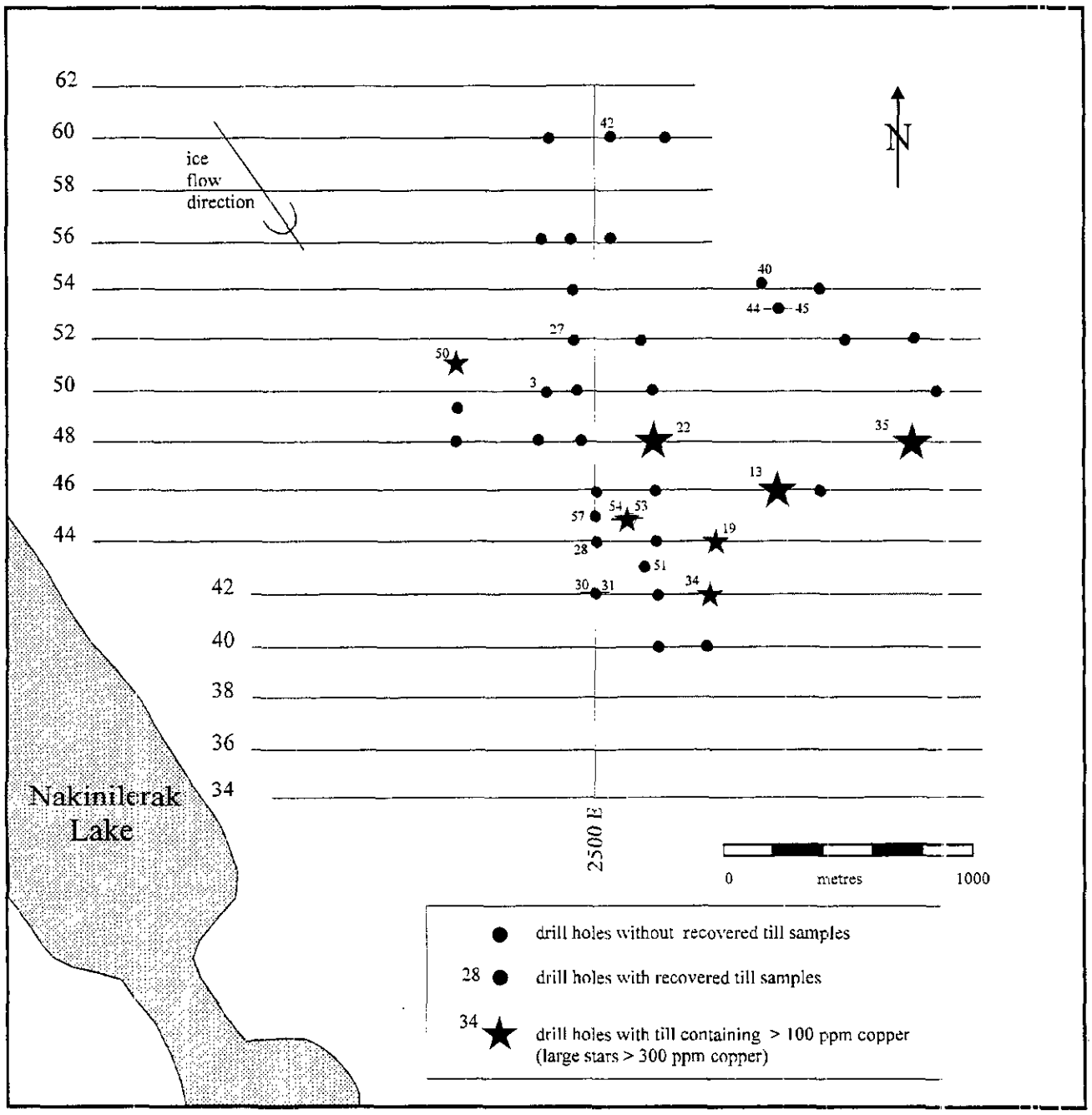

Figure 2. Location map of drill holes at the Nak property showing holes with recovered till (numbered) and holes with highly anomalous copper concentrations in till.

addition, the high copper concentrations in till at holes 13, 19, 22, 34 and 54 suggests an up-glacier copper source to the northwest of these sites, possibly in the region between holes 22 and 27 or even further northwest.

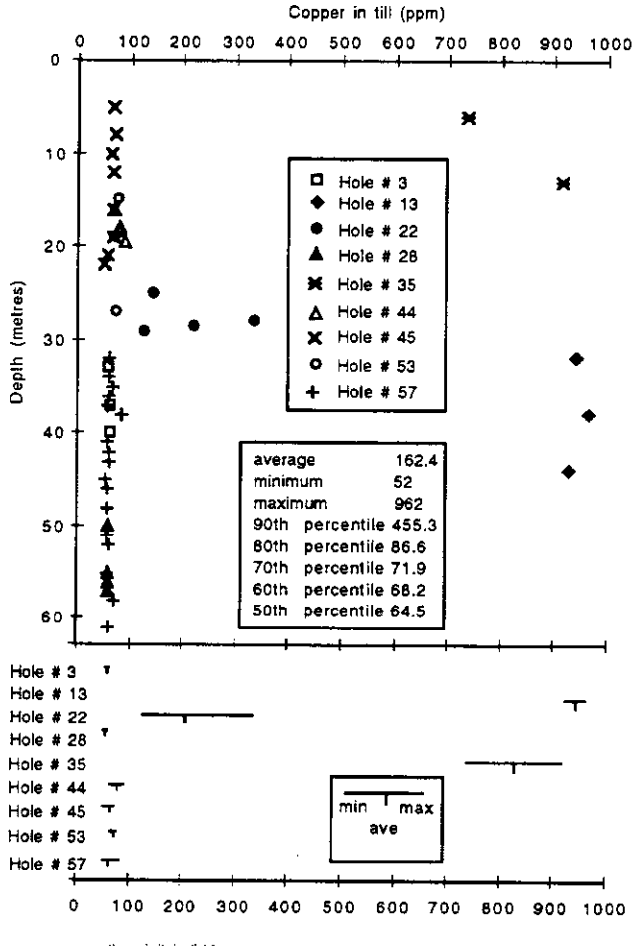

Figure 3. Copper concentrations in basal till (-63 µm fraction, analyzed by ICP) recovered from diamond drill holes at the Nak prospect versus depth; the lower half shows the range of variation in each hole (see text for explanation).

Copper concentrations in till at the Nak property, as shown by the drill hole data, are remarkably uniform over a substantial thickness (> 60 m) at many of the drill hole sites (Figure 3). Of the 9 holes with more than one sample, only three (holes 13, 22 and 35) yielded copper values greater than 100 ppm. Significantly, all three of these holes occur in the same part of the drill zone and there are few holes located between them. Copper concentrations in the remaining six holes have a relatively narrow range, generally between 55 and 80 ppm (Figure 3, lower half). These data strongly suggest that compositional stratification in the till is not well developed. This geochemical homogeneity may be a reflection of the relatively large size of the porphyry copper prospect that underlies the till.

The three holes at the site (13, 22 and 35) that show very high copper concentrations in till (Figures 2 and 3), indicate that at least one pronounced dispersal plume is present in the subsurface in the area. This high concentration plume (or plumes) apparently is superimposed on a much larger, till geochemical anomaly with elevated, but not extremely high, copper concentrations. Copper values in the high concentration plume show a relatively wide range compared with other till samples in the area (Figure 3, lower half) as expected. However, at one site (hole 13; Figure 3) highly anomalous copper concentrations are relatively uniform over at least a 12 metre thick interval, between about 32 and 44 metres depth. This observation, combined with copper concentrations in till at this site that are higher than at any other hole in the area, suggests that exploration for a higher grade copper zone in the porphyry may be warranted in the area northwest of hole 13. Since relatively few holes have been drilled in this region, the potential for a new, higher grade discovery in that area is enhanced.

The interpretations presented here are considered preliminary, as no attempt has been made to reconcile the till geochemical data with the results of recent drilling in the area. The information presented is provided only as an illustration of how till geochemical data from drill holes might be applied on an exploration property of this type.

SUMMARY

Current geochemical studies in the Babine porphyry belt include both regional (1:50 000 scale) till sampling programs and detailed (property scale) case study investigations. Regional till geochemical sampling is combined with surficial geology mapping and has been completed on five NTS map sheets including all of 93 L/16, M/1 and M/8 and parts of 93 M/2 and M/7. The purpose of these programs is to detect geochemical anomalies associated with glacial dispersal of mineralized bedrock. These anomalies may be readily detected by regional surveys because they are up to several kilometres long and a few kilometres wide. Regional till geochemical sample density in the Babine belt is about 1 per 3 square kilometres.

Although typically much larger than soil anomalies, till dispersal plumes are more subtle. For example, maximum element concentrations in till on the Old Fort Mountain map sheet (93 M/1) are 1550 ppm copper, 84 ppb gold, 38 ppm molybdenum, 97 ppm lead, 626 ppm zinc, 39 ppm nickel, 130 ppm arsenic and 4.2 ppm antimony. Till anomalies are elongated parallel to ice-flow direction, with mineralized source rocks occurring at or near the up-ice end of the dispersal plume. In areas of thick till, bedrock sources do not immediately underlie the anomaly but may occur 500 metres or more in the up-glacier direction. Exploration targets in these areas should be up-ice, rather than in the centre or at the head, of the geochemical anomaly. In order to understand mineral anomaly patterns, sedimentologic data should be collected at all sample sites so that till can be distinguished from

other surficial sediment types with different processes of transportation and deposition.

Geochemical case study investigations in 1996 were conducted at the Lennac, Hearne Hill, Trail Peak, Nak and Dorothy porphyry copper prospects. Preliminary results of a unique study of till recovered from diamond drill core at the Nak property, show that copper concentrations in tills overlying the porphyry prospect are invariably elevated above regional background values but they are surprisingly uniform over great depths. Copper in till generally increases in the down-glacier direction. Localized areas of highly anomalous copper concentrations suggest that specific, and possibly undiscovered, zones of relatively high-grade copper mineralization are present within the Nak porphyry.

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