Geochemical-Exploration Models for Porphyry Deposits in British Columbia

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Introduction

Exploration geochemistry using surficial material has been used to great success in British Columbia for a number of years and is a commonly used tool in porphyry-deposit exploration. However, as deposits become scarcer and exploration focuses on areas under deeper and/or more complex cover, greater care has to be taken in the choice of sampling media and/or analytical method as well as in the interpretation of the resulting geochemical data to achieve maximum benefit. Exploration is further complicated by the introduction of newer techniques in recent years, including proprietary selective leaches and analytical methods, making it necessary to be aware of both the strengths and limitations of these various techniques and methods. In many cases, time or budget limitations or a lack of knowledge about an area preclude carrying out a proper site-specific orientation survey, which makes it very difficult to determine proper sampling media and analytical techniques. In these cases, it is necessary to turn to historical exploration studies of similar deposits covered by similar surficial environments to help predict the geochemical expressions of the deposit in the surficial material and maximize one's chances of success. Geochemical-exploration models, which are developed from known processes and deposits, can provide the necessary framework to develop successful geochemical-exploration programs.

Geochemical-exploration models were first developed and presented by Bradshaw (1975) for deposits in the Canadian Cordillera and Canadian Shield. Bradshaw (1975) created general, conceptual geochemical-exploration models for ore deposits in BC, based on fundamental scientific principles and a limited number of case histories. The exploration models summarized the potential controls on geochemical dispersion and dispersal, and the expected results on geochemical distribution.

Keywords: *geochemical-exploration models, geochemistry, regional geochemical survey, geochemical survey, orientation survey, porphyry deposits, soil, till, vegetation*

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Subsequently, much research has been done expanding on these models for varied environments in the Canadian Shield (Cameron et al., 2004) and areas outside of Canada, in arid (Butt, 2005; Aspandiar et al., 2008) and tropical environments (Butt and Zeegers, 1992), as well as for volcanogenic massive sulphide and shale-hosted Pb-Zn-Ag deposits in the Canadian Cordillera (Lett, 2000, 2001; Lett and Bradshaw, 2003). Although proposed by Lett and Bradshaw (2003), further refinement of models for porphyry deposits in the Canadian Cordillera has not been addressed until this time. This study expands on the general conceptual models presented by Bradshaw (1975) and develops empirically-defined geochemical-exploration models for specific surficial environments, specifically for porphyry deposits in BC. These empirically-defined models will be based on historical exploration data from both industry and government sources. The data necessary to complete this study have been captured from many sources, including regional geochemical surveys carried out by the Geological Survey of Canada and the BC Geological Survey (BCGS); the results of updated sampling and archival-sample analysis available from Geoscience BC; deposit- and area-specific studies carried out by the BCGS and Geoscience BC; and historical geochemical data generated through exploration by industry.

Industry-generated geochemical-exploration data have been collected and maintained in the BC assessment report indexing system (ARIS) since the early 1950s. There is a wealth of historical information available within this dataset for deposits that have been subsequently well characterized. However, the majority of this information has been submitted in paper form, and is stored and made available to the public in Adobe® Acrobat® PDF format; therefore, the geochemical data is not currently available in a readily-accessible digital format. A secondary purpose of this project was to capture this data digitally and produce a province-wide geochemistry database for porphyry deposits.

Objectives for the project include

- compiling a consistent and comprehensive geochemical database for porphyry deposits in BC through acquisition of data from assessment reports and industry sources;

- categorizing deposits and geochemical data based on deposit and environmental variables likely to affect geochemical distribution;
- generating geochemical-exploration models for specific deposit types and surficial environments based on relevant classification criteria to provide
  - dominant geochemical dispersion and dispersal mechanisms;
  - typical or expected mineralization-element associations;
  - location, extent and magnitude of element enrichments or depletions;
  - potential sources of false anomalies or of element enrichments or depletions and, where possible, the means to identify them;
  - preferred sampling material and horizon, as well as preferred analytical method; and
  - guidelines for data interpretation.

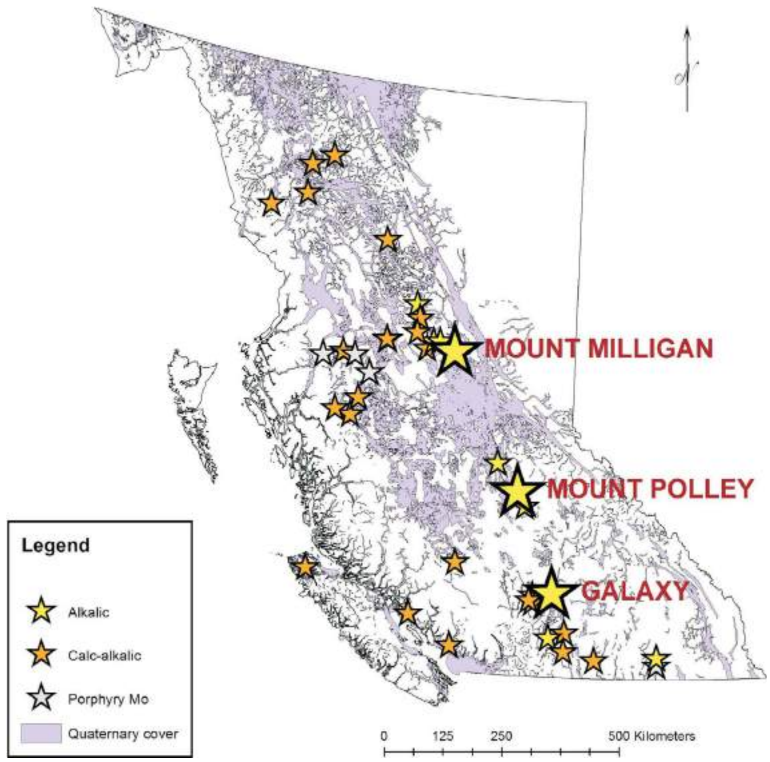

Figure 1. Location of selected porphyry deposits and distribution of Quaternary cover in British Columbia (from Massey et al., 2005).

Porphyry Selection and Data Collection

Of the 279 porphyry deposits listed within MINFILE (BC Geological Survey, 2011) and classified as 'developed prospect', 'past producer' or 'current producer', 73 were determined to have geochemical data contained within 273 assessment reports in ARIS. These geochemical reports present the results of industry-conducted, surficial geochemical surveys involving over 150 000 samples. However, the data contained within these reports are of highly variable quality and much of the data is of limited use or is not extractable due to poor print quality. The initial 73 porphyry deposits were subsequently reduced to 41 (Figure 1) and, to date, data for some 70 500 samples, summarized in Table 1, have been captured from assessment reports. To be selected for entry, reports must contain a minimum amount of information, including sample type and sampling horizon, digestion method, analytical finish and detailed spatial data. For inclusion into the porphyry geochemical database, it is necessary to convert local grid co-ordinates to UTM; where conversion is not possible, data are included for interpretation purposes only.

A combination of manual entry and optical character recognition (OCR) using ABBYY® FineReader® software was used to capture the data from the assessment reports. All OCR-collected data were manually verified against analytical certificates or submitted data tables to ensure the highest level of data quality and consistency. Due to the large amount of data, various data sources and often incomplete or missing quality-control data, full quality-assurance–quality-control procedures were not completed for all surveys; however, comments on data quality will eventually be included in the completed database. Where data were reported below the detection limit of the method, values were maintained in the database as the negative of the detection limit.

All geochemical data and metadata were converted to a consistent format, including column headings, units and projection method; metadata was added as required; and data were added to the master database, which was compiled using Microsoft® Access®. This database will be made available at the conclusion of the project and will be included with the final report.

Table 1. Summary of industry-generated geochemical data collected from the British Columbia assessment report indexing system (ARIS).

Sample Type	Current Totals
Soils (B-horizon)	61 000
Soils (other)	6 000
Tills	2 000
Streams	1 000
Vegetation	500
TOTAL	**70 500**

Controls on Geochemical Distribution and Porphyry-Classification Criteria

Although this study is restricted to porphyry deposits in a relatively restricted area, there are a number of variables that influence both the nature and geometry of the deposits and that also affect the development of the associated geochemical signature in the surficial material. These variations result in a unique set of conditions for each porphyry system and even for individual deposits in a single porphyry system. Therefore, in order to develop usable and appropriate geochemical-exploration models, deposits must be categorized based on a limited number of processes or deposit characteristics, which will control the dominant geochemical expressions of a porphyry deposit in the surficial environment, and on the factors that control or influence these processes, which can be broadly categorized as primary, secondary and postsecondary processes. Classification of the porphyry deposits of interest is found in Table 2 and explained below.

Primary Processes

In this paper, primary processes are deposit-specific mechanisms that control the geochemical distribution of elements within the deposit itself and relate to the ore-forming processes and/or mineralization styles. These primary processes control the inherent geochemical signature of the deposit itself and any associated alteration, which is subsequently modified or redistributed by secondary processes. Moreover, to address primary processes, deposits are classified based on the porphyry-type classification developed by Lefebure and Ray (1995), which categorizes porphyry deposits as 'alkalic', 'calc-alkalic' and 'porphyry Mo' deposits. It is recognized that this is somewhat of a generalization since individual deposits will vary within these groupings and whenever possible, the characteristics of individual deposits that can affect the resulting surficial geochemistry are discussed.

Secondary Processes

Secondary processes result in the transfer or modification of the ore-deposit material and can include both physical and chemical mechanisms. These processes include the physical transport of material through geomorphological processes (colluvial, alluvial, fluvial, eolian and glacial), and weathering of the ore deposits and overlying bedrock. Glaciation is the secondary process that will perhaps exert the greatest control on the geochemical expression in BC, as widespread glaciation throughout the province has occurred most recently during the Late Wisconsinan (maxima circa 14 500 BP; Clague and James, 2002). This glacial event has caused widespread distribution of tills and other glacial deposits throughout BC (Figure 1), and the nature and distribution of these materials has had a profound effect on the geochemical signature of deposits. For the purpose of identifying secondary processes, surficial cover is divided into four categories based upon soil (terrain) mapping done by the BC Ministry of Environment (2011):

Table 2. Classification of selected British Columbia porphyry deposits, based on factors that can affect the surficial geochemical expression, as well as the dispersion and dispersal mechanisms. These factors are temperature, expressed in terms of periods of frost-free days (ffp) and amount of non-snow precipitation (nsp); relief, expressed in terms of topography; and porphyry type, as presented in Lefebure and Ray (1995).

		Warm (> 50 days ffp)			Cold (<50 days ffp)		
		Steep	Moderate	Slight	Steep	Moderate	Slight
Dry (<500 mm nsp)	Calc-alkalic	May Hearne Hill Morrison Indata Schaft Creek	Brenda HED Highmont Alwin Poplar	Getty South Jean	Takla (Redton-Rainbow) Kemess Red Chris	Gnat Pass Eaglehead	
	Alkalic	Mount Polley Col Mount Milligan	Prime Getty Mouse Mountain	Galaxy Ajax Woodjam	Chuchi Lake		
	Mo	Carmi Mo Stewart Davidson	Mineral Hill		Storie		
Wet (>500 mm nsp)	Calc-alkalic	OK North Hushamu	Louise Lake	Gambier Island	Taseko (Empress) Huckleberry New Nanik Whiting Creek		
	Alkalic	Kena Gold Kena (Gold Mountain)					
	Mo	Pitman					

Abbreviations: ffp, frost-free period; nsp, non-snow precipitation.

- Residual soils: soils developed directly from the weathering of the bedrock on which they reside
- Locally-derived transported cover (geochemically attached): these materials have a direct connection to the underlying bedrock and may be developed through glacial weathering and localized transport (a few tens of metres) or through colluvial processes (colluvium and some till veneers)
- Transported cover (geochemically detached): these materials have no direct geochemical connection to the underlying bedrock and are sourced from distal materials (i.e., till blankets, outwash, glaciolacustrine deposits)
- Blind deposits: the current surface of weathered bedrock has not reached these deposits and they are therefore blind to the surface

Postsecondary Processes

Postsecondary processes, for the purpose of this paper, are defined as those processes that modify or transport a geochemical signature after the deposition of the material, and which are generally independent of the physical transport of mineralized material. These processes include hydromorphic, phreatic, vadose zone and gaseous transport, as well as transportation by vegetation. Also included in these postsecondary processes are bio- and cryoturbation, as they are processes that modify the postdepositional distribution of material; however, these processes are not prevalent throughout most of BC.

Controlling Factors

Climate

The overall climate in BC during the last postglacial period has been fairly stable, becoming steadily cooler and wetter throughout approximately the past 14 000 years (Hebda, 2007). However, due to the broad range of climate zones within BC, climatic conditions can vary greatly between deposits, a factor which can have a considerable effect on the generation of geochemical anomalies by controlling the secondary and postsecondary processes (Butt, 2005; Aspandiar et al., 2008). The two dominant climatic controls are temperature and availability of water (precipitation). Climate data for deposit locations (from BC Geological Survey, 2011) were determined using the ClimateBC model developed at the University of British Columbia (2011) and based on the PRISM (Parameter-Elevation Regressions on Independent Slopes Model) climate-mapping system presented in Daly et al. (2002). Although climate can be an important factor, the influence of temperature and water availability decreases as relief increases; as a result, physical transport processes will dominate in areas of steep topography (Butt, 2005).

Temperature

Temperature can affect the geochemical signature of an ore deposit in the surficial environment through a number of different mechanisms. Warmer climates promote chemical weathering and increase the availability of elements liberated through weathering. Moreover, temperature controls the availability of water throughout the year as water is not available during winter months due to freezing. Low temperatures and long periods of frost can also promote frost-induced fracturing, leading to weathering and increased colluvial processes.

Porphyry deposits were classified based on temperature according to their frost-free period (ffp), which is the number of consecutive days that the area experiences temperatures above freezing. Two classifications were made, with deposits falling into period categories of either more or less than 50 frost-free days. Frost-free period was chosen over mean annual temperature, as it was considered a better indicator of the potential effects of temperature, highlighting the unavailability of water and frost-driven processes that prevail during winter months.

Precipitation

Precipitation, or the availability of water, is the main factor controlling postsecondary processes and it can also have an effect on secondary physical-transport mechanisms. Although the amount of precipitation (Butt, 2005) is an important factor, so is seasonality; therefore, the classification of the deposits falls into two categories based upon whether the amount of non-snow precipitation (nsp) is greater or lesser than 500 mm. Precipitation received as snow will more likely be introduced to the hydrological system as runoff, thus increasing alluviation, rather than, to any significant extent, to the local groundwater system, where the aforementioned postsecondary processes occur.

Increased availability of water in areas of low to moderate relief will generally cause a higher water table and increase the likelihood of phreatic and hydromorphic processes occurring, whereas in areas with lower water tables, the dominant processes will be gaseous transport and vadose zone processes.

Physiography

The relief of the area surrounding a deposit has strong control over the processes responsible for physical transport and soil development. Steep areas will prevent soil formation and result in physical transport (alluvial and colluvial processes) exerting the dominant control on geochemical dispersal. Moreover, in steep areas rainfall will be more likely to manifest itself in the form of runoff, decreasing the likelihood of water infiltration and increasing that of alluvial processes. Deposits are classified, generally based on topography, as being of slight (<100 m elevation-change/km), moderate (100–300 m elevation-change/km) or steep (>300 m elevation-change/km) relief; however, local variations in relief are common and interpretation is based primarily on local assessment of elevation.

Development of Geochemical-Exploration Models

The geochemical-exploration models for this project were developed by determining the element associations and their distribution between sampled media and mineralization, and linking those distributions to the process generating the geochemical pattern. Relating the geochemical expression to mineralization and/or geology, and relating the expression to a process is a necessary exercise for each deposit as well as within each deposit. At the conclusion of the project, these geochemical expression-process relationships will be compiled into a generalized graphical representation of the individual geochemical-exploration models. At this stage, these models are incomplete and are also beyond the scope of this paper. Geochemical expressions and related processes for selected deposits are discussed below to highlight the importance of their study and that of the data extracted from assessment reports.

Discussion

This paper presents a preliminary discussion and interpretation of observed geochemical behaviour for the Mount Polley (MINFILE 093A 008; BC Geological Survey, 2011), Mount Milligan (MINFILE 093N 194) and Galaxy (MINFILE 092INE007) porphyry deposits, over which substantial B-horizon surveys were conducted and the results reported in ARIS; details of the deposits and surveys are summarized in Table 3.

The Mount Polley and Mount Milligan deposits are alkalic porphyry deposits characterized by a warm, dry climate (>50 days ffp and <500 mm nsp) and predominantly steep topography (although locally variable). The mineralized areas at Mount Polley and Mount Milligan are covered with material of variable type and thickness (Figures 2, 3), with areas covered by predominantly colluvial material due to the steep topography. The Galaxy deposit is an alkalic porphyry deposit characterized by a warm, dry climate (>50 days ffp and <500 mm nsp) and predominantly slight topography. A relatively consistent till cover of variable thickness (up to 2–3 m) blankets the mineralized areas at Galaxy (Figure 4).

The results discussed here show that there is a broad range of potential anomaly-formation mechanisms, even in a limited number of deposits, illustrating the need for both properly-mapped surficial units and interpretation of the geochemistry based on this mapping. Many of the elements analyzed show an association with underlying geology, although this association is not discussed in this paper. Interpreted geochemical expressions are based on the analysis of multi-element geochemistry and element associations are explained in the text. However, due to length restrictions and to maintain clarity, only the data for copper (Figures 2–4) and gold (Figure 5) are presented; all geochemical data and maps will be included in the final report.

Shallow, Locally Derived Cover

The simplest case for interpreting geochemical signatures, aside from residual soils, is in those areas where the deposits are concealed beneath shallow (on the order of 1–3 m), locally-derived cover, such as basal-till veneers or colluvium, or areas that are characterized by predominantly locally-derived cover sediment (tens of metres). In this case, the soils are developed directly from material transported from the deposit and, as a result, the geochemical signature can be preserved and detected in B-horizon soils. Two locations where this is interpreted as occurring are the Galaxy

Table 3. Summary of B-horizon soil surveys at Mount Polley, Mount Milligan and Galaxy porphyry deposits.

	Mount Polley	Mount Milligan	Galaxy
ARIS number	16040 (McNaughton, 1987)	12912 (Heberlein et al., 1984)	29628 (Caron, 2007)
Availability of water	Dry	Dry	Dry
Temperature	Warm	Warm	Warm
Topography	Variable - steep	Variable - steep	Slight
Surficial material	Varible simple to complex Transported Till veneer Till blanket with colluvium	Varible simple to complex Transported Colluvium Till blanket Glaciofluvial	Simple Transported Till veneer or blanket
Geochemical survey	B-horizon soils, 80 mesh, aqua-regia digest, ICP-ES	B-horizon soils, 80 mesh, aqua-regia digest, ICP-ES finish	B-horizon soils, 80 mesh, aqua-regia digest, ICP-ES
Elements analyzed	Ag, As, Au, Cd, Co, Cr, Cu, Fe, La, Mg, Mo, Mn, Ni, Pb, V, W, Zn	Cu, Ti , P, K, Cr, La, B, Mg, Ca, Mo, Sr, Zn, Pb, Al, Sn, Cd, Th, U, Bi, V, Ba, W, Ni. Fe, Ag, Mn, Sb, As, Co, Au	La, P, Bi, Al, Zn, Na, Ba, Au, Cu, Ag, Mo, Co, Cd, Fe, Ni, Cr, As, Ca, Mg, V, Sr, Ti, Sb

Abbreviations: ARIS, BC assessment report indexing system; ICP-ES, inductively coupled plasma-emission spectrometry

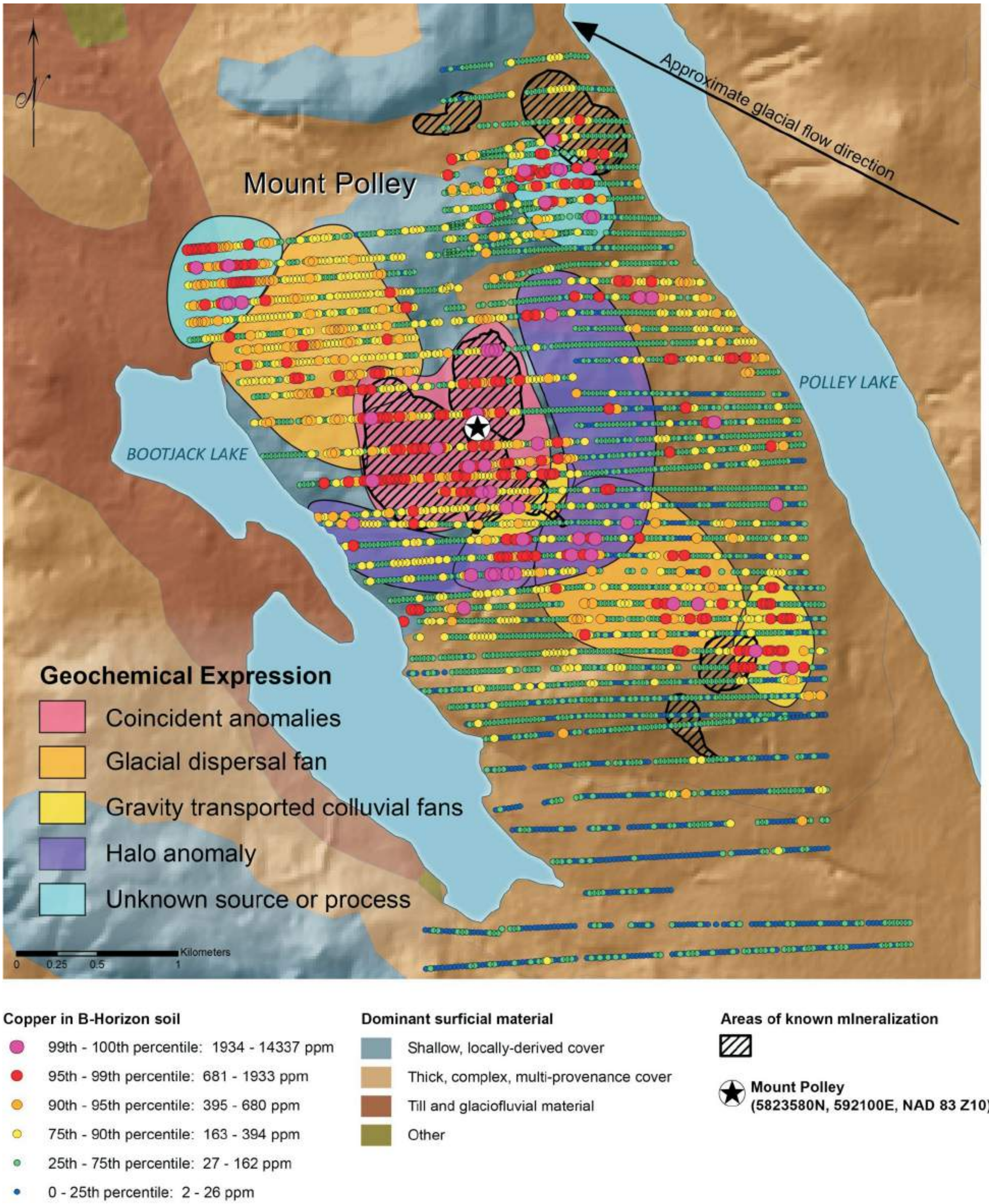

Figure 2. Copper distribution in B-horizon soils at the Mount Polley porphyry deposit, and illustration of associated geochemical expressions and distribution processes. Surficial material data modified from soil (terrain) mapping by the BC Ministry of Environment (2011); digital elevation data obtained from GeoBase® (Canadian Council on Geomatics, 2000); lake information obtained from Massey et al. (2005); and geochemical data from McNaughton (1987). Note: complete dataset extends beyond the limits of the map.

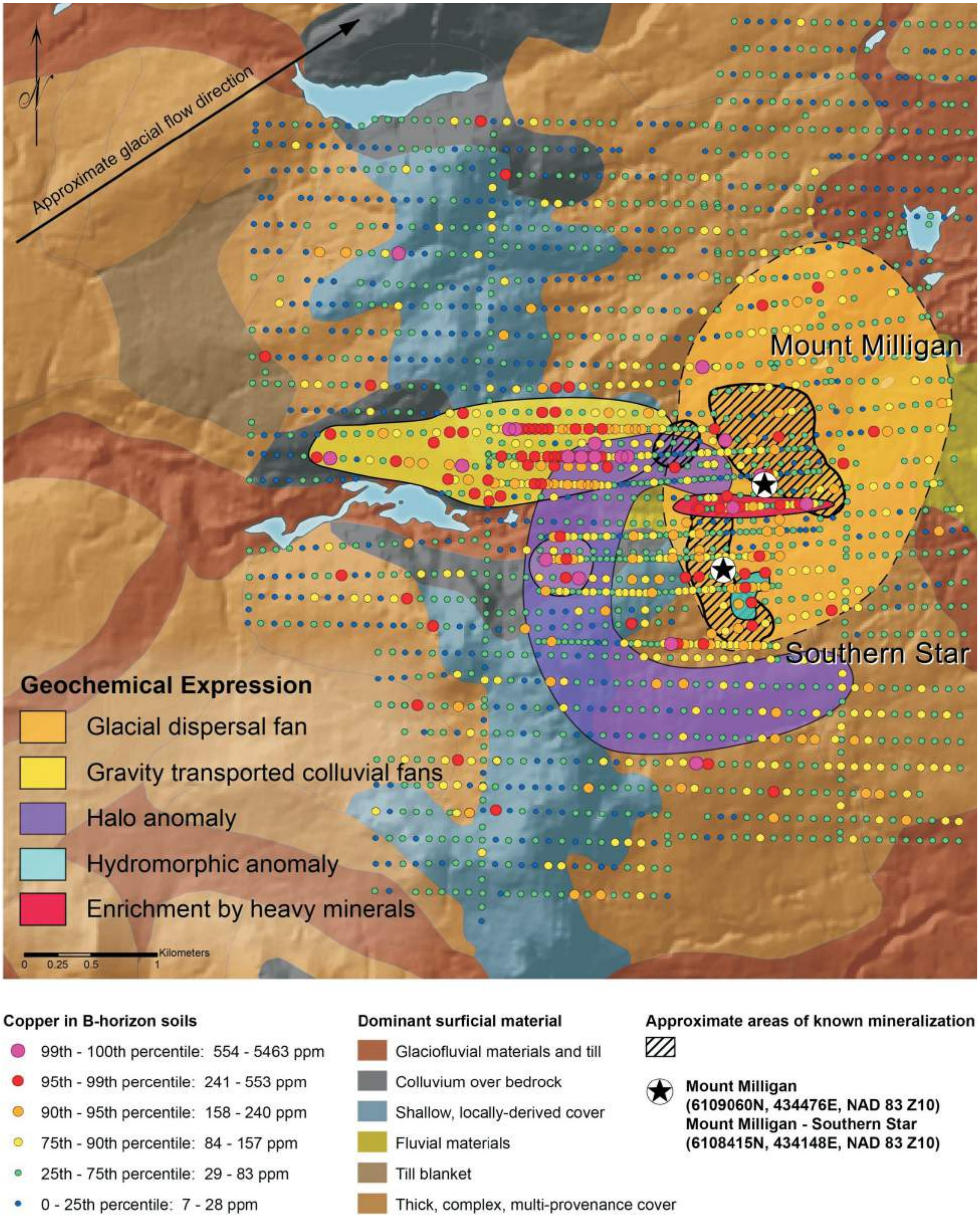

Figure 3. Copper distribution in B-horizon soils at the Mount Milligan porphyry deposit, and illustration of associated geochemical expressions and distribution processes. Surficial material data modified from soil (terrain) mapping by the BC Ministry of Environment (2011). Digital elevation data obtained from GeoBase® (Canadian Council on Geomatics, 2000); lake information obtained from Massey et al. (2005); and geochemical data from Heberlein et al. (1984). Note: complete dataset extends beyond the limits of the map.

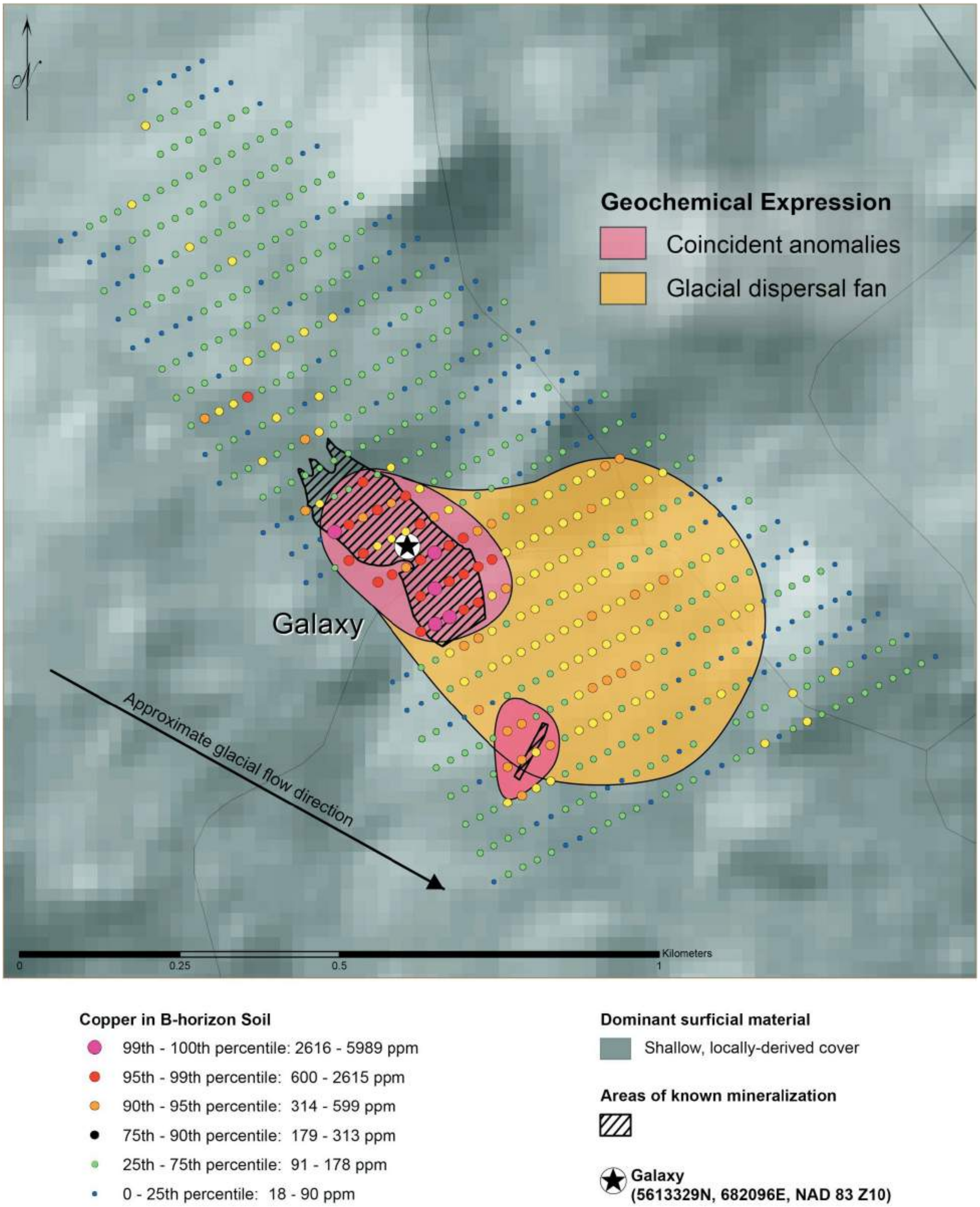

Figure 4. Copper distribution in B-horizon soils at the Galaxy porphyry deposit, and illustration of associated geochemical expressions and distribution processes. Surficial material data modified from soil (terrain) mapping by the BC Ministry of Environment (2011); digital elevation data obtained from GeoBase® (Canadian Council on Geomatics, 2000); and geochemical data from Caron (2007).

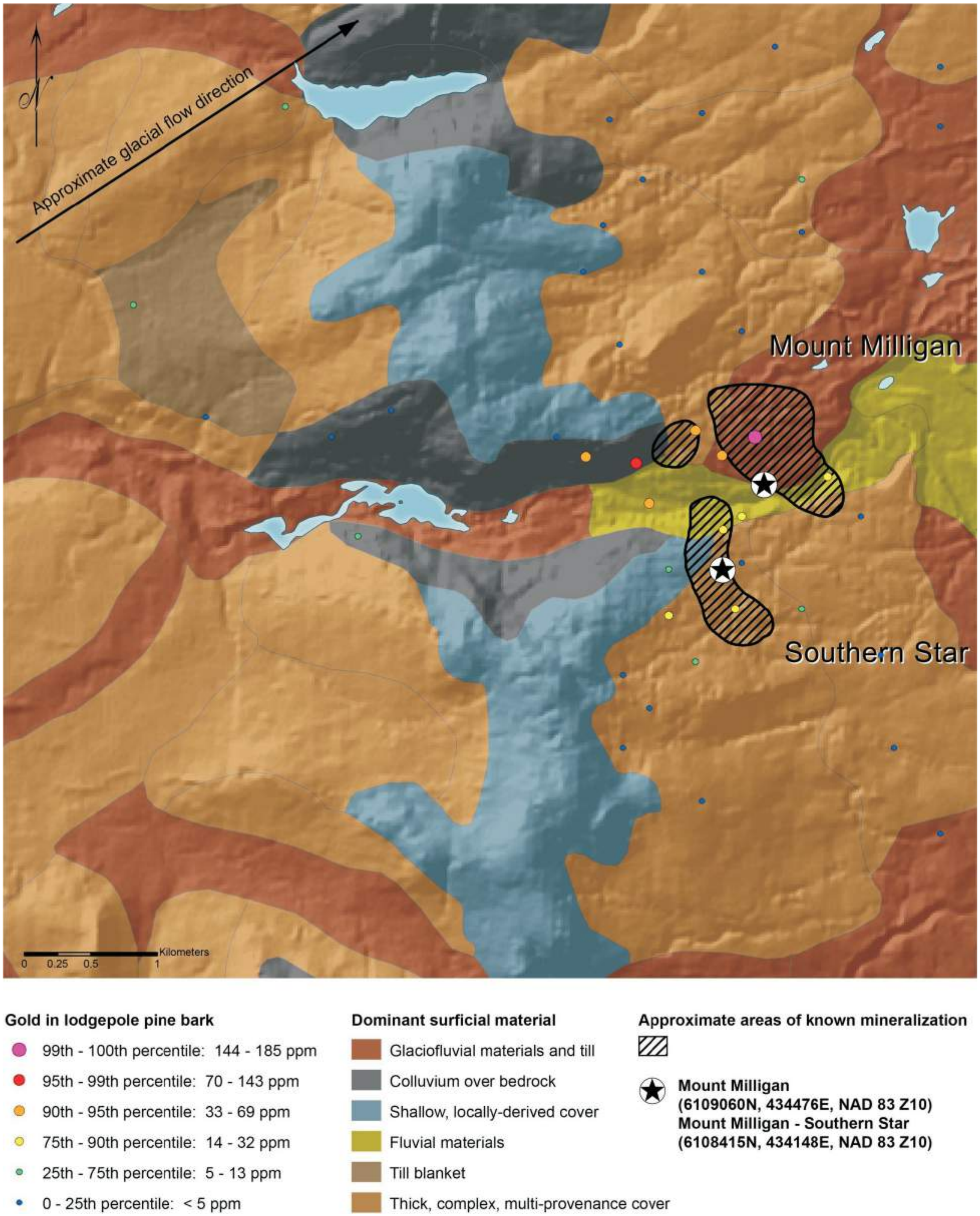

Figure 5. Gold distribution in lodgepole-pine (*Pinus contorta latifolia*) bark at the Mount Milligan porphyry deposit, and illustration of associated geochemical expressions and distribution processes. Surficial material data modified from soil (terrain) mapping by the BC Ministry of Environment (2011); digital elevation data obtained from GeoBase® (Canadian Council on Geomatics, 2000); lake information obtained from Massey et al. (2005); and geochemical data from Dunn et al. (1997). Note: complete dataset extends beyond the limits of the map.

deposit and areas in the vicinity of the Mount Polley deposit.

At Mount Polley, in areas covered by a shallow till veneer (approximately 1 m or less), there are elevated (Cu, Mo, Au) and reduced (As) soil geochemical signatures coincident with the mineralization (Figure 2). This area is also bounded by elevated Pb and Zn in soil forming a halo around the mineralized bedrock (Figure 2). Compared to Mount Polley, the till cover at the Galaxy deposit is slightly thicker; however, the B-horizon soil geochemistry also exhibits elevated Cu, Mo and Au coincident with the mineralized zone (Figure 3). Evident at Galaxy, though not at Mount Polley, is a zone of depressed barium concentrations in soil also coincident with the mineralized zone, but this may be an effect related to the low solubility of some Ba minerals (e.g., barite) in the aqua-regia digestion of the soil samples. The geochemical analyses of soil samples at Galaxy did not generate reliable data for As, Pb and Zn, and therefore these elements cannot be compared with the data collected at the Mount Polley deposit.

Associated with the coincident soil geochemical anomalies discussed above at the Mount Polley and Galaxy deposits are glacial dispersal fans, in the shallow cover, which extend the soil anomalies in the direction of glacial transport. At Mount Polley (Figure 2), the glacial dispersal fan shows elevated Cu, Au and Mo, the highest values being coincident with mineralization. At Galaxy, the dispersal fan shows elevated Cu (Figure 4) and Au, but provides no conclusive evidence for glacial dispersal of Mo.

Another possibility for predominantly locally-derived cover is material transported by gravity or colluvial processes. Both the Mount Polley and Mount Milligan deposits have areas of steep relief proximal to mineralization, where colluvial processes have the potential to transport mineralized material. These areas of steep elevation show evidence of gravity-transported anomalies and geochemical analysis of B-horizon soils reveals elevated Cu, Au, ±Mo and ±Co values in soils overlying colluvium developed from mineralized zones (Figures 2, 3).

Complex, Multiprovenance Cover

Areas of the Mount Polley and Mount Milligan deposits are covered by complex multiprovenance till blankets, which may be intermixed with local colluvium. In most cases involving complex cover, B-horizon soils are inadequate to determine the location of mineralization and there is no conclusive, coincident, elevated geochemical signature in soil relating to the mineralization at these deposits. However, at Mount Milligan there is evidence of geochemical haloes in the B-horizon soils, which show elevated levels of As, Zn and Pb surrounding mineralization (Figure 3).

Although there are no coherent coincident geochemical indicators within the B-horizon soils overlying the thicker, complex transported cover at Mount Polley and Mount Milligan, there are patchy, elevated concentrations of Cu, Mo and Au in soils following the direction of glacial dispersal at both deposits, which may be related to the up-ice mineralization (Figures 2, 3). These elevated values could indicate the presence of lenses of locally-derived material in the till blankets or of small windows to the underlying till veneer.

Vegetation and Tills

The vegetation survey of lodgepole-pine (*Pinus contorta latifolia*)-bark conducted at the Mount Milligan deposit by Dunn et al. (1997) was successful in identifying areas of mineralization under areas of complex cover and revealed elevated Au (Figure 5), Cu, Mo and As in bark directly overlying or immediately adjacent to mineralization. A till survey by Sibbick et al. (1997) conducted at the same time as the sampling of lodgepole-pine bark, also found similar element-distribution patterns. The maximum Au value in bark (Figure 5), located over the northeastern area of mineralization, may reflect transported cover material from the southern mineralized area and may not be an in situ anomaly; this situation may also apply in the case of Cu, As and Mo.

Hydromorphic Anomalies

Hydromorphic anomalies are formed through transport and concentration of elements by an aqueous process and are generally recognized through the common association of elements that are enriched during these processes. An example of a hydromorphic anomaly interpreted from the soil geochemical data from the Mount Milligan deposit is shown in Figure 3; a small soil-Cu anomaly overlying a mineralized area has formed in a topographic depression and yielded elevated Mn, Fe and Co concentrations; these elements are generally found associated with hydromorphic anomalies.

Fluvial Concentration of Heavy Minerals

An elongate area of elevated Cu, Co and Fe concentration in soil labelled ‘enrichment by heavy minerals’ (Figure 3) is located along a valley bottom overlying fluvial sediments at the Mount Milligan deposit. It should be noted that the linear appearance of this anomaly is somewhat exaggerated due to a slight baseline shift in the geochemistry between the main survey lines and the infill lines; however, when comparing this anomaly to the adjacent infill lines, it remains readily apparent. The higher concentration of Cu, Co and Fe in the soil is also an association typical of a hydromorphic anomaly; however, Mn is not elevated and there are also elevated Ti and V associated with this area. The higher Ti and V can be indicative of elements concentrated by accumulation of heavy minerals; the proximity of the soil anomaly to the fluvial sediments, in which heavy minerals (e.g., magnetite) might accumulate, supports this possibility.

Summary

Available data from multiple sources, including government, Geoscience BC, academic institutions and industry, have been compiled to allow the generation of empirically derived geochemical-exploration models. This compilation included geochemical data for over 70 000 surficial-material samples collected by industry; although publicly available, these data were only available in a largely unusable PDF format. The data were integrated into a comprehensive geochemical database for 41 porphyry deposits throughout BC (presented in Table 2). This database is being used, along with data for known mineralization, surficial-material mapping, digital elevation models, climate models, geology and geophysics, to generate geochemical-exploration models showing generalized or expected geochemical dispersion and dispersal patterns for porphyry deposits in BC. These models, developed for specific deposit types and climatic environments, provide the framework for the interpretation of geochemical-exploration–program design and data in areas not covered by proper orientation surveys, maximizing the potential for success in areas for which limited information is available.

The limited data presented here highlight the importance of integrating detailed surficial mapping and geochemical-distribution controls and processes into survey design and data interpretation. Without this integration, an area can easily be excluded, based on perceived negative results, or upgraded, based on false positive results. The selection of the proper sample media and method is the key to exploration success and, in many cases, one sample media may not be suitable to properly cover even a relatively small area.

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