Quaternary Geology and Till Geochemistry of the Colleymount Map Area, West-Central British Columbia (NTS 093L/01)

T. Ferbey, British Columbia Ministry of Forests, Mines and Lands, Victoria, BC, travis.ferbey@gov.bc.ca

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Introduction

The Tahtsa Lake district, and surrounding area, has high potential to host new porphyry Cu±Mo and polymetallic vein–style (including Au) mineralization. Centred on Tahtsa Lake (approximately 100 km south of Houston, British Columbia; Figure 1) this district, and areas immediately adjacent to it, have a rich mineral exploration history and at present host a producing porphyry Cu-Mo mine (Huckleberry mine) and numerous developed Cu±Mo prospects (e.g., Berg, Lucky Ship, Whiting Creek). This district also hosts epithermal vein and perhaps volcanogenic massive sulphide (VMS)–style mineralization, as suggested by past producers such as Equity Silver, Emerald Glacier and Silver Queen (MacIntyre, 1985; MacIntyre et al., 2004; Alldrick et al., 2007; Figure 2).

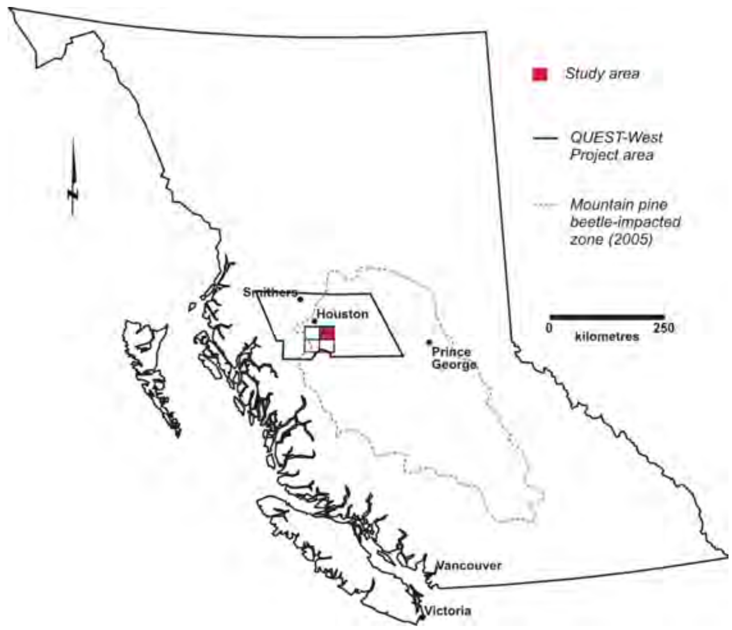

Figure 1. Location of study area in west-central British Columbia.

A two-year Quaternary geology and till geochemistry program is currently underway within the northern portion of the Tahtsa Lake district, within NTS map areas 093E/15, /16 and 093L/01, /02 (Figure 2). Presented here are observations made and details on till samples collected during the 2010 field season within Colleymount map area (NTS 093L/01). This is the second and final year of this program and builds on previous Quaternary geology and till geochemistry work by Ferbey (2010a, b) conducted immediately to the southwest in NTS 093E/15.

The Colleymount map area is ideally suited for a Quaternary geology and till geochemistry program as much of the map area is covered with glacial drift and continuous bedrock outcrop is limited. Till geochemical surveys are an effective method for assessing the metallic mineral potential of areas covered with glacial drift and can be used to follow-up airborne geophysical surveys conducted over drift-covered areas.

Keywords: *Nechako Plateau, Quaternary geology, surficial mapping, till geochemistry, heavy minerals, gold grain counts, porphyry Cu-Mo, polymetallic vein, volcanogenic massive sulphide*

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The objectives of this two-year Quaternary geology and till geochemistry program are to

- characterize and delineate the Quaternary materials that occur in the study area and reconstruct the region's glacial and ice-flow history; and
- assess the economic potential of covered bedrock (subcrop) by conducting till geochemistry surveys.

The study area falls within the Mountain Pine Beetle–Impacted Zone and Geoscience BC's QUEST-West Project area. The goal of this project is to provide the mineral exploration community with high quality, regional-scale, geochemical data that will help guide exploration efforts. In addition to geochemical and geophysical data recently collected by Geoscience BC in the QUEST-West Project area, historic regional bedrock mapping and geochemical data have been published by the British Columbia Geological Survey (BCGS) and the Geological Survey of Canada (GSC). The BCGS has also made significant contributions towards an understanding of the region's metallogeny (e.g., Carter, 1981; MacIntyre, 1985, 2001; MacIntyre et al., 2004; Alldrick, 2007a, b; Alldrick et al., 2007). New dis-

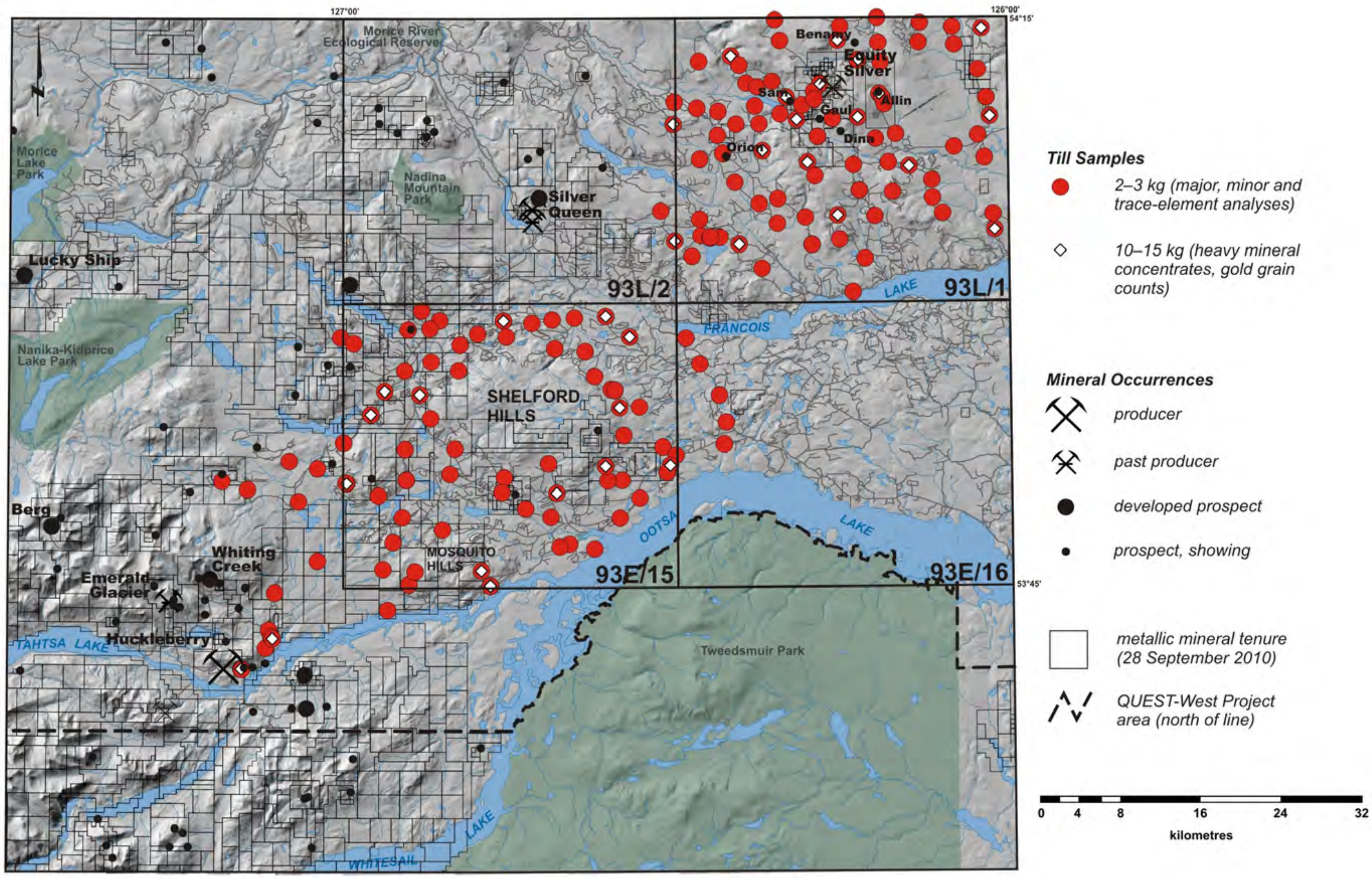

Figure 2. Study area including locations of mineral occurrences. Also shown are locations of till samples collected during the 2009 and 2010 field seasons within NTS 093E/16 and 093L/01, respectively.

coveries, and new insights into known mineral occurrences, will likely be a product of the integration of these new and existing datasets.

Study Area

The study area is located in west-central BC, approximately 65 km southeast of Houston, BC (Figures 1, 2), and is accessible by Forest Service, mine and mineral exploration roads. Quaternary sediments were studied in detail within NTS 093L/01 while a regional-scale glacial history and ice-flow study was conducted within NTS 093L/01, /02 and /08. The primary objective of this year's till geochemistry survey is to assess the mineral potential of NTS 093L/01. To do this, additional infill till samples were collected within the easternmost portions of NTS 093L/02, to cover a lack of appropriate sample material within NTS 093L/01 (Figure 2).

The study area is situated in the Nechako Plateau, a subdivision of the Interior Plateau. The Nechako Plateau is an area of low relief with flat or gently rolling topography and near-continuous forest cover (Figure 3; Holland, 1976). Elevations within the study area range from 715 to 1624 m asl. Although glacial sediments are ubiquitous, bedrock outcrop can be found along lake shorelines, on high ground and surrounding steep flanks, and on local small-scale erosional remnants that stand above Quaternary sediment cover in lower elevation settings. Small lakes and low discharge streams are common within the study area. The largest lake within the study area is Francois Lake, which is fed at its west end by Nadina River and drained 100 km away at its east end by Stellako River.

Bedrock Geology

The bedrock geology of the study area was first described and mapped by Hanson et al. (1942). More detailed mapping has since been completed by Tipper (1976), Church and Barakso (1990) and Alldrick (2007a, b). The following is a summary of the main geological subdivisions found in the study area from this more recent work.

Figure 3. Subdued topography of the study area, west-central British Columbia. View is to the north towards the saddle that hosts the past-producing Equity Silver Ag-Cu-Au mine (central background).

The study area lies within the Stikine terrane, just east of the Coast Crystalline Belt (Monger et al., 1991). The oldest rocks within it are calcalkaline volcanic rocks belonging to the Telkwa Formation of the Early Jurassic Hazelton Group. Unconformably overlying these rocks are coarse clastic marine sedimentary and volcanic rocks belonging to the Early Cretaceous Skeena Group. The Early Cretaceous volcanic succession (assigned to the Mount Ney volcanic package) is significant from a mineral exploration perspective as a pyroclastic unit (a distal dacitic dust tuff) within it hosts Ag-Cu-Au mineralization at the past-producing Equity Silver mine (Alldrick, 2007a, b; MacIntyre and Villeneuve, 2007). These rocks are in turn unconformably overlain by volcanic rocks of the Late Cretaceous Kasalka Group and Eocene Ootsa Lake and Endako groups. Andesite and basalt flows belonging to the Buck Creek Formation, and trachyte to basalt flows of the Goosly Lake Formation (both of the Endako Group), are the most areally extensive bedrock units of the study area.

Small- to medium-sized stocks of Late Cretaceous to Early Tertiary age intrude these Jurassic and Cretaceous volcanic and sedimentary units. Here, as elsewhere in the region, there is a strong positive relationship between the location of intrusive lithologies (in particular porphyritic intrusions like those of the Late Cretaceous Bulkley suite) and the locations of Cu, Mo, Ag, Pb, Zn and/or Au mineralization (Carter, 1981; MacIntyre, 1985).

Significant contributions towards the understanding of the region's metallogenesis, in particular porphyry Cu-Mo deposits, have been made by Carter (1981) and MacIntyre (1985). More recently MacIntyre (2001), MacIntyre et al. (2004), Alldrick (2007a, b) and Alldrick et al. (2007) have investigated the mineral potential of the Skeena Group.

Mineral Occurrences

There are seven documented metallic mineral occurrences within the study area (Figure 2). With the exception of Orion showing (MINFILE 093L 330; BC Geological Survey, 2010; Ag, Zn), for which a mineral deposit type has not yet been assigned, all metallic mineral showings and prospects within the study area are considered to be transitional, intrusion-related stockworks and veins (Panteleyev, 1995). Minimal exploration work has been conducted on Sam (MINFILE 093L 260; Ag, Zn), Dina (MINFILE 093L 313; Cu, Ag) and Benamy (MINFILE 093L 331; Ag) showings while prospecting and mapping, geochemical, geophysical and diamond-drill programs have been conducted on Gaul (MINFILE 093L 256; Ag, Cu, Zn) and Allin (MINFILE 093L 293; Cu, Ag, Zn, Pb, Mo) prospects.

Equity Silver (MINFILE 093L 001; Ag, Cu, Au), located in the north-central part of the study area, is a past-producing Ag-Cu-Au mine. While in operation from 1980 to 1994, it was BC's largest silver mine and produced 33.8 million tonnes of ore grading 64.9 g/t Ag, 0.4% Cu and 0.46 g/t Au (MINFILE 093L 001). Since its discovery, there has been some debate over the style of mineralization at Equity Silver and the relationship, if any, between the orebodies and a Paleocene quartz monzonite stock to the west and an Eocene gabbro-monzonite stock to the east. The five genetic models that have been proposed for mineralization at Equity Silver, summarized from Alldrick et al. (2007), are

- Early Cretaceous syngenetic exhalative mineralization with later remobilization resulting from emplacement of the eastern Eocene stock (Ney et al., 1972; MacIntyre, 2006);
- Early Cretaceous epithermal mineralization with later remobilization resulting from emplacement of the eastern Eocene stock (Wojdak and Sinclair, 1984);
- Early Cretaceous porphyry-epithermal (transitional) mineralization with later remobilization resulting from emplacement of the eastern Eocene stock (Panteleyev, 1995);
- epigenetic mineralization related to emplacement of the western Paleocene stock (Cyr et al., 1984); and
- epigenetic mineralization related to emplacement of the eastern Eocene stock (Church and Barakso, 1990).

A U-Pb zircon crystallization age of 113.5 +4.5/–7.2 Ma, reported by MacIntyre and Villeneuve (2007), confirms that the volcanic hostrock at Equity Silver is Early Cretaceous and part of the Mount Ney volcanic package of the Skeena Group (Alldrick, 2007a, b; Alldrick et al., 2007). Galena lead isotope studies by Godwin et al. (1988) and Alldrick (1993) indicates that Pb was introduced into the ore zones during the Early Cretaceous, and may have been contemporaneous with the deposition of the dacitic dust tuff that hosts these mineralized zones (Alldrick et al., 2007). Of the five genetic models proposed, the first three fit this geochronological control best. Understanding the timing and style of mineralization at Equity Silver, and the bedrock lithologies that host this mineralization, is important for the success of future exploration programs in the region.

Quaternary Geology

Previous Quaternary geology work conducted within the study area was limited to soils and terrain mapping. Researchers with the BC Ministry of Environment, Lands and Parks were the first to map the area, producing a 1:50 000 scale soil and landform map (BC Ministry of Environment, Lands and Parks, 1976). Singh (1998) has completed the most recent mapping within the study area, a terrain classification map completed at 1:20 000 scale.

Quaternary geological studies have been conducted in areas adjacent to the study area. To the north and northwest, Clague (1984), Tipper (1994), Levson (2001a) and Levson (2002) discuss the Quaternary geology and geomorphic features of portions of NTS 093L, M and 103I, P. To the northeast, Plouffe (1996a, b) mapped the surficial deposits and described the Quaternary stratigraphy of the west half of NTS 093K. Mate (2000) conducted a similar study to the southeast in NTS 093F/12 while Ferbey and Levson (2001a, b, 2003) and Ferbey (2004) conducted a detailed study of the Quaternary geology and till geochemistry of the Huckleberry mine region. Included in this work was surficial geology mapping and detailed sedimentological descriptions for Quaternary sediments in the vicinity of Huckleberry mine and an investigation into the region's ice-flow history. Most recently Ferbey (2010a, b) presents data and interpretations on the Quaternary geology and till geochemistry of NTS 093E/15, located immediately to the southwest of the study area.

Surficial Geology

During the 2010 field season, surficial materials were described at 141 sites within the study area. Observations were made at roadcuts and streamcuts, in hand-dug pits, and at discontinuous exposures along Francois Lake. Data collected at each site included map unit, topographic position, slope aspect and angle, and sedimentological characteristics, such as texture, structure, lateral and vertical variability, lower contacts and relationships with adjacent sediment types.

The dominant surficial material found in the study area is an overconsolidated, light brown diamicton with a clayey silt- to silt-rich matrix, similar to that described by Ferbey (2010a, b). It is typically massive and matrix supported, and in many examples vertical jointing and subhorizontal

Figure 4. Clayey silt- to silt-rich, overconsolidated diamicton, interpreted as a basal till. The blocky appearance of this till is due to well developed vertical jointing and subhorizontal fissility. Pick for scale (65 cm).

fissility is well developed giving it a blocky appearance (Figure 4). Matrix proportion varies from 65 to 75% and modal clast size is small pebble but can include boulder-sized material. Clast shape is typically subangular to subrounded. This diamicton generally conforms to underlying bedrock topography. Unlike areas to the south and southeast, however, streamlined or drumlinized and fluted terrain is relatively uncommon in NTS 093L/01 (cf., Ferbey, 2010a, b). Nevertheless, this overconsolidated, silt- and clay-rich diamicton is thought to be a subglacially derived diamicton (Dreimanis, 1989) and is interpreted as a basal till; the ideal sample medium for a till geochemistry survey.

Other glacial sediments occur within the study area. Glaciofluvial sands and gravels can be found along the south end of Parrott Lakes and extend southeast through Parrott Creek (locally known as Trout Creek) in a late-glacial to deglacial drainage system. Other similar, but smaller scale, systems occur in south-flowing creeks that drain into Francois Lake. Sandy, cobble-sized gravels occur in outwash plains and fan-deltas where these creeks approach Francois Lake. Another deglacial drainage system occurs within the Allin and Buck creek valleys east of Goosly Lake. Glaciofluvial hummocks in this system are up to 425 m long, 225 m across and 20 m high, and are composed of sandy pebble to cobble-sized gravels.

Glaciolacustrine and lacustrine sediments appear to be rare within the study area, even along the shore of Francois Lake. This and the almost exclusive occurrence of sands and gravels suggests that larger physiographic features such as the Francois and Goosly lake valleys last acted as conduits for meltwater drainage rather than basins for meltwater ponding.

Surficial geology mapping is currently in progress for NTS 093E/15 and 093L/01. This mapping is being conducted at 1:50 000 scale using aerial photographs (1:40 000 scale black and white), digital orthophotographs and other available remotely sensed imagery (e.g., Landsat). An integral part of this mapping, and of field data collection, is the reconstruction of the region's glacial and ice-flow history.

Ice-Flow History

During the 2010 field season, ice-flow data were observed and recorded at 33 field stations. These data supplement data collected from an additional 153 field stations, and 207 moderately well to well-preserved, streamlined landforms measured in aerial photographs, which were presented and discussed by Ferbey and Levson (2001a, b) and Ferbey (2004, 2010a, b). The majority of ice-flow indicators studied during the 2010 field season were outcrop-scale features such as striations, grooves and rat tails. These features are typically found on the lower flanks of hillslopes where relatively unweathered bedrock has been exposed in roadcuts. As seen in Figure 5, the degree of preservation of these smaller scale features can be high.

Orientations of these features indicate that there are two dominant ice-flow directions in the study area, 062–092° and 252–288°. These values are in agreement with those presented by Stumpf et al. (2000), Ferbey and Levson (2001a, b) and Ferbey (2004, 2010a, b) and confirm that an ice-flow reversal occurred within the study area during the Late Wisconsinan. During the onset of glaciation, ice flowed radially from accumulation centres such as the Coast Mountains towards central BC. Sometime during the glacial maximum, however, the ice divide over the Coast Mountains migrated east into central BC resulting in an ice-flow reversal. Glaciers that were once flowing east were now flowing west across some parts of the western Nechako Plateau, over the Coast Mountains and towards the Pacific Ocean. Eastward ice flow resumed once the ice divide migrated back over the axis of the Coast Mountains, and continued until the close of the Late Wisconsinan glaciation.

Till Geochemistry Survey

Till geochemical surveys are well suited to assessing the mineral potential of ground covered by glacial drift (Levson et al., 1994; Cook et al., 1995; Levson, 2002; Lett et al., 2006). Basal till, the sample medium used in these surveys, is ideal for these assessments as in most cases it has a relatively simple transport history, is deposited directly down-ice of its source, and produces a geochemical signature that is areally more extensive than its bedrock source and therefore, at a regional scale, can be more easily detected (Levson, 2001b).

Approximately 60 km southwest of the study area, Ferbey and Levson (2001b) and Ferbey (2004) conducted a de-

Figure 5. Well-preserved rat tails on an outcrop of Goosly Lake trachyandesite. The outcrop is located 3 km southeast of the Equity Silver minesite, on a southeastern aspect slope. Orientations of these rat tails indicated ice flow towards 272°. Pen for scale (14 cm).

tailed till geochemistry survey of the Huckleberry mine region. These studies demonstrate a clear relationship between till samples elevated in Cu, Mo, Au, Ag and Zn and Cu-Mo ore zones at Huckleberry mine and smaller scale polymetallic vein occurrences on the mine property. Lateral and vertical variability in trace-element concentrations in till at Huckleberry mine provide further evidence for an ice-flow reversal in the region during the Late Wisconsinan glacial maximum (Ferbey and Levson, 2007). Results from another case study conducted by Ferbey and Levson (2010) near the Copper Star Cu±Mo±Au occurrence, approximately 50 km west-northwest of the study area, also provide geochemical evidence for an ice-flow reversal. These results suggest that interpreting trace-element geochemical data from tills or soils in this region, in particular transport direction, can be complex.

Ney et al. (1972) recognized this ice-flow reversal during the early stages of exploration on the Sam Goosly deposit (eventually to become Equity Silver mine) when Ag anomalies in soils were initially unsuccessfully followed up with trenching and drilling. An eventual recognition of westward transport of glacial sediments (resulting from studies of ice-flow indicators on bedrock outcrop and in aerial photographs) led to drilling up-ice or northeast of the Ag anomalies in soils. A mineralized zone was soon outlined and a close relationship was demonstrated between the surface trace of this zone and westward-transported sediments that produced Ag anomalies in soils.

Plouffe and Ballantyne (1993), Plouffe (1995), Plouffe et al. (2001) and Levson and Mate (2002) have also conducted till geochemistry surveys to the east of the study area, in NTS 093F and K. Using percentile plots of precious-metal, base-metal and pathfinder element concentrations, and/or gold grain counts, each of these surveys identifies prospective ground where there were no known mineral occurrences.

Sample Media

During the 2010 field season, 2–3 kg till samples were collected at 85 sample sites for major-, minor- and trace-element geochemical analyses (Figure 2). An additional 18 till samples, each weighing 10–15 kg, were collected for heavy mineral separation and gold grain counts (Figure 2). These larger samples were collected at sites where an adequate amount of sample material was exposed. Till sample density for this survey is one sample per 10.5 km^2. The majority of unweathered till in the study area occurs at approximately 1 m below surface so most till samples were collected at this depth.

Till samples collected for major-, minor- and trace-element analyses are being sieved, and decanted and centrifuged to produce a silt plus clay–sized (<0.063 mm) and clay-sized (<0.002 mm) fraction. This sample preparation is being conducted at Acme Analytical Laboratories Ltd. (Vancouver, BC). Heavy mineral samples have been sent to Overburden Drilling Management (Nepean, Ontario), where heavy mineral (0.25–2.0 mm) and gold grain (<2.0 mm) concentrates are being produced using a combination of gravity tabling and heavy liquids.

On the 2–3 kg samples, minor- and trace-element analyses (37 elements) will be conducted on splits of the silt plus clay– and clay-sized fractions, respectively, by inductively coupled plasma–mass spectrometry (ICP-MS), following an aqua-regia digestion. Major-element analyses will be conducted on a split of the silt plus clay–sized fraction only using inductively coupled plasma–emission spectrometry (ICP-ES), following a lithium metaborate/tetraborate fusion and dilute nitric acid digestion. This analytical work will be conducted at Acme Analytical Laboratories Ltd. (Vancouver, BC).

Also as part of this project, a split of the silt plus clay–sized fraction (<0.063 mm) will be analyzed for 35 elements by instrumental neutron activation analysis (INAA) at Becquerel Laboratories Inc. (Mississauga, Ontario). Instrumental neutron activation analyses for elements such as Au, Ba and Cr complement those produced by aqua-regia digestion followed by ICP-MS, as they are considered to be a near-total determination and hence more representative of rock-forming and economic mineral geochemistry. Additionally, INAA determinations will be conducted on bulk heavy mineral concentrates produced from the 10–15 kg samples.

Quality Control

Quality control measures for analytical determinations include the use of field duplicates, analytical duplicates and reference standards. For each block of 20 samples submitted for analysis, one field duplicate (taken at a randomly selected sample site), one analytical duplicate (a sample split after sample preparation but before analysis) and one reference standard will be included in INAA and aqua-regia digestion followed by ICP-MS analysis. Reference standards used will be a combination of certified Canada Centre for Mineral and Energy Technology (CANMET) and in-house BCGS geochemical reference materials. Duplicate samples will be used to measure sampling and analytical variability, whereas reference standards will be used to measure the accuracy and precision of the analytical methods.

Summary

During the 2010 field season, 85 basal till samples were collected for major-, minor- and trace-element geochemical analyses, while an additional 18 till samples were collected for separation and analysis of heavy mineral concentrates and gold grain counts. The goal of this till geochemical survey is to assess the mineral potential of the

Colleymount map area (NTS 093L/01), an area ideally suited for a till geochemistry program as much of the map area is covered with glacial drift and continuous bedrock outcrop is limited. Ongoing and complementary to this till geochemical survey is 1:50 000 scale surficial geology mapping and a regional ice-flow study. Delineating and characterizing surficial materials of the study area and quantifying the net transport direction of basal tills are integral to the interpretation of resultant till geochemical data and will be useful to mineral exploration companies conducting their own surficial sediment geochemistry surveys in the area.

The 2010 field season saw the completion of fieldwork for the second and last year of a Quaternary geology program designed to assess the mineral potential of the northern portion of the Tahtsa Lake district, and adjacent areas (NTS 093E/15, /16 and 093L/01, /02). This study area falls within Geoscience BC's QUEST-West Project area, where additional geochemical data have recently been compiled and collected, mineral occurrence data have been updated (i.e., MINFILE, BC Geological Survey, 2010), and helicopter-borne time domain electromagnetic and gravity data have been acquired. These new data, in combination with the previous data published by the BCGS and GSC, the region's prospective bedrock geology and good road access make the Colleymount map area an attractive area to explore.

Till geochemical data for the Colleymount map area (NTS 093L/01) will be the topic of a combined BCGS Open File and Geoscience BC Report to be released in late spring 2011.

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