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

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

INTRODUCTION

The Tahtsa Lake district, and surrounding area, has high potential to host undiscovered 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; Figure 2). 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).

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 Quaternary geology studies and till geochemical exploration as much of the map area is covered with glacial drift and continuously exposed bedrock outcrop is limited. Till geochemical surveys are an effective method for assessing the metallic mineral potential of areas covered with glacial drift (Levson, 2001a) and can be used to follow-up airborne geophysical data acquired over drift covered areas.

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Forests, Mines and Lands website at http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork.

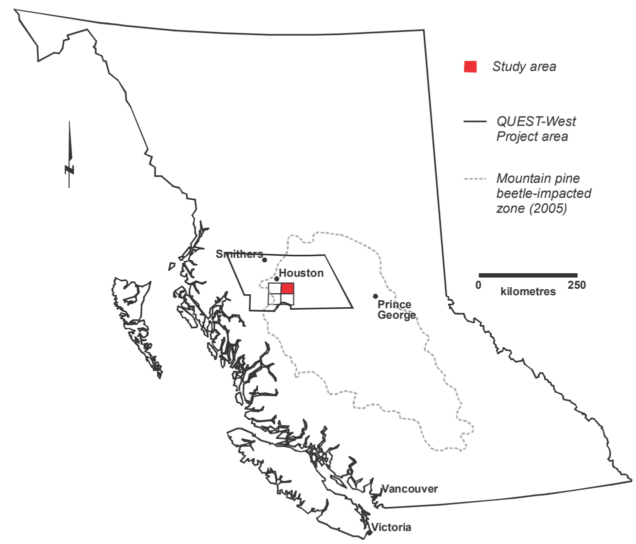

Figure 1. Location of study area in west-central British Columbia.

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

1) characterize and delineate the Quaternary materials that occur in the study area and reconstruct the region's glacial and ice-flow history; and
2) 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 the project discussed here 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, historic regional bedrock mapping and geochemical data have been published by the British Columbia Geological Survey (BCGS) and the Geological Survey of Canada (GSC) (Hanson *et al.* ,1942; Tipper, 1976; Church and Barakso, 1990; Alldrick, 2007a, b). 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 discoveries, and new insights into known mineral occurrences, will likely be realized through the integration of these new and existing datasets.

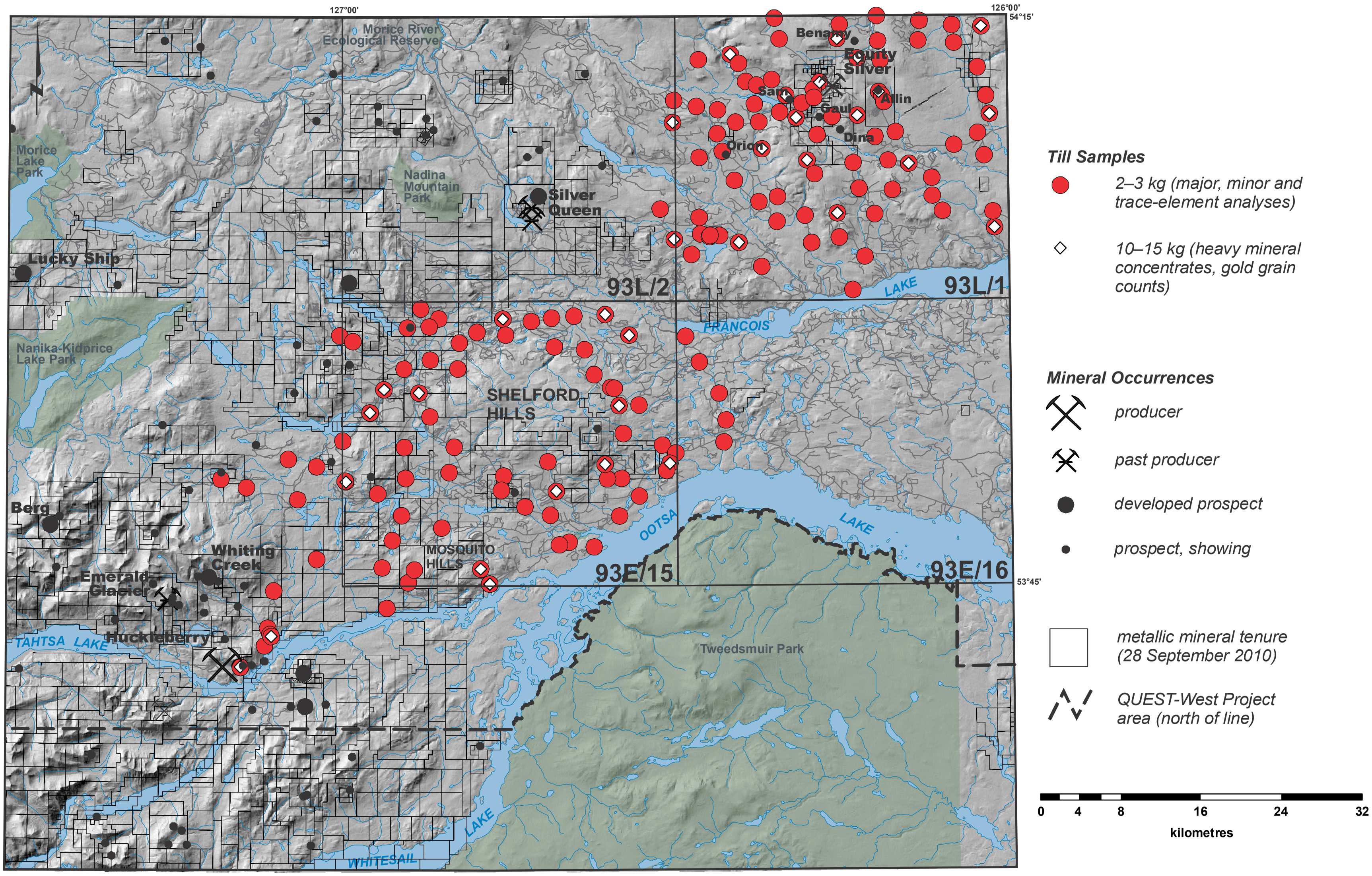

Figure 2. Study area including locations of mineral occurrences. Also shown are locations of till samples collected during the 2009 and 2010 field seasons within NTS 093E/15 and 093L/01, respectively.

STUDY AREA

The study area is located in west-central British Columbia, approximately 65 km southeast of Houston (Figures 1, 2), and is accessible by Forest Service, mine, and mineral exploration roads. Quaternary sediments were studied in detail within 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 the 2010 till geochemistry survey is to assess the mineral potential of NTS 093L/01. To do this, additional infill till samples were collected within the most eastern 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 (Holland, 1976). The Nechako Plateau is an area of low relief with flat or gently rolling topography and near continuous forest cover (Figure 3). 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 (at elevations above 715 m asl) on the flanks of steep terrain, and on local small scale erosional remnants that stand above Quaternary sediment at lower elevations. 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 at its east end into Stellako River.

Figure 3. Subdued topography of the study area.

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.

The study area lies within the Stikine terrane, just east of the Coast Crystalline Belt (Monger *et al.*, 1991). The oldest rocks include calcalkaline volcanic rocks belonging to the Telkwa Formation of the Early Jurassic Hazelton Group (Figure 4). Unconformably overlying these rocks are coarse clastic marine sedimentary and volcanic rocks belonging to the Lower Cretaceous Skeena Group. The Lower Cretaceous volcanic succession is significant from a mineral exploration perspective as a pyroclastic unit within it (a distal dacitic dust tuff) 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 Upper 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 exposed at surface in the study area (Figure 4).

Small to medium-sized stocks of Late Cretaceous to Early Tertiary age intrude these Jurassic and Cretaceous volcanic and sedimentary units (Figure 4). Here, as in elsewhere in the region, there is an association 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 understanding the metallogenesis of the region's porphyry Cu-Mo deposits has been made from 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 4). With the exception of Orion showing (MINFILE 093L 330; 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 British Columbia'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, 2010). 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

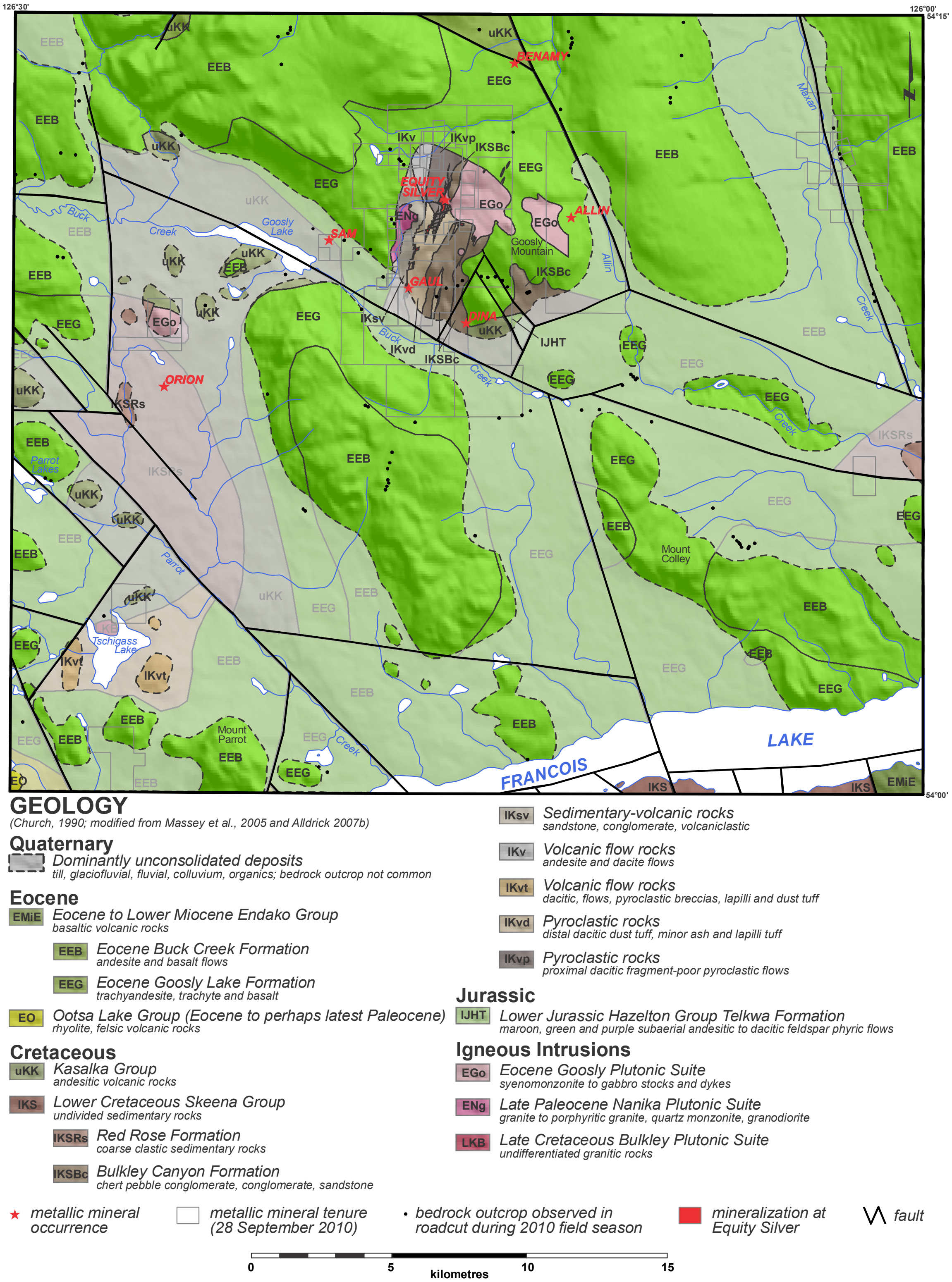

Figure 4. Bedrock geology of the study area. Quaternary sediment cover is approximated by the light grey transparent overlay and black dashed line.

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:

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

A U-Pb zircon radiometric 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 (Alldrick, 2007a, b; Alldrick *et al.*, 2007). Galena Pb isotope studies by Godwin *et al.* (1988) and Alldrick (1993) indicate 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 is limited to soils and terrain mapping. Researchers with the British Columbia Ministry of Environment 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 adjacent areas. 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 units.

The dominant surficial material found in the study area is an overconsolidated, light brown coloured diamicton with a clayey silt to silt-rich matrix, similar to that described by Ferbey (2010a, b) for areas to the southwest. It is typically massive and matrix supported, and often exhibits vertical jointing and subhorizontal fissility giving it a blocky appearance (Figure 5). 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 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

Figure 5. Clayey silt to silt rich, overconsolidated diamicton, interpreted as a basal till. Well developed vertical jointing and subhorizontal fissility give this basal till a blocky appearance. Pick for scale (65 cm).

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 Parrot Creek (locally known as Trout Creek) in a late-glacial to de-glacial 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 de-glacial 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 immediately adjacent to the larger physiographic features (such as the Francois and Goosly lake valleys), suggest that during deglaciation they were 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 153 field stations and 207 moderately well to well preserved streamlined landforms presented by Ferbey and Levson (2001a, b) and Ferbey (2004, 2010a, b) that summarize the ice-flow history of the region. The majority of ice-flow indicators recorded during the 2010 field season were outcrop-scale features such as striations, grooves and rat tails (Benn and Evans, 1998). These features are typically found on the lower flanks of hill slopes where relatively unweathered bedrock has been exposed in road cuts. In some cases, these features are remarkably well developed and preserved (Figure 6).

Orientations of the ice-flow indicators show 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-British Columbia and the coast. Sometime during the glacial maximum the ice divide migrated from the Coast Mountains east into central British Columbia. Ice was now flowing radially from central British Columbia resulting in a reversal of ice flow over the study area. 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 within the study area once the ice divide migrated back over the axis of the Coast Mountains, and continued until the close of the Late Wisconsinan glaciation.

Figure 6. Photograph of well preserved rat tails on an outcrop of Goosly Lake Formation trachyandesite. The outcrop is located 3 km southeast of the Equity Silver minesite, on a southeastern aspect slope. Orientations of these rat tails indicate ice flow towards 272°. Pen for scale (14 cm).

TILL GEOCHEMISTRY SURVEY

Till geochemical surveys are well suited for assessing the mineral potential of areas 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 glacial processes that erode and distribute sediment produce a geochemical signature that is areally more extensive than the bedrock source from which it was derived and therefore, at a regional scale, can be more easily detected (Levson, 2001a).

Approximately 60 km southwest of the study area, Ferbey and Levson (2001a) and Ferbey (2004) conducted a detailed till geochemical 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 the ice-flow reversal mentioned above, that occurred 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 exploratory trenching and drilling of Ag anomalies in soils was initially unsuccessful. The 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. This resulted in the delineation of a mineralized zone.

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 previously reported 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 there was an adequate exposure of sample material. Till sample density for this survey is one sample per 10.5 km^2. Most samples were collected from unweathered till typically 1 m below surface.

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

On the 2-3 kg samples, minor and trace element analyses (37 elements) were 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 were 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 was conducted at Acme Analytical Laboratories Ltd. (Vancouver, British Columbia).

Also as part of this project, a split of the silt plus clay-sized fraction (<0.063 mm) was analyzed for 35 elements by instrumental neutron activation analysis (INAA) at Becquerel Laboratories Inc. (Mississauga, ON). Instrumental neutron activation analyses for elements such as Au, Ba and Cr complement those produced by an aqua regia digestion followed 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 is included in INAA and ICP-MS (following an aqua regia digestion) analyses. Reference standards used are a combination of certified Canada Centre for Mineral and Energy Technology (CANMET) and in-house BCGS geochemical reference materials. Duplicate samples are used to measure sampling and analytical variability, whereas reference standards are 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). Mineral exploration of this area will benefit from a regional till geochemistry program as much of the map area is covered with glacial drift and continuous bedrock outcrop is limited. Ongoing surficial geology mapping at 1:50 000-scale and a regional ice-flow study will complement this till geochemical survey. 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 field work 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, 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, makes 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.

ACKNOWLEDGMENTS

The author would like to thank L.J. Diakow and S.M. Rowins for discussions on, and their insight into, local bedrock lithologies. The Touronds (Nanika Guiding Limited) and Slots (Wild Rose Camp) are thanked for their hospitality during the 2010 field season and sharing their local knowledge on the region's mineral exploration history. L. Howarth is thanked for her assistance in the field. T.E. Demchuk, P. Schiarizza, and A.S. Hickin are thanked for their review of an earlier version of this manuscript.

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