Quaternary Geology and Till Geochemistry of the Nadina River Map Area (NTS 093E/15), West-Central British Columbia

T. Ferbey

KEYWORDS: Tahtsa Lake district, Quaternary geology, surficial mapping, till geochemical survey, till geochemistry, trace-element geochemistry, heavy minerals, gold grain counts, porphyry Cu, porphyry Cu-Mo, polymetallic vein, volcanogenic massive sulphide

INTRODUCTION

The Tahtsa Lake district 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; MacIntyre, 1985). This district also hosts epithermal vein and perhaps volcanogenic massive sulphide (VMS)–style mineralization, as suggested by past producers such as Equity Silver and Emerald Glacier (MacIntyre, 1985; MacIntyre et al., 2004; Alldrick et al., 2007; Figure 2).

Currently there are large areas of unstaked ground within, and adjacent to, the northern and northeastern portion of the Tahtsa Lake district. Much of this area is covered with glacial drift and continuous bedrock outcrop is limited to the higher peaks and their steep flanks. Till geochemical surveys are an effective method for assessing the metallic mineral potential of areas covered with glacial drift and are ideally suited to assessing the potential for new mineralization in this area. Till geochemical surveys are also well suited for following up on airborne geophysical data recently acquired by Geoscience BC for the QUEST-West Project area (Kowalczyk, 2009), where drift can cover electrically anomalous bedrock.

A two-year Quaternary geology and till geochemistry program is currently underway within the northern portion of the Tahtsa Lake district, and adjacent areas (NTS map areas 093E/15, 16, 093L/01, 02; Figure 2). The objectives of this 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.

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

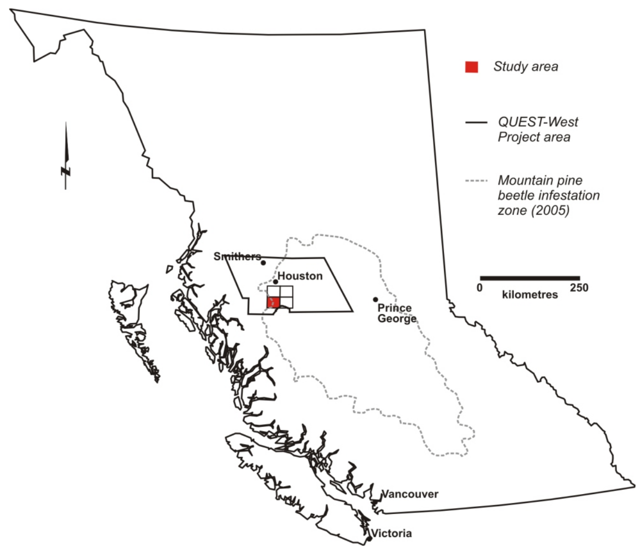

Figure 1. Location of study area in west-central British Columbia.

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 to the mineral exploration community high-quality, regional-scale, geochemical data that will help guide exploration efforts. Integrating interpretations of these data with other geochemical and geophysical data being collected by Geoscience BC in the QUEST-West Project area, and historic data that have been collected by the British Columbia Geological Survey (BCGS) and the Geological Survey of Canada (GSC), will provide a powerful tool for companies exploring in this drift-covered area.

The focus of this paper is surficial geology mapping and the sampling component of a till geochemical survey completed within the Nadina River map area (NTS 093E/15) during the 2009 field season.

STUDY AREA

The study area is located in west-central BC, approximately 100 km southwest of Houston, in NTS map area 093E/15 (Figures 1, 2). It is accessible by Forest Service, private and abandoned mine and mineral exploration roads. Quaternary sediments were studied in detail within NTS 093E/15 while a regional-scale glacial history and ice-flow study was conducted within NTS 093E/15 and 16. The primary objective of this year's till geochemistry survey is to assess the mineral potential of NTS 093E/15. To do this, ad-

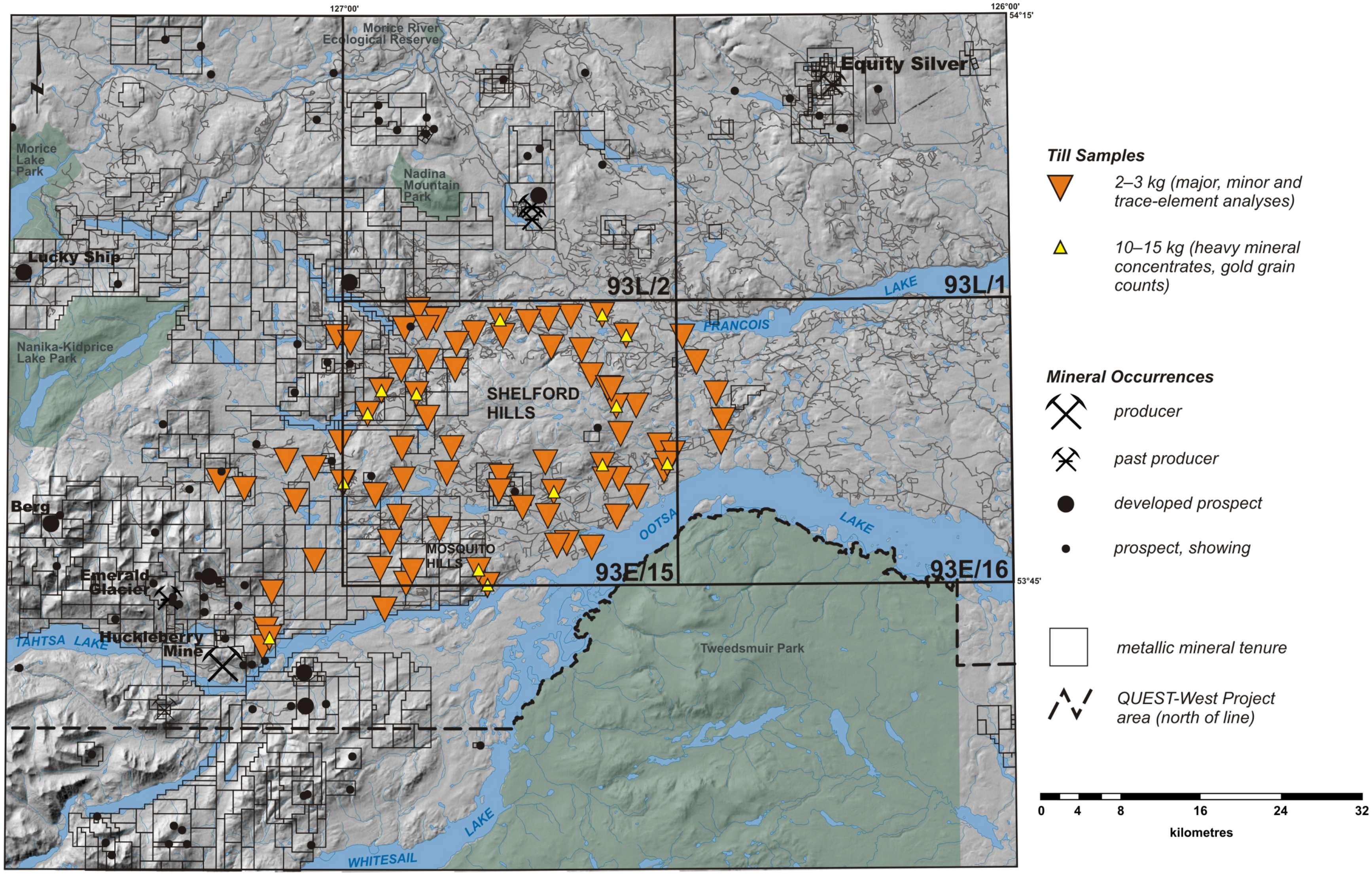

Figure 2. Study area including locations of mineral occurrences, west-central British Columbia. Also shown are locations of till samples collected during the 2009 field season.

ditional till samples were collected within portions of NTS 093E/11, 14 and 16 to take into account the study area's complex ice-flow history.

The majority of 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 (within the study area, 880–944 m asl) most of which is covered by a package of glacial sediments (Figure 2; Holland, 1976). Although bedrock outcrop is relatively uncommon, some exposures can be found at the stoss (i.e., up-ice) end of crag-and-tail forms, along lake shorelines, on higher ground within Shelford (1494 m asl) and Mosquito (1402 m asl) hills, and on local small-scale erosional remnants that stand above the plateau surface to the west and northwest of Shelford Hills (Figure 3). Bedrock outcrop can also be found in the upper reaches of the Nadina River valley and within roadcuts associated with newly constructed forestry roads. The very southwest corner of the study area is situated in the Tahtsa Ranges, a northwest-trending belt of nongranitic mountains that range in elevation from 2100 to 2431 m asl (Holland, 1976). These mountains are situated between the Nechako Plateau to the east and the Coast Mountains to the west. While the majority of hills and mountains within the Nechako Plateau are forested, the Tahtsa Ranges extend up into subalpine and alpine environments.

Small lakes are common within the study area and can be interconnected forming lake chains. The largest lake within the study area is Ootsa Lake, which is part of an interconnect series of large lakes (i.e., Tahtsa, Ootsa, Whitesail, Eutsuk, Tetachuk, Natalkuz lakes) that make up the Nechako Reservoir. Nadina River flows in an arc through the north-central part of the study area, connecting Nadina Lake to Francois Lake, and is the largest river in the study area.

Figure 3. Subdued topography of the southwest corner of the study area, west-central British Columbia. View is towards the east with Mosquito Hills in the background. Note red-coloured pine trees in middle of photograph, indicating that mountain pine beetles have moved through the area.

BEDROCK GEOLOGY

The bedrock geology of the study area was first described and mapped by Hedley (1935) and was included in subsequent mapping by Duffell (1959). The main geological subdivisions found in the study area, as summarized from Woodsworth (1980), MacIntyre (1985), MacIntyre et al. (1994) and Diakow (2006), are as follows. The Tahtsa Lake district lies within the Stikine terrane, just east of the Coast Crystalline Belt (Monger et al., 1991). The western part of the study area is underlain mainly by Early to Middle Jurassic Hazelton Group volcanic and sedimentary rocks (Figure 4). In places, these rocks are unconformably overlain by Early Cretaceous Skeena Group marine sedimentary rocks and local basalt to andesite flows. These rocks are in turn unconformably overlain by felsic pyroclastics, felsic flows and younger basaltic flows of the Early to Late Cretaceous Kasalka Group volcanic rocks. Small- to medium-sized, Late Cretaceous to Early Tertiary stocks have intruded these volcanic piles and sedimentary packages. Elsewhere in the region, there is a strong positive relationship between the location of intrusive rock types (in particular porphyritic intrusions like those of the Late Cretaceous Bulkley suite) and the locations of Cu, Mo, Au, Pb, Zn and/or Ag mineralization (Carter, 1981; MacIntyre, 1985).

In the most eastern part of the study area, Eocene Ootsa Lake Group felsic to mafic volcanic rocks dominate. Younger, and less widespread, Eocene to Lower Miocene Endako Group basaltic and alkaline volcanic rocks do also occur locally. An approximation of the areal extent of Quaternary sediment cover has been included in Figure 4 and is represented by a light grey transparent overlay and black dashed line.

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). Other detailed work has been conducted on specific metallic mineral deposits adjacent to the study area (e.g., Panteleyev, 1981; Cyr et al., 1984; Jackson and Illerbrun, 1995) and additional geological information on local mineral occurrences and claims is available in the BCGS Assessment Report Indexing System (ARIS). More recently, MacIntyre (2001), MacIntyre et al. (2004), Alldrick (2007a, b) and Alldrick et al. (2007) have investigated the mineral potential of mid-Cretaceous rhyolites of the Rocky Ridge Formation. This work suggests that these rhyolites have potential to host VMS-type deposits. While rhyolites do occur within the study area, they have been assigned to the younger, Eocene Ootsa Lake Group. Limited outcrop and a lack of observable field relationships make it difficult to assess whether these rhyolites are

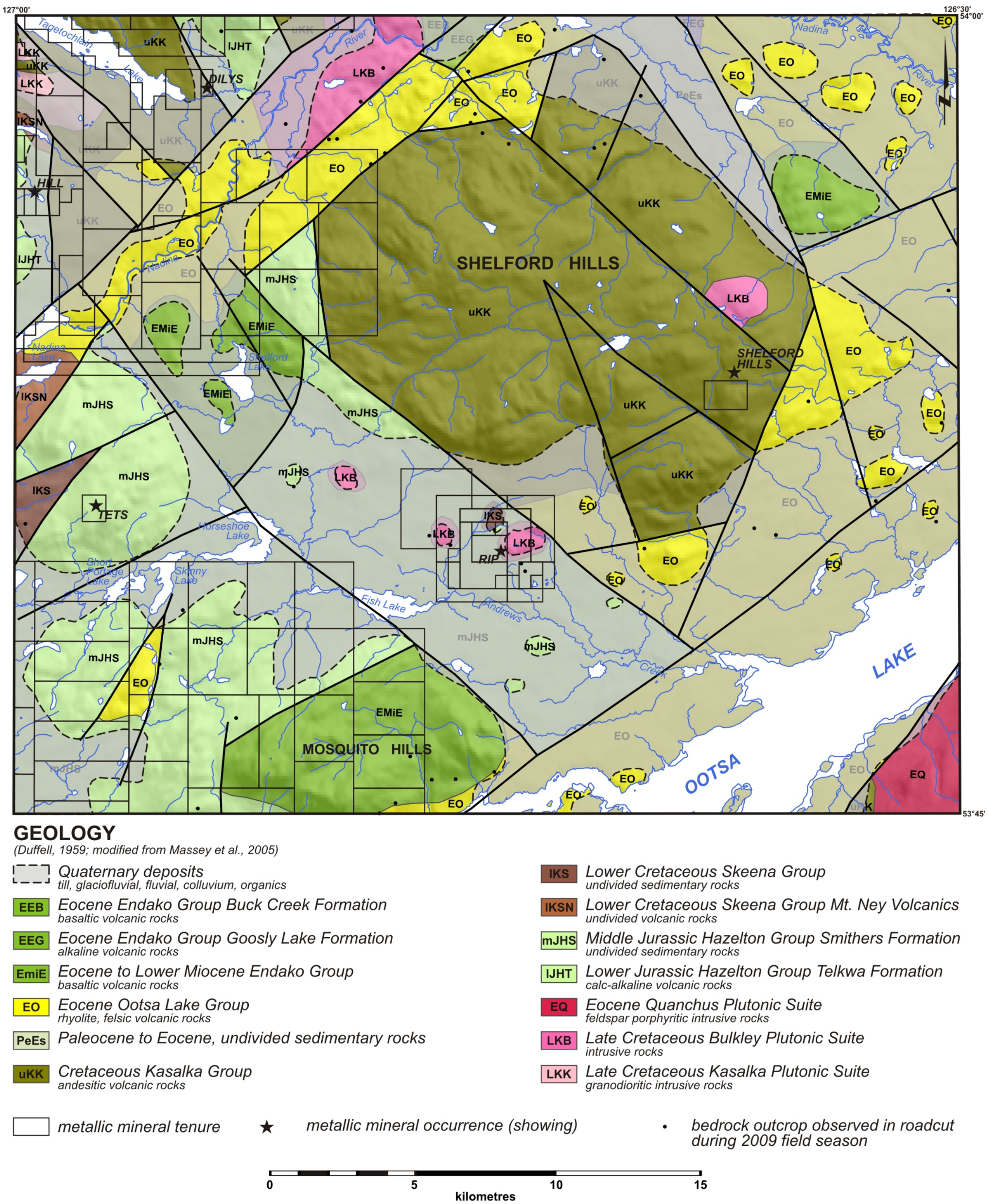

Figure 4. Bedrock geology of the study area, west-central British Columbia. Quaternary sediment cover is approximated by the light grey transparent overlay and black dashed line. Bedrock contacts have been extended beneath this transparent overlay.

in fact Eocene in age or older and perhaps equivalent to Rocky Ridge Formation rhyolites.

Mineral Occurrences

There are five documented mineral occurrences within the study area (Figure 4). Tets (MINFILE 093E 084; MINFILE, 2009; Cu, Zn, Pb, Ag veins) and Shelford Hills (MINFILE 093E 085; Zn, Pb, Au epithermal veins) are vein-type showings while Rip (MINFILE 093E 092; Cu and Mo calcalkaline porphyry), Dilys (MINFILE 093E 094; Cu mineralization) and Hill (MINFILE 093E 097; Cu, Au, Zn alkalic porphyry) are porphyry-type showings. Although there is no MINFILE occurrence associated with it, there is a claim block in the southwest corner of the study area, centred on Mosquito Hills (Figure 4). Known as the Rox claims, mineralization here consists of sulphide and precious metal-bearing veinlets, predominantly hosted in Middle Jurassic Smithers Formation sedimentary rocks. Mineralization is likely associated with either a porphyry, polymetallic vein or epithermal system (Ogryzlo, 2003; Lane, 2008). Immediately west of Tahtsa Reach Road, this claim block butts against a claim block held by Huckleberry Mine Ltd. This adjacent block extends to the west and is continuous from the mineral lease that covers the Huckleberry minesite.

The region has a rich exploration history and is well endowed with metallic mineral deposits. Adjacent to the study area are noteworthy past-producing mines and one still in operation (Figure 2). Approximately 13 km to the southwest of the study area is Huckleberry mine, a producing porphyry Cu-Mo mine with a production rate of approximately 17 000 tonnes of ore per day. Average grades for 2008 were 0.316% Cu and 0.006% Mo. Mine life is expected to extend to the end of 2011(Imperial Metals Corporation, 2009). Another 9 km northwest of Huckleberry mine is the past-producing Emerald Glacier mine, a Pb, Zn, Ag and Au vein deposit. This mine operated intermittently between 1951 and 1968 and produced 2.6 million g of Ag, 1524 g of Au, 891 t of Zn, and 766 t of Pb (MINFILE 093E 001). Approximately 26 km to the northeast of the study area is Equity Silver, a past-producing Cu-Ag-Au mine, which was in production from 1980 to 1994. Combined mine production here was 33.8 million tonnes grading at 64.9 g/t Ag, 0.4% Cu and 0.46 g/t Au (MINFILE 093L 001). Developed prospects in the region such as Berg (porphyry Cu-Mo), Whiting Creek (porphyry Cu-Mo), and Lucky Ship (porphyry Mo) also demonstrate the potential for ore-grade bedrock to occur within the region (Figure 2). In all instances mentioned here, ore-grade bedrock is closely associated with Late Cretaceous and younger plutonic rocks. Intrusive suites of similar age and composition do exist within the study area.

QUATERNARY GEOLOGY

Previous Quaternary geology work conducted within the study area is limited to soils and terrain mapping. Researchers with the BC Ministry of Environment were the first to map the area, producing a 1:50 000 scale soil and landform map (Young, 1976). Singh (1998) has completed the most recent mapping within the study area, a terrain classification map. Directly south and adjacent to the study area, 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. Also included in work was an investigation into the region's ice-flow history.

Quaternary geological studies have been conducted in areas adjacent to the study area. To the north and northwest, Clague (1984), Tipper (1994) and Levson (2001a, 2002) discuss the Quaternary geology and geomorphological 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 map area 093F/12.

Surficial Geology

During the 2009 field season surficial materials were described at 131 sites within the study area. Observations were made at roadcuts and streamcuts, discontinuous exposures along Ootsa Lake and in hand-dug pits. 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, grey to brown diamicton with a silt-rich matrix. It is typically massive and matrix supported, and in many examples vertical jointing and subhorizontal fissility is well developed (Figure 5). Matrix proportion varies from 70 to 80% and modal clast size is small pebble but locally can include boulder-sized material and larger. Clast shape is typically subangular to subrounded. In lower valley settings, it occurs as thick units (>2 m thick) that typically overlie glacially eroded and polished bedrock. On hill flanks and in higher elevation settings, it occurs as thinner units (<2 m thick), including veneers (<1 m thick), that are closely associated, and discontinuous, with locally derived diamicton (e.g., colluvium) and bedrock. The surface expression of this diamicton most often conforms to underlying bedrock topography but also can be streamlined, as seen in the drumlinized and fluted terrain between the south

Figure 5. Silt- and clay-rich, overconsolidated diamicton, interpreted as a basal till (west-central British Columbia). Moderately well developed vertical jointing and subhorizontal fissility give this basal till a blocky appearance. Pick for scale (65 cm long).

and southeast flanks of Shelford Hills and the northern shore of Ootsa Lake. These characteristics are consistent with those of a subglacially derived diamicton (Dreimanis, 1989). This unit is interpreted to be a basal till, the ideal sample medium for a till geochemistry survey.

Glaciofluvial sand and gravel can also be found within the study area. Sandy, pebble- to cobble-sized gravels occur in fan-like features at the mouths of gulleys that head in higher ground, such as Shelford and Mosquito hills, and are related to meltwater draining off this high ground from stagnant ice. Similar sized gravels also occur within late-glacial to deglacial drainage systems (now abandoned) as outwash plains and esker-like ridges (e.g., in the Fish Lake area and south through the Andrews Creek area towards Ootsa Lake). Silt- and clay-rich glaciolacustrine and lacustrine sediments only rarely occur within the study area. Thick organic units are, however, common along the shorelines of smaller lakes and in low-lying areas that separate these smaller lakes when they occur in chains.

Surficial mapping is currently in progress for NTS 093E/15. This mapping is being conducted at a scale of 1:50 000, 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 is the reconstruction of the region's glacial and ice-flow history using macro-scale landforms (e.g., drumlins, flutes, crag-and-tail forms) identifiable in remotely sensed imagery.

Ice-Flow History

Ferbey and Levson (2001a, b) and Ferbey (2004) built on previous work by Stumpf et al. (2000) that indicated there was an ice-flow reversal in west-central BC during the Late Wisconsinan glacial maximum. 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 were then 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.

Evidence for this ice-flow reversal in the Huckleberry mine region is seen in macro-scale glacial landforms (e.g., crag-and-tail forms, roches moutonnées) and micro-scale ice-flow indicators (e.g., rat tails, roches moutonnées) on bedrock outcrop in valley bottoms and at higher elevation sites (i.e., >1500 m asl; Figure 6). This ice-flow reversal is also detectable in trace-element till geochemical data from Huckleberry mine (Ferbey and Levson, 2007). One of the challenges of interpreting till geochemical data collected as part of this project, and other similar projects being conducted within the region, will be determining transport direction of basal till and conversely the direction to a bedrock source of till samples elevated in elements of interest.

During the 2009 field season, ice-flow data were observed and recorded at 33 field stations. These data were used to supplement an additional 120 field stations, and 207 moderately well to well preserved streamlined landforms measured in aerial photographs, presented and discussed by Ferbey and Levson (2001b). The majority of bedrock outcrop studied in the field is located on the lower flanks of hillslopes exposed in roadcuts. In these exposures, outcrop-scale features such as striations, grooves and rat tails were studied and measured (Figure 7). Landform-scale features such as crag-and-tail ridges and roches moutonnées were also measured. Orientations of these features indicate that there are two dominant ice-flow directions in the region, 054–096° and 252–306°. These values are in agreement with those presented by Ferbey and Levson (2001a, b) and Ferbey (2004) and confirm that there was an ice-flow reversal within the study area during the Late Wisconsinan.

TILL GEOCHEMISTRY SURVEY

Till geochemical surveys can detect known sources of mineralization and identify new geochemical exploration targets (e.g., Levson et al., 1994; Cook et al., 1995; Sibbick and Kerr, 1995; Plouffe, 1997; Levson, 2002; Ferbey, 2009). Till geochemical surveys are well suited to assessing the mineral potential of ground covered by glacial drift. 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).

Directly south and adjacent to the study area, Ferbey and Levson (2001a) and Ferbey (2004) conducted a detailed 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). These results suggest that interpreting trace-element geochemical data from tills or soils in this region can be complex, in particular when considering transport direction.

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 map areas 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 are no known mineral occurrences.

Sample Media

During the 2009 field season, 2–3 kg till samples were collected at 84 sample sites for major, minor and trace-element geochemical analyses (Figures 2, 8). An additional 16 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. Given that net transport direction in the study area was likely affected by an ice-flow reversal during the Late Wisconsinan glacial maximum, till samples were collected outside of NTS 093E/15 to take into account possible east and west transport of basal till. Till sample density for this survey is one sample per 14 km^2. For simplicity, areas inaccessible by truck (e.g., Shelford Hills), and areas where till does not oc-

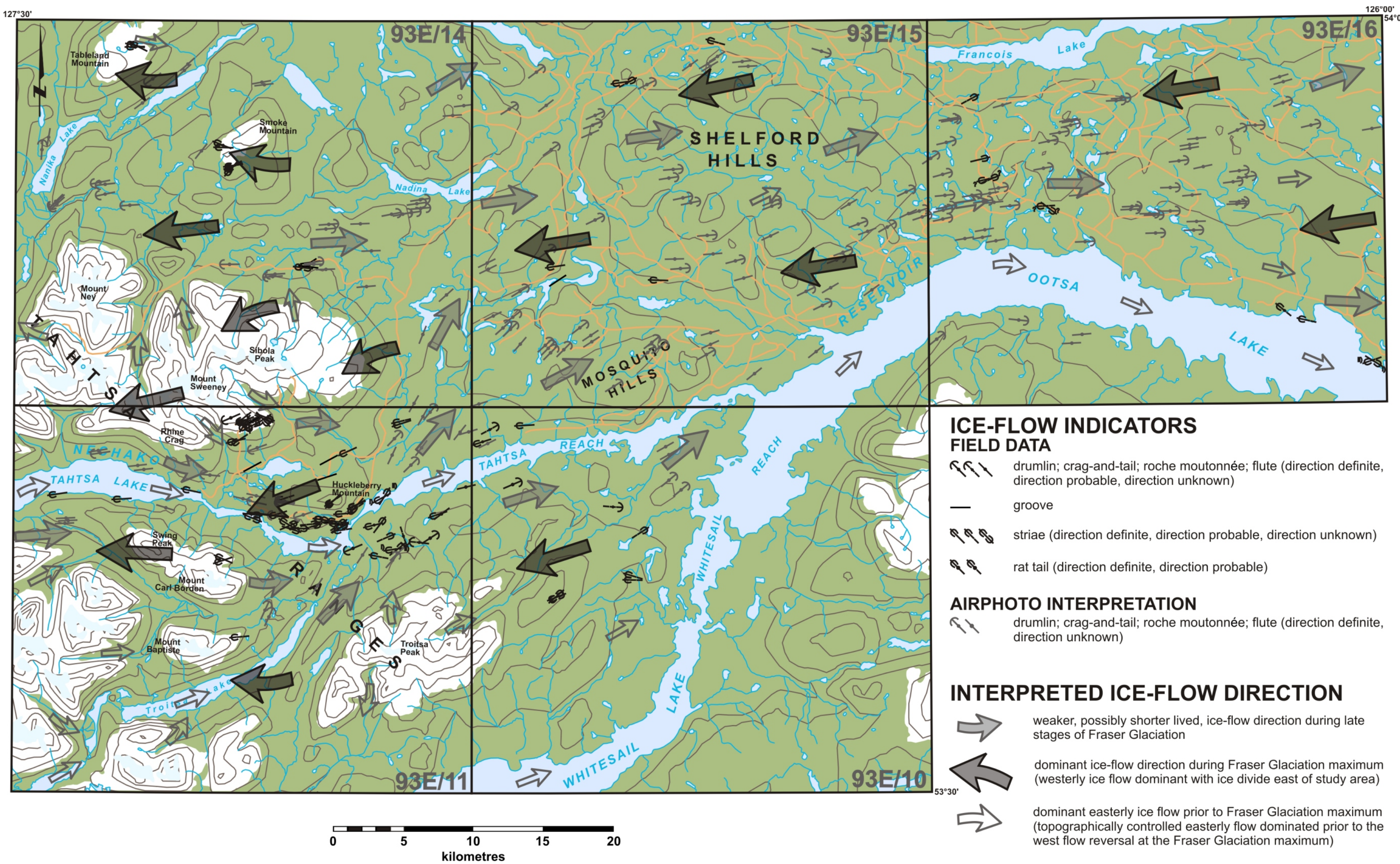

Figure 6. Ice-flow history of the Tahtsa Lake–Ootsa Lake region, west-central British Columbia (after Ferbey and Levson, 2001b).

cur, were included in this calculation. The majority of unweathered till in the study area occurs >1 m below surface and so most till samples were collected at this depth or lower.

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 (ODM; Nepean, ON), 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, ON). INAA 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. Heavy mineral picking, scanning electron microscopy analyses on difficult-to-identify heavy mineral grains, and pebble counts may be conducted on these samples at a later date. Instrumental neutron activation analysis will dictate for which samples, if any, these additional and costly analyses are warranted.

Figure 7. Moderately well preserved rat tails on an outcrop of Skeena Group conglomerate, west-central British Columbia. In the centre of this photograph is a large rat tail indicating ice flow towards the west-southwest. Note that just above it and to the right is a smaller rat tail indicating ice flow towards the east. This outcrop is located on the southern flank of Shelford Hills, north of Andrews Creek, and is the only outcrop of Skeena Group conglomerate observed within the study area.

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 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.

QUATERNARY DRIFT COVER AND MINERAL EXPLORATION

Observations made during the 2009 field season suggest that drift cover within the study area may not be a significant hindrance to mineral exploration. In general, drift appears to be less areally extensive than was once thought. Also, a recent increase in logging activity has not only resulted in improved access to the study area, through the building of new roads, but has also resulted in the creation of new bedrock exposures. For example, a previously unmapped quartz diorite ridge was observed in a roadcut on the southeast flank of Shelford Hills (Figure 9). Similar observations were made by Mihalynuk et al. (2008, 2009) while conducting bedrock mapping and resource potential studies in NTS map areas 093C/1, 8 and 9, areas that had received little attention by the mineral exploration industry because of a perceived problem with thick and continuous Late Oligocene to Pleistocene Chilcotin Group basalt and Quaternary drift cover. Mihalynuk et al. determined that this perception was unfounded and that bedrock exposures do exist. While conducting foot traverses at sufficient enough density for 1:50 000 scale bedrock mapping, they described ten new metallic mineral occurrences. A similar

Figure 8. Typical till sample site (west-central British Columbia). Shown is a 2–3 kg sample collected for major, minor and trace-element geochemical analyses. Pick for scale (65 cm long).

Figure 9. New forestry roads have created new bedrock exposures. Shown here is an unmapped quartz diorite ridge observed in a roadcut on the southeast flank of Shelford Hills, approximately 6 km south-southeast of Shelford Hills mineral occurrence, west-central British Columbia. Pick for scale (65 cm long).

approach to bedrock mapping and prospecting within NTS map area 093E/15 could result in similar success.

Within the study area, not only is drift less areally extensive than was once thought, it is also likely not as thick. It is relatively common to see small bedrock knobs (metres to a couple tens of metres across) extending through Quaternary cover to surface. Additionally, as observed in roadcuts, Quaternary cover may only be 1–2 m thick, with basal till directly overlying glacially eroded and polished bedrock. Exceptions can be found in some of the larger valleys like Nadina River valley, or in abandoned late-glacial and deglacial drainages, such as the one that extends south from Fish Lake, down Andrews Creek to Ootsa Lake. In these examples, valley fill and glaciofluvial sequences are typically thick and blanket much if not all underlying bedrock units. These general observations could prove useful in guiding and interpreting data from future geological, geophysical and/or geochemical surveys.

SUMMARY

The 2009 field season saw the completion of fieldwork for year one of a two-year Quaternary geology program that is designed to assess the mineral potential of the northern portion of the Tahtsa Lake district and adjacent areas (NTS 093E/15, 16, 093L/01, 02). This study area falls within Geoscience BC's QUEST-West Project area where additional geochemical data have been compiled and collected, mineral occurrence data have been updated (i.e., MINFILE, 2009), and helicopter-borne time domain electromagnetic and gravity data have been acquired. The focus of this year's work is the Nadina River map area (NTS 093E/15) where 84 basal till samples, each weighing 2–3 kg, were collected for major, minor and trace-element geochemical analyses, and an additional 16 till samples, each weighing 10–15 kg, were collected for separation and analysis of heavy mineral concentrates and gold grain counts. Ongoing and complementary to this till geochemical survey, is a 1:50 000 scale surficial geology mapping and regional ice-flow study. Given that the study area experienced an ice-flow reversal during the Late Wisconsinan glacial maximum, assessing and quantifying net transport direction of basal till in the study area will be a significant contribution to the understanding of detrital dispersion for the region. An understanding of these variables must exist prior to further investigation of any till samples, collected as part of this study, that are elevated in an element(s) of interest. An assessment of net transport direction will also be of interest to mineral exploration companies working in the area, who are conducting their own surficial sediment geochemistry surveys. Observations made during the 2009 field season suggest that Quaternary sediments within the study area are not necessarily as areally extensive nor thick as was once thought, and therefore may not be a significant hindrance to mineral exploration.

Till geochemical data for the Nadina River map area (NTS 093E/15) will be the topic of a combined BCGS Open File and Geoscience BC Report to be released in late spring 2010. Field crews will return to the study area during the 2010 summer field season and complete data and till sample collection for the Wistaria, Colleymount and Owen Lake map areas (NTS 093E/16, L/01, 02).

ACKNOWLEDGMENTS

This year's program has truly been a collaborative effort and the author would like to gratefully acknowledge Geoscience BC for analytical support; the Smithers Exploration Group (C. Ogryzlo and J. L'Orsa) and Northwest Community College (T. Reedy and R. Maurer) for sponsoring a graduate of their Reclamation and Prospecting Program to assist with fieldwork; and Huckleberry Mine Ltd. (B. Mracek, W. Curtis and F. Sayeed) for allowing the field crew to stay at the minesite. R.E. Gawa is thanked for his assistance in the field. The author would also like to thank L.J. Diakow and D.G. MacIntyre for discussions on, and their insight into, local bedrock lithologies. R.E. Lett is thanked for assistance with geochemical reference standards. The author would also like to thank P.L. Ogryzlo for so freely sharing his ideas on porphyry Cu deposits and how and where he believes the next ones will be found. T.E. Demchuk is thanked for her review of an earlier version of this manuscript.

REFERENCES

Alldrick, D.J. (2007a): Geology of the Skeena Group, central British Columbia (NTS 93E, 93F, 93K, 93L, 93M, 103I, 103P); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2007-8, scale 1:250 000.

Alldrick, D.J. (2007b): Geology of the Equity Silver mine area; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2007-9, scale 1:10 000.

Alldrick, D.J., MacIntyre, D.G. and Villeneuve, M.E. (2007): Geology, mineral deposits, and exploration potential of the Skeena Group (NTS 093E, L, M; 103I), central British Columbia; *in* Geological Fieldwork 2006, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2007-1, pages 1–17.

Carter, N.C. (1981): Porphyry copper and molybdenum deposits, west-central British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 64, 150 pages.

Clague, J.J. (1984): Quaternary geology and geomorphology, Smithers-Terrace-Prince Rupert area, British Columbia; *Geological Survey of Canada*, Memoir 413, 71 pages.

Cook, S.J., Levson, V.M., Giles, T.R. and Jackaman, W. (1995): A comparison of regional lake sediment and till geochemistry surveys: a case study from the Fawnie Creek area, central

British Columbia; *Exploration Mining Geology*, Volume 4, pages 93–101.

Cyr, J.B., Pease, R.B. and Schroeter, T.G. (1984): Geology and mineralization at Equity Silver mine; *Economic Geology*, Volume 29, pages 947–968.

Diakow, L.J. (2006): Geology of the Tahtsa Ranges between Eutsuk Lake and Morice Lake, Whitesail Lake map area, west-central British Columbia (parts of NTS 93E/5, 6, 7, 10, 11, 12, 13, 14, and 15); *BC Ministry of Energy, Mines and Petroleum Resources*, Geoscience Map 2006-5, scale 1:150 000.

Dreimanis, A. (1989): Tills: their genetic terminology and classification; *in* Genetic Classification of Glacigenic Deposits, Goldthwait, R.P. and Matsch, C.L., Editors, *A.A. Balkema*, Rotterdam, pages 17–83.

Duffel, S. (1959): Whitesail Lake, Coast District; *Geological Survey of Canada*, Map 1064A, scale 1 in. to 4 mi.

Ferbey, T. (2004): Quaternary geology, ice-flow history and till geochemistry of the Huckleberry mine region, west-central British Columbia; MSc thesis, *University of Victoria*, 301 pages.

Ferbey, T. (2009): Till geochemical exploration targets, Redstone and Loomis Lake map areas (NTS 93B/04 and 05), central British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2009-9, 52 pages.

Ferbey, T. and Levson, V.M. (2001a): Quaternary geology and till geochemistry of the Huckleberry mine area; *in* Geological Fieldwork 2000, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2001-1, pages 397–410.

Ferbey, T. and Levson, V.M. (2001b). Ice flow history of the Tahtsa Lake–Ootsa Lake region; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2001-8, scale 1:110 000.

Ferbey, T. and Levson, V.M. (2003): Surficial geology of the Huckleberry mine area; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2003-2, scale 1:15 000.

Ferbey, T. and Levson, V.M. (2007): The influence of ice-flow reversals on the vertical and horizontal distribution of trace elements in tills, Huckleberry mine area, west-central British Columbia; *in* Application of Till and Stream Sediment Heavy Mineral and Geochemical Methods to Mineral Exploration in Western and Northern Canada, Paulen, R.C. and McMartin, I., Editors, *Geological Association of Canada*, Short Course Notes 18, pages 145–151.

Hedley, M.S. (1935): Tahtsa-Morice area; *Geological Survey of Canada*, Map 367A, scale 1 in. to 4 mi.

Holland, S.S. (1976): Landforms of British Columbia: a physiographic outline; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 48, 138 pages.

Imperial Metals Corporation (2009): Annual report 2008; *Imperial Metals Corporation*, 48 pages.

Jackson, A. and Illerbrun, K. (1995): Huckleberry porphyry copper deposit, Tahtsa Lake District, west-central British Columbia; *in* Porphyry Deposits of the Northwestern Cordillera of North America, Schroeter, T.G., Editor, *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, pages 313–321.

Kowalczyk, P.K (2009): QUEST-West geophysics in central British Columbia (NTS 093E, F, G, K, L, M, N, 103I): new regional gravity and helicopter time-domain electromagnetic data; *in* Geoscience BC Summary of Activities 2008, *Geoscience BC*, Report 2009-1, pages 1–6.

Lane, R.A. (2008): A geological report on the Rox property, Omineca Mining Division, British Columbia; submitted by Lowprofile Ventures Ltd., *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 30342, 86 pages.

Levson, V.M. (2001a): Quaternary geology of the Babine porphyry copper district: implications for geochemical exploration; *Canadian Journal of Earth Sciences*, Volume 38, pages 733–749.

Levson, V.M. (2001b): Regional till geochemical surveys in the Canadian Cordillera: sample media, methods, and anomaly evaluation; *in* Drift Exploration in Glaciated Terrain, McClenaghan, M.B., Bobrowsky, P.T., Hall, G.E.M. and Cook, S.J., Editors, *Geological Society*, Special Publication, Number 185, pages 45–68.

Levson, V.M. (2002): Quaternary geology and till geochemistry of the Babine porphyry copper belt, British Columbia (NTS 93 L/9, 16, M/1, 2, 7, 8); *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 110, 278 pages.

Levson, V.M. and Mate, D.J. (2002): Till geochemistry of the Tetachuck Lake and Marilla map areas (NTS 93F/5 and F/12); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2002-11, 180 pages.

Levson, V.M., Giles, T.R., Cook, S.J. and Jackaman, W. (1994): Till geochemistry of the Fawnie Creek area (93F/03); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-18, 40 pages.

MacIntyre, D.G. (1985): Geology and mineral deposits of the Tahtsa Lake District, west-central British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 75, 82 pages.

MacIntyre, D.G. (2001): The mid-Cretaceous Rocky Ridge Formation – a new target for subaqueous hot-spring deposits (Eskay Creek type) in central British Columbia; *in* Geological Fieldwork 2000, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2001-1, pages 253–268.

MacIntyre, D.G., Ash, C.H. and Britton, J. (1994): Skeena Arcview data (NTS 93E,L,M; 94D; 104A,B; 103G,H; 103 I,P); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-14, digital data.

MacIntyre, D.G., McMillan, R.H. and Villeneuve, M.E. (2004): The mid-Cretaceous Rocky Ridge Formation – important host rocks for VMS and related deposits in central British Columbia; *in* Geological Fieldwork 2003, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2004-1, pages 231–247.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. and Cooney, R.T. (2005): Digital geology map of British Columbia: whole province; *BC Ministry of Energy, Mines and Petroleum Resources*, GeoFile 2005-1, 1:250 000 scale, URL <http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Geofiles/Pages/2005-1.aspx> [December 2009].

Mate, D.J. (2000): Quaternary geology, stratigraphy and applied geomorphology in southern Nechako Plateau, central British Columbia; MSc thesis, *University of Victoria*, 253 pages.

Mihalynuk, M.G., Peat, C.R., Terhune, K. and Orovan, E.A. (2008): Regional geology and resource potential of the Chezacut map area, central British Columbia (NTS 093/08); *in* Geological Fieldwork 2007, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2008-1, pages 117–134.

Mihalynuk, M.G., Orovan, E.A., Larocque, J.P., Friedman, R.M. and Bachiu, T. (2009): Geology, geochronology and mineralization of the Chilanko Forks to southern Clusko River area, British Columbia (NTS 93C/01, 08, 09S); *in* Geological Fieldwork 2008, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2009-1, pages 81–100.

MINFILE (2009): MINFILE BC mineral deposits database; *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://minfile.ca> [November 2009].

Monger, J.W.H., Wheeler, J.O., Tipper, H.W., Gabrielse, H., Harms, T., Struik, L.C., Campbell, R.B., Dodds, C.J., Gehrels, G.E. and O'Brien, J. (1991): Cordilleran terranes (Chapter 8: Upper Devonian to Middle Jurassic assemblages); *in* Geology of the Cordilleran Orogen in Canada, Gabrielse, H. and Yorath, C.J., Editors, *Geological Survey of Canada*, Geology of Canada Series, Number 4, pages 281–327.

Ogryzlo, P.L. (2003): Geophysical surveying and diamond drilling on the Rox 1 mineral claim, Omnieca Mining Division; submitted by Gary Thompson, *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 27050, 48 pages.

Panteleyev, A. (1981): Berg porphyry copper-molybdenum deposit; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 66, 158 pages.

Plouffe, A. (1995): Geochemistry, lithology, mineralogy, and visible gold grain content of till in the Manson River and Fort Fraser map areas, central British Columbia (NTS 93K and N); *Geological Survey of Canada*, Open File 3194, 119 pages.

Plouffe, A. (1996a): Surficial geology, Cunningham Lake, British Columbia (NTS 93K/NW); *Geological Survey of Canada*, Open File 3183, scale 1:50 000.

Plouffe, A. (1996b): Surficial geology, Burns Lake, British Columbia (NTS 93K/SW); *Geological Survey of Canada*, Open File 3184, scale 1:50 000.

Plouffe, A. (1997): Reconnaissance till geochemistry on the Chilcotin Plateau (92O/5 and 12); *in* Interior Plateau Geoscience Project: Summary of Geological, Geochemical and Geophysical Studies (092N, 092O, 093B, 093C, 093F, 093G, 093G), Diakow, L.J., Metcalfe, P. and Newell, J., Editors, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1997-2, pages 145–157.

Plouffe, A. and Ballantyne, S.B. (1993): Regional till geochemistry, Manson River and Fort Fraser area, British Columbia (93K, 93N), silt plus clay and clay size fractions; *Geological Survey of Canada*, Open File 2593, 210 pages.

Plouffe, A., Levson, V.M. and Mate, D.J. (2001): Till geochemistry of the Nechako River map area (NTS 93F), central British Columbia; *Geological Survey of Canada*, Open File 4166, 66 pages.

Sibbick, S.J. and Kerr, D.E. (1995): Till geochemistry of the Mount Milligan area, north-central British Columbia; recommendations for drift exploration for porphyry copper-gold mineralization; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P., Editors, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 167–180.

Singh, N. (1998): Terrain classification map phase 3, 93E.076, 077, 086, 087, 088, 096, 097, 098; *BC Ministry of Forests*, scale 1:20 000.

Stumpf, A.J., Broster, B.E. and Levson, V.M. (2000): Multiphase flow of the Late Wisconsinan Cordilleran Ice Sheet in western Canada; *Geological Society of America Bulletin*, Volume 112, pages 1850–1863.

Tipper, H.W. (1994): Preliminary interpretations of glacial and geomorphic features of Smithers map area (93L), British Columbia; *Geological Survey of Canada*, Open File 2837, 7 pages.

Woodsworth, G.J. (1980): Geology of Whitesail Lake (93E) map area, British Columbia; *Geological Survey of Canada*, Open File 708, scale 1:250 000.

Young, G. (1976): 93E/15 soils and landforms, Nadina River; *BC Department of Lands and Forests*, scale 1:50 000.