Quaternary Geology and Till Geochemistry of the Redstone and Loomis Lake Map Areas, Central British Columbia (NTS 093B/04, 05)

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INTRODUCTION

This paper summarizes Quaternary geology mapping and till geochemistry studies conducted as part of the regional mineral potential assessment of the Redstone and Loomis Lake map areas (NTS 093B/04, 05; Figure 1). This study was initiated to complement an ongoing regional bedrock mapping program and mineral potential assessment being conducted in NTS 093C/01, 08 and 09 (Mihalynuk et al., 2008a, b), and a previous surficial mapping and till geochemical survey in NTS 093C/01, 08, 09 and 16 (Giles and Kerr, 1993; Proudfoot, 1993; Lett et al., 2006). Historic gold and silver prospects (e.g., Chili prospect, MINFILE 093C 015; MINFILE, 2008; Clisbako prospect, MINFILE 093C 015), as well as newly discovered copper (e.g., Punky, Orovain, Vampire and Gumbo) and gold and silver showings (e.g., Pyro, Mihalynuk et al., 2008a, b), occur within Mesozoic to Eocene volcanic rocks adjoining the study area. These strata are thought to extend into the study area but an extensive cover of glacial drift makes this speculative. As a result, and despite its mineral potential, the study area has been overlooked and considered a frontier area by the mineral exploration community. There are no known metallic mineral occurrences within the study area and there is no staked ground.

The objectives of this study are to

- characterize and delineate the Quaternary materials that occur in NTS 093B/04 and 05 and establish the regional ice-flow history; and
- assess the mineral potential of covered bedrock (subcrop) using a till geochemistry survey.

The goal of this study is to provide the mineral exploration community with new, high-quality, regional-scale, geochemical data, which will help guide exploration efforts in this drift-covered area. Integrating interpretations of these data with other historic geological and geochemical data collected by the British Columbia Geological Survey (BCGS), Geological Survey of Canada (GSC) and Geoscience BC provides a new exploration tool. The study area falls within the mountain pine beetle infestation zone, which has been a focus of provincial and federal economic diversification initiatives. It is hoped that data from this study will contribute to long-term economic diversification from increased mineral exploration.

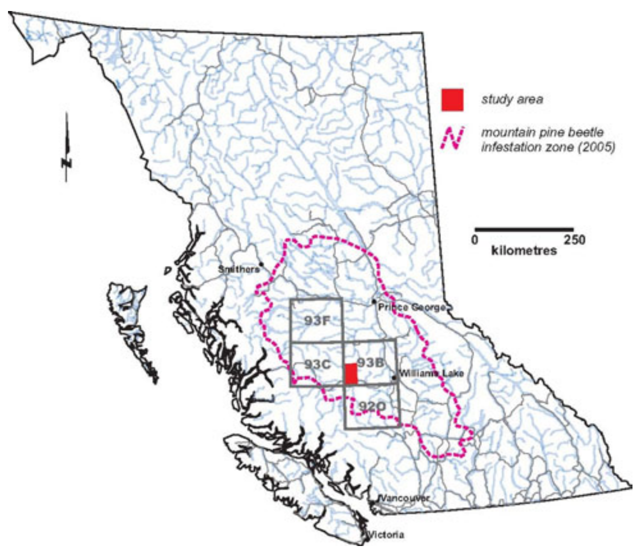

Figure 1. Location of study area, central British Columbia.

LOCATION AND PHYSIOGRAPHY

During the 2008 field season, detailed sedimentological, glacial history and till geochemical studies were conducted in Redstone and Loomis Lake (NTS 093B/04, 05; Figure 1). The area is located approximately 150 km west of Williams Lake, British Columbia, within the Fraser Plateau, a subdivision of the Interior Plateau physiographic region (Holland, 1976). The area can be described as flat to gently rolling with a relatively undissected upland (Figure 2). An exception to this are the broad valleys of the Chilcotin River and its larger tributaries (e.g., Chilanko and Chilko rivers), which are incised below the plateau surface (Tipper, 1971). The subdued plateau topography is largely attributed to the subhorizontal, Late Oligocene to Pleistocene Chilcotin Group basalt flows thought to underlie it. Mantling these basalt flows is a sequence of glacial drift.

Valley settings have thick sequences of Quaternary, and locally pre–Late Wisconsinan, sediments while the upland or plateau surface is dominated by till. At 1377 m asl, Mount Alexis is the highest, named elevation in the area. North of Temapho Lake, the plateau surface rises to over 1500 m asl in a series of unnamed peaks and ridges (Figure 2). For the most part, bedrock outcrop is limited to higher elevations, meltwater channel flanks, and recent

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Figure 2. View of study area looking south towards Mount Alexis (centre of the background), central British Columbia. Note the flat to gently rolling topography in foreground and higher peaks and ridges in background.

scarps that define the larger Chilanko, Chilcotin and Chilko river valleys.

Homesteads and cattle ranches characterize the study area. Redstone (population 500), located south of Punti Lake on the north bank of Chilanko River, is the largest established community. The southern portion of the study area is traversed by Highway 20 and the remainder is accessible using an extensive network of Forest Service roads.

BEDROCK GEOLOGY

The bedrock geology was first described by Tipper (1959). This work was compiled by Massey et al. (2005) and recently studied in greater detail locally by Ferri and Riddell (2006) and Riddell and Ferri (2008) as part of an assessment of oil and gas potential of the Nechako Basin. Adjacent to the study area, an ongoing regional bedrock mapping and mineral potential assessment in NTS 093C/01, 08 and 09 has yielded new occurrences of metallic mineralization (Mihalynuk et al., 2008a, 2009).

The main geological subdivisions found in the study area, as summarized from Tipper (1959), Diakow et al. (1997) and Massey et al. (2005), are as follows. The study is situated within the Stikine terrane, close to its eastern contact with the Cache Creek terrane (Monger et al., 1991). The oldest rocks are found in the westernmost portion of NTS 093B/04 and belong to the Early to Middle Jurassic Hazelton Group. Locally, they are composed of andesite and basalt with related tuff, breccia and volcaniclastic deposits, which resulted from subaerial and submarine volcanism. Submarine sedimentary rocks, associated with activity in an island arc, are also locally present. These are all overlain by a sedimentary succession of fluvial conglomerate, sandstone and siltstone from the Early and Late Cretaceous Skeena Group. These rocks are locally exposed in the Chilko River valley, south and southwest of Sisters Hills, and northwest of Temapho Lake.

Subduction-related arc volcanism resumed within the Stikine terrane in the Late Cretaceous, changing to a continent margin setting with subaerial volcanism in the Paleogene. Paleogene assemblages include the Ootsa Lake and Endako groups. Eocene volcanic deposits of the Ootsa Lake Group are widespread at Sisters Hills, and underlie topographically higher terrain in much of the northern portion of NTS 093B/05. They consist of a diverse succession, ranging from rhyolite to basalt, and were mapped in detail to the west by Mihalynuk et al. (2008a, b). They include maroon-brown basalt flows and breccia, acicular hornblende dacite flows, maroon and grey flow-banded rhyolite, and vitreous black dacite. In NTS 093C, conglomerate is locally found lying at the base of the Ootsa Lake Group, unconformably overlying the older Jurassic Hazelton Group.

Within the study area, Eocene to Oligocene volcanic rocks of the Endako Group unconformably overlie the Ootsa Lake Group. They occupy higher ground in the northern portion of NTS 093B/05 and to the northeast of Sisters Hills. They consist mainly of inclined, massive to crudely stratified andesite to basaltic andesite flows. Although the flows can include vesicular and amygdaloidal varieties, characteristically they are dense, black and aphanitic.

The youngest rock unit consists of basalt flows and associated volcaniclastic rocks that unconformably overlie older rock units and are correlated with the Late Oligocene to Pleistocene Chilcotin Group. These rocks consists of distinctly layered, subhorizontal, relatively thin flows, commonly with colonnades associated with shield-like volcanic centres, interpreted to occur north of the study area (Mihalynuk et al., 2008a). When compared to other basalt within the study area, they differ and are dark brown to grey, highly vesiculated, and contain unaltered phenocrysts of olivine and feldspar. Fine-grained, less vesiculated varieties have a felted grey-brown texture.

Geological maps by Tipper (1959) and Massey et al. (2005) show that upwards of 70% of the study area is underlain by basalt of the Chilcotin Group. Although the areal extent of these rocks within the Nechako Plateau is certainly significant, recent work by Mihalynuk et al. (2008a, b, 2009) and Andrews and Russell (2007) demonstrated that this cover may not be as widespread or thick as originally thought. This is positive for mineral exploration and drift prospecting, as these recent studies report significant thickness variations and even windows through Chilcotin Group flow sequences exposing older more prospective basement units.

Massive granite occupies the southwest corner of NTS 093B/04. It is interpreted to be part of an intrusive body mapped by Tipper (1969) and Mihalynuk et al. (2009) to the west. Mihalynuk et al. (2008a, b, 2009) reported positive correlation between intrusive bodies and intrusion-hosted veins with copper mineralization. As this is the only intrusive body within the study area, a higher density of till samples was collected down-ice, to the northeast, in order to investigate a potential association with mineralization.

Mineral Occurrences

There are no known metallic mineral occurrences within the study area. To the west, however, historic gold and silver prospects are known within the eastern portion of NTS 093C (e.g., Chili, MINFILE 093C 011; Chilcotin River East and West, MINFILE 093C 013 and 093C 014; Baez, MINFILE 093C 015; Clisbako, MINFILE 093C 016), as well as newly discovered copper (e.g., Punky, Orovain, Vampire and Gumbo) and gold and silver showings (e.g., Pyro). Lett et al. (2006) and Mihalynuk et al. (2008a) provided summaries of these occurrences.

QUATERNARY GEOLOGY

The Quaternary geology of the study area was first described by Tipper (1971) in a glacial features map at a 1:250 000 scale. The BC Ministry of Environment, Lands and Parks (1976a, b) produced 1:50 000 scale soils and landforms maps for NTS 093B/04 and 05. Other Quaternary geological studies have been conducted in the region in areas adjacent to NTS 093B (Figure 1; e.g., Giles and Kerr, 1993; Proudfoot, 1993; Levson and Giles, 1997; Mate and Levson, 1999; Mate and Levson, 2000; Plouffe and Levson, 2001). The following is a summary of data collected during the 2008 field season.

Surficial Geology

Detailed sedimentological and stratigraphic descriptions were conducted at 266 stations within the study area (Figure 3). These stations were selected with the objective of gaining a better understanding of Quaternary processes during the Late Wisconsinan and of the area's glacial history. Most Quaternary exposures were the result of logging-related activity (e.g., roadcuts and borrow and gravel pits) but also included natural exposures (e.g., sides of valleys and meltwater channels, tree throws) and hand-dug soil pits. Exposures ranged from a few to several tens of

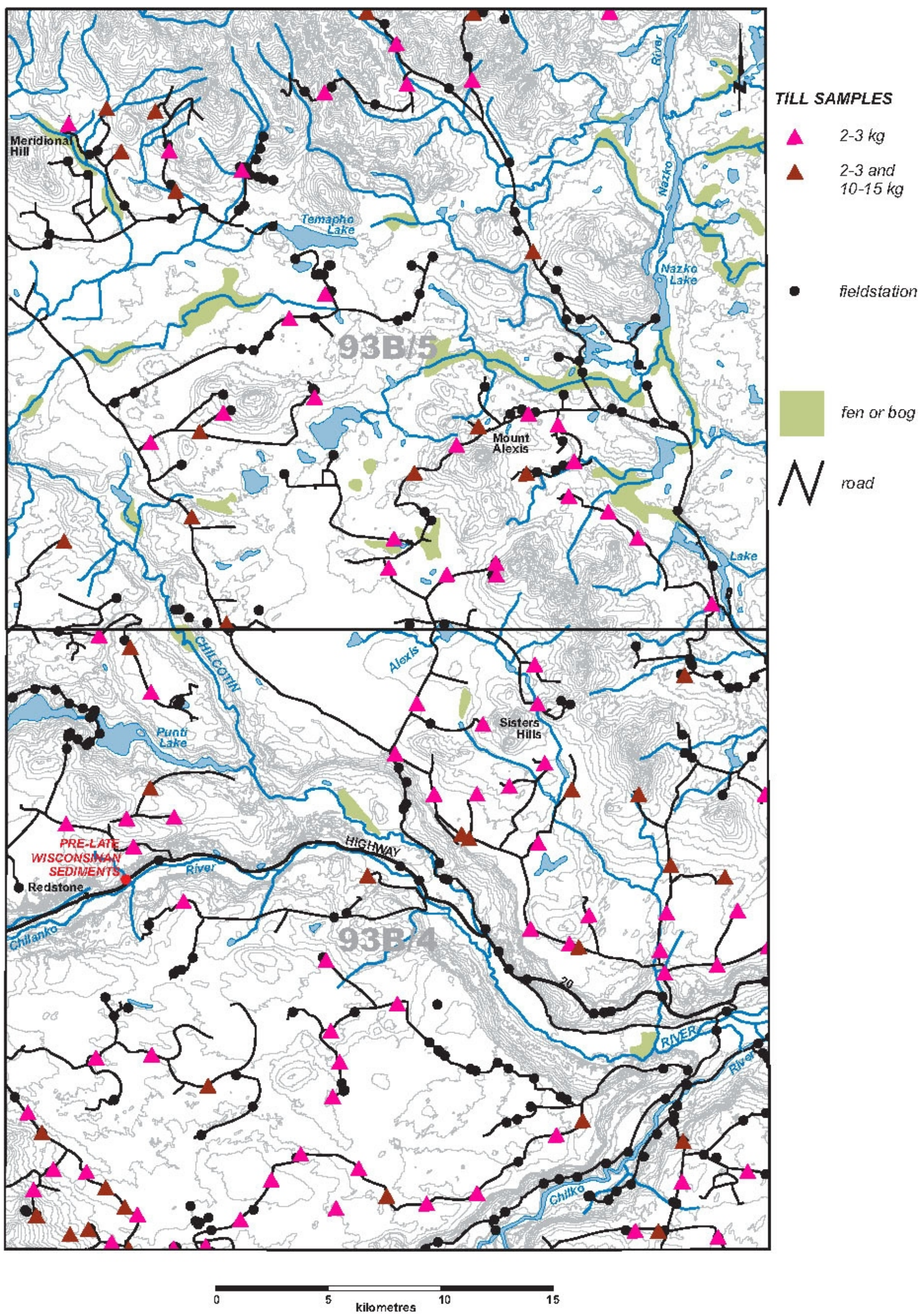

Figure 3. Location of field stations and till samples within the study area, central British Columbia.

Figure 4. Pre-Late Wisconsinan sequence of sand, gravel and tephra, near Redstone, British Columbia. The overlying Late Wisconsinan Fraser glaciation basal till is shown with an asterisk (*).

Figure 5. Hummocky, englacial or supraglacial till, central British Columbia.

metres in height. In the case of hand-dug soil pits, depth only occasionally exceeded 1 m below surface.

PRE-LATE WISCONSINAN

Exposed in a 12 m vertical section are the oldest sediments to occur in the study area (Figure 3). Preliminary data indicate that this is a 6.8 m thick sequence of pre–Late Wisconsinan stratified sand, gravel and tephra (Figure 4). These pre–Late Wisconsinan sediments are unconformably overlain by 2.2 m of basal till and 3.0 m of glaciofluvial gravel deposited during full glacial and retreat-phase conditions, respectively, of the Late Wisconsinan Fraser glaciation. The thick crossbedded sand and gravel succession that occurs in the lower portion of the section is lithologically distinct from the gravel that overlies the Late Wisconsinan basal till as the succession appears to be devoid of intrusive clasts. A 30 to 50 cm thick, grey horizon of silt-sized material of possible volcanic origin separates the lower sand and gravel from a 2.5 m thick unit of interbedded buff to white tuff and oxidized and indurated silt. The tuff is rhyolitic, with biotite and feldspar crystals up to 1.0 mm across. The 40 to 60 cm thick indurated and oxidized silt horizons that separate tuff layers could be weakly developed paleosols. This exposure, and another exposure located 5 km to the east on Highway 20, is believed to be the first observation of pre–Late Wisconsinan sediments in the area. More detailed work is required to confirm these interpretations.

LATE WISCONSINAN GLACIAL SEDIMENTS

The dominant surficial material found in the study area is diamict. Based on physical characteristics such as matrix texture and proportion, modal clast size and clast shape, and surface expression, the sediments are divided into two genetically separate units. The first, and likely dominant in terms of areal extent, is a grey, sand-rich, gravelly diamict. In this diamict, characteristics such as vertical jointing, subhorizontal fissility and compaction or over-consolidation are lacking. Clast shape is commonly subangular to subrounded and modal clast size is small pebble but ranges from granule to large pebble. The unit is clast rich compared to the second diamict described below and the proportion of matrix is typically 55 to 75%. Near surface (in the upper 1 to 2 m), this matrix can be oxidized and clasts, in particular intrusive rock types, can be weathered. The lower contact of this diamict, observed in only a few localities, is gradational downward into a grey, silt-rich, overconsolidated diamict (described below). Minimum thickness is ~1 m and ranges up to several metres in some areas.

The surface expression of this sand-rich, gravelly diamict, as observed in aerial photographs and in the field, is distinctive. The upper surface is typically undulating to hummocky and commonly has pebble to boulder-sized clasts sitting at surface (Figure 5). The physical and geomorphological characteristics are consistent with till of englacial or supraglacial origin. The transport history of this till facies can be complex and this uncertainty precluded sampling for till geochemistry. Windows through this facies to an underlying silt-rich, overconsolidated diamict are occasionally found. This underlying material is an ideal sample medium for a till geochemical survey and is described below.

The underlying silt-rich, overconsolidated diamict is grey and is the other commonly occurring diamict within the study area. This diamict is massive; vertical jointing and subhorizontal fissility are locally well developed (Figure 6). Matrix proportion ranges from 65 to 85%. Modal clast size is small pebble and ranges from granule to large pebble. Clast shape is typically subangular to subrounded but locally, down-ice from larger river valleys, there can be a concentration of rounded, subdiscoidal to spherical clasts and a more sandy textured matrix. These clasts are interpreted to have been incorporated by the Cordilleran Ice Sheet as it moved across existing valley fills.

This diamict can occur at surface or underlie the englacial or supraglacial till unit described above. Its surface expression is also distinctive. The morphology of the upper surface is variable and can be rolling or ridged (e.g., in the case of fluted, drumlinized or crag-and-tail terrain) or a more subtle variation of the bedrock surface it blankets. At some sites, this basal till directly overlies grooved and striated Chilcotin Group basalt flows. The texture, primary structures and degree of consolidation of this unit are consistent with those of subglacially derived diamict (Dreimanis, 1989) and this unit is interpreted as basal till.

LATE WISCONSINAN RETREAT-PHASE SEDIMENTS

Late-glacial ice-marginal and retreat-phase glaciofluvial sand and gravel commonly occur, within and adjacent to meltwater channels, as terrace and outwash deposits in the larger Chilanko, Chilcotin and Chilko river valleys. Meltwater channels can be isolated features a few metres across and tens of metres long, or can be complex kilometre-scale meltwater channel systems composed of multiple tributary channels. The most prominent is located in the eastern portion of NTS 093B/05 and hosts the Alexis and Nazko lakes system. Surficial materials in these systems range from moderately well-sorted, silty sand to cobble gravel. Tipper (1971) proposed that this meltwater channel system was the outlet for a Late Wisconsinan glacial lake that occupied the Chilcotin River valley, a product of damming of the Chilcotin River at its confluence with the Fraser River by a late-glacial readvance of ice from the Cariboo Mountains to the west across the Fraser Plateau. Based on the elevation of the drainage divide that separates the modern-day Nazko River watershed from that of Chilcotin River, a minimum upper elevation for this glacial lake is 1047 m asl.

Glaciolacustrine sediment associated with this ice-dammed lake dominates the larger river valleys such as Chilanko, Chilcotin and Chilko, and many of their tributaries (Figure 7). The sediment is typically parallel-laminated and bedded silt and fine sand. Near lake margins, the silt and fine sand are interbedded with coarse sand, and ripples and cross-stratification are common. They are commonly deeply gullied and can be associated with valley-side, mass-wasting deposits. The juxtaposition of large-scale esker systems in the bottom of Chilcotin River valley, upstream of the confluence of Chilcotin and Chilanko rivers, and in the bottom of Chilko River valley, upstream of the confluence with Chilcotin River, against these glaciolacustrine sediments is both impressive and a curiosity as they demonstrate a contrast in depositional environments. These esker systems are composed of sand and pebble- to cobble-sized gravel ridges up to 50 m high and 2 km long. They are free of any fine-grained glaciolacustrine sediments. Their occurrence suggests that large stagnant ice masses were sitting at least locally in the Chilcotin River and upper Chilko valleys while they were flooded.

Figure 6. Silt-rich, overconsolidated diamict (interpreted to be basal till), central British Columbia. Note well-developed jointing and subhorizontal fissility. The maroon hue is attributed to the colour of its source rock, Ootsa Lake Group volcanic rocks that occur up-ice of this exposure.

HOLOCENE DEPOSITS

Glacial units are typically capped on steeper valley slopes by colluvial deposits. The parent material of these deposits can be pre-existing glacial sediment or Chilcotin Group basalt flows that have moved downslope from bedrock scarps that rim larger valleys (e.g., Chilanko, Chilcotin, Chilko valleys). Historic mass-wasting deposits can be clearly seen in aerial photographs while ongoing translational displacement of Chilcotin Group basalt blocks can be observed on the ground. Holocene organic deposits in the study area are typically found bordering small lakes or flooring some of the larger glaciofluvial meltwater channels and channel systems.

Ice-Flow History

The study area was covered by the Cordilleran Ice Sheet during the Late Wisconsinan Fraser glaciation (Tipper, 1971). The occurrence of crag-and-tail features on higher ground within the north and southeast parts of NTS 093B/04 (>1330 m asl) and 093B/05 (>1400 m asl), and the northeast-tapering drift tail of an unnamed peak in the southwest part of 093B/04 (Figure 8), provide a minimum elevation for this ice of approximately 1500 m asl. The consistent orientation of these landform-scale features with striations, grooves and other drumlins and flutings at lower elevation shows that ice movement through the study area was relatively unaffected by topography during the glacial maximum (Figure 9). A minor deflection can be observed when comparing ice-flow indicators occurring in the southwest to those in the northwest and north, a result of the interaction of northeast-flowing ice from the Coast Mountains with westward-flowing ice from the Cariboo Mountains. The confluence and turning of these two ice flows occurred during the Late Wisconsinan glacial maximum to the east of this map area, near the Fraser River valley (Tipper, 1971).

Both bidirectional (e.g., flute) and unidirectional (e.g., drumlin, crag-and-tail) landform-scale, ice-flow indicators, in various topographic settings, can be observed in aerial photographs and on the ground. In both cases, the features (Figure 9) trend 035° (in the northwest and north) to

Figure 7. View of glaciolacustrine sequence in Chilcotin River valley, central British Columbia.

055° (in the southwest). The preservation and definition of these features can vary; excellent examples can be observed where topographic features are oriented perpendicular to regional ice flow. For example, on the east side of the upper Chilcotin River valley (upstream of its confluence with Chilanko River), clear, well-defined drumlins and crag-and-tail features up to 60 m across can be observed in the valley bottom for 850 m up the valley side onto the plateau surface. Excellent examples of crag-and-tail features occur on much of the higher ground in the vicinity of Sisters Hills. Smaller, outcrop-scale features such as striations and grooves are rare. These, and outcrop-scale roches moutonnées, consistently trend 048 to 052° (Figure 9). The orientations of ice-flow indicators observed as part of this study are in general agreement with areas to the west in NTS 093C (Giles and Kerr, 1993; Proudfoot, 1993; Lett et al., 2006; Mihalynuk et al., 2008a, b) and with data and interpretations presented by Tipper (1971).

The proximity of the study area to accumulation centres such as the Coast and Cariboo mountains resulted in a complex late-glacial and deglacial history. To the west, a late-glacial readvance was identified by Tipper (1971), Giles and Kerr (1993) and Proudfoot (1993) and named the Ahahim Lake advance. Piedmont lobes, fed by valley glaciers originating in the Coast Mountains to the west, flowed onto the Fraser Plateau and fanned out to the north, east and southeast. Based on differential ice-flow directions and the occurrence of pitted and kettled terrain, a limit of this advance has been placed within the eastern portions of NTS 093C (Tipper, 1971; Giles and Kerr, 1993; Proudfoot, 1993). A similar readvance is thought to have occurred east of the study area. There, ice advanced west out of the Cariboo Mountains and fanned out onto the Fraser Plateau. Lateral overflow channels and intersections of drumlinoid forms associated with this readvance, and those associated with the northeasterly flow of the Cordilleran Ice Sheet during the Late Wisconsinan glacial maximum, indicate that this readvance crossed and extended up to 30 km west of the Fraser River valley (Tipper, 1971). It has also been proposed that a late-glacial advance, named the Kleena Kleene, occurred down Kleena Kleene, Tatlayoko, Tatla and Chilko valleys. Along the Tatla Lake valley, an elevation limit of approximately 1200 m asl has been suggested for this advance (Tipper, 1971).

Deglaciation was dominated by thinning and downwasting of ice masses (cf. Fulton, 1991). This resulted in higher ground being exposed first, leaving valleys choked with stagnant ice. Hummocky till, glaciofluvial deposits and eskers (in valley settings and on the plateau surface) are evidence in support of this interpretation. In the northern part of the study area, these deglacial features are likely related to the Cordilleran Ice Sheet during the waning stages of the Fraser glaciation. In the southern portions of the study area, however, it is unclear whether they are related to retreat of the Cordilleran Ice Sheet or to the later Kleena Kleene readvance. The occurrence of lateral meltwater channels and a rare recessional moraine (Figure 10) suggest that there was some minor component of marginal retreat during deglaciation.

TILL GEOCHEMICAL SURVEYS

Till geochemical surveys have not been conducted within the study area. Till samples were collected, however, within NTS 093C/01, 08, 09 and 16 to assess the mineral potential of these areas (Giles and Kerr, 1993; Proudfoot, 1993; Lett et al., 2006). Plouffe and Ballantyne (1994), Plouffe (1997) and Plouffe et al. (2001) conducted till geochemistry surveys to the north and south of the study area. To the north of the study area, in the Fawnie Creek map area (093F/03), Cook et al. (1995) conducted a comparative study on the ability of regional lake sediment and till geochemistry surveys to identify known mineral occurrences. In this study, till identified all seven known prospects in the study area with >95th percentile element concentrations. Nine of eleven potential new geochemical prospects presented in the study were also identified with till samples, which had >95th percentile concentrations of multiple elements.

Figure 8. View of an unnamed peak in the southwest of NTS 093B/04 (looking north-northwest), central British Columbia. Note the drift tail of this crag-and-tail that tapers towards the northeast.

Sample Media

Basal till, a first derivative of bedrock (Shilts, 1993), is transported in a relatively linear fashion parallel to ice-flow direction, down-ice from its bedrock source. The contrast between elevated and background geochemical values is clear and the area represented by till samples with elevated values can be areally more extensive than that of their bedrock source. The geochemical patterns found in basal till produce a regional signature that is in contrast to residual soils and bedrock-derived colluvium, which typically reflect more local geochemical variations in bedrock (Levson, 2001). The relatively simple transport history of basal till makes it an effective tool for tracing elevated geochemical values back to their bedrock source. In the Canadian Cordillera, the efficiency of conducting a till geochemistry survey, and the quality of geochemical interpretations, are largely dependent on appropriate sample material, access and the detail to which the region's Quaternary and ice-flow history can be determined.

While conducting a till geochemistry program, it is imperative that the sample medium is correctly identified. This ensures consistency between sample sites and understanding of the origin and mode of sediment transport and deposition (Levson, 2001). To this end, sedimentological data, such as texture, colour, thickness, primary and secondary structures, density, matrix percentage, clast mode, shape and presence of striae, were collected at each site in order to ensure the proper discrimination of basal till from other sediment types such as colluvium, debris flows and glaciolacustrine diamict. As well, at each sample site, notes were made of type of exposure sampled, terrain map unit, sample site geomorphology (e.g., topographic position, aspect, slope, drainage), stratigraphy, and type and thickness of soil horizons present. This information can be critical when interpreting resultant geochemical data. Clasts in till were examined in detail at most sites; data such as lithology, angularity, size, presence of striae, and occurrence of mineralization were recorded. From these data, inferences on clast provenance were made and allow insight into local, covered bedrock units.

For this study, major, minor and trace-element geochemical analyses of till will be conducted on the silt- plus clay-sized (<0.063 mm) and the clay-sized (<0.002 mm) fractions. Traditionally, the silt- plus clay-sized (<0.063 mm) fraction is most commonly used as it can be separated quickly and cost effectively (Levson, 2001). For this study, the clay-sized (<0.002 mm) fraction in basal till will also be analyzed as the contrast between elevated and background element concentrations can be higher. This contrast is due to the tendency of some base metals (more specifically, chalcophile elements such as copper, zinc and lead) to con-

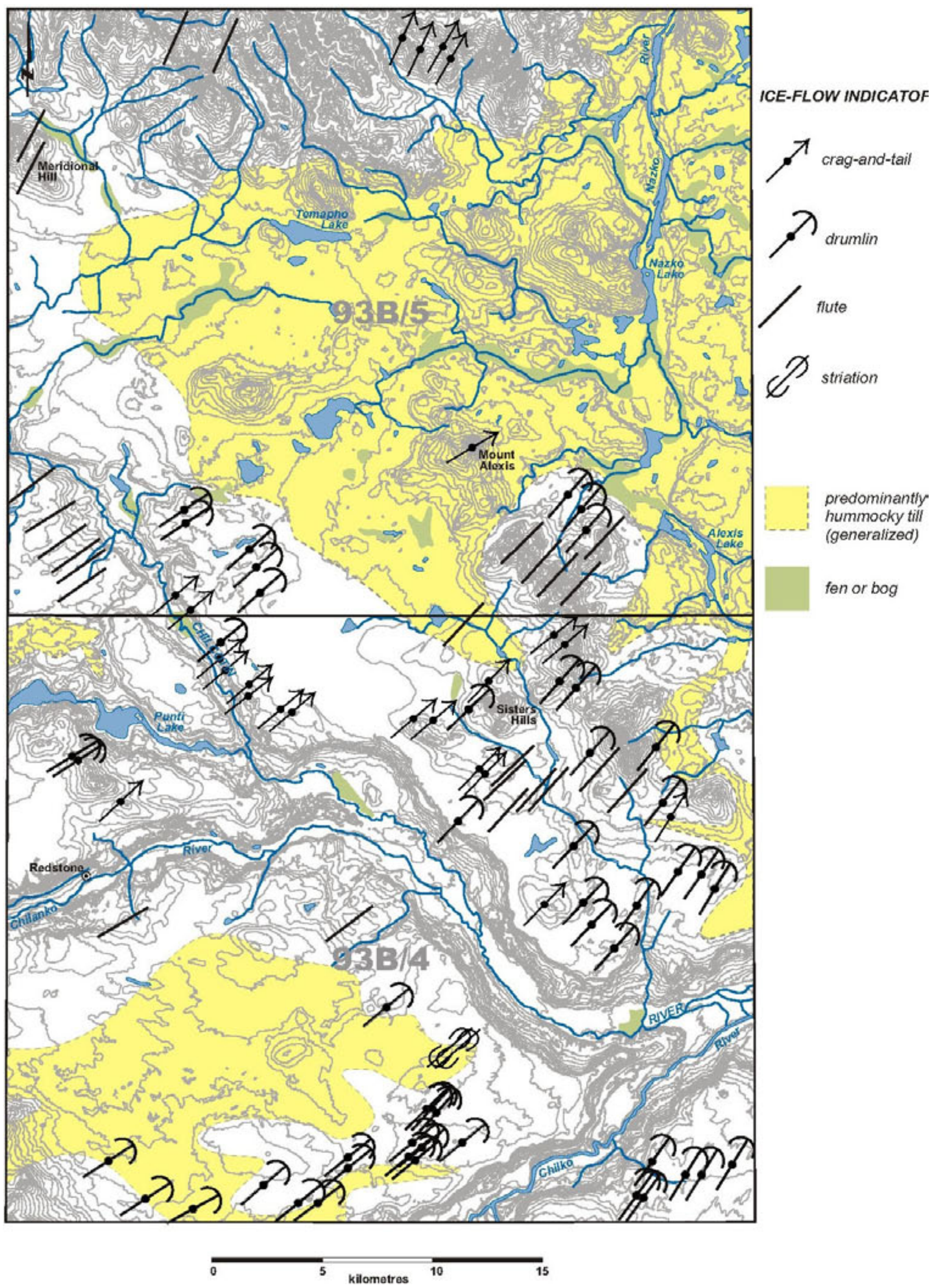

Figure 9. Summary of ice-flow indicators observed as part of this study, central British Columbia. Areas of hummocky till (englacial or supraglacial origin) are shown in yellow (*adapted from* Tipper, 1971).

centrate in this fraction due to the high cation exchange capacity of clay-sized particles (Nikkarinen et al.,1984; Shilts, 1984, 1995; DiLabio, 1995).

Heavy mineral separations are planned for the medium- to very coarse-grained sand (0.25–2.0 mm) fraction, while gold grain counts will be conducted on the very coarse-grained sand fraction and smaller (<2.0 mm). Gold grains in till, based on their morphology and abundance, can provide insight into transport history and genesis. These data can also provide insight into the genesis of source rocks through identification and analysis of heavy mineral assemblages (Averill, 2001).

Sample Types

As part of this study, 117 basal till samples (2–3 kg) were collected for major, minor and trace-element geochemical analyses, while 38 basal till samples (10–15 kg) were collected for analysis of heavy mineral concentrates and for gold grain counts. Sample sites were selected to optimize spatial coverage, taking into account ice-flow direction and availability of appropriate sample material. The average till sample density for the survey is one sample per 15 km^2. This is lower than other regional-scale till geochemistry surveys conducted in central British Columbia, which had sample densities of approximately one sample per 5 to 10 km^2. The lower density is mainly due to the absence of appropriate sample media in the study area and to limited access (e.g., deactivated Forest Service roads, private land or lack of roads). Till samples were collected mainly from roadcuts but also from soil pits and gullies. Average sampling depth was 100 cm below surface but ranged from 45 to 510 cm.

Laboratory Methods

Till samples collected for major, minor and trace-element analyses are being sieved, 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 the Geological Survey of Canada's Sedimentology Laboratory (Ottawa, ON), following procedures outlined by Girard et al. (2004). 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 liquid separation techniques.

For the 2–3 kg samples, minor and trace-element analyses (37 elements) will be conducted on splits of the silt- plus clay-sized (<0.063 mm) and clay-sized (<0.002 mm) 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 (<0.063 mm) 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 by Acme Analytical Laboratories Limited (Vancouver).

Also as part of this project, a split of the silt- plus clay-sized (<0.063 mm) fraction will be analyzed for 35 elements by instrumental neutron activation analysis (INAA) at Activation Laboratories Limited (Ancaster, ON). Additionally, INAA determinations will be conducted on bulk heavy mineral concentrates produced from the 10–15 kg samples. Heavy mineral picking, scanning electron microscopy (SEM) analyses on difficult-to-identify heavy mineral grains, and pebble counts may be conducted at a later date on these concentrates. Minor and trace-element concentrations, as well as the abundance of heavy minerals and gold grains, will be used to assess whether the additional analyses are warranted.

Figure 10. Northwest-trending recessional moraine, a glacial feature not commonly observed on the Nechako Plateau, central British Columbia. View is towards the southeast.

In each block of 20 samples submitted for major, minor and trace-element analyses, 16 are routine field samples. The remaining four samples are quality control measures, utilized in both the sample collection and sample analysis components of the study, to differentiate true geochemical trends from those that reflect random and systematic sampling or analytical errors. Quality control measures include the use of field duplicates, analytical duplicates and control standards.

IMPLICATIONS FOR MINERAL EXPLORATION

The single biggest challenge in assessing the area's mineral potential is the cover of englacially or supraglacially derived till, which is not a favourable sample medium for a till geochemical survey. The quality of geochemical determinations, and the interpretations that follow, are entirely dependent on the quality of field sample selection. Although challenging, till geochemical surveys can be successfully completed in areas with the physiographic and geological characteristics encountered in NTS 093B/04 and 05. An initial review of existing surficial geology map data and aerial photographs can help identify most likely till occurrences, such as where rolling or ridged till occurs (e.g., fluted, drumlinized or crag-and-tail terrain), or where thin till conforms to an underlying bedrock surface. Meltwater channels, even those surrounded by glaciofluvial sediments or hummocky till, should be investigated as they can expose underlying basal till units on their flanks. Areas with hummocky till can offer windows through this material into an underlying basal till. Investigating these areas, however, remains a secondary priority.

Interpretation of glacial history can be a challenge in areas with similar physiographic and geological characteristics. For this study, the streamlined landform record is relatively well preserved and provides a reliable indication of ice-flow direction during the Fraser glaciation maximum. Smaller-scale features, such as grooves, striations or rat tails which provide insight into local variation of ice flow, however, are rare. Although not part of this study, till fabric analyses can provide insight into ice-flow history when other data are lacking. Because till fabric analysis is time consuming and may not be conclusive, however, these analyses should be conducted as a lower priority.

It is worth considering a multimedia approach to geochemical sampling in areas where basal till is not extensive. Raw geochemical data from different sample media (e.g., till, colluvium or bedrock) cannot be combined for interpretation. Integration of interpretations of different sample media, however, is recommended. Local, bedrock-derived colluvium could be sampled, as could locally derived colluvium whose parent material can be confidently identified as basal till. Stream sediment sampling could also be considered.

SUMMARY AND FUTURE WORK

During the Late Wisconsinan glacial maximum, the Cordilleran Ice Sheet moved northeast across the study area, depositing a silt-rich, overconsolidated, basal till. Fluted, drumlinized and crag-and-tail terrain is common where topographic features such as valley sides and peaks or ridges are oriented perpendicular to the regional ice-flow direction. There is good agreement between ice-flow indicators in valley settings, on the plateau surface, and in the higher ground in the south and eastern portions of the study area, indicating that ice flowed generally unaffected by topography.

The late-glacial history appears to be complex and readvances from the Coast Mountains, and further to the east out of the Cariboo Mountains, have left their mark. The dominant material type is an englacial or supraglacial till. It is unclear whether this gravelly and hummocky till is derived from the stagnation and downwasting of Late Wisconsinan Cordilleran Ice Sheet or at least in part related to the east and northeastward late-glacial readvance of glaciers from the Coast Mountains. Hummocky glaciofluvial deposits and eskers (located in valleys and on the plateau) provide evidence for ice-stagnation. In contrast to this, a rare recessional moraine in the northwest portion of the study area suggests that ice-marginal retreat occurred at least locally. A thick sequence of silt commonly occurs in the Chilanko, Chilcotin and Chilko river valleys. These were deposited in an ice-dammed lake following a late-glacial readvance of ice from the Cariboo Mountains west across the Fraser Plateau, which dammed Chilcotin River at its confluence with Fraser River.

The dominance of a gravelly, englacial or supraglacial till presents a challenge to till geochemistry assessment and the evaluation of bedrock mineral potential. This till facies is not appropriate for a till geochemical survey, and as a result the total number of till samples collected and resultant sample density are less than ideal. A silt-rich, overconsolidated, jointed and fissile basal till (the sample medium of choice) occurs at surface within the study area and in windows through the gravelly till unit. Samples of this facies were collected for major, minor and trace-element analyses and for heavy mineral separations and gold grain counts. At the time of writing, geochemical determinations and heavy mineral separations were in progress. These data, and accompanying glacial features and surficial geology maps, are planned for release as soon as available in 2009.

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