QUATERNARY GEOLOGY AND DRIFT PROSPECTING STUDIES IN THE NORTH CENTRAL NECHAKO PLATEAU (93 F AND K)

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(British Columbia Geological Survey Branch contribution to the Nechako NATMAP Project)

KEYWORDS: Applied geochemistry, ice-flow history, glaciation, mineral exploration, surficial geology, Quaternary stratigraphy

INTRODUCTION

This paper provides an overview of Quaternary geology and drift prospecting studies conducted in the Nechako River and Fort Fraser 1:250 000 map areas (NTS 93 F and K, respectively) by the British Columbia Geological Survey in 1998. Research efforts were concentrated in the Tetachuck Lake (93 F/5), Marilla (93 F/12) and Pendleton Bay (93 K/12E) 1:50 000 NTS map areas (Figure 1). This work included surficial geology mapping, Quaternary stratigraphy and landslide hazard studies in the Tetachuck Lake and Marilla map areas, and till geochemistry and ice flow studies on all three map sheets. These investigations are part of the Nechako National Mapping Project, coordinated by the Geological Survey of Canada and the British Columbia Geological Survey (MacIntyre and Struik, 1999). Summaries of results of associated Quaternary geology and regional till geochemistry surveys previously conducted in parts of the Nechako Plateau were provided by Levson and Giles (1997) and Levson *et al*. (1997a,b, 1998). A more detailed description of surficial geology mapping and Quaternary studies in the Marilla map area is provided by Mate and Levson (1999).

The main objectives of the Quaternary geology component of this work are to understand and map the distribution of surficial deposits, decipher the glacial history and ice-flow patterns, locate areas most suitable for conducting drift exploration programs, and provide data to aid in interpreting till geochemical results. Procedures used include compilation of existing surficial geology data, interpretation of air photographs, field checking, till sampling, and stratigraphic and sedimentologic investigations

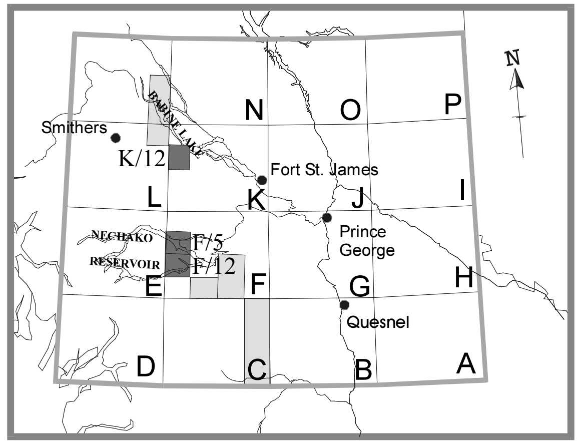

Figure 1. Location map of the study region. Dark shading shows area of Quaternary geology studies conducted in 1998 (93 F/5, F/12, K/12); lightly shaded blocks are areas previously mapped at 1:50 000 scale.

of Quaternary exposures. Ice-flow history was largely deciphered from measurement of the orientation of crag-and-tail features, flutings, drumlins and striae.

The main objectives of the drift prospecting component of this study are to collect regional till geochemical samples, conduct case study investigations around known mineral occurrences, evaluate geochemical dispersal processes and locate mineralized erratics in surficial materials. Procedures used for this work including field methods, types of data collected, laboratory analyses and quality control procedures, are described in detail by Levson and Giles (1997).

PREVIOUS WORK

Reconnaissance (1:250 000-scale) mapping of glacial features in the Nechako River map area was originally conducted by Tipper (1963). This mapping shows dominant landforms such as drumlins, eskers and meltwater channels. Terrain mapping of the southern part of the Nechako Plateau area, showing surficial materials and landforms, was completed by Howes (1977). More recently, Plouffe (1996a,b, in press) conducted 1:100 000-scale surficial geology mapping in the Burns Lake (93 K/SW), Cunningham Lake (93 K/NW) and Binta Lake (93 F/11, 13, 14) regions. The ice flow history and Quaternary geology of the study area and surrounding regions are described by Levson *et al*. (1997a, 1998). The implications of these studies for mineral exploration, in terms of geochemical transport distance and direction, are discussed by Levson and Stumpf (1998) and Stumpf *et al*. (in prep.). Levson and Giles (1997) and Levson *et al*. (1997b) provided descriptions of till geochemistry programs previously conducted on the Nechako Plateau.

PHYSIOGRAPHY AND GEOLOGY

The Nechako Plateau is an area of low relief with surface elevations generally ranging from about 850 to 1500 metres above sea level. The Tetachuck Lake and Marilla map areas occur near the centre of the Nechako Reservoir system where the land rises to only about 500 m above lake level (Figures 1 and 2). Relief generally increases from east to west with the highest elevations (about 1370 m) in the Windfall Hills area (Figure 2). Tetachuck Lake, Chelaslie Arm and Ootsa Lake are all part of the Nechako Reservoir and are joined via Euchu Reach just east of the map sheets. These map areas are dominated by volcanic and sedimentary rocks of the Jurassic Hazelton Group as well as by mainly volcanic rocks of the Tertiary Ootsa Lake and Endako Groups. The bedrock geology of the Nechako River map area was described by Tipper (1963). The Pendleton Bay map area straddles the southern end of Babine Lake. Northeast of the lake, the map sheet is dominated by a low relief plateau area with elevations up to about 900 m asl (Figure 3). An area of relatively high relief occurs in the southeast corner of the map area where the highest peak is about 1400 m asl. The geology of the Pendleton Bay map area is discussed by Schiarizza and MacIntyre (1999).

Glacial drift is extensive in the Nechako Plateau and well developed flutings and drumlinoid ridges are dominant landform features. Although these landforms obscure the bedrock in many areas, small bedrock exposures can often be found at the up-ice end of crag-and-tail

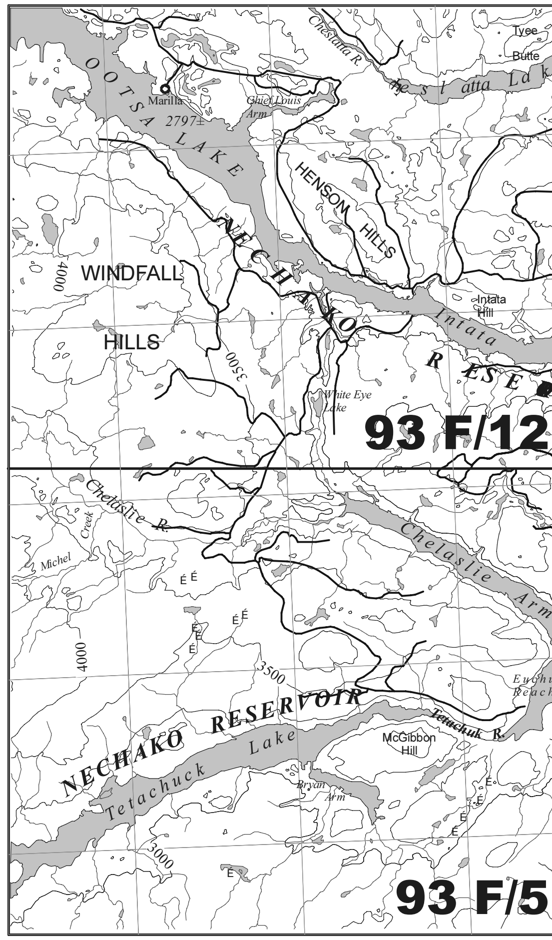

Figure 2. Physiography and access in the Tetachuck Lake (93 F/5) and Marilla (93 F/12) map areas. Road access south of Ootsa Lake is via private barge only. Note low relief; highest elevations are in the Windfall Hills (~1370 m) about 500 m above lake level. Contour interval 150 m (500 ft).

features. These landforms are locally well developed and their identification and application in mapping and exploration programs is probably under utilized. Other glacial features commonly present in the study area include stagnant ice topography, large esker complexes, glaciofluvial deposits and meltwater channels that developed during deglaciation. Recognition of these features is locally important for the identification of aggregate resources for road building and other construction purposes.

1998 TILL GEOCHEMISTRY SURVEYS

Regional till geochemical sampling in 1998 was completed in the, Tetachuck Lake, Marilla and east half of the Pendleton Bay map sheets (Figure 1). The primary objectives of till geo-

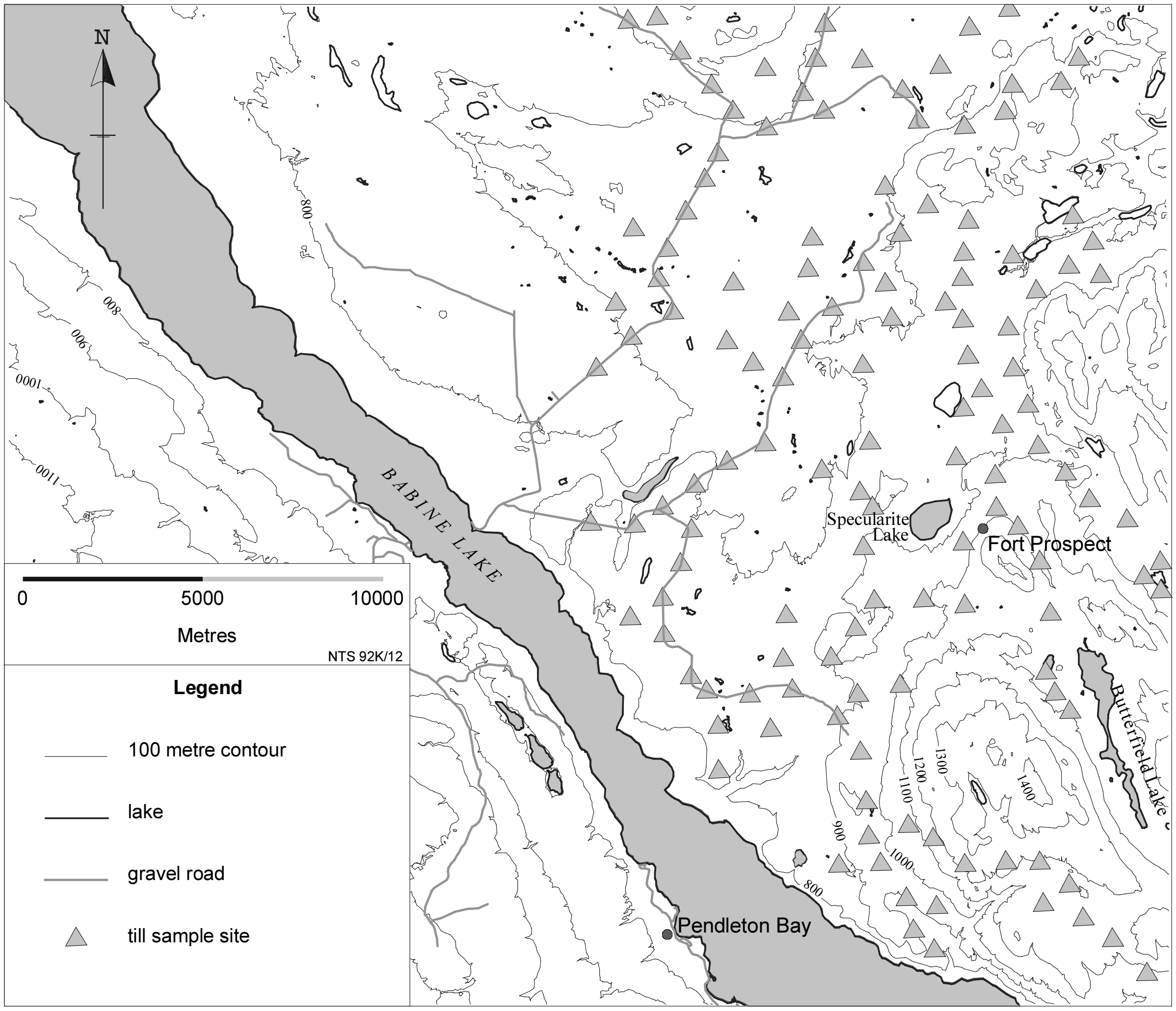

Figure 3. Regional till geochemical sites in the Pendleton Bay map area (93 K/12E). Case study till geochemical sample sites in the vicinity of the Fort mineral prospect are not shown.

chemical studies conducted in the region were to identify geochemically anomalous sites that might reflect areas of buried mineralization and to investigate patterns of glacial dispersal. Regional till geochemistry surveys previously conducted elsewhere in the Nechako Plateau for this purpose have been described by Levson and Giles (1997) and Levson *et al*. (1997b, 1998). The effects of glaciation on till geochemical dispersal patterns in west central British Columbia were discussed by Levson (1998) and Levson and Stumpf (1998).

Approximately 450 regional till geochemical samples were collected in the Tetachuck Lake, Marilla and east half of the Pendleton Bay map sheets. The distribution of samples in the Pendleton Bay map area is shown in Figure 3. In addition to samples taken in 1998, over 100 samples were collected in the Tetachuck Lake and Marilla map areas in 1997. Till dispersal studies were also carried out in the vicinity of known gold and copper prospects including the Uduk Lake (93F/12) and Wolf (93K/12) prospects. Till and profile sampling were conducted at these sites to document glacial dispersal and mineral concentrations in various soil horizons. Sulphide-rich mineralized erratics were found at a number of sites that are not explained by known mineral showings and, in one region, define an dispersal train several kilometres in length.

QUATERNARY STRATIGRAPHY AND SIGNIFICANCE FOR EXPLORATION

The Quaternary stratigraphy of the study area was first described from exposures along the shores of Nechako Reservoir by Levson and

Giles (1997) and Levson *et al*. (1998). These sections provide a relatively rare record of pre-Late Wisconsinan events in the region. The only sub-till radiocarbon date reported from this area (27,790 ± 200 BP; Beta-101017), was obtained on wood recovered from interstadial lacustrine deposits underlying till along Chelaslie Arm on Euchu Lake (Levson *et al*., 1998). These deposits were mapped in detail in 1998 and were found to be much more extensive than previously thought. The interstadial unit consists of organic silts and clays, interpreted as lacustrine deposits, that are overlain by a thick glaciolacustrine, glaciofluvial and till sequence. Interstadial deposits are rare in central British Columbia.

The widespread presence of sub-till sediments in the Nechako Reservoir basin has important implications for interpretation of geochemical data in the region. For example, tills overlying older lacustrine and glaciolacustrine deposits will be enriched in clay-rich sediments that probably were not derived locally. Element concentrations within these tills, normally useful for locating buried mineral deposits, will therefore be diluted by the more regionally derived clays and will not be directly comparable with geochemical results from tills derived from more local sources. Sub-till clays are also significant because they may be an important controlling factor in the distribution of large landslides in the region. The clay rich sediments are relatively impermeable and highly plastic. They have been observed at the base of numerous large slumps in the study region, as well as in surrounding areas such as the Bulkley and Morice River valleys. They are commonly sheared with abundant slickensided surfaces. These observations suggest that the clays act as slip surfaces for these large slides. The spatial association of the clays with areas of active slumping suggests that detailed mapping of their distribution may aid in the identification of high slide hazard areas.

A section representative of the interstadial stratigraphy is provided in Figure 4. The lowest exposed unit (Unit 1, Figure 4) is a horizontally laminated silt with minor clay and sand. The unit generally coarsens upwards and shows increasing internal deformation towards the top, in the form of folded laminae and small scale, normal faulting. Abundant, finely disseminated, organics are present throughout much of the unit resulting in a dark grey to black color. These strata are interpreted as interstadial lacustrine sediments correlative with the radiocarbon dated unit described by Levson *et al*. (1998). An increase in rhythmic bedding towards the top of the unit may reflect more pronounced seasonal effects due to climate change associated with the onset of glaciation. Unit 2 (Figure 4) is a complex unit of fine sands and silts with horizontal to wavy bedding that is commonly folded and faulted. The general coarsening-upward trend in Unit 2 probably is due to the increase of more proximal (coarser) sedimentation associated with the advance of glaciers into the lake drainage area. Abundant deformation in the unit probably reflects lake bed instability caused by one or more of several glacially-induced processes such as ice-damming, increased glaciofluvial activity, fluctuating lake levels, rapid sedimentation, slope oversteepening and the advance of ice into the lake basin.

Unit 3 (Figure 4) consists of a remarkably widespread mud breccia that is intermittently exposed across a distance of about 10 kilometres. The breccia generally has a clay-rich matrix with silt and clay clasts that vary in shape from

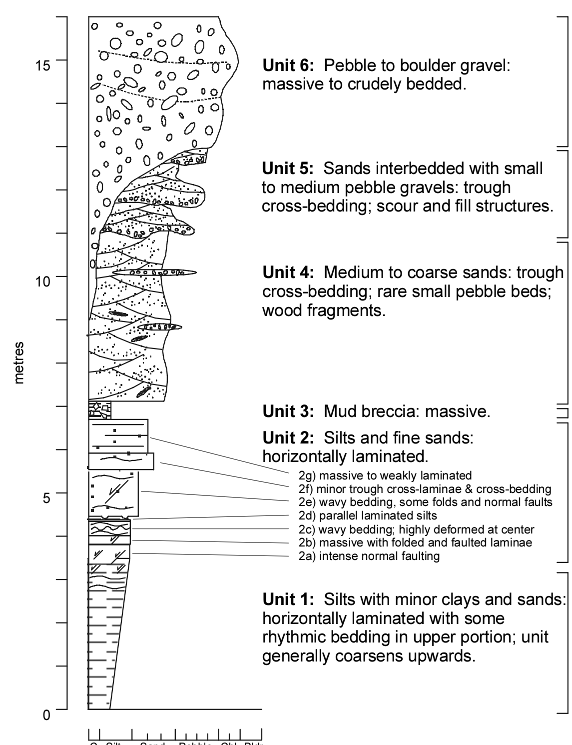

Figure 4. Stratigraphic section of interstadial site on Chelaslie Arm of Tetachuck Lake.

angular to rounded. Some of the clasts are rhythmically laminated. The breccia is interpreted as a mud flow deposit derived from a subaqueous failure of glaciolacustrine sediments. Clast angularity and size generally increase to the southeast, suggesting a source from that direction. The mud flow is sharply overlain by relatively coarse, trough cross-bedded sands and gravels (Units 4 to 6, Figure 4) of inferred fluvial and glaciofluvial origin. The mud breccia stratigraphically separates subaqueous and subaerial deposits and the catastrophic event that resulted in its deposition may have also been responsible for the change in depositional environment.

A widespread, massive, matrix-supported, dense, silty diamicton unit, interpreted as a till, stratigraphically overlies the stratified sands and gravels. Loose, massive to crudely bedded, sandy diamictons of inferred debris-flow origin are commonly interbedded in the gravels and sands that both underlie and overlie the till. The diamictons often have loaded or gradational contacts with the interbedded sediments. These deposits indicate that debris-flow deposition occurred during both the advance and retreat phases of the last glaciation.

Due to the widespread presence of these debris flow deposits in the study region, care must be taken to sample only basal tills while conducting till geochemistry programs. Fortunately, the extent of other surficial sediment types such as glaciolacustrine and glaciofluvial deposits in the study area is not great and tends to be concentrated in specific areas.

ICE-FLOW HISTORY AND EFFECTS ON DISPERSAL

Pendleton Bay map area

The ice flow history of the Babine Lake valley, west and northwest of the Pendleton Bay map area was described by Levson *et al.* (1997a). Glaciers flowing southeast along the Babine Lake valley were deflected to the east at the south end of the lake by east-flowing ice in the Bulkley River valley. In the Pendleton Bay map area, Plouffe (1996a) identified a few easterly-trending crag-and-tail forms on the northern periphery of the map sheet as well as a large number of glacial flutings, mainly in the northern half of the map area, that generally show a southeast to east-northeast paleoflow direction (Figure 5). Although the down-ice flow direction can not be determined from the flutings alone, their association with the crag-and-tails suggests a paleoflow direction towards the southeast along Babine Lake in the northwest corner of the map area, gradually shifting towards easterly flow, and locally east-northeasterly flow, in the north central and northwest parts of the map area (Figure 5). Late Wisconsinan ice flow indicators described in this study generally conform to this pattern with the exceptions described below.

In the southeast corner of the map area, a number of southeast trending topographic ridges rise up to several hundred metres above the surrounding valleys. No glacial flow indicators were mapped by Plouffe (1996a) in this region. Topographic control on ice flow in this area is illustrated by a number of sites with well developed, valley parallel (110° to 155°) striae. With the development of a relatively thick regional ice sheet as glaciation progressed, the influence of topography on ice flow direction decreased. The eventual dominance of an ice centre to the west of the map area is reflected by easterly to northeasterly ice flow indicators including both large scale forms (i.e. crag-and-tails, drumlins and flutings) and small scale forms (striae, rat-tails and roches-moutonnées) throughout the region (Figure 5). At a few sites, valley-parallel striae are cross-cut by younger striae sets reflecting this regional flow. For example, at site 2 (Figure 5), southeast-trending flutes and roches-moutonnées are cross-cut by younger, east to east-northeast trending striae and roches-moutonnées.

Evidence for a gradual eastward migration of this ice centre is seen in the striae record at a number of sites. In the northeast corner of the map area, the oldest and most dominant striae sets invariably show east to east-northeast flow (Figure 5). Cross-cutting striae in this region indicate later flows to the northeast, southeast and south-southwest. These complicated patterns may reflect variable flow directions in the ice divide area. The best evidence for migration of an ice centre to at least the east side of the map area, comes from site 3, located along a valley side in the southeast corner of the map sheet at about 1050 m asl. A glacially molded and heavily striated outcrop at this site clearly indicates a westerly ice-flow direction. On a bedrock ridge

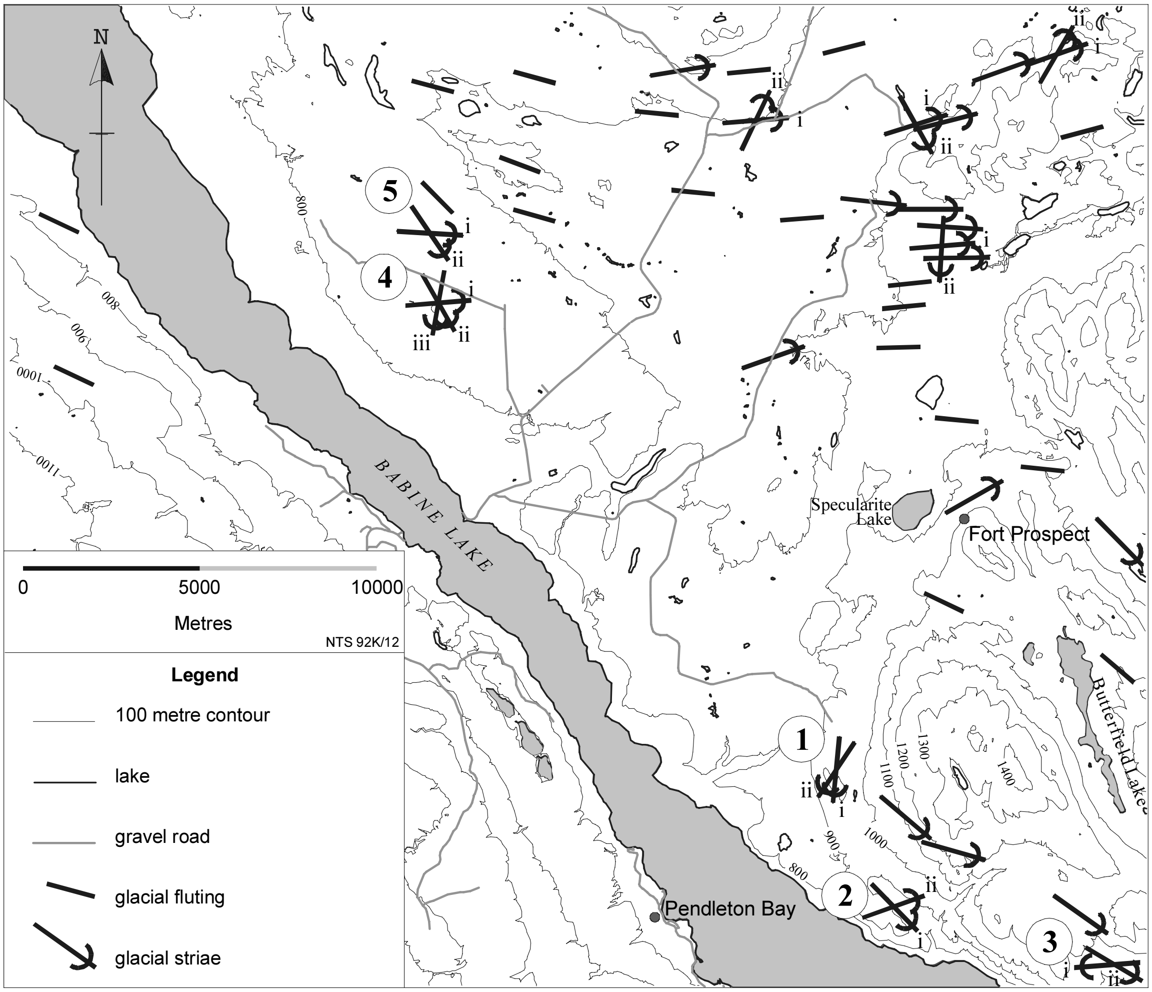

Figure 5. Inferred ice flow directions in the Pendleton Bay map sheet. At multiple striae sites, striae are shown in relative temporal sequence (i - oldest, ii - younger, etc.) at each site, but no time equivalence is suggested between sites. Striae data are from this study; fluting orientations are generalized from Plouffe (1996a). Contour intervals are in metres above sea level.

crest at about 975 m asl (site 1, Figure 5) striae record a strong south-southeast (190°) flow followed by a relatively weak southwesterly (218°) flow. Finally, at sites 4 and 5 in a low relief area in the north central part of the map sheet, ice flow indicators show a progressive shift from easterly (090°-119°) to southeasterly (145°-155°), to south-southwesterly (180°-195°) flow. Although the latest westerly and southwesterly paleoflow at these four sites may locally be explained by late-stage, topographically controlled flow into the Babine Lake valley, it is unlikely that the same pattern would be observed across much of the map area in a variety of topographic settings. Instead, an ice divide located east of the Babine Lake valley is suggested as the cause of the westerly flow in this area. Regardless, evidence for this event in the Pendleton Bay map sheet is rare and confined mainly to small scale features and, as a consequence, its effects on glacial dispersal in the area are probably not extensive.

Marilla and Tetachuck Lake map areas

The dominant regional ice flow direction in the Marilla and Tetachuck map sheets was northeasterly. This is clearly indicated by well developed northeast trending crag-and-tail ridges, drumlinoids, flutings, roches-moutonnées and striae throughout the map areas. An average paleoflow direction of about 065° is consistent with that reported by Tipper (1963) and Plouffe (in press) in the surrounding map sheets. The extent of well developed streamlined landforms associated with this northeasterly flow strongly suggests that glacial dispersal in these map sheets was controlled mainly by this event. This is also supported by till geochemical studies in the Uduk Lake area and at two other sites in the Nechako River map area (O'Brien *et al*., 1997).

Anomalous westward ice flow during the Late Wisconsinan glaciation, recently described by Levson and Stumpf (1998), Levson *et al*. (1997a, 1998), and Stumpf *et al*. (in prep) from the region east of the study area, was also found this field season at a few sites near the west side of the Marilla map sheet as well as in the Pendleton Bay map area (see above). This indicates that a Late Wisconsinan ice divide was located east of the Tweedsmuir area, subjecting that region to westerly ice flow and consequent west-directed glacial dispersal. Westerly flow was independent of large topographic barriers such as the Tweedsmuir, Babine and Hazelton mountains and occurred when ice centres over the Hazelton and Coast mountains migrated eastward into the Interior Plateau. Evidence for westerly flow was only found in the westernmost part of the map region and is absent in the east. Consequently, the effects of westward flow on geochemical dispersal are expected to rapidly diminish eastward. Westerly ice-flow locally extended to the end of the last glaciation as indicated by preservation of paleoflow indicators at unprotected low elevation sites. These observations confirm that the maximum buildup of interior ice extended late into the last glaciation and that a topographically controlled, late-glacial, ice-flow phase was short-lived in this part of the Interior Plateau (Levson *et al*., 1998).

CONCLUSIONS AND RECOMMENDATIONS

Stratigraphic studies indicate that clay-rich, interstadial lacustrine, and glaciolacustrine sediments are widespread in the Nechako Reservoir basin. These sub-till clay-rich sediments are a probable cause of slope instability in the region and their presence has important implications for interpretation of geochemical data. Element concentrations in overlying tills probably are diluted by these regionally derived clays and therefore may not be directly comparable with other regional till geochemical results. Surficial mapping in the study area indicates the widespread presence of basal till but debris flow deposits, glaciolacustrine sediments and glaciofluvial deposits overlie till in a number of areas. As a consequence, till geochemical programs should be effective in the map areas but care must be taken to sample only basal tills. In some areas till sampling will be hindered by glaciolacustrine or glaciofluvial surficial sediments.

Results of ice-flow studies indicate that for most areas the dominant flow-direction was easterly. Glacial dispersal patterns appear to be dominated by this regional ice-flow direction. However, in the westernmost parts of the study area, a regionally anomalous, westerly ice-flow event occurred. Westerly ice flow appears to have occurred when ice centres over the Hazelton and Coast mountains migrated eastward into the Interior Plateau. Evidence for west flow is most readily found west of the study areas and diminishes eastward suggesting that the study areas were near the eastward limit of the divide or that ice-centre migration east of those areas was not long-lived. Consequently, westward flow apparently did not influence glacial dispersal to any great extent in valleys such as the Babine Lake valley but it did have a significant effect further west. Since evidence for westward flow is preserved in valleys at unprotected, low elevation sites, the erosional effects of the later, topographically-controlled flows must have been minimal. These observations suggest that the maximum buildup of interior ice extended late into the last glaciation and that a topographically controlled, late-glacial, ice-flow phase was short-lived in this part of the Nechako Plateau.

Implications of shifting ice divides for exploration are significant because 180° changes in ice flow direction and complex glacial dispersal patterns are possible. Explorationists working in these regions should base paleoflow interpretations on directional features such as roches-moutonnées, drumlinoids and rat-tails. Some locations show both eastward and westward flow directions, even on outcrops that occur in close proximity, and therefore a clear understanding of the temporal relationships of multiple flow events is required. We recommend that inferences regarding glacial dispersal directions in this area be based on regional data and that sampling strategies initially be designed to evaluate the dominant dispersal direction before intensive 'up-ice' surveys are conducted.

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