QUATERNARY GEOLOGY AND ICE-FLOW STUDIES IN THE SMITHERS AND HAZELTON MAP AREAS (93 L AND M): IMPLICATIONS FOR EXPLORATION

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

INTRODUCTION

This paper provides an overview of surficial geology, ice flow history, Quaternary stratigraphy and preliminary till geochemistry studies conducted in the Smithers and Hazelton map areas (NTS 93 L and M) by the British Columbia Geological Survey in 1997. These studies are part of the Nechako National Mapping (NATMAP) Project, coordinated by the Geological Survey of Canada and the British Columbia Geological Survey. A summary of results of associated surficial geology mapping and regional till geochemistry surveys previously conducted in parts of the Anahim, Nechako, Smithers and Hazelton map areas (93 C, F, L and M, respectively) was provided by Levson and Giles (1997).

The main objectives of these surficial geology studies are to understand and map the distribution of Quaternary deposits, decipher the glacial history and ice-flow patterns, and locate areas most suitable for conducting drift exploration programs. Stratigraphic and sedimentologic studies of Quaternary deposits are conducted in order to define the glacial history and aid in interpreting till geochemical data.

RELATED STUDIES

Reconnaissance (1:250 000-scale) mapping of Quaternary deposits in the Interior Plateau was conducted by Tipper (1971). Wittneben (1981) completed 1:50 000 scale terrain mapping in parts of the Hazelton map sheet (NTS 93 M/NW, NE, SW). More recently, Plouffe (1994, 1996) completed several 1:100 000-scale surficial geology maps in the central part of the Nechako Plateau. The surficial geology of the Babine region (93L/16, M/1, M/8) was described by Levson *et al.* (1997a). A summary of 1:50,000 scale surficial geology mapping, conducted as part of the NATMAP and Interior Plateau programs, was provided by Levson and Giles (1997). Nine regional (1:50 000-scale) surficial geology maps have been published as part of this work throughout the study area (Figure 5-1). Regional geochemical surveys conducted in the province in 1997 are discussed by Jackaman *et al.* (1998).

FIELD PROCEDURES

Procedures used in these surficial geology studies included compilation of existing terrain-mapping data, interpretation of air photographs, field checking, and stratigraphic and sedimentologic investigations of Quaternary exposures in the study areas. Ice-flow history was largely deciphered from measurement of the orientation of crag-and-tail features, flutings, drumlins and striae. Reconnaissance ice flow studies were conducted in the Smithers (93 L) and Hazelton (93 M) map areas, and to a lesser extent in the Terrace (103 I) and Whitesail (93 E) map areas.

PHYSIOGRAPHY AND LANDFORMS

The study area is largely within the Nechako Plateau, an area of low relief, flanked by the Hazelton Mountains to the west, the Skeena Mountains to the north and the Omineca Mountains to the east. Surface elevations generally range from about 1200 to 1500 metres in the Nechako Plateau. Flat lying or gently dipping Tertiary lava flows, locally forming steep escarpments, cover older rocks throughout much of the plateau. Glacial drift is extensive and often as little as 5 per cent of the bedrock is exposed.

Well developed flutings and drumlinoid ridges are dominant landform features on the plateau. Stagnant ice topography, large esker complexes, glaciofluvial deposits and meltwater channels that developed during deglaciation are also present in many areas. Much of the variation in topography and differences in surficial geology in the plateau are due to these features. Extensive belts of glaciolacustrine sediments occur in low-lying regions, generally below 950 metres elevation, in valleys such as those now occupied by Nechako River, Babine Lake, and Nechako Reservoir. Topography in these areas is subdued and older glacial landforms are often difficult to identify.

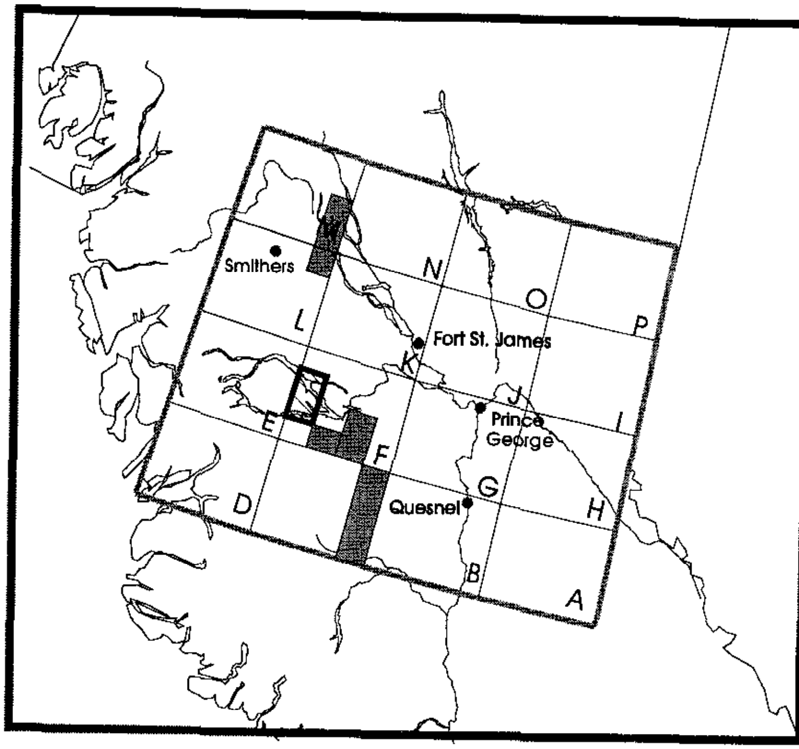

Figure 5-1. Location map of the study region. Outline shows area of surficial geology mapping conducted in 1997 (93F/5, 12); shaded blocks are previously mapped 1:50,000 scale map areas.

1997 TILL GEOCHEMISTRY SURVEYS

The primary objectives of till geochemical 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. Several regional till geochemistry surveys have been conducted in the Nechako Plateau for this purpose (Levson and Giles, 1997; Levson *et al.*, 1997b). Regional till geochemical sampling in 1997 was initiated on the Tetachuck Lake (93 F/5) and Marilla (93 F/12) 1:50,000 map sheets (Figure 5-1) where over 100 samples were collected. The 1997 regional program was combined with preliminary surficial geology mapping. Descriptions of the sampling medium, sampling methods used, types of data collected, laboratory analyses and quality control methods are provided by Levson *et al.* (1997b).

QUATERNARY STRATIGRAPHY

The Quaternary stratigraphy of the study area has been reconstructed from a number of exposures in the region. Quaternary sediments underlying till are rarely exposed in the region. The most complete stratigraphic sections encountered mainly occur in the vicinity of the Nechako Reservoir (Levson and Giles, 1997). The stratigraphic record of pre-Late Wisconsinan events elsewhere in the area was largely removed during the last glaciation.

Morainal sediments in the Nechako Plateau region were assigned by Tipper (1971) to the Fraser glaciation which is dated in several parts of British Columbia as Late Wisconsinan (Ryder and Clague, 1989). A Late Wisconsinan age for the last glaciation in the region is also indicated by radiocarbon dates on wood and mammoth bones recovered from lacustrine deposits under till at the Bell Copper mine (NTS 93 L/16) on Babine Lake. Single fragments of spruce (*Picea* sp.) and fir (*Abies* sp.), yielding dates of 42 900±1860 years B.P. (GSC-1657) and 43 800±1830 years B.P. (GSC-1687), and a date of 34 000±690 years B.P. (GSC-1754) on mammoth bone collagen from the interglacial sediments (Harington *et al.*, 1974), indicate that the overlying till was deposited during the Late Wisconsinan glaciation.

The Quaternary stratigraphy of the Nechako Reservoir area was described by Levson and Giles (1997) and is summarized here. A widespread, massive diamicton unit, interpreted as a till, is stratigraphically underlain both by stratified sands and gravels, of inferred fluvial and glaciofluvial origin, and by horizontally bedded sand, silt and clay sequences, interpreted to be advance-phase glaciolacustrine sediments. The upper part of the older glaciofluvial sequence locally contains sand wedges and dikes that may be relict permafrost features formed in cold environments just prior to the last glaciation. Advance-

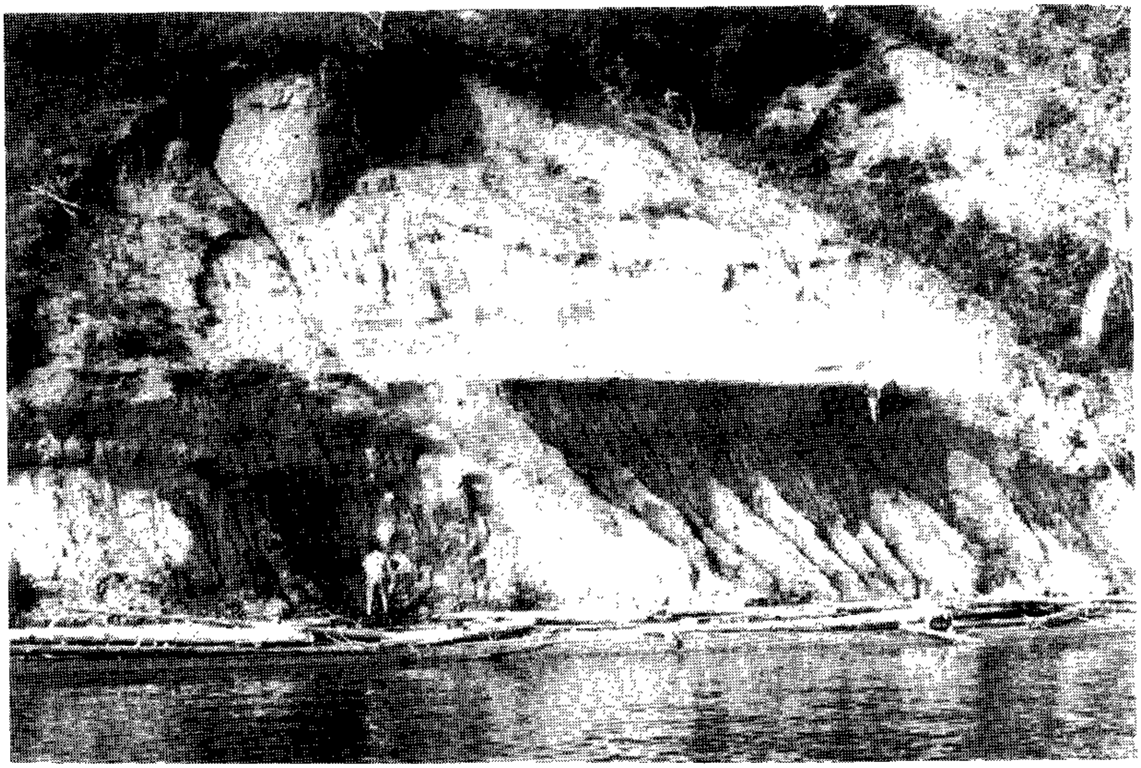

Photo 5-1. Interstadial site on Chelaslie Arm of Tetachuck Lake. Organic-bearing lacustrine silts and clays in the lower part of the section (dark unit) are overlain by glaciofluvial sands and gravels (light unit) and capped by a thin till (1-2 m thick at section top). Rare fragments of wood occur in the sand and gravel sequence (see text for discussion).

phase glaciolacustrine deposits are rarely seen, but they are locally well preserved and include well bedded fine sands and silts with dropstones. Compressive deformation structures, such as shear planes, occur near the base of the till, and overturned folds and thrust faults, interpreted as glaciotectonic structures, are locally present in the upper part of the underlying sediments.

Loose, massive to stratified, sandy diamictons of inferred debris-flow origin are commonly interbedded with gravels and sands that both underlie and overlie till. They 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 in both subaerial glaciofluvial and subaqueous glaciolacustrine environments.

A new interstadial site discovered on the shores of Chelaslie Arm on the Nechako Reservoir, reveals a thick sequence of lacustrine, glaciolacustrine and glaciofluvial deposits (Photo 5-1) that are overlain by till deposited during the last glaciation. These deposits are locally capped by post-glacial gravels and sands. The lowest exposed unit consists of well stratified, locally deformed, dense, fine sands, silts and clays. These sediments are interpreted as lacustrine and glaciolacustrine deposits. The lacustrine deposits near the middle of the lower unit (Photo 5-1) contain fine organic detritus that yielded a radiocarbon date of 27,790 ± 200 BP (Beta-101017).

A thick unit of gravels and sands (Photo 5-1) that overlies the lacustrine and glaciolacustrine deposits is interpreted as a glaciofluvial sequence that was deposited during the advance phase of the last glaciation in the region. The sand and gravel sequence is sharply overlain by a massive, matrix supported, dense, silty diamicton, interpreted as till. The upper part of the diamicton is less dense, has a gravelly-sand matrix and locally is crudely bedded. This unit probably was deposited as a series of debris flows during deglaciation.

ICE-FLOW HISTORY

During Late Wisconsinan glaciation, ice moved east and northeast into the Nechako Plateau from the Coast and Hazelton mountains and southeast from the Skeena Mountains, before flowing easterly and northeasterly towards the Rocky Mountains (Tipper, 1971, Levson and Giles, 1997). In the eastern Nechako Plateau, results of ice-flow studies indicate that in most areas there was one dominant flow direction during the Late Wisconsinan glaciation, that shifted from southeast, in the north part of the plateau (Babine Lake region), to east in the central part (Francois Lake area) and east-northeast in the south (Nechako Reservoir area; Levson and Giles, 1997). However, in the western Nechako Plateau and in the adjoining Babine Range and Hazelton Mountains, anomalous westerly ice-flow indicators are present and indicate a regional, west to southwest flow event, extending over much of west central British Columbia (Figure 5-2; Levson *et al.*, 1997a). Results suggest this

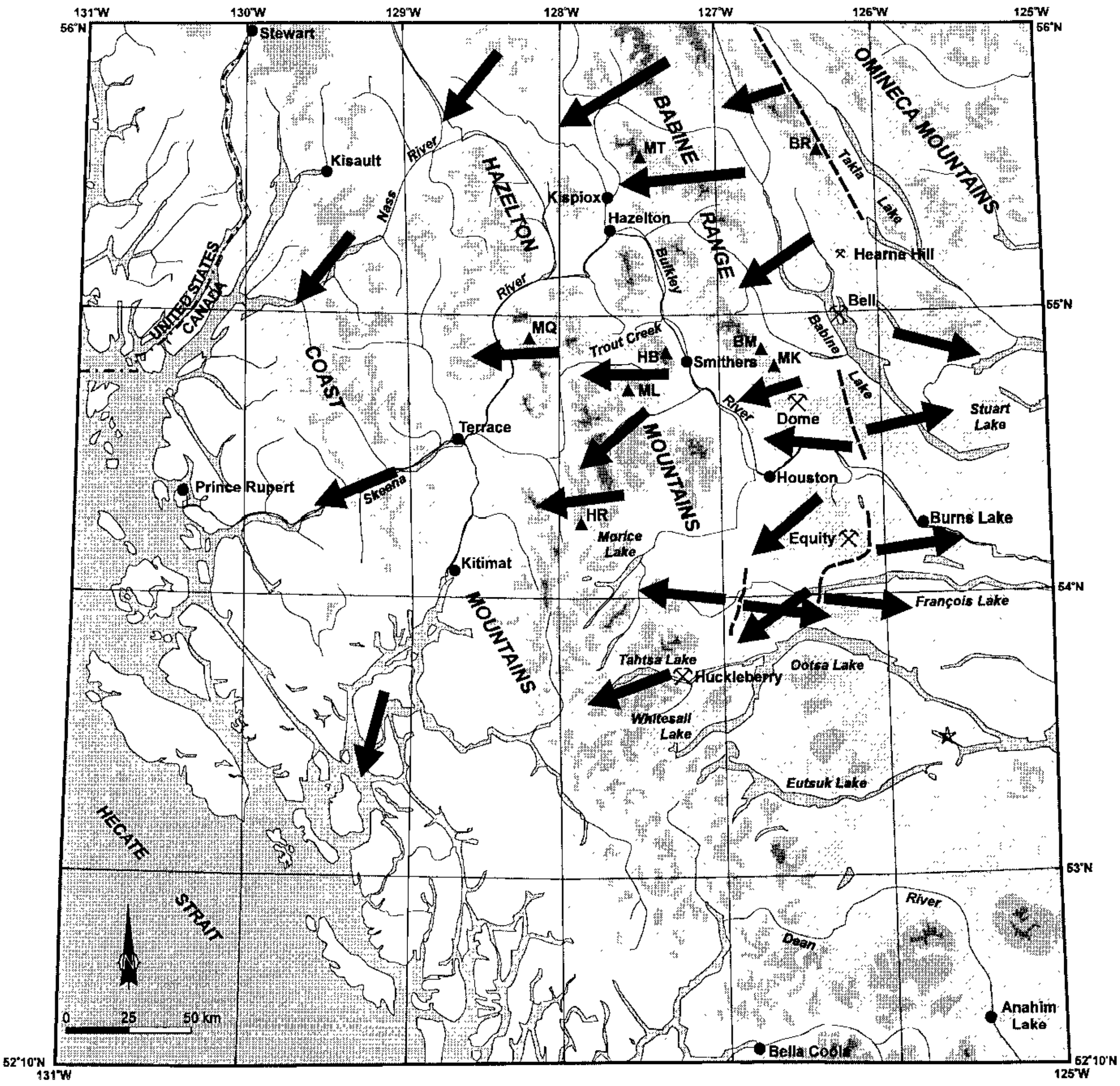

Figure 5-2: Inferred ice flow directions in west central British Columbia at the last glacial maximum. Paleoflow directions shown in the Nass River valley, and west of Terrace and Kitimat are from McCuaig (1997) and Clague (1984), respectively. Dashed lines represent the easternmost position of ice divides inferred from available data. Ice divides may have extended further east at the glacial maximum and, during late glacial times, they locally shifted further west. Shaded contour intervals are 1000, 1500 and 2000 m above sea level. Star in lower right shows location of section in Photo 5-1.

was a more recent and widespread event than previously thought (Stumpf *et al.*, in prep). This new data is significant for drift exploration programs in central British Columbia and may be useful for modelling ice sheet dynamics and climate change.

Indications of this westerly ice-flow event include well developed roche-moutonnée, drumlinoids and rat-tails (Photos 5-1 and 5-2) that indicate ice-flow toward the west over the Babine Range and Hazelton Mountains. In many areas this westerly flow was independent of topography as indicated, for example, by upslope flows in the Dome Mountain area (Figure 5-2, see also Levson *et al.*, 1997a, Photo 9). Similar westerly ice-flow indicators were previously reported in the Babine Range and in the vicinity of the Equity Silver mine (Tipper, 1994). This study has extended their distribution further to the south, west and east and new evidence on the timing of this event has important implications for the Quaternary history of the region. West ice flow extends across the area bounded to the north by the Skeena Mountains, to the northeast by the Omineca Mountains, and to the southeast by François and Ootsa lakes. The northwest and southern limits of this anomalous westerly flow have not yet been defined.

At the Late Wisconsinan glacial maximum, ice covered all but the highest peaks in the region and movement appears to have been relatively unaffected by topography. In the Bait Range for example, the ice surface was in excess of 1950 metres as indicated by glacial erratics and regionally trending striae and flutings on top of Frypan Peak (elevation 1931 m, Levson et al., 1997a). At the height of the last glaciation, ice flowed from ice domes/divides located to the east of the Babine Lake valley toward the Coast. Ice overtopped most mountain peaks with elevations up to at least 2200 m (upper limit of ice defined by striae at sites on Hudson Bay Mountain (HB) at 2212 m or 7300 feet; Southern Babine Mountains (BM) at 2239 m or 7390 feet; Howson Range (HR) at 2206 m or 7280 feet, Figure 5-2). Preserved evidence of west flow is not restricted to elevations above 2000 m but occurs at lower elevations on mountains such as Mount McKendrick (1742 m) and Mount Leach (1822 m, sites MK and ML, respectively on Figure 5-2), and also is present locally along valley bottoms such as the Babine Lake valley, especially in the lee of topographic obstructions, where it was preserved from later valley-parallel flow. Cross-cutting striae observed at several locations suggest that the westward event occurred at the maximum of the Late Wisconsinan glaciation, after glacier advance along valleys and prior to late-stage, retreat-phase flow that was topographically controlled in some areas. Topographic control of ice flow in a few areas in the Nechako Plateau during early glacial phases is indicated by local, valley-parallel striae on bedrock surfaces that are buried by thick till sequences (Levson and Giles, 1997).

Westerly ice flow in this region appears to have continued into the later stages of the last glaciation as indicated by stratigraphic, lithologic and geomorphic criteria (Levson *et al.*, 1997a). This includes the presence of westerly ice-flow indicators at the surface in areas where preservation from later ice erosion would not likely occur (*e.g.* in stoss-side positions). For example, westerly ice-flow indicators in the Dome Mountain area (Figure 5-2) are preserved on the top of the mountain as well as on the east side at relatively low elevations. During the last glaciation, ice flowed along the east side of the mountain from the Babine Lake area and would have eroded or at least partially obscured the exposed features on the east side of the mountain. In addition, investigations of glacial dispersal in surface tills in these areas indicate westerly dispersal. Tracing of erratics with distinctive lithologies and known source areas in the Babine Mountains, for example, has shown substantial westerly and upslope transport of the erratics from their source areas. At sites northwest of Mount Thomlinson and northeast of Mount Quinlan (MT and MQ, respectively, on Figure 5-2), indicator lithologies were identified which have sources to the northeast. Similarly, previous studies in the vicinities of the Bell (Stumpf *et al.*, 1997) and Equity Silver mines (Ney *et al.*, 1972) have identified southwest directed transport of material in till and soil from mineralized bedrock.

Tipper (1994) postulated that westerly ice flow patterns in the southern Babine Mountains and in the Equity Silver area (Figure 5-2) represented a relict flow pattern from an earlier glaciation or possibly from an early phase of the last glaciation when movement of ice towards the Coast Mountains occurred as the result of the development of an ice dome in the central part of the Interior Plateau. Levson *et al.* (1997a), however, inferred that the westerly ice-flow features that they observed in 1996 formed during the later part of the Late Wisconsinan glaciation. The main evidence of this is the preservation of westerly trending paleoflow indicators at low elevations in the Babine and Bulkley valleys at sites that would not have been protected from later valley-parallel (southeasterly) flow. Levson *et al.* (1997a) suggested that rapid calving of tidewater glaciers in large valleys on the west side of the Coast Mountains, such as the Skeena River valley, may have resulted in a draw-down of ice in that area. Rapid calving and significant lowering of the ice surface in these valleys may have resulted in the eastern migration of ice divides, the 'capture' of glacial ice from east of the Coast Mountains and reversal of ice flow into valleys such as the Skeena and its tributaries. This hypothesis is consistent with the development of westerly ice flow indicators late in the last glaciation and with their relatively limited extent. However, the full extent, timing and duration of this westerly ice flow event and its influence on glacial dispersal was the subject of further research in 1997 and it is now known that the westerly ice-flow event was more extensive than previously thought. Evidence for late westerly flow was found not only in the southern Babine Mountains but also in the central and northern Babine Range and over a large area in the Hazelton Mountains (Figure 5-2). In addition, westerly ice flow indicators were found at a number of low elevation sites in east-trending valleys such as the Morice Lake and Trout Creek valleys (Figure 5-2). The main exception to this was found in a few valleys with headwaters in high mountain areas, such as the Telkwa River valley, where indicators of late-stage, down-valley (easterly) flows were observed. These

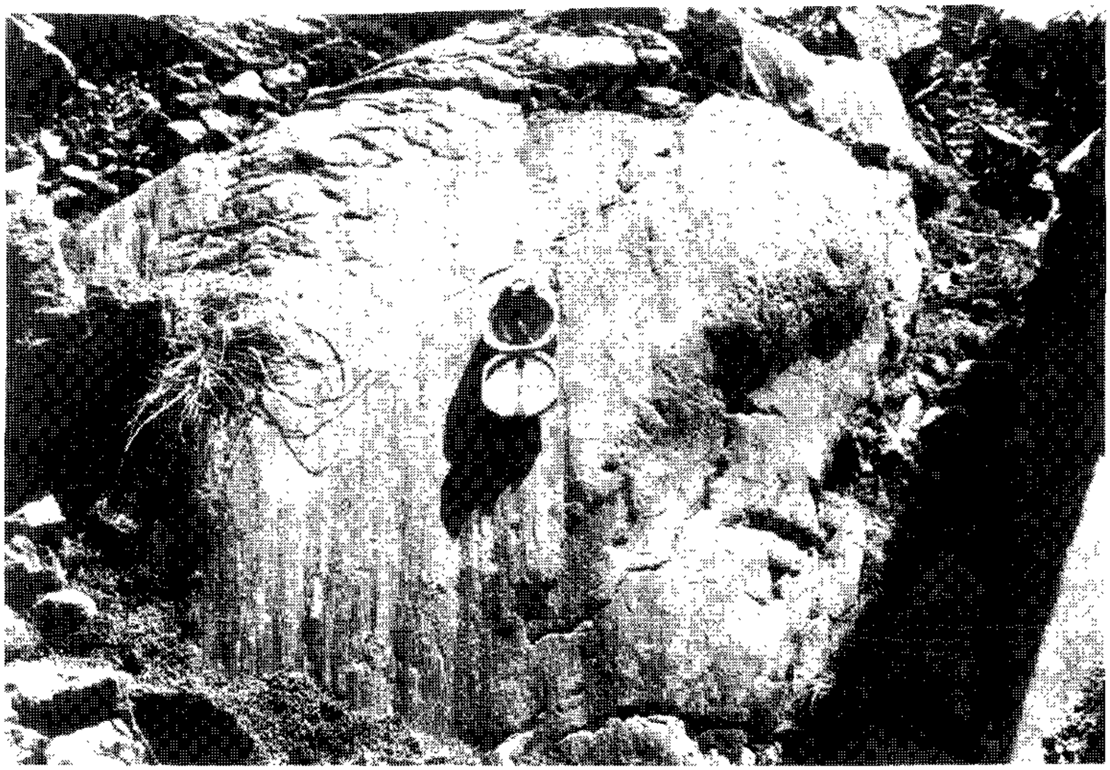

Photo 5-2. Striae with directional indicators on bedrock in the Bait Range (site BR on Figure 5-2).

Photo 5-3. Fluted ridges and drumlinoid forms on a unnamed mountain top northwest of Smithers in the Hazelton Mountains (near site MQ on Figure 5-2). Paleoflow is left to right (west) at this site.

observations have led to the expansion of our hypothesis for the westerly event. We now propose a working model suggesting that an extensive, maximum phase, ice divide, or series of smaller divides, formed in the central part of the Nechako Plateau (east of the Babine Mountains). This ice divide persisted until near the end of the Late Wisconsinan and was not modified by late-stage, topographically-controlled, ice flow except in areas of strong alpine glaciation. Valleys in the Hazelton Mountains such as the Morice Lake and Skeena River valleys and their tributaries, that have low elevation passes that open westward into Pacific Ocean drainages, did not experience late-stage flow reversals, unlike more constricted valleys fed by high mountain alpine glaciers such as the Telkwa River valley.

During deglaciation, ice flow was increasingly controlled by topography as the glaciers thinned. Striae and other ice-flow indicators that locally diverge from the regional trend reflect this topographically influenced ice-flow during waning stages of glaciation. A more complex local ice-flow history is indicated by highly variable striae trends at a few sites. Topographic control of ice flow during the latter phases is also apparent in many areas of high relief. In these areas, ice flow is clearly indicated by the presence of well developed cirque basins on the north and east facing sides of large mountains. During deglaciation, ice flow was increasingly controlled by topography as the glaciers thinned. Cirque glacier activity dominated during the later phases of the last glaciation and this activity may have extended into the Holocene.

SUMMARY

Results of ice-flow studies indicate that for most areas in the eastern part of the Nechako Plateau, the dominant flow-direction was easterly. Glacial dispersal patterns appear to be dominated by this regional ice-flow direction. However, in the Babine and Hazelton Mountains and in the northwest part of the Nechako Plateau, a regionally anomalous, westerly ice-flow event occurred and dispersal directions are much more complex. Westerly ice flow in this region appears to have occurred at the last glacial maximum when ice centers over the Hazelton and Coast mountains migrated eastward into the interior plateau areas. The full extent and timing of this event and its effects on dispersal are currently being investigated (Stumpf *et al.*, in prep.). Evidence for west flow is most readily found west of the Babine Lake valley and diminishes eastward suggesting that the Babine valley was near the eastward limit of the divide or that ice-center migration east of that area 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.

Westerly ice-flow locally extended to the end of the last glaciation, especially in valleys with large passes opening westward to the Pacific Ocean, such as the Skeena and Morice valleys. A postulated mechanism for maintenance of an interior ice-divide late into the last glaciation, is due to the rapid calving of tide-water glaciers fed by ice in the interior. This may have allowed for significant lowering of glaciers in those valleys relative to ice in the interior and inhibition of topographically controlled, ice-flow reversals. Late glacial ice-flow, back to the east from the Hazelton Mountains, did occur in valleys with high or relatively restricted mountain passes such as the Telkwa River valley. Further east in the Babine Lake valley, late-glacial topographically controlled, eastward flow also occurred. However, since evidence for westward flow is preserved in the Babine Lake area and in other 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. In the Babine and Hazelton mountains, late-phase glaciers flowing down valleys that presently drain eastward, were probably restricted to alpine cirques and to valleys with relatively confined, high mountain passes. In other east-draining river valleys with wide passes to the Pacific, upslope westward flow apparently continued to the end of the last glaciation.

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