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BABINE PORPHYRY BELT PROJECT: QUATERNARY GEOLOGY AND REGIONAL TILL GEOCHEMISTRY SAMPLING IN THE OLD FORT MOUNTAIN (93M/01) AND FULTON LAKE (93L/16) MAP AREAS, BRITISH COLUMBIA

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INTRODUCTION

The Babine porphyry belt in the northern Nechako Plateau has long been known as an area of productive copper, molybdenum and gold mineralization (Carter, 1981). A regional mapping program was initiated as part of the Nechako Plateau National Mapping Program to stimulate further exploration and define new mineralization targets in the Babine Lake area (MacIntyre *et al.*, 1996, this volume; McMillan and Struik, 1996, this volume). The surficial geology component of this integrated project focused on the Old Fort Mountain (93M/01) and Fulton Lake (93L/16) map areas (Figure 1). In this paper we report:

- An outline of field methods used in surficial mapping and till geochemistry sampling.
- A descriptive inventory of Quaternary deposits and selected glacial landforms.
- A preliminary discussion of the local glacial history.

Details of supplementary research at several mineral prospects in the map area are discussed elsewhere (Stumpf *et al.*, 1996, this volume).

PHYSIOGRAPHIC SETTING

The glaciated Babine and Hautête drainage basins lie close to the northern edge of the Nechako Plateau (Figure 1; Holland, 1980). Three physiographic elements are common to these basins (Figure 2). Broad valleys are occupied by numerous lakes. Fulton and Morrison lakes drain east and southeast into Babine Lake, which in turn drains northward into the Skeena River. Hautête Creek lies within the Fraser River catchment and drains southeast, through Hautête and Natowite lakes into Takla Lake. Valleys are flanked by undulating to rolling plateaus and uplands (Figure 2). The central and northeastern portions of the 93M/01 map area are more mountainous than other parts of the study area, and contain several peaks over 1200 metres (4000 feet), including Old Fort Mountain (1570 m; 5146 ft), Hearne Hill (1370 m; 4500 ft) and Wedge Mountain (1250 m;

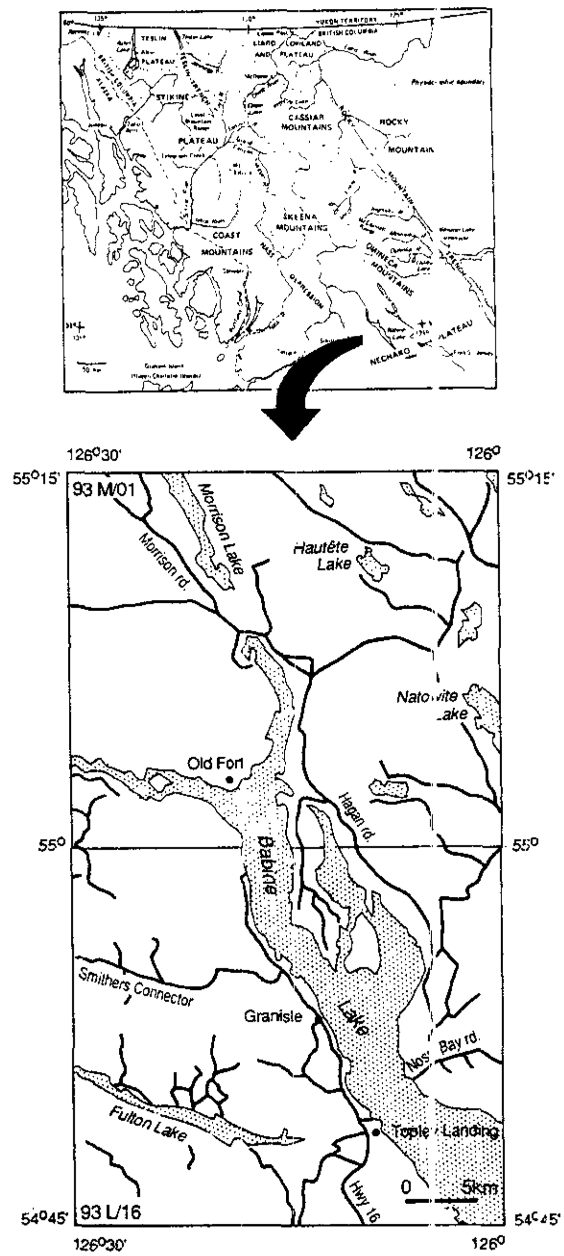

Figure 1. Location of the Old Fort (93M/01) and Fulton Lake (93L/16) map areas. Upper map modified from Ryder and Maynard (1991).

4100 ft). In contrast, the western part of 93M/01 and much of the 93L/16 map area are dominated by plateau terrain, with glacially eroded hills standing 100 to 150 metres above surrounding lowlands.

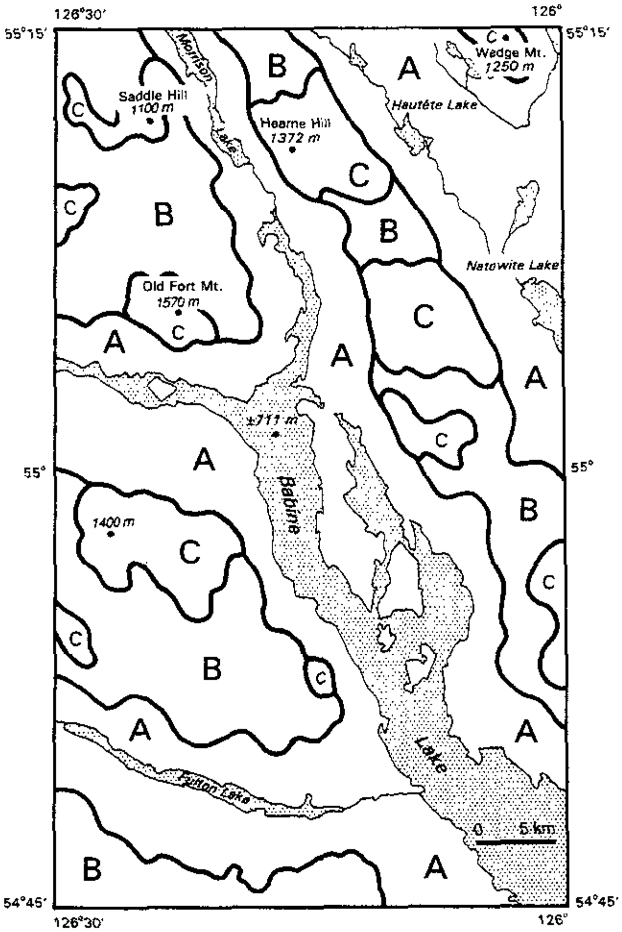

Figure 2. Phyiosography of study area. A - Ponded and free-draining valleys; B - Undulating and rolling plateaus; C - Uplands.

FIELD METHODS

SURFICIAL GEOLOGY

Preliminary 1:50 000-scale surficial geology maps were prepared before fieldwork using existing soils and terrain classification maps (*e.g.*, Wittneben, 1981) and airphotos (suites BC 86048 and BC 87062). Terrain unit polygons were defined according to surficial material type and surface expression. These criteria were coded and landforms symbolized using mapping standards similar to those detailed in Howes and Kenk (1988). Preliminary mapping and airphoto interpretations were verified during field traverses.

The town of Granisle is reached by driving 48 kilometres north from Highway 16 at Topley. Much of the area was accessed by an extensive network of gravel roads (Figure 1). Access to eastern and northern parts was provided by a private barge crossing operated by Northwood Forest Products. Off-road access was by helicopter, boats, mountain bikes, or on foot. A variety of natural and anthropogenic sites exposed overburden cover, including stream cutbanks, forest blowdowns, borrow pits, trenches and roadcuts. Where exposure was poor or lacking, observation pits were dug by hand.

Surficial sediments and glacial landforms were described to aid the interpretation of till geochemistry data. Regional and local paleo-iceflow patterns were defined by plotting the distribution of directional glacial indicators, including troughs, roches moutonnées, crag-and-tails, flutes and striae, on preliminary surficial geology maps. Glacier margins were identified from the spatial distribution of morainal, glaciofluvial and glaciolacustrine deposits. Between 20 and 50 pebble to cobble-sized clasts and surface boulders in surficial deposits identified as basal tills were examined for mineralization and rock type at till sample sites (*cf.* Giles *et al.*, 1995). Thirty mineralized boulders were sampled for assay. These data will be useful for tracing mineralized float to source and determining bedrock lithology in areas of extensive drift cover.

REGIONAL DRIFT GEOCHEMISTRY

Regional drift geochemistry sampling focused on basal tills (lodgement and basal melt-out till). These sediments are first derivative products of erosion and deposition with relatively simple transport histories (Shilts, 1993; Levson *et al.*, 1994). As such, mineralized debris dispersed within basal tills can be more readily traced to origin than in most other deposits. Undisturbed basal till matrix samples (1 to 3 kg per sample) were collected at 293 stations on the 93M/01 map sheet and 304 stations on map sheet 93L/16 (Figure 3). Sample sites were located with a Trimble "Scoutmaster" global positioning system (accuracy ± 50 m) or by compass triangulation, then plotted on a base map using the UTM coordinate system (North American datum 1927). Elevations were determined using a Thommen altimeter, periodically benchmarked to spot heights and contours. At each site, exposures were logged using traditional Quaternary geology mapping techniques to document the drift cover. Observations included general attributes such as map unit, sample medium, depth to bedrock, depth of oxidation, surface expression, slope and vegetation cover. Additional records were made of the internal structure (fissility and jointing), texture, density, colour and clast characteristics (mode, shape and presence of striae) in surficial deposits. Sampling was confined to the unweathered C-horizon, which ranged from 0.2 to 6 metres below surface. An average density of one sample per 2.5 square kilometres was achieved. The greatest density of samples was along transects perpendicular to inferred iceflow direction, in areas of perceived higher mineral potential or around known mineral prospects. Sample density parallel to regional iceflow was lower (Figure 3). This sample design is consistent with similar regional till geochemistry surveys (Levson *et al.*, 1994; Giles *et al.*, 1995). An additional 173 samples of basal and ablation tills, glaciofluvial and glaciolacustrine sediments and colluvium were collected at five mineral prospects (Table 1; Stumpf *et al.*, 1996, this volume).

Samples were stored in heavy-mil plastic bags, air dried (at 25-30°C), split, crushed and sieved to -230 mesh (<63 µm) in the laboratory. Ninety-six analytical duplicates, field duplicates and analytical standards were integrated into the sample database prior to analysis for quality control. Representative splits have been submitted for aqua regia inductively coupled plasma emission spectroscopy (ICP-ES) and instrumental neutron activation (INA) analysis for 47 elements.

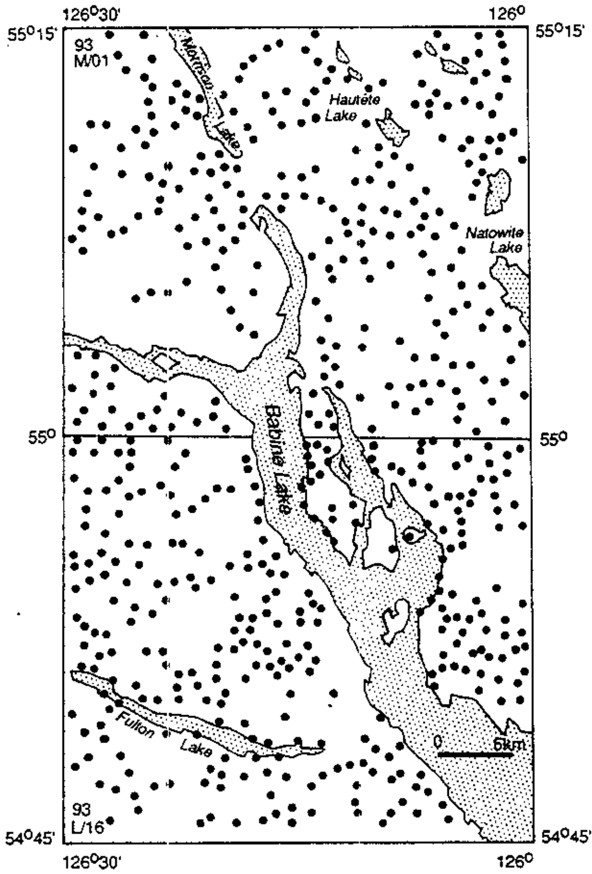

Figure 3. Location of till geochemistry samples.

SURFICIAL SEDIMENTS

Six surficial sediment types occur in the study area: tills, glaciofluvial, glaciolacustrine, colluvial, fluvial and organic deposits (Figure 4). Their relative abundance and areal distribution are physiographically controlled. The greatest range of sediment types is observed in ponded and free-draining valleys, where complex sediment assemblages may be preserved (Figure 5A). Deposit thicknesses in valleys can exceed 10 metres (*e.g.*, Babine Lake valley). Undulating and rolling plateaus are covered by till, colluvium and glaciofluvial sediments (Figure 5B and C). In upland settings, colluvial deposits dominate on steeper slopes; tills and glaciofluvial sediments are confined to more gentle slopes (Figure 5D).

BASAL TILLS

Throughout the area, glacially streamlined bedrock is mantled by massive, matrix-supported diamicton. Deposit thicknesses range from less than 1 metre in montane uplands, to greater than 5 metres along valley sides (log 1; Figure 4; Figure 5A). Surface expressions of deposits range from gently undulating to drumlinized or fluted. The matrix component ranges from about 70 to 90%, and is composed of moderately to well compacted sand, silt and clay. Moderate to strong bedding-parallel fissility and moderate to strong jointing are characteristic. Colour is variable and is often reflective of underlying bedrock. As such, it is not a distinguishing characteristic. Oxidation, if present, is predominantly confined to joints or fissility planes and discolours matrices orange to red-brown. Clasts range in size from small pebbles to large cobbles, and consist of subrounded to subangular local and distally derived lithologies. Subrounded, prolate clasts usually have striated, faceted surfaces and show alignment parallel to palaeo-iceflow. Massive, matrix-supported diamictons are interpreted as lodgement tills deposited at the base of active glacier ice (Dreimanis, 1988). Lodgement tills are occasionally interbedded with thin lenses of dense, stratified, matrix-supported diamictons, gravel and sand. Subordinate interbeds may represent basal melt-out till and subglacial fluvial deposits.

SUPRAGLACIAL TILLS AND GLACIGENIC DEBRIS FLOWS

In many areas, bedrock and basal till are mantled by massive and stratified, matrix-supported diamictons (log 2, Figure 4; Figure 5B). Deposits typically have undulating or hummocky surface expressions. Basal contacts with underlying till are either gradational (for massive diamictons) or erosional (for stratified diamictons). In contrast to basal tills, these diamictons are less compact, have silt and clay-deficient matrices and are pervasively oxidized. Massive diamictons have clast contents ranging from about 20 to 40%. Subangular to subrounded pebbles and cobbles are the dominant clast sizes, although boulders (up to 3 m in diameter) are exposed close to upper surfaces. Distally derived lithologies predominate. Massive diamictons are interpreted as supraglacial tills, deposited by retreating or stagnating glacier ice. Stratified diamictons may be lithogically similar to underlying tills, and are interbedded with subordinate silt, sand or gravel. Stratified diamictons resemble glacigenic debris flows derived from steep, debris-covered ice margins or remobilized tills exposed in ice-proximal settings (*c.f.* Lawson, 1988). Below 760 metres (2500 ft), linear diamicton-filled ridges, lying perpendicular to inferred iceflow, drape till. These ridges are interpreted as crevasse fills.

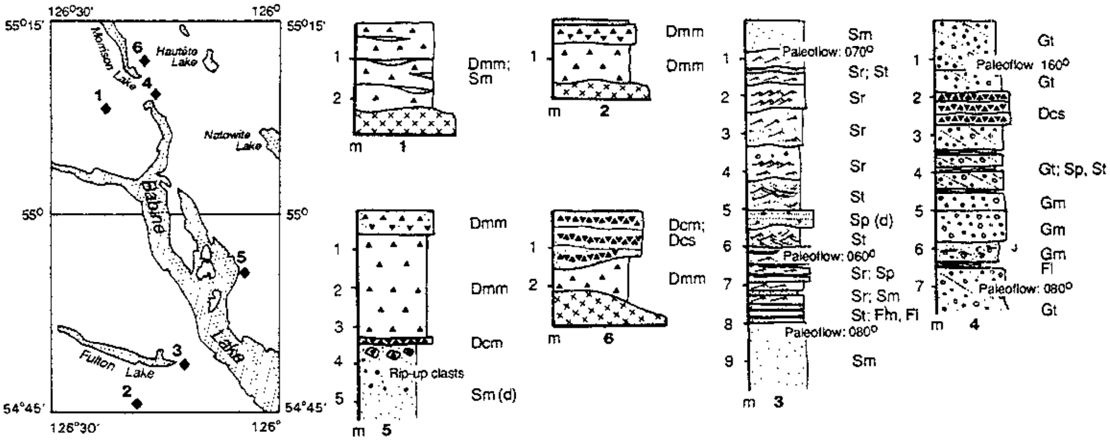

Figure 4. Selected logged profiles. Legend: Dmm - massive, matrix-supported diamicton; Dcm- massive, clast-supported diamicton; Dcs - stratified, clast-supported diamicton; G - massive gravel; Gt - cross-trough-bedded gravel; Sm - massive sand; Sp - planar bedded sand; Sr - ripple bedded sand; Fm - massive silt and clay; Fl - laminated silt and clay. Additional qualifiers: d - dropstones.

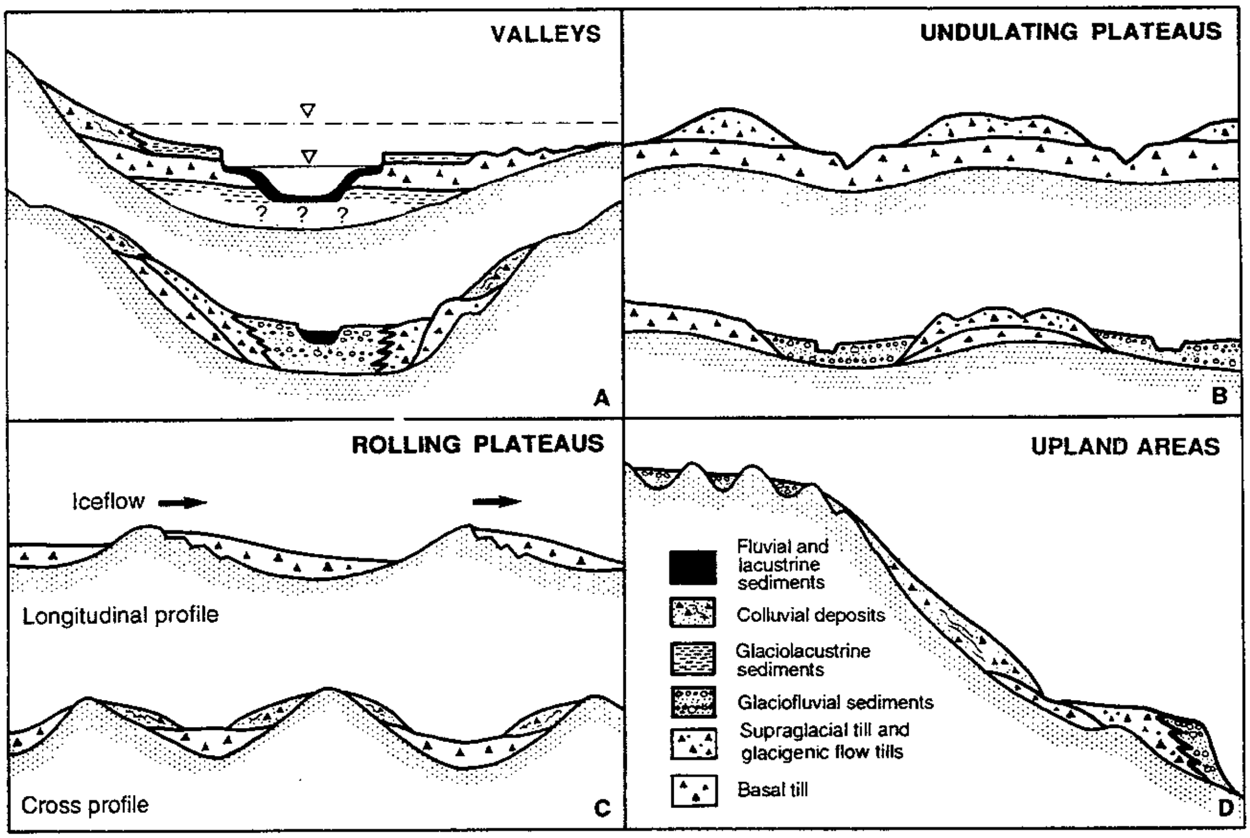

Figure 5. Simplified depositional models for valleys, plateau and upland areas in the Old Fort (93M/01) and Fulton Lake (93L/16) map areas. Note figures are not to scale.

GLACIOFLUVIAL SEDIMENTS

Sequences of interbedded clast-supported gravel, subordinate sand and stratified, matrix-supported diamictons are confined to bedrock and till-walled channels in upland areas (Figure 5D). In valleys and plateaus, similar sediment assemblages form terraced benches (kames), sinuous ridges (eskers) or undulating terraces (spillways and outwash plains) in proximity to ablation and basal till (Figure 5A and B). Raised deltaic sequences (fan deltas) are also preserved above contemporary lake margins. Thickest deposits (> 5 m) occur along valley floors (log 3, Figure 4). Gravels are composed of poorly sorted, rounded, polymictic clasts, ranging in size from pebbles to cobbles. Crude may be imbricated. Upward coarsening is seen in some fan delta sequences (log 4; Figure 4). Sand interbeds are well sorted and normally graded. Planar cross-bedding, trough-cross bedding and ripple-drift bedding are preserved and frequently indicate paleoflows contrary to contemporary drainage directions. Locally, in the Fulton Lake basin, sand beds contain numerous calcite concretions of unknown origin. Gravel, sand and diamicton assemblages are interpreted as ice-proximal glaciofluvial deposits (Rust and Koster, 1984). Interbedded diamictons closely resemble glacigenic debris flows.

GLACIOLACUSTRINE SEDIMENTS

On the Newman Peninsula and the south-central flank of Babine Lake, massive clays and sands with dispersed dropstones, outcrop to a maximum elevation of 790 metres (2600 ft). These deposits are truncated and overlain by thin clast-supported debris-flow diamictons and basal till. Rip-up clasts, containing diamicton, are locally preserved in the sand unit close to the overlying contact (log 5; Figure 4). Along the valley margins of Hautête Creek, rhythmically bedded silts and sands locally overlie kame deposits up to an elevation of 885 metres (2900 ft). Around the margins of Babine and Natowite lakes, massive and laminated fine sand, silt and clay beds are draped over winnowed tills up to elevations of 760 metres (2500 ft) and 790 metres (2600 ft), respectively. Generally, unit thicknesses range from 0.2 to 1.5 metres. Deposits up to 3 metres thick occur close to flanks of fan deltas and other stream outlets. Crevasse fills, glacigenic debris flows and fan delta deposits are locally interbedded with, or prograde over finer sediments, for example in the Morrison Creek and Fulton River areas (logs 3 and 4; Figure 4). Faceted and striated clasts (interpreted as dropstones) are dispersed throughout these deposits and frequently display load structures. Similar sediments are rare in the Morrison Lake valley, where sediment assemblages, bedding characteristics and grain-size distributions are consistent with deposition in ice-proximal glacial lakes.

COLLUVIUM

Bedrock and glacial deposits on slopes greater than 15^{o} are commonly mantled by massive and stratified, clast-supported diamictons, and massive deposits of bouldery rubble (Figure 5D). Proportionally, these sediments are most common in upland areas. Deposit form varies from homogenous blankets to fan aprons (log 6, Figure 4). When seen, basal contacts with underlying glacigenic deposits are predominantly erosional. Diamicton matrices comprise predominantly poorly consolidated sand that may display slope-parallel fissility and bedding. Diamictons are primarily composed of subangular, mechanically weathered bedrock fragments; subrounded, distal clasts may be present if diamictons are derived from glacigenic sediments. Clast contents range from 45 to 80%. Prolate clasts are crudely aligned parallel to slope. Boulder deposits are generally monolithic and composed of locally weathered bedrock. Clast-supported diamictons and boulder deposits are interpreted as postglacial sequences derived from subaerial weathering and gravity-induced mass movement, and include hill-slope colluvium and talus

FLUVIAL AND ORGANIC SEDIMENTS

Throughout the area, streams have incised gullies and channels into older deposits or bedrock (Figure 5A and B). Along active stream beds, sands and gravels are stored in migrating point, and in-channel bars. More stable deposits are found in broad, relict floodplains, now drained by underfit streams. Sand beds are generally well sorted and normally graded. Gravel clasts are rounded to well rounded, range from pebble to cobble size, and have highly variable provenances. When seen, paleoflow indicators (*e.g.*, trough-cross and ripple-drift bedding) are consistent with contemporary drainage directions. In plateau and montane areas, organic deposits are confined to hummocky depressions, and overlie till and glaciofluvial sediments. In ponded valley reaches, organic deposits form floating vegetation mats that encroach upon open water.

GLACIAL GEOMORPHOLOGY

EROSIONAL LANDFORMS

Cirques, horns, arêtes, and other landforms indicative of alpine glacier accumulation areas, are found northwest of the study area, in the Babine Range and Skeena Mountains (Figure 1). Within the area, glacial troughs, crag-and-tails, roches moutonnées, drumlins and flutes occur where southeasterly iceflow from these sources followed the prominent regional structural grain. These features probably record the last dominant regional iceflow direction (Figure 6A). Small-scale grooves, rat-tails and striae are best preserved on fine-grained volcanic and clastic rocks, and chert-pebble conglomerate. Striae in some montane areas, and on larger streamlined landforms, indicate localized south to southwest deflection of regional iceflow (Figure 6A). These deviations imply that small bedrock obstacles controlled basal iceflow patterns at a local scale. No limit to glaciation was observed in the study area.

MORAINAL COMPLEXES

In montane uplands, bedrock is covered by veneers or patchy morainal blankets, comprising glacigenic debris flows, subordinate glaciofluvial sediments and basal till. Postglacial talus and hill-slope colluvium unconformably overlie moraine sediments on steeper

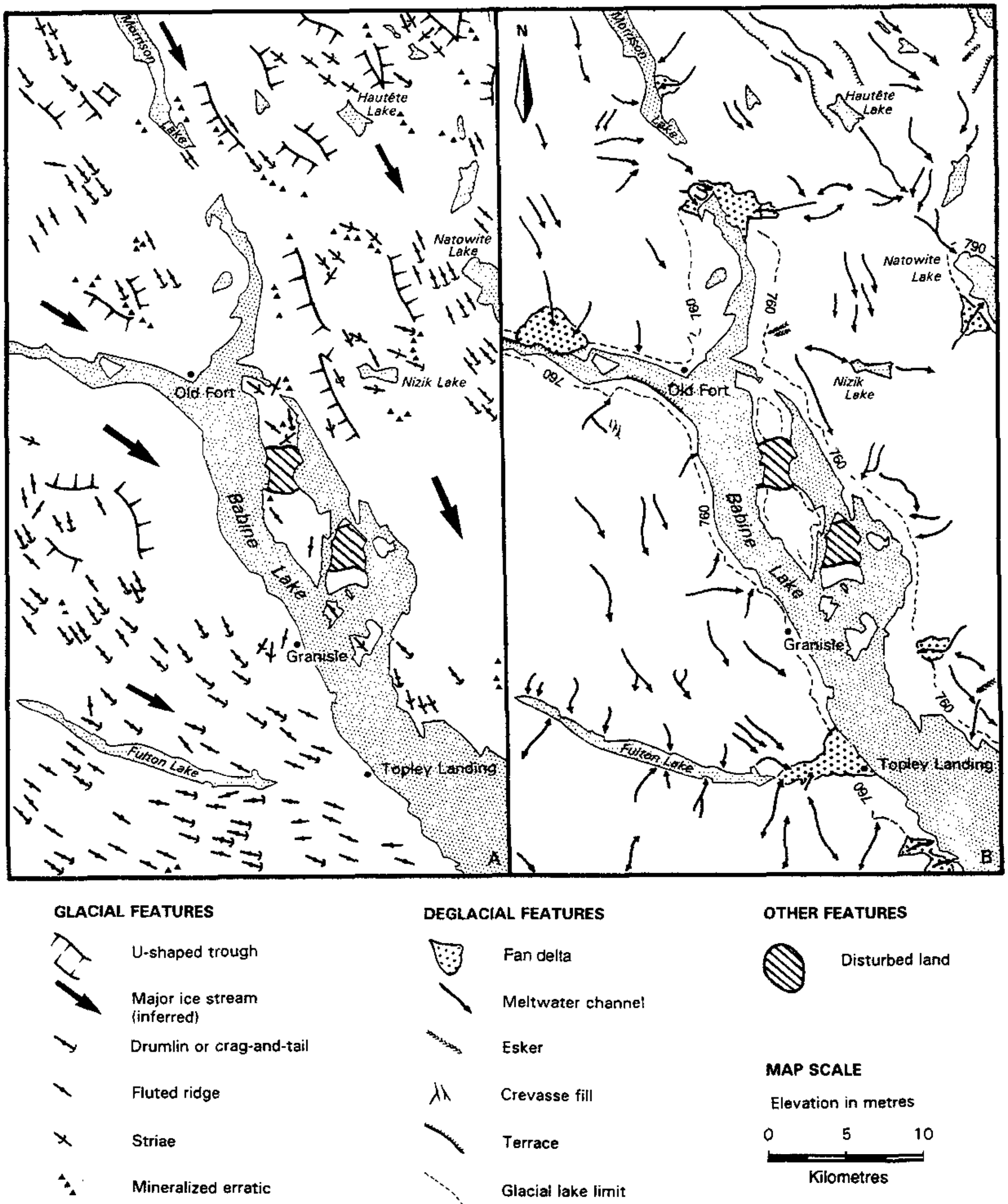

Figure 6. Glacial geomorphology of the study area.

slopes (*e.g.*, Figure 5D). Plateaus are mantled by fluted and drumlinized ground moraines composed of basal till, with subordinate supraglacial till and glaciofluvial sediments (*e.g.*, Figure 5C). Colluvium is locally dominant in hilly areas. Ground moraines deposited in the Babine, Fulton and Hautête valleys comprise undulating, hummocky or kettled blankets of basal and supraglacial tills in equal abundance (Figure 5B, upper diagram). A lateral moraine is preserved in the northeast corner of the map area. Subordinate glaciofluvial deposits form outwash plains, eskers and kame terraces (*e.g.*, Figure 5A, lower diagram; Figure 5B, lower diagram). Morrison and Babine lakes are separated by a morainal complex of basal and supraglacial till, with a maximum surface elevation of 780 metres (2560 ft). The moraine is incised by meltwater channels that drain south to fan deltas formed at 760 metres (2500 ft; Figure 6B). Below this elevation, washed tills are overlain by fan delta sequences, crevasse fills and massive glaciolacustrine silts around much of Babine Lake.

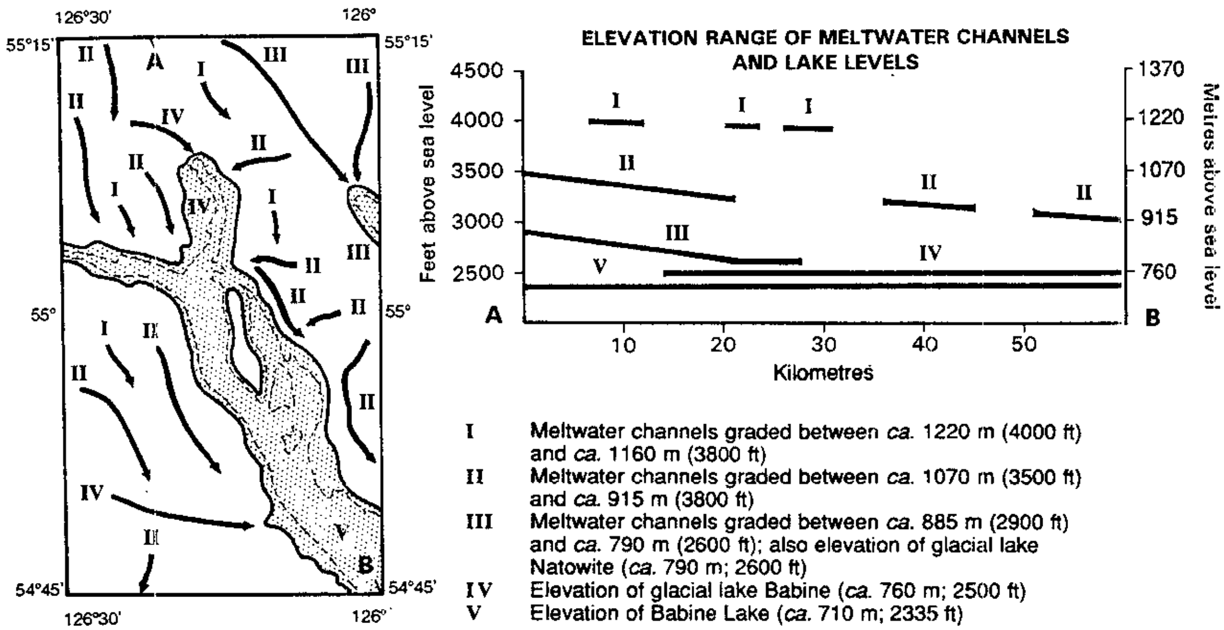

Figure 7. Simplified elevational distribution and drainage directions of meltwater channels and lakes in the study area.

ERRATICS, INDICATORS AND BOULDER TRAINS

Mineralized erratics are found throughout the area (Figure 6A). Linear boulder trains, up to 5 kilometres long, originate 2.5 and 7 kilometres southeast of Hearne Hill, and 2 kilometres east of Hautête Lake (Figure 6A). Although dispersal patterns are consistent with southeasterly transport by ice, identification of sources is complicated as many boulder lithologies are superficially similar, or have several potential provenances. Two indicator lithologies are recognized and provide a first order approximation of clast transport distances. In the western half of the 93L/16 map area, ground moraine and glaciofluvial sediments contain a significant proportion of granodiorite boulders and pebbles. A probable source area for this lithology lies 70 kilometres northwest, near Mount Thoen (D.G. MacIntyre, personal communication, 1995). Chert-pebble conglomerate, eroded from outcrops in the northwest part of the 93M/01 map sheet, is observed in moraines throughout the study area. Generally, clast size decreases and roundness increases down-ice from source. The distribution of conglomerate boulders suggests potential debris transport distances of a minimum of 60 kilometres from source.

GLACIOFLUVIAL AND GLACIOLACUSTRINE LANDFORMS

In montane uplands, meltwater flow was focused in bedrock channels formed on hill crests (Figure 6B; Figure 7). These relict landforms are graded between *ca.* 1220 metres (4000 ft) and 1160 metres (3800 ft); paleoflow was to the southeast. Hydrological continuity between hill crests was probably maintained by supraglacial channels formed on ice below 1220 metres. A second system of meltwater channels, with originating elevations *ca.* 975 metres (3200 ft), drained westward from Hautête valley to kame terraces formed at about 915 metres (3000 ft.) along the eastern flank of the Babine valley (Figure 6B; Figure 7). This drainage pattern implies that glacier ice occupied the Hautête valley to a minimum elevation of 975 metres (3200 ft). Elsewhere in the Babine valley, southeasterly paleoflow was confined to ice-marginal spillways incised into morainal sediments over the plateau. The presence of eskers in the Babine and Fulton valleys indicates that drainage was partly through subglacial conduits. Westward drainage into the Babine valley ended when ice levels in the Hautête valley fell to below *ca.* 975 metres (3200 ft). Below this elevation, kame terraces, eskers and spillways in the Hautête valley have profiles graded from *ca.* 885 metres (2900 ft) to *ca.* 790 metres (2600 ft; Figure 7). This latter elevation is the minimum water level of an ancestral Natowite Lake, informally named "glacial lake Natowite". In the Babine valley, another system of meltwater channels and fan deltas is graded to 760 metres (2500 ft; Figure 7). By this stage, contemporary drainage patterns were established. The 760-metre elevation defines a minimum water level for a deglacial lake partly impounded by morainal sediments between Morrison and Babine lakes (Figure 6B). This lake is informally named "glacial lake Babine".

QUATERNARY HISTORY

The contemporary landscape of the central Babine Lake area is the product of multiple glacial and fluvial cycles operating throughout the Quaternary. Pre-late Wisconsinan fluvial and lake deposits are documented in the study area (Harrington *et al.*, 1974). Mammoth skeletal remains and plant material provide an Olympia nonglacial interval age of *ca.* 34 ka for these sediments. Pre-late Wisconsinan deposits rest unconformably on glacially eroded bedrock, which suggests at least one phase of pre-Fraser glaciation in the area.

Most sediments and landforms are inferred to be the product of the late Wisconsinan Fraser Glaciation. Glacier advance was probably marked by ice accumulation in the southern Skeena Mountains and Babine Range, northwest of the study area (Figure 1). Broad valley glaciers from these sources probably flowed southeast into the Babine and Hautête valleys. Glaciolacustrine sediments overlain by basal till indicate that a glacial lake was ponded in the Babine valley during ice advance. Deposition in this lake continued to a minimum upper elevation of 790 metres (2600 ft) before being overridden by Fraser Glaciation ice (log 5; Figure 4). It is unclear how this lake was impounded.

No limit to glaciation was observed. This suggests that by the glacial maximum, ice had inundated the entire area. At this time, the dominant iceflow was southeast. Minor deviations in this pattern occurred in upland areas, or in areas with ice-sculpted bedrock. In many areas, bedrock is mantled by Fraser Glaciation basal till. These tills are the dominant components of extensive drumlinized and fluted ground moraines. Recent studies by Plouffe (1991) and Tipper, (1994) have identified an area of glacial ice coalescence along the southern part of Babine Lake. Glaciers moving southward out of the Skeena Mountains, across the Babine Lake valley, were diverted eastward by glaciers originating in the Coast Mountains and flowing northeast along the Nechako valley.

The distribution and composition of moraines and glaciofluvial landforms is consistent with frontal recession of active glaciers and downwasting of stagnant ice confined to valleys (Ryder and Maynard, 1991). During the later stages of ice retreat, Babine and Natowite lakes were dammed by moraines, outwash and ice, and ponded to elevations of 760 metres (2500 ft) and 790 metres (2600 ft). Outlets for these deglacial lakes have yet to be identified. In addition, the hydrologic relationship of these lakes to glacial lake Fraser, which had a similar range of surface elevations (Clague, 1988), has yet to be investigated.

CONCLUDING REMARKS

Current research in the central Babine Lake area has been directed to understanding sediment and iceflow patterns in a landscape extensively modified by multiple glacial cycles throughout the Quaternary. Physiographic setting and topographic position during glacial advance and retreat largely determine the areal distribution and sediment characteristics of glacigenic sediments. Glacially streamlined landforms and striae indicate regional iceflow toward the southeast. Localized deviations in basal iceflow patterns were effected by smaller bedrock obstacles. The possibility of interaction between coalescing glaciers from multiple sources suggests a complex depositional history for the area. This observation has important implications when interpreting geochemical dispersion patterns in basal tills.

At least three glacial meltwater systems evolved during deglaciation, progressively grading to lower base levels. Not only do these drainage networks appear to be interconnected with the evolution of glacial lake Fraser, but the lowest base level is coincident with a lake impounded behind morainal sediments, informally named glacial lake Babine. Further work will be undertaken to investigate the complex relations between the glacial lake Fraser and glacial lake Babine drainage systems.

The extent to which physiographic setting and topography have influenced iceflow, sedimentation patterns, and geochemical distribution patterns, down-ice from known mineral prospects remains unclear. We are currently developing an effective drift exploration model to study the glacial and sedimentation processes occurring in mineralized areas with variable relief and complex geology.

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