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TILL GEOCHEMISTRY OF NORTHERN VANCOUVER ISLAND AREA (92L/5, 6W, 11W, 12)

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INTRODUCTION

This report presents the results of a drift prospecting program conducted by the British Columbia Geological Survey Branch (BCGS) on northern Vancouver Island in an area south and west of Port Hardy (Figure 1). The three year till geochemistry (1991, 1993, 1994) project discussed here is part of a larger, multidisciplinary, integrated resource assessment program the aim of which was to define the mineral potential of this part of the province (*see* Panteleyev *et al.*, 1994, 1996b). The northern Vancouver Island drift prospecting program is one of several provincial till geochemistry surveys to demonstrate the utility of integrating surficial geology mapping and exploration geochemical methods to locate buried mineral deposits in areas of drift covered terrain (*see* Bobrowsky *et al.*, 1995b for a review). The northern Vancouver Island, drift prospecting program focused on four 1:50 000 scale map sheets including NTS 92L/5 (Mahatta Creek), L/6 (Alice Lake), L/11 (Port McNeill) and L/12 (Quatsino). Fieldwork involved mapping of surficial geology (Bobrowsky and Meldrum, 1994b, 1994c; Huntley and Bobrowsky, 1995b; Kerr, 1992), shallow subsurface geophysics and drilling (Bobrowsky *et al.*, 1995a), collection of bulk till samples for geochemical analysis (this report and previous data release by Kerr *et al.*, 1992) and pebbles for clast lithological analysis (in preparation). All these aspects are integral components to successful mineral exploration in areas of significant drift cover and limited bedrock exposure.

The presence of the Island Copper Cu-Mo-Au porphyry deposit, located on the northeast shore of Rupert Inlet, contributed to the selection of this area for regional till geochemistry studies (Figure 2). The success of this mine operation is borne out by the fact it has been in operation since 1971, with estimated reserves of 257 million tonnes averaging 0.52% Cu, 0.017% Mo and grades averaging 0.22 ppm Au (Cargill *et al.*, 1976; Perello *et al.*, 1989). Secondly, the closure of this operation, with the abandonment of an existing mining facility infrastructure, was imminent when this project began and warranted renewed exploration activities with the intent to improve the database for industry. The possiblity for contamination around the mine site within a till media is much less than for soils, hence, till prospecting is effective even in areas affected by previous mining.

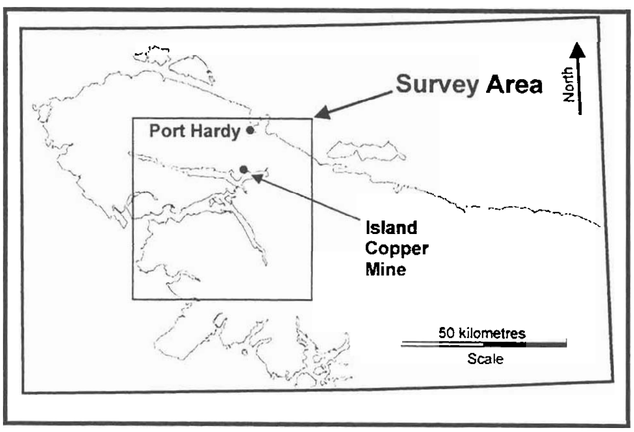

Figure 1. Location of northern Vancouver Island till geochemistry survey area. Includes 1:50 000 scale map sheets NTS 92L/5, 6, 11 and 12.

Mapping of the surficial sediments was undertaken to document the variability in the type and distribution of unconsolidated sediments. The character, origin and age of the various types of unconsolidated sediments present in an area of glaciated terrain are important parameters to document as part of any drift exploration program, and their understanding provides a framework for a complementary till geochemistry and pebble lithology sampling program (Salonen, 1988). The till geochemistry study consisted of a systematic sampling program (1-5 kilograms) primary basal till and colluviated till deposits which were first identified and then targeted during the surficial mapping. Pebble lithology studies consisted of the collection and subsequent identification of 100 clasts at each of the till sample stations.

The integration of mineral deposit studies, detailed bedrock mapping, surficial mapping and till geochemistry addresses the main objective of drift prospecting: to provide data that will lead to the discovery of economic mineralization, covered by a blanket of unconsolidated sediments. We do this by interpreting down-ice glacial dispersal patterns (mechanical dispersal trains) that will help locate the sources of geochemical anomalies and changed clast lithologies (*see* Coker and DiLabio, 1989). For northern Vancouver Island, mineral deposit studies have been described and presented in detail elsewhere (Panteleyev, 1992; Panteleyev and Koyanagi, 1993, 1994; Panteleyev *et al.*, 1995, 1996a), as have the results of detailed bedrock mapping (Hammack *et al.*, 1994, 1995; Nixon *et al.*, 1993a, 1993b, 1994, 1995). Stream sediment geochemistry (Sibbick and Laurus, 1995), Regional Geochemical Survey (Gravel and Matysek, 1989) and geochemical catchment basin analyses (Sibbick, 1994) have also been completed for the study area. Geophysical studies have been described by Bobrowsky *et al.* (1995a) and Lowe *et al.* 1995). Preliminary Quaternary geology results have been summarized in a series of papers (Bobrowsky and Meldrum, 1994a; Huntley and Bobrowsky, 1995a; Kerr and Sibbick, 1992; Kerr *et al.*, 1992) and maps (Bobrowsky and Meldrum, 1994b, 1994c; Huntley and Bobrowsky, 1995b, 1995c; Kerr, 1992).

Open File 1996-7 provides a final summation of the till geochemical data collected for northern Vancouver Island. All samples considered reliable and useful for further exploration research are included in the report. This consists of

Figure 2. View to the east of the Island Copper mine, a copper-molybdenum-gold porphyry deposit on the northeast shore of Rupert Inlet, northern Vancouver Island. (Photo by D. Kerr).

ICP, INAA and whole rock analytical results on some 435 basal till and colluviated till samples. An important part of this report is the information provided regarding the regional Quaternary geologic history. Finally, the discussion regarding the distribution of anomalies for several elements (Ag, Au, Cu, Mo, Zn, Pb and Fe) is as it draws on the relevance of sample media, deposit genesis and probable mineral prospects.

DESCRIPTION OF THE SURVEY AREA

LOCATION AND ACCESS

The northern Vancouver Island project (NTS map areas 92L/5, 6, 11 and 12) is located within the area west of Port McNeill, north of the Brooks Peninsula and east of Cape Scott. An extensive network of logging roads blanket most of the study area. These roads are easily accessed from Highway 19 approaching from Campbell River. Several additional secondary highways extend westward to the communities of Alice Lake and Coal Harbour and secondary roads to communities such as Holberg and Winter Harbour.

The area also experienced a long history of mineral exploration with some 352 known mineral occurrences as of May, 1995 for NTS 92L and 102I. Historical and current activity associated with these mineral showings, and in particular with the Island Copper deposit, has also improved access.

Much of the area is bounded or incised by coastal waters including the open water of Brooks Bay in the southwest, Quatsino Sound in the centre west, as well as the centrally located Neroutsos, Holberg and Rupert inlets. These bodies of water provide good marine access to much of the region (Figure 3).

PHYSIOGRAPHY

The surficial geology study covers an area of approximately 3945 square kilometres on the northernmost part of Vancouver Island and includes all of NTS map sheets 92L/5 (Mahatta Creek), L/6 (Alice Lake), L/11 (Port McNeill) and L/12 (Quatsino). Within this larger area, till geochemistry sampling was restricted to all of map sheets 92L/5 and 12 and the west half of maps 92L/6 and L/11 or 2958 square kilometres. Subtraction of water covered areas results in a land surface area potentially available for sampling of approximately 2500 square kilometres.

Completely within the Western System as defined by Holland (1976), the area is further divisible into two prominently different physiographic units: the Nahwitti Lowland of the Hecate Depression and the Vancouver Island Ranges of the Insular Mountains. The Nahwitti Lowland encompasses the area north of a line drawn eastward from Quatsino Sound and is best described as a region generally below 600 metres in elevation and one characterized by subdued relief and low rounded hills. In the west half of the Nahwitti Lowland, relief is moderately higher with a few highland areas scattered throughout including prominent locations

Figure 3. View looking southeast, along Alice Lake. The large inland lakes and numerous coastal inlets within the study area provide extensive access to the region where road systems are not available. Note the high relief, steep slopes and rugged topography common in this part of the study area.

Figure 4. View looking northeast, of the flat and rolling topography found along the coastal reaches of northern Vancouver Island. This area is part of the Suquash Basin near Port Hardy. Contrast this area with the mountainous area shown in Figure 3.

such as the Pemberton Hills north of Holberg Inlet and the Mt. McIntosh (elevation of 395 metres) area directly south of Nahwitti Lake. The Nahwitti Lowland includes one small subunit, the Suquash Basin in the extreme east which consists of flat rolling hills and an elevation generally below 300 metres (Figure 4). The Suquash Basin includes the area defined by a triangle from Port Hardy south to Coal Harbour and east to Port McNeill.

The north end of the Vancouver Island Ranges terminates in the area south of Holberg Inlet. Here, the glaciated and rugged, high peaks range between 900 and 1200 metres and are dissected by a network of steep, creeks and rivers which drain into a few large northwest trending lakes (Nimpkish, Victoria and Alice lakes) and numerous coastal fjords (*e.g.*, Klaskino and Foreward inlets in the west and Neroutsos and Rupert inlets centrally). Most of the area can be described as montane. The highest mountains include Merry Widow Mountain (1400 metres), Mount Wolfenden (1273 metres), and Tlakwa Mountain (1457 metres). In general, the highest peaks and ranges occur in the south part of the study area, from which point the elevation of the terrain slopes gently northward toward Quatsino Sound.

Northern Vancouver Island experiences warm and dry summers and cool, wet winters with most precipitation falling between the months of October and March. The area was glaciated at least twice during the Pleistocene, events which strongly influenced the present day landscape geomorphology. North to westward aligned hills and ridges, at onetime covered and smoothed by ice action, are a common feature throughout the area as are deep glacially eroded valleys now occupied with complex suites of Holocene valley-fill sediments. The high angle slopes, high annual precipitation and thin surficial sediment cover contribute to a disproportionately significant number of mass movements in the area (Howes, 1981).

BEDROCK GEOLOGY

The study area consists of a northwesterly aligned, thick sequence of Late Triassic and Early Jurassic volcanic and sedimentary rocks and minor Cretaceous sedimentary rocks which are all part of the Wrangellia Terrane. Detailed mapping by the BCGS since 1989 by Massey and Melville (1991) and Nixon *et al.* (1993, 1994, 1995) has constrained much of the local and regional stratigraphic relationships. Chronometric studies have clarified our understanding of the ages of the major strata (*cf.* Archibald and Nixon, 1995; Panteleyev *et al.*, 1995).

Late Triassic rocks of the Vancouver Group dominate the bedrock geology. Subaerial flood basalt, submarine basalt, breccia and tuff of the Karmutsen Formation underlie Triassic Quatsino and Parson Bay formations. The former consists primarily of massive limestone, whereas the latter consists mainly of carbonaceous mudstone and argillaceous limestone (Nixon *et al.*, 1994). Early Jurassic Bonanza Group volcanic and sedimentary rocks, consisting of subaerial tuffs and basaltic lavas, and clastic sediments and limestones, respectively, occur over much of the area (Nixon *et al.*, 1995). Early to Middle Jurassic granitoid and porphyry rocks of the Island Plutonic Suite intrude the Quatsino and Parson Bay assemblages, as well as the Bonanza volcanics. They give rise to the magnetite rich skarn and sulphide ore deposits which occur in the Triassic sediments. A number of mineral deposits are hosted by Bonanza volcanics which exhibit both advanced argillic alteration and an intimate association with the plutonic intrusions.

MINERAL DEPOSITS

The complex geology, magmatic activity and structural architecture have long made this area a prime target for mineral exploration. As of May, 1996 there were 170 known mineral occurrences in the study area (MINFILE, 92L and 102I) which can be categorized according to several primary deposit classes (Table 1). Massey and Melville (1991) summarize several types of mineralization including, but not restricted to:

- iron-copper-molybdenum-gold skarns (*e.g.* Merry Widow and Coast Copper mines)
- copper-molybdenum porphyry stockworks (*e.g.* Island Copper mine, Expo and Red Dog properties)
- lead-zinc mantos and replacement bodies (*e.g.* H.P.H. showing)
- gold-silver-arsenic-antimony-mercury found in epithermal to mesothermal shear-hosted quartz veins.

Detailed mineral deposit studies were recently undertaken by Panteleyev (1992), primarily within the Quatsino map sheet along an area underlain by Bonanza volcanics and Island intrusions. The objective of the studies centred on the potential recognition of additional copper-gold-silver mineralization. Attention was directed to both epithermal high-sulphidation and "transitional" environments.

Fieldwork was conducted and diamond-drill hole cores were examined from Mt. McIntosh, Hushamu and Island Copper mine to develop a mineral occurrence model. The model addresses the conundrum of whether advanced argillic alteration zones and associated acid-leached rocks are part of hydrothermal systems capable of mineralization or are both simply products of vapour-dominated acid-leached systems. According to Panteleyev and Koyanagi (1993, 1994), the geology of the Hushamu and Mt. McIntosh areas supports the contention that acid sulphate hydrothermal systems containing advanced argillic rocks displays high-sulphidation mineralization.

The geochemistry of acidic waters reflecting porphyry copper and high sulphidation mineralization, as well as advanced argillic/acid sulphate alteration has been presented by Panteleyev *et al.* (1996a), Koyanagi and Panteleyev (1993, 1994) and Sibbick and Laurus (1995).

TABLE 1
MINERAL OCCURRENCE FREQUENCIES, PRIMARY COMMODITIES AND DEPOSIT CLASSES FOR NTS 92L/5, 6, 11 AND 12

Deposit Class	Primary Commodities	No.
Vein	Cu, Zn, Pb, Ag, Ma, Si	55
Skarn	Cu,Ma,Zn,Fe,Ag,Au,Co	52
Porphyry	Cu,Fe,Au,Ag,Mo	21
Replacement	Cu,Ag,Au,Mn,Zn	8
Volcanogenic	Cu	2
Other		32

SURFICIAL GEOLOGY

Surficial geomorphology and landform studies first involved air-photographic interpretation at a 1:50 000 scale (*see* Bobrowsky and Meldrum, 1994a and Huntley and Bobrowsky, 1995a for details). Terrain maps produced by the Resource Analysis Branch of the Ministry of Environment, Lands and Parks during the 1970s and 1980s provided background morphological landform data (*see* Howes and Kenk, 1988). Air-photographic evaluation was used in conjunction with the existing morphological landform data portrayed on the terrain maps to construct preliminary surficial geology maps. Ground-truthing and modification of the preliminary maps was completed during the fieldwork using procedures described in the *Guidelines and Standard for Terrain Mapping in BC* (RIC, 1996).

A good logging-road network provided the opportunity to identify and study a broad range of glacial and non-glacial deposits. A diverse suite of landforms and deposits were eventually documented. The landforms range in relief from flat and subdued for coastal areas in the east (Figure 4) to steep, rocky mountainous areas in the south and west (Figure 3) to rolling, hummocky topography in the north (Figure 5). The area includes an extensive area of coastal environment, with a number of large fjords, so that marine and glaciomarine landforms and deposits were often encountered. The high inland ranges are densely interrupted with creek and riverine environments which provided ample evidence for fluvial and glaciofluvial deposition. Finally, poor drainage and rolling topography support present day lakes and are often the site of past lacustrine or glaciolacustrine deposition.

A common phenomenon in coastal regions and high mountains occurs when high relief topography generates a substantial amount of colluvium. By definition, gravity driven reworked deposits of all types, can fall within this category. The shared characteristic of such deposits, is that the source of colluvium is always local (*i.e.*, up-slope), and is considered to be a first order derivative product if the source material is bedrock or a second order derivative product if the source material is till (Shilts, 1993). The

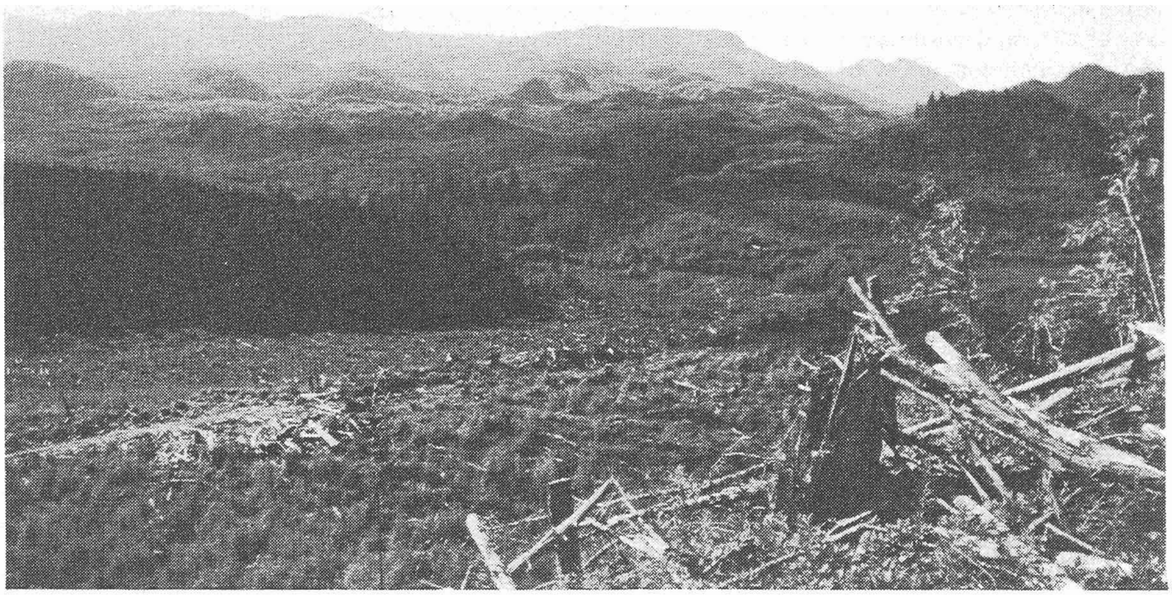

Figure 5. View of typical rolling to moderately hummocky topography consisting of a blanket of morainal debris primarily supraglacial in the background area and basal till in the centre and foreground.

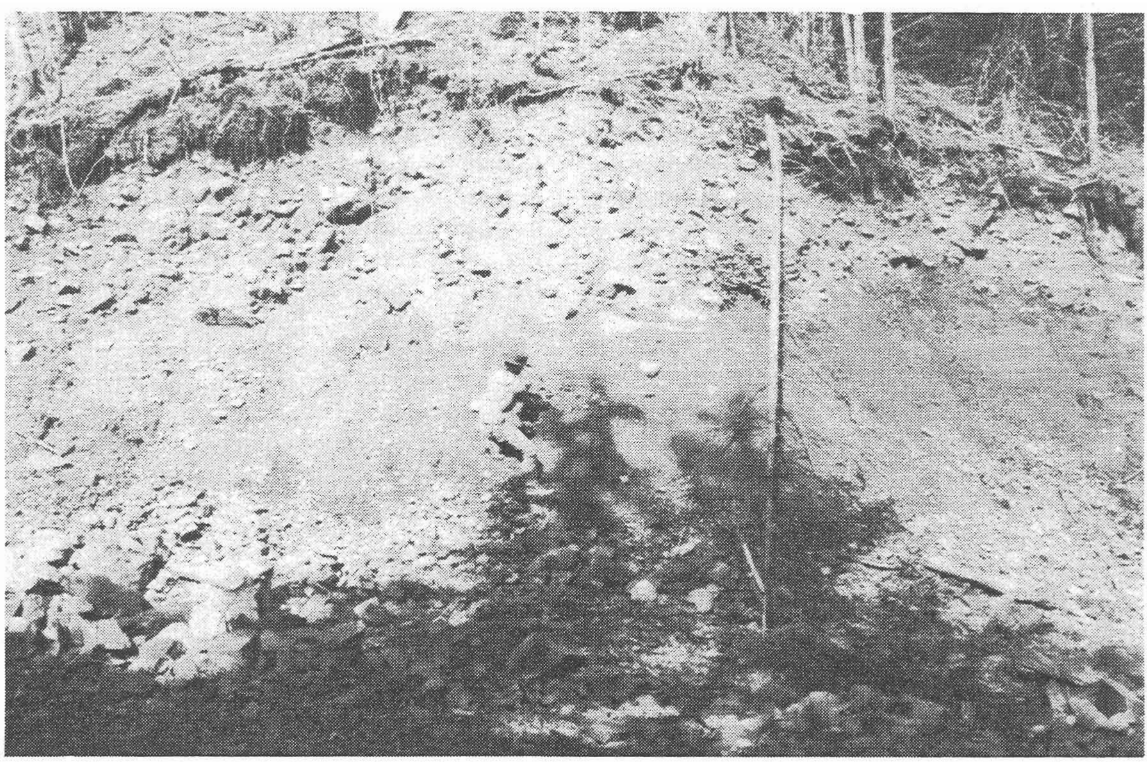

Figure 6. View of loose, coarse, clast-supported colluvium overlying unconsolidated glaciomarine sediments. Note the high angularity of the clasts contained within the colluvium. The lithology of the clasts is almost entirely local and identical to the bedrock outcrop up-slope. Such material represents a first order derivative product whose clast lithology and sediment geochemistry can be used to infer proximal bedrock composition.

derivative order can progressively increase as the number of cycles or phases of resedimentation increase for the source material.

The two most common and important colluvial facies encountered in this study consisted of bedrock colluvium (locally reworked sediments derived from bedrock upslope) and colluviated till (reworked sediments derived from till located upslope). Both are ideal media for investigating dispersal trains of local origin. Bedrock colluvium observed in this study is usually a very loose, poorly consolidated, and poorly-sorted clast-supported diamicton (Figure 6). The facies is massive to crudely bedded and primarily brown in color. The clast content is high (averaging about 41%), consisting mainly of angular to very angular, cobble to boulder sized stones which lack both striations and faceting (Bobrowsky and Meldrum, 1994a). The pebble fabric is poor, and the lithologies represented are almost entirely local in origin. On northern Vancouver Island, the deposits are generally one to two metres thick with a sharp basal contact, usually overlying bedrock. In contrast, colluviated till is generally a loose, poorly-sorted, matrix to clast-supported diamicton. The facies is also massive to crudely bedded and primarily olive-brown to brown in color. Clast content is marginally less (averaging about 37%), and consists of rarely striated or faceted stones, which are angular to subrounded in shape. Clasts are primarily pebble to boulder in size, mainly of local lithology, but occasionally containing exotic lithologies. This facies is found in deposits ranging from one to three metres thick, displaying a gradational to sharp basal contact. Colluviated till deposits are found overlying basal and supraglacial tills or bedrock. Very common in the study area, both facies are ideally suited for till geochemistry studies. Their genetic history is easily decipherable and transport distances are categorically minimal, two important attributes for successful drift exploration work. Although both media were sampled extensively in 1993 and 1994, only data for samples interpreted as colluviated till are presented in this report.

Two types of glacial deposits represent the most commonly observed morainal sediments. Both sediment types are considered first order derivative phases from a transport-depositional model and both are ideal media for drift prospecting (Shilts, 1993). Emphasis was placed on the identification, description and sampling of those sediments eventually interpreted to be till (i.e., deposited directly by glacial ice). The most abundant facies observed on northern Vancouver Island consists of a compact, cohesive, dense, matrix-supported diamicton interpreted to be a basal lodgment till (Figure 7). The facies is primarily massive, very poorly-sorted and with a low clast content (average of 77 samples is 26%). A granulometric analysis of 21 basal till samples by Kerr *et al.* (1992) indicates the following average texture: 25.4% granules, 34.7% sand, 33.0% silt and 6.9% clay. Clasts range in size from granule to boulder and

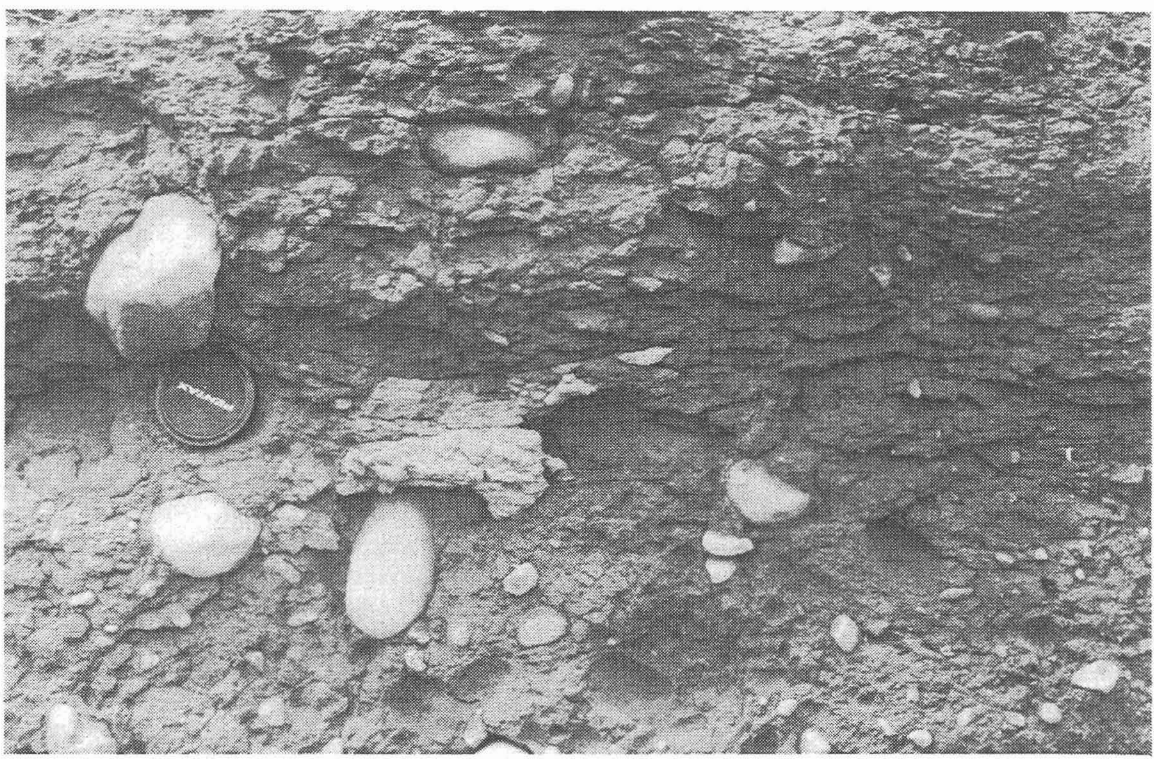

Figure 7. Close up view of dense, cohesive, matrix-supported diamicton interpreted to be a basal till. Note clasts range in shape from subangular to rounded and clast content of this exposure is about 25%. Horizontal parting structures and fissility also evident in this photograph. Lens cap to left for scale.

are subangular to rounded in shape, but mainly consist of subrounded small pebbles. Striations and faceting are also common and lithologies are mainly of local provenance. The pebble fabric is strong and bullet-shaped boulders are occasionally present. The basal contact of the facies varies from sharp to indeterminate. This type of sediment commonly overlies bedrock (Bobrowsky and Meldrum, 1994a). A second type of glacigenic diamicton often observed is primarily a loose, poorly-sorted, massive to crudely bedded, matrix-supported deposit and is interpreted to be a supraglacial meltout till. Clast content is moderate (average of 24 samples is 33%), consisting of granule to boulder size stones, ranging in shape from subangular to subrounded. Faceting is absent and striations are rare, but pebble fabrics are moderately strong (Bobrowsky and Meldrum, 1994a). Stone lithologies include both local and exotic types. Basal contacts vary from gradational to indeterminate, and the till rarely overlies bedrock, but more commonly overlies diamictons interpreted to be basal till.

It has been shown elsewhere, that glaciers commonly transport sediments in any of three positions, referred to as basal, englacial and supraglacial (Dreimanis, 1988). The relative position of sediment and clast transport within the ice carries important connotations for mineral prospecting. Generally, the lower in the ice that material is transported the shorter is the transport distance. Thus, a reliable interpretation of the original transport position within the ice is essential, as it has serious implications regarding transport distance. Transport distance is the primary objective in the evaluation of dispersal trains (Kujansuu and Saarnisto, 1990).

Interpretation of sediment carried by ice is a complex process which is best clarified in a genetic classification of the deposits. Key factors in the classification of glacigenic sediments include position in relation to ice, environment of deposition and depositional processes (Dreimanis, 1988). Although marine and glaciomarine environments and deposits were documented in the study area, their distribution is limited to flat-lying coastal areas at low elevations thus they had little impact on the till sampling program. All of the non-colluvial samples discussed in this report represent glacigenic diamictons which were deposited in a terrestrial environment. Thus, the influence of water in the accumulation of the sampled sediments was minimal. Second, with respect to position in relation to the ice, glacigenic sediments sampled in this study were primarily supraglacial and subglacial in origin. Although ice marginal deposits were observed in the study, the sediments often displayed evidence of resedimentation and a lack of in situ context. As such, these diamictons were not included in the till sampling program. Finally, only those sediments interpreted to be directly deposited by ice were sampled (excluding colluviated tills). This included tills deposited supraglacially and subglacially by the common processes of either melt-out or lodgment. The majority of diamictons studied and sampled in this program were interpreted to be lodgment till. Although a number of other diamictons, interpreted to represent subaqueous debris flow deposits, alluvial fans and subaerial landslide accumulations, were encountered, none were sampled as part of the drift prospecting project.

The surficial cover in the study area ranges in thickness from less than a metre in upland areas and montane valleys to greater than several tens of metres in the lowlands. Generally, in areas of moderate to high relief, colluvial veneers and blankets one to three metres thick occur directly down-slope of bedrock outcrops. On gentler slopes, till veneers or blankets, often overlain by colluvium, occur in thicknesses approaching 10 metres. The most sedimentologically complex and thickest deposits occur in low flat areas, and occasionally between prominent topographic highs. In the lowland valleys, interbedded sequences of till, fluvial or glaciofluvial deposits may be encountered with depths exceeding 30 metres. An evaluation of data for some 448 drill holes from a number of settings (provided by BHP-Minerals Canada Ltd.) indicated that over half (249) of the holes had less than 10 metres of overburden, averaging five metres in thickness. However, 29% (129) of the holes encountered bedrock between 11 and 30 metres below surface and the remaining 15% of the drill holes exceeded 30 metres in depth (Bobrowsky and Meldrum, 1994a). East of Rupert Inlet, one drill hole passed through 215 metres of drift and a second hole nearby through 146 metres of drift.

QUATERNARY GEOLOGIC HISTORY

Early Quaternary geologic investigations by Dawson (1887) during the last century recognized the importance of Pleistocene glacial activity in sculpting this area of British Columbia. Dawson realized that the action of glacial ice was critical in shaping the landscape and accelerating erosion, but he also noted that ice represented the primary method of redistributing sediments. Much later, Howes (1981, 1983) published results of his regional work on the island and concluded that northern Vancouver Island was glaciated twice during the Quaternary. He based this conclusion on both ground observations collected during routine mapping and drill-hole evidence collected during specialized geotechnical investigations. More recently, Kerr and Sibbick (1992) concluded that field mapping in the area north of Quatsino Sound showed evidence for only one glaciation. Although the authors did not discount Howes' conclusions, they concluded that surficial sediments, and in particular "till" deposits, most likely reflected Fraser Glaciation drift. Subsequent mapping by Bobrowsky and Meldrum (1994b, 1994c) to the east and Huntley and Bobrowsky (1995b) to the south also failed to identify "older till" deposits. However, unpublished borehole data collected near Island Copper mine supports the interpretation of Howes. In the end, it is clear that most, if not all, near-surface sediments, relate to the last phase of glaciation and deglaciation, that is Port McNeill till and Port McNeill deglacial sediments, respectively. However, glacial and non-glacial sediments predating Fraser Glaciation drift are present, and appear to be restricted in distribution to isolated and deep depo-centres

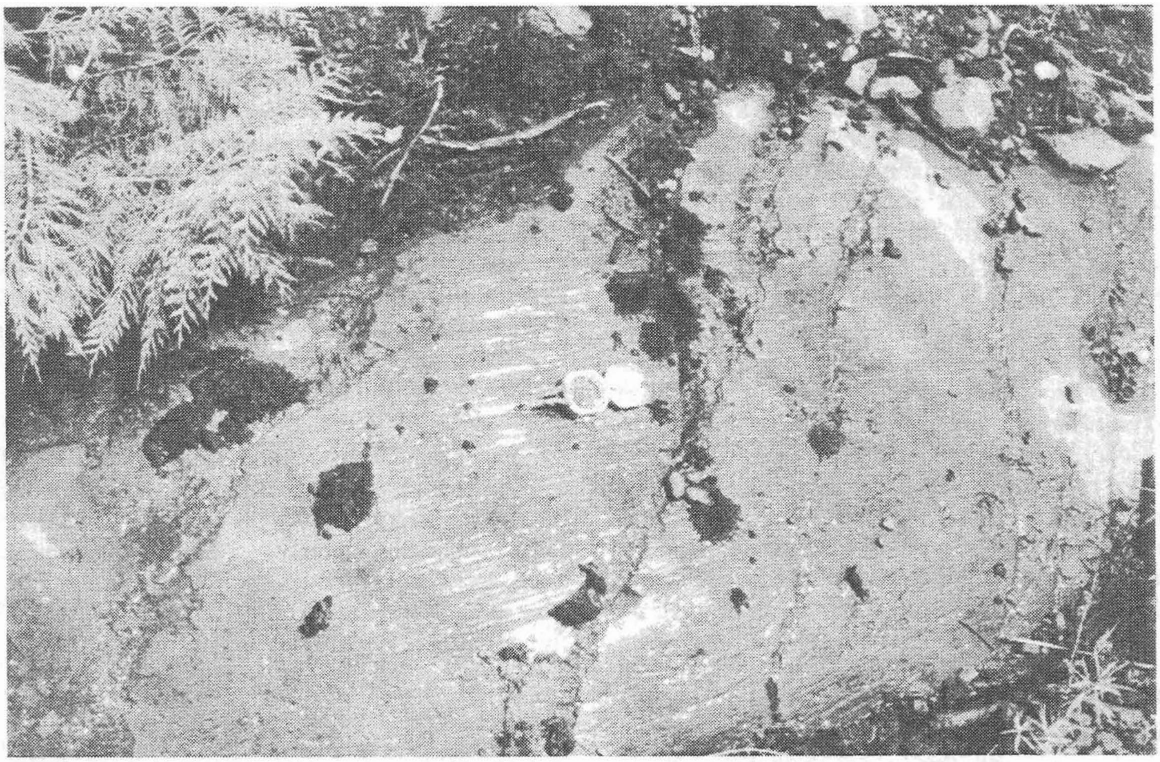

Figure 8. View of striated outcrop with compass for scale (interpreted ice-flow right to left). Striated surfaces such as this one near Coal Harbour provide the best evidence for dominant ice flow directions.

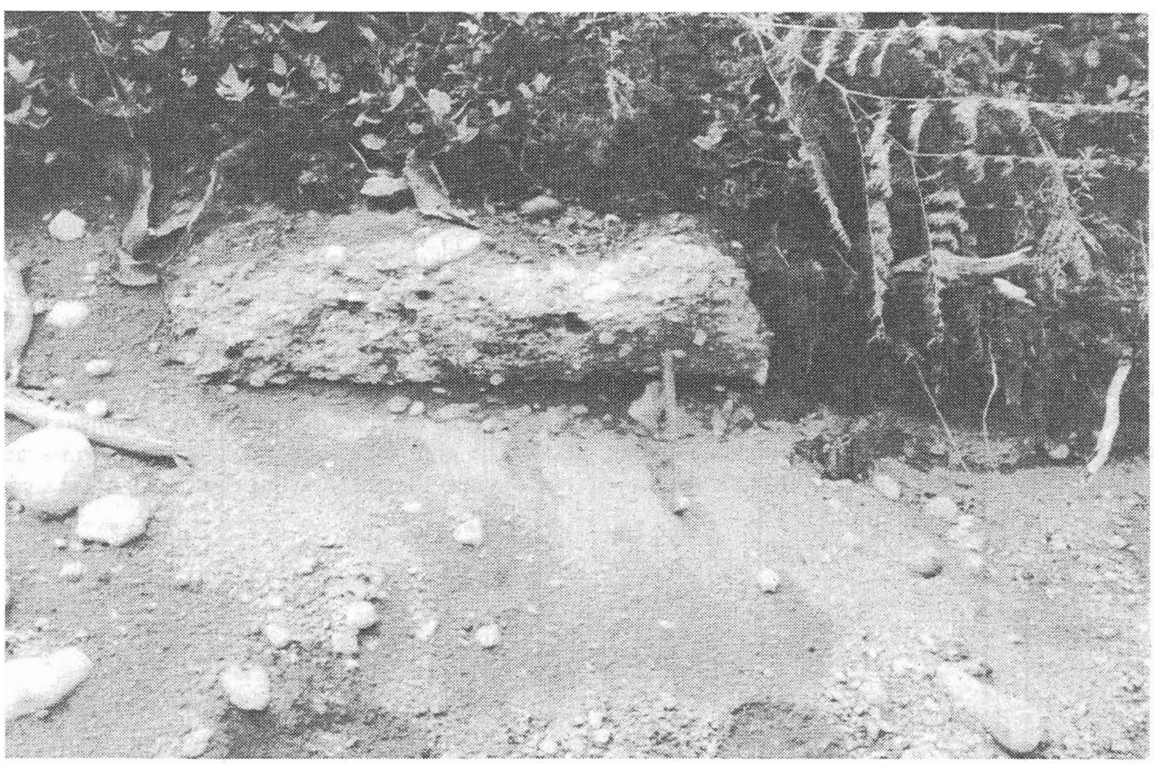

Figure 9. View of typical "hard-pan" accumulation in coarse gravels underlying podzolic soil in the Mt. McIntosh area. The indurated gravels result from the precipitation of iron in an active groundwater leaching environment.

such as buried valleys. At present, no interpretation regarding the nature and origin of these older deposits can be offered. The two tills are tentatively interpreted to indicate two separate glaciations, most likely correlative to the early Wisconsinan Muchalat River drift (Howes, 1981) or Dashwood drift (Alley, 1979) and the Late Wisconsinan Fraser Glaciation. Olympia Nonglacial interval sediments are rare in the area, suggesting that materials were deposited in transient sedimentary environments (Howes, 1983).

During the early part of the Late Wisconsinan, approximately 25 000 years ago, ice began to accumulate in several centres of British Columbia, including central Vancouver Island and the Coast Mountains north of Vancouver. With continued climatic deterioration, ice north of Vancouver expanded eastward into the interior and westward into the Strait of Georgia and Queen Charlotte Strait. Glacial ice accumulating on northern Vancouver Island also expanded locally from mountain ice caps to occupy topographic lows through a system of valley glaciers (*cf.* Davis and Mathews, 1944). Local ice-flow paths dominated as ice flowed down-valley from the local accumulation centres. For example, in NTS 92L/5 this involved ice flow to the southwest down Klaskish Creek, westward into Klaskino Inlet, northward down the Mahatta Creek valley and north-eastward down Cayuse and Colonial creeks.

With time and continued cooling conditions, there was a significant global net transfer of water from the oceans to the ice sheets. The result of this change in water storage was an eustatic lowering of sea level. Similarly, there was an appreciable thickening of the ice mass to up to two kilometres in the Queen Charlotte Strait and up to 700 metres on parts of Vancouver Island, as well as a concomitant glacio-isostatic depression of the land surface up to a maximum of 200 metres in several areas (Clague *et al.*, 1982; Clague, 1983). Surrounding this depression was a forebulge which moved westward in union with the advancing ice sheet.

Aradiocarbon date of 20 600 ± 330 years BP (GSC-2502) indicates that the coast area east of Port Hardy and Port McNeill may have been depressed up to 100 metres, inundating the study area up to this present day elevation with glaciomarine conditions. Raised deltas, beach deposits and strand-lines up to 100 metres above sea level support this marine transgression interpretation. Isostatic depression on the west side of the island was also about 100 metres based on off-shore data collected by the Geological Survey of Canada (Luternauer *et al.*, 1989). With isostatic depression and marine incursion, glaciomarine sediments were deposited in submerged areas adjacent to the advancing glaciers. During the full glacial maxima, about 15 000 years ago, the Cordilleran Ice Sheet expanded from the mainland and captured local ice masses. This modified local ice flow patterns into a regional dominant flow to the west and northwest, in many cases well beyond the present limit of land (Figure 8). During this active glaciation, significant deposits of subglacial till accumulated in depressions and thinner veneers coated topographic highs. Ice began to retreat from northern Vancouver Island before 13 630 ± 310 years BP (lab number: WAT-721) primarily depositing thin but extensive accumulations of glaciofluvial sediments in areas of active retreat and less extensive blankets of supraglacial debris in areas of *in situ* ice decay.

Late glacial, ice-free conditions were present at the end of the Pleistocene. An accelerator mass spectrometry date on wood of 10 650 ± 350 years BP (RIDDL-984), obtained from a submarine vibrocore in the Pacific Ocean some 20 kilometres north of Vancouver Island indicates a period of very low sea level at this time. The dated material comes from a paleosol surface presently 95 metres below sea level and buried below marine sediments (Luternauer *et al.*, 1989).

During the last 10 000 years a number of geological processes have been active and continue to be active in modifying the landscape. Soil creep, colluviation and other more catastrophic mass movement phenomena have been very active during the Holocene and continue to pose a hazard in this region (*cf.* Howes, 1981). Soil formation has been the most notable process, resulting in an extensive blanket of podzolic soils through the in situ modification of all surficial sediments. The acidic bedrock which occurs in this part of the island favors development of these aluminum and iron-rich soils. Sulphides in the parent materials are easily oxidized and removed through groundwater leaching and are often replaced by in situ oxidates, such as limonite, which absorb heavy metals. Iron which often precipitates in the lower B-horizon can form a distinct "hard-pan" containing complex salts of fulvic acids (*cf.* Kauranne *et al.*, 1992; Figure 9).

Fluvial and mass-wasting processes are also common to this area. Creeks, streams and rivers are ubiquitous, providing an efficient mechanism for sediment redistribution. The high relief and wet climate provides an ideal environment for mass-wasting over much of the study area.

SURVEY METHODOLOGY

SAMPLE COLLECTION

Fieldwork was conducted out of two base camps, one established at the Mahatta River log sort, about 65 kilometres west of Port Alice on the south shore of Quatsino Sound and the second at Coal Harbour, about 15 kilometres south of Port Hardy, on the north shore of Holberg Inlet. Much of the survey area was accessible by logging roads using a four wheel drive vehicle. Off-road access was by mountain bike, foot traverse and helicopter. Natural exposures such as bluffs and tree-throws, and cultural exposures such as road cuts, provided the primary means of sampling subsurface sediment. In areas with no downcut features, hand-dug pits using shovels and mattocks were used to create new exposures.

Pedogenic oxidation ranges in depth from 0.8 to 1.4 metres, depending on the sedimentary facies exposed at the surface (Bobrowsky and Huntley, 1994a). For this reason, all geochemical sampling was restricted to fresh, unweathered C-horizon or parent material profiles. Commonly, sample depths ranged from 1 to 2+ metres, where possible samples as deep as nine metres were obtained. Where sediment other than till occurred near the surface, deeper samples were needed.

Most sample stations were located (UTM coordinates) with the aid of a hand held Trimble Navigation Global Positioning System (accuracy approaching ± 30 metres). Elevations were determined from 1:20 000 TRIM maps or a Thommen altimeter, which was benchmarked to daily mean sea level at the base camp (accuracy ± 5 metres).

Traditional Quaternary geology mapping techniques were used at each station to document the nature, type and extent of the overburden. Observations included general exposure attributes such as depth to bedrock, depth of oxidation, surface expression, section height, length and number and type of units present. Specific characteristics of the various facies were also recorded and included information on the type of basal contact, texture, sorting, percentage of clasts and fines, clast shape, roundness and size, presence of sedimentary and deformational structures, and lateral extent. Paleocurrent directions were determined in water-borne sediments from orientations of relict channels, cross-bedding and clast imbrication. Paleo-iceflow data were derived from pebble fabrics measured in exposures of lodgment till, bullet-shaped boulders in till, glacial striae on bedrock and meso-scale bedforms such as roches moutonees.

Several hundred samples were collected for geochemical analysis. This included undisturbed basal (lodgment) till,

TABLE 2
DETECTION LIMITS FOR INAA, ICP AND WHOLE ROCK ANALYSIS FOR NORTHERN VANCOUVER ISLAND SAMPLES

	INAA	ICP		INAA	ICP	Whole-rock	
Sb	0.1 ppm		Mn		1 ppm	SiO2	0.01%
Al		0.01 %	Mo	1 ppm	1 ppm	Al2O3	0.01%
As	0.5 ppm	2 ppm	Nd	5 ppm		Fe2O3	0.01%
Ba	50 ppm	2 ppm	Ni		1 ppm	MgO	0.01%
Bi		2 ppm	P		0.001 %	CaO	0.01%
B		2 ppm	K		0.01 %	Na2O	0.01%
Br	0.5 ppm		Rb	5 ppm		K2O	0.01%
Cd		0.2 ppm	Sm	0.1 ppm		TiO2	0.01%
Ca	1 %	0.01 %	Sc	0.1 ppm		P2O5	0.01%
Ce	3 ppm		Ag		0.1 ppm	MnO	0.01%
Cr	5 ppm	1 ppm	Na	0.01 %	0.01 %	Cr2O3	0.001%
Co	1 ppm	1 ppm	Sr		1 ppm	LOI	0.01%
Cu		1 ppm	Ta	0.5 ppm			
Eu	0.2 ppm		Tb	0.5 ppm			
Fe	0.01 %	0.01 %	Th	0.2 ppm			
Au	2 ppb		Ti		0.01 %		
Hf	1 ppm		U	0.5 ppm			
La	0.5 ppm		W	1 ppm			
Pb		2 ppm	V		2 ppm		
Lu	0.05 ppm		Yb	0.2 ppm			
Mg		0.01 %	Zn		1 ppm		

colluviated basal till, ablation till, undifferentiated colluvium and glaciofluvial sediment samples. Samples ranged in size from 1-5 kilograms in weight. All samples were stored in heavy-mil plastic bags. Given the total sampling area of about 2500 kilometres, this provided an average sample density of approximately 1 per 5 square kilometres. Only the results for the geochemical analysis of basal till and colluviated basal till samples (N = 435 samples) are included in this report. Using these samples only, the sampling density was approximately 1 in 6 square kilometres.

SAMPLE PREPARATION AND ANALYSIS

Samples collected were first air-dried at 25-30°C for a minimum of 48 hours, disaggregated and quarter-split for sieving at the British Columbia Geological Survey sample preparation laboratory in Victoria, British Columbia. Representative sub-samples of the -230 mesh (-62.5 micron) fraction from each sample were analyzed by instrumental neutron activation analysis (INAA) for 35 elements at Activation Labs Ltd., in Ancaster Ontario and by aqua regia digestion inductively coupled plasma emission spectroscopy (ICP-AES) for 30 elements at Acme Analytical Laboratories Ltd., in Vancouver, British Columbia. Whole-rock (major element oxides) analysis by ICP was determined at Acme Analytical Laboratories Ltd., by fusing 0.2 grams of a -230 mesh subsample with 1.2 grams of lithium borate and dissolving in 100 millimetres of 5% nitric acid. Loss on ignition (LOI) was also determined during the ICP procedure.

Analytical results are provided as Appendix A (ICP), Appendix B (INAA) and Appendix C (Whole Rock). Data for 26 of the 35 INAA elements and 24 of the 30 ICP elements are presented. Elements excluded from the database are those that contained an excessive number of values at or below the detection limit. For the INAA analysis, the excluded elements are iridium, cesium, mercury, nickel, selenium, tin, silver, strontium and zinc. Elements excluded from the ICP results include lanthanum, antimony, gold, thorium, uranium and tungsten. Detection limits for the included elements for all methods of analysis are shown in Table 2. Summary statistics are included with the element maps.

QUALITY CONTROL

METHODOLOGY

Distinguishing geochemical trends resulting from geological features versus those resulting from spurious sampling or analytical errors is a critical part of a regional geochemical survey. In order to evaluate sampling and analytical variability, field and laboratory duplicate samples and reference standards were used and integrated into the sample suites submitted for commercial laboratory analysis. Field duplicates were collected from arbitrarily selected sample sites and subjected to the same laboratory preparation and analytical procedures as the replicate pair. Analytical duplicates consist of representative splits taken from samples following the sample preparation process but preceding geochemical analysis. Control reference standards consist of three different 'prepared' sediments of known element concentration. In total, the quality control consisted of 32 pairs of field duplicates and 17 pairs of analytical duplicates (Appendix G). In general, it is common to observe a greater variability in the field duplicate pairs as compared to the analytical duplicates, since the former represents two different but 'adjacent' samples (= field sampling + preparation + analytical variability), whereas the latter represents two parts of the same sample (= analytical variability).

Scatter-plots of the analytical and duplicate pairs were generated. The field duplicate data contained a number of cases where outliers clearly skewed the bivariate analysis. For example, within the ICP data, station 919172 had aberrant paired values for copper (710 ppm and 222 ppm) and lead (108 ppm and 44 ppm). This station was located near the Island Copper mine and may indicate the presence of discrete mineralized particles. Station 949023 had disparate ICP values for zinc (837 ppm and 92 ppm) and also aberrant INAA values for arsenic (180 ppm and 6.6 ppm). Hence scatter-plot results for copper, lead, zinc and arsenic are based on a sample of 31 pairs, whereas the remaining elements, gold, antimony, SiO_2 and CaO are based on 32 pairs of data (Figures 10 and 11). The results of these scatter-plots provide a more realistic view of the regional duplicate pair comparability and difference. Inclusion of the aberrant values would skew the regional reliability interpretations.

In general, the results show good correlation for most field duplicate pairs with correlation coefficients ranging from 0.559 to 0.979. All values of r are significant at the 0.01 level. The presence of individual, anomalous samples would have significantly reduced the overall correlation coefficients for each analysis. Analytical duplicate pairs show a much higher degree of correlation with most r values between 0.818 and 0.996, $p = 0.01$. One exception is lead ($r = 0.676$, $p = 0.01$) which reports a high proportion of values below 5 ppm which is close to the detection limit of 1 ppm.

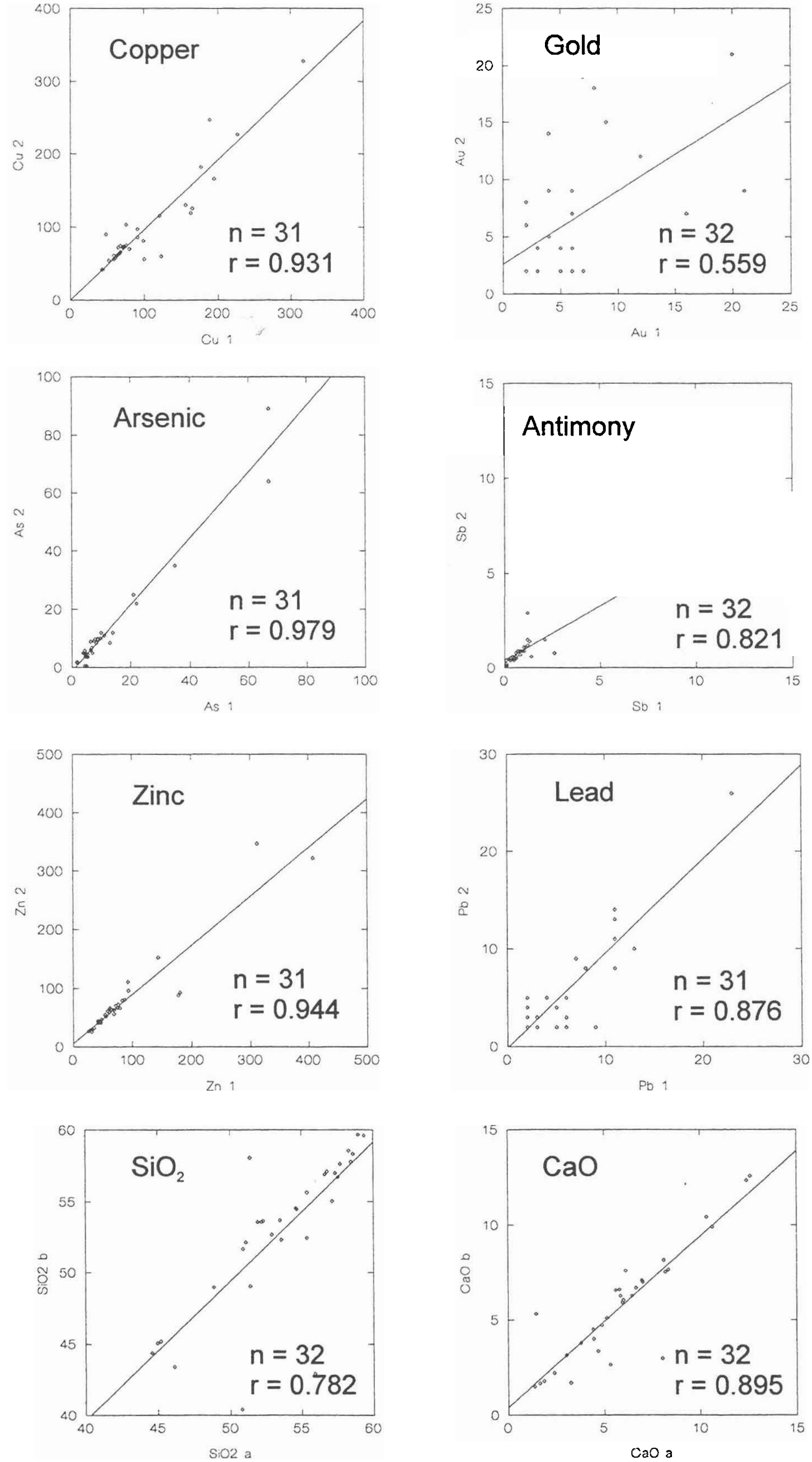

Figure 10. Bivariate scatter-plots of field duplicate pairs for the northern Vancouver Island study. Note sample size for copper, lead, zinc and arsenic is n =31, whereas n = 32 for gold, antimony, SiO_2 and CaO.

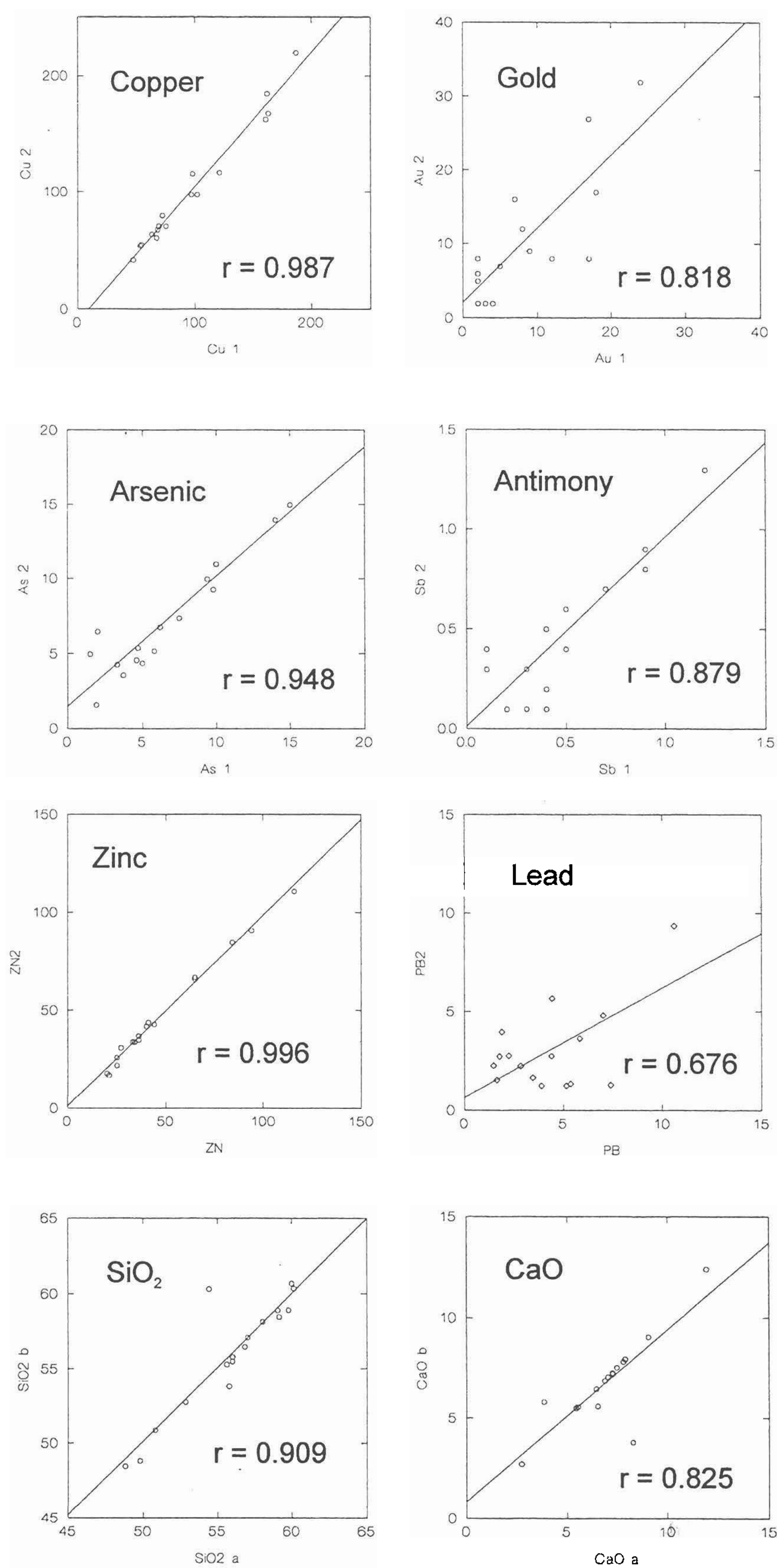

Figure 11. Bivariate scatter-plots of analytical duplicate pairs for the northern Vancouver Island study (n = 32).

DATA INTERPRETATION

The results of the till geochemical survey program provide a reconnaissance level guide to geochemical patterns. From an exploration perspective the relation between 'anomalous' values of certain elements such as copper, gold, silver, lead, zinc, iron, and molybdenum and the surficial geologic history warrants further discussion to ensure that follow-up studies are executed with a good knowledge of probable source areas.

As noted previously, analytical results for 24 of the 30 ICP elements are presented here (Appendix A) and 26 of the 35 INAA elements (Appendix B). The whole rock analysis data provides the results of analysis for 11 major oxides as well as Loss-On-Ignition (LOI) values (Appendix C). The ICP data in Appendix A consists of a map identification column (MAP), station identification label (ID), UTM zone (UTMZ), easting and northing (UTME and UTMN, respectively), field duplicate identification (Rep), and sample media (Med - C for colluviated till and M for till). The 24 individual elements are listed along the top axis under which a unit of measurement (*e.g.* ppm or %) is provided followed by the level of detection. The INAA analytical data in Appendix B consists of the same first seven columns as in the ICP data. Under each of the 26 elements provided for the INAA data, units of measurements included ppb, ppm and %, which in turn are underlain by levels of detection. The whole rock analysis data in Appendix C consist of the same first seven columns as for the ICP data. The major oxides and LOI concentrations are all presented as a percentage of the total; the final column gives the analytical summed value for each sample.

Appendix D provides graphical plots of the 24 elements analyzed by ICP. Each illustration consists of an element specific map covering the sample area (all of 92L/5, 12 and the west half of L/6 and 11), geographical reference points (*e.g.* towns, villages and inlet names), geographical coordinates (UTM and latitude and longitude), and symbol legend. The symbol legend describes the distribution of values for eight percentile categories, minimum and maximum values within each percentile category and a graphic representation of the symbol size used to denote the particular category. The facing page of each element map provides a frequency histogram of the specific distribution, as well as a normal cumulative probability curve. Analytical summary data presented includes the fraction analyzed, the analytical method and the detection limit. Summary statistics for each element consist of number of samples, minimum and maximum values, mean, mode, median, lower and upper quartiles, standard deviation and a coefficient of variation.

The graphical representation, analytical summary and statistical summary is duplicated for the 26 elements analyzed by INAA and for the 11 major oxides. These results are provided as Appendix E and F, respectively. To assist in station identification, a mylar overlay map with all the station locations and identification labels is included as Appendix H.

The elements presented here are those for which analytical results appear to be both minimally biased and well above detection limits. Moreover, the data presented include results for comparable media (basal tills and colluviated till). Hence, the integrity of the data is interpreted to be exceptionally high in comparison to any discussion centered on mixed media samples (*e.g.*, till, colluvium, soils, outwash, etc.). Given the nature of the surficial sediments on northern Vancouver Island, both types of media sampled and presented here reflect 'parent' materials or sources which are 'local' origin, that is, where transport distances are on the order of tens of metres to a few kilometres from source area, and rarely exceeding tens of kilometres.

In the following discussion, several of the more important elements associated with porphyry-copper, skarn, vein, replacement and volcanogenic deposits (gold, copper, lead, silver, zinc, iron and molybdenum) are reviewed. Elevated element concentrations are highlighted and evaluated with reference to known mineral occurrences (see MINFILE, 92L and 102I). Interpretations regarding likely associations between the till geochemistry anomalies and known mineral occurrences are provided. Similarly, as yet unexplained associations are emphasized with suggestions for probable source areas. Glacial ice-flow directions, deposit types and drift thickness are discussed and integrated into the element interpretation to assist explorationists in follow-up efforts.

COPPER

Concentrations of copper (ICP) ranged from 9 ppm to 910 ppm. Moderately high mean and median values of 98 ppm and 75 ppm Cu, respectively, are present. Some 106 samples occur in the upper tenth percentile distribution, with values equal to or exceeding 116 ppm. Of the 435 samples analyzed, three had copper values equal to or greater than 459 ppm, five had values between 404 and 459 ppm and an additional 13 had values between 225 ppm and 404 ppm. As expected, the distribution of many of the high copper values tend to cluster over and directly west of Island Copper (*e.g.*, 919172 - 710 ppm, 919175 - 584 ppm, 919175 - 459 ppm, 919184 - 436 ppm, 919099 - 320 ppm, 919143 - 310 ppm). Duplicate analysis of 91972 reproduced poorly, suggesting the presence of discrete mineralized grains within the sample. Several other high copper concentrations are recognized and have distributions which can be readily associated with known mineral occurrences other than Island Copper.

Copper values of 474 ppm and 453 ppm were obtained from till at stations 919133 and 919135, respectively, on the west and south margin of Nahwitti Lake (NTS 92L/12). These values can be associated with any number of known mineral occurrences in the vicinity including, but not restricted to three recorded mineral prospects (South Shore, South Shore-RAS4, and South Shore -HSW3). To the west of Nahwitti Lake, two high values (412 ppm and 405 ppm, stations 919158 and 919160) were obtained at the Red Dog prospect. Other elements with high concentrations in the Red Dog area include Au and Mo.

Directly southeast of Holberg, on the south shore of Holberg Inlet, stations 919047, 919048 and 919049 provided till sample copper values of 309, 275 and 227 ppm, respectively. Drift cover in the area is moderately thin and interpreted ice-flow directions indicate movement from the east along Holberg Inlet. At present, two copper mineral showings, Hol and Seal, are known and may represent the bedrock sources for the observed values. Finally, a value of 246 ppm copper from colluviated till was obtained at station 919151 at the east end of Kains Lake (NTS 92L/12) and may be associated with mineral occurrences, WOB 48 and WOB 52, farther east.

Several anomalies cannot be readily associated with known mineral occurrences. These all contain moderately high copper values and may indicate areas of exploration potential. Source area interpretations for each station are briefly discussed below. Station 949046, located directly west of O'Connell Lake (NTS 92L/5) has a copper value of 404 ppm. This deposit of till is not down-ice from any known mineral occurrence and most likely has a source area down-valley, to the northeast when regional ice-flow was to the southwest. Stations 949119 and 949120, northeast of Klaskino Inlet (NTS 92L/5), with copper concentrations of 318 ppm and 328 ppm respectively, are also from unkown bedrock sources. The source area for these two anomalies appears to be up-valley in Buck Creek, to the northeast. Station 919091 directly east of Winter Harbour has a till sample copper concentration of 359 ppm. The source area for the copper anomaly at this station is most likely to the northeast.

High copper concentrations at Island Copper and Red Dog correspond well to high gold values at these locations. Similarly, copper anomalies noted at Island Copper and adjacent to Nahwitti Lake have lead and zinc highs at these stations or nearby.

GOLD

The mean and median concentrations of gold (INAA) are 9.8 ppb and 5 ppb, respectively. Values ranged from 2 to 687 ppb, for the 434 samples of till and colluviated till analyzed. There are eight samples in the upper 0.7 percentile, five with gold concentrations between 36 ppb and 114 ppb and three with gold values greater than 114 ppb. The distribution of high gold values corresponds well with several known mineral occurrences, especially in parts of NTS 92L/12 and less so in 92L/6 and 11. Gold concentrations in the Mahatta River map area (92L/5) are all low.

As with the distribution of copper, several of the gold anomalies correspond well with the Island Copper area. Two of the highest gold values were obtained from till samples (919159 - 687 ppb and 919160 - 140 ppb) near the Red Dog prospect, stations which also produced high Cu and Mo concentrations. Equally respectable gold concentrations were derived from till samples several kilometres to the southeast of Red Dog and west of the headwater of Hushamu Creek. Here stations 919210, 919112 and 919106 provided gold concentrations in till of 181 ppb, 114 ppb and 50 ppb, respectively. The highest value in this group occurs directly down ice-flow from the Expo Prospect. The station also produced high concentrations of Pb and Ag. Station 919106 also provided anomalous Mo and Ag concentrations, but cannot be easily related to a known mineral occurrence. A likely source area is the highland directly to the east.

A value of 47 ppb gold was obtained from till at station 939112 directly south of the west end of Kathleen Lake (NTS 92L/6). This sample occurs down ice-flow from a cluster of prospects including Merry Widow and Bluebird 1 and most likely is related to one of these or another of the many gold occurrences nearby.

At station 939149, on the southwest shore of Victoria Lake (92L/6), a gold concentration of 44 ppb was obtained from a colluviated till sample. The source of this material cannot be related to any nearby mineral occurrence, but most likely comes from either directly up-slope of the station or from the south. This interpretation is based on both the steep local topography and paleo-ice-flow history.

SILVER

The 435 till samples collected and analyzed by ICP provided silver concentrations ranging from 0.2 ppm to 1.1 ppm. A mean value of 0.2 ppm and a median value of 0.1 ppm was determined. The majority of the samples were in the lower 91st percentile (396 samples), with only six samples having concentrations of 0.7 ppm or better (upper 99.5 percentile and higher). Only the six samples with the highest values are discussed in this report.

A colluviated till sample at station 919177, located north of Victoria Lake and on the west side of Alice Lake (92L/6) produced the highest documented silver value (1.1 ppm). The most probable source for this sample appears to be either one of two known Ag occurrences, the June prospect directly south or the Pilgrim showing to the southeast. Less likely is the Alice Lake silver prospect to the west.

A colluviated till sample (station 919210) near the Expo property provided a value of 1.0 ppm for silver. The anomaly corresponds to high Pb and Au concentrations and moderately high Cu values at the same station. Other high silver concentrations in map sheet 92L/12 include stations 919100 near Island Copper and 919106 at the north end of Hushamu Creek. The latter station also produced high Mo and Au concentrations.

On the south shore of Kains Lake (92L/12), a value of 0.7 ppm Ag was obtained from till (station 919149). The nearest mineral prospect/showing is the A-Property, which happens to contain Ag and it is located to the south, but since the regional ice-flow was to the west, this location is clearly not the source area. There are no other known mineral showings east of this station which can be considered candidate sources at this time.

On the Mahatta Creek sheet, station 949067, directly southwest of LeMare Lake produced a value of 0.7 ppm Ag, as well as moderately high Pb and very high Zn concentrations. There are no known mineral occurrences containing silver in the vicinity to explain this anomaly. Although located on a steep slope facing east, the high zinc value at this station and the inferred regional ice-flow to the south suggests the source may in fact be related to the LeMare 1 showing.

ZINC

Zinc (ICP) concentrations ranged from a minimum of 8 ppm to a maximum of 857 ppm for the 435 samples. A mean value of 81.3 ppm and median value of 65 ppm result from this distribution. Samples display an equitable distribution, and those in the upper 99.3 percentile have a minimum value of 265 ppm Zn.

The highest concentration of zinc in this study occurs on the west side of the Mahatta Creek map sheet at station 949067, directly west of LeMare Lake. The station has already been highlighted as one exhibiting high silver and lead values. To reiterate the earlier interpretation, this sample may reflect an association with the LeMare 1 showing. A second high zinc concentration occurs at station 949103 on the southwest side of Neroutsos Inlet, where a value of 321 ppm zinc was obtained. This till sample probably reflects a source area to the southeast and may be associated with either the Paystreak or Quatsino King showings.

On the east side of NTS 92L/12, stations 919102 and 919174 yielded Zn concentrations of 566 ppm and 529 ppm, respectively and both stations provided high lead values. These and the following three stations are part of the Island Copper Mine suite. Three other high zinc concentrations in this suite occurred at stations 919173 (347 ppm), 919184 (321 ppm) and 919172 (312 ppm), the latter two supporting high copper and lead values.

An unexplained anomaly occurs on the west side of NTS 92L/12, where lead concentrations of 408 ppm and 322 ppm resulted from duplicate samples 919116 and 919117. There are no known mineral occurrences within a few kilometres in an up-ice direction of these samples. Station 919125, directly west of Nahwitti Lake had a zinc concentration of 283 ppm. Given the glacial history in this area, the most probable sources are any one of the several prospects south of the lake including, but not restricted to, South Shore and Hep.

IRON

Concentrations of iron determined ranged in value from a minimum of 0.72% to a maximum of 13.4%. The calculated mean and median concentrations are 5.2% and 5.1%, respectively. The frequency distribution of iron is fairly uniform, the upper 99.3% values having values of 8.99% or better.

Several iron anomalies were established in NTS 92L/5. The highest value, 13.4% iron occurred at station 949078, located some three kilometres west of O'Connell Lake. There are no known mineral showings within several kilometres of this station. The glacial geologic history suggests that a probable source area would be in the vicinity of O'Connell Lake. Two high iron concentrations occurred on the east side of the map sheet at stations 949006 (10.74%) and 949099 (9.31%). There are no known mineral occurrences related to either anomaly. The most likely source for the former concentration is to the southeast towards Teeta Creek, whereas the most probable source of the latter occurrence is to the southwest up stream in Teeta Creek. A duplicate sample at station 949024 provided an iron concentration of 10.19%. Unfortunately, the paired samples from this station are not considered reliable given the significant difference in the duplicate values of zinc (see Quality Control section).

High iron concentrations were observed near Island Copper Mine at station 919179 (9.01%) and to the west. The highest iron value in map sheet NTS 92L/12 occurs at station 919104 (11.04%) on Hushamu Creek near the Hushamu showing. Another high iron concentration is evident at station 919091 (10.04%) south of Winter Harbour. This location also has a moderately high copper concentration but cannot be associated with any known mineral occurrence. The source area for this sample is most likely to the east southeast towards Quatsino Inlet. Duplicate samples near Red Dog yielded high iron concentrations (919117 - 10.05%, 919118 - 9.54%).

Lastly, only one moderate anomaly was recorded in the southeast part of the study area. In NTS 92L/6, station 939159, located south of Neroutsos Inlet near Utluh Creek yielded an iron concentration of 9.01%. There are no known mineral showings within several kilometres of this anomaly. The most likely source for this sample is to the south-southwest.

LEAD

Mean and median concentrations of lead (ICP) are 9 ppm and 5 ppm, respectively. Lead concentrations ranged from a minimum of 2 ppm to a maximum of 215 ppm. Of the 435 samples analyzed, the top three had values of 108 ppm and higher and the top eight had values of 49 ppm and higher.

The greatest number of lead anomalies cluster over and down-ice of the Island Copper Mine. Here stations 919100 (215 ppm Pb; also high Ag), 919102 (142 ppm Pb; also high

Zn), 919174 (133 ppm Pb; also high Zn), 919172 (108 ppm; also high Cu and Zn), 919184 (84 ppm Pb; also high Cu and Zn) and 919166 (58 ppm Pb) provide a classic down-ice dispersal pattern to the west.

In the far west part of NTS 92L/12, directly west of Nahwitti Lake, a till sample at station 919125 yielded an anomalous lead concentration of 49 ppm. The source area for this anomaly is most likely any one of the several mineral occurrences at the west end of Nahwitti Lake. Directly to the south of 919125, sample 919210 provided a concentration of 55 ppm Pb. In this case, there is no obvious mineral source to account for the anomaly in the up-ice vicinity.

MOLYBDENUM

Molybdenum concentrations (ICP) range from 1 ppm to 61 ppm (n = 435). Mean and median values of 2.3 ppm and 1 ppm Mo, respectively were determined. The highest eight values in the upper 99.3 percentile had Mo concentrations of 21 ppm or greater. Most anomalous samples occur in the northern part of the study area.

Several molybdenum anomalies are present in the west end of NTS 92L/12 near Red Dog where stations 919160, 919159 and 919158 yielded Mo concentrations of 61 ppm, 45 ppm and 24 ppm, respectively. A series of samples in this area provide a good example of down-ice glacial dispersal with the head of the distribution starting at Red Dog. Station 919106 at the headwaters of Hushamu Creek generated a value of 40 ppm Mo. The source for this sample is most probably to the southeast. Another cluster of samples at the west end of Nahwitti Lake also illustrates a good example of a down-ice dispersal train with the highest anomalous value at station 919134 (31 ppm Mo). The source for this cluster of values is one of several occurrences on the south shore of the lake.

A well developed dispersal train for molybdenum occurs over the Island Copper mine area starting with a value of 33 ppm at the head of the distribution located at station 919175. The final anomalous station on the Quatsino sheet occurs in the southeast corner where sample 919228 yielded a value of 33 ppm Mo. There is no known mineral occurrence in the area which can be associated with this last anomaly.

In NTS 92L/6 an anomalous occurrence of molybdenum occurs at station 939159 (27 ppm Mo) directly south of Neroutsos Inlet near Utluh Creek. From this point northward a well-developed dispersal train is evident. The likely source area for this anomaly is directly to the south where there are no known mineral occurrences.

PATHFINDERS FOR PORPHYRY STYLE MINERALIZATION

Inspection of data surrounding the three significant porphyry Cu-Au-Mo deposits in the study area (Island Copper, Hushamu and Red Dog) reveals potential pathfinder elements for these deposit types. In the vicinity of the Island Copper deposits, tills are anomalous in As, Au, Fe (including Fe_2O_3), Mo, Ba, Cd, Cu, Pb, and Zn. Near the Hushamu deposit, the elements Au, Mo, Pb and Al (as Al_2O_3) are anomalous. The Red Dog deposit reports a similar anomalous element suite to Hushamu (Au, Mo, Pb and Al_2O_3) with the addition of Cu. The larger number of pathfinder elements associated with the Island Copper area reflects the more complex nature of mineralization in the Island Copper cluster, where porphyry, vein and skarn mineralization are well documented. The lack of highly anomalous (98th percentile) Cu concentrations near the Hushamu deposit, compared to Island Copper and Red Dog, is conspicuous. This feature may be a result of dilution by barren material derived from up ice (east). It may also be due to the presence of large quantities of pyritic, acid sulphate altered bedrock which, upon weathering, creates acidic conditions causing copper to leach from the weathered layer of the till.

SUMMARY AND RECOMMENDATIONS

This report presents the results of a drift exploration program involving surficial geology mapping and till geochemistry sampling on northern Vancouver Island. Surficial geology data and Quaternary geologic history information relevant to explorationists is reviewed. The results of ICP, INAA and whole rock analyses for 435 basal till and colluviated till samples are presented and discussed. Collectively, these data provide a good reconnaissance level study of the mineral potential of this glaciated and drift covered region.

Most the study area (NTS 92L/5, 6, 11 and 12) is covered by a variable thickness of drift ranging from one to several metres. The high relief areas in the southern and western part of the study support thin veneers of colluvium (1 m) over bedrock on steep slopes and higher elevations and thicker blankets of colluvium (<1 m) over till on mid slope regions. At lower elevations and over much of the flat rolling lowlands to the north and east, morainal deposits in the form of ablation and basal till can be found. These deposits range in thickness from less than a metre to over several tens of metres depending on the relief of the underlying bedrock. Fluvial deposits are restricted to within a few metres elevation of all present day creeks, streams and rivers. Marine and glaciomarine sediments are also restricted in their distribution to the coastal areas and at elevations not exceeding 100 metres. Glaciofluvial and glaciolacustrine sediments occur throughout the study area, often as thin deposits overlying till, but their occurrence is proportionately minor in comparison to till.

Quaternary geology plays an important role in mineral exploration studies in areas of glaciated terrain. The principles of drift exploration rely on an accurate understanding of the regional geological history, the distribution of various types of sediment, the genesis of individual deposits and the relationship of sediment cover to bedrock lithology (Liverman, 1992). Terrain and surficial geology mapping provides the first step towards attaining this understanding, whereas ground-truthing including stratigraphic and sedimentologic descriptions further the process. Sampling for till geochemistry and clast lithologies provides two mechanisms to recognize glacial dispersal trains and consequently infer potential mineral occurrences covered by drift. But the successful integration of these data with the surficial geology studies is the key for determining their location.

It is recommended, that terrain and surficial geology mapping must precede drift exploration studies which rely on till geochemistry and pebble lithology analysis. Such mapping not only identifies where preferred sediments for sampling occur, but also provides information regarding drift thickness and paleo-ice-flow direction. Unique deposit types must be identified and consistency in sampling such deposits must be maintained to ensure comparability of the results. For example, one recent study of glacial dispersal of till constituents clearly illustrated how both flow-paths and transport distances differed between various types of morainic landforms (Aario and Paeuraniemi, 1992).

Adequate sampling density suited to the objectives of the project must always be determined, hence the 435 samples collected in this study from a sampling area of about 2500 square kilometres (1 per 6 km^2) was intended to provide reconnaissance level data. Such data provide a good departure point for further exploration at more detailed scales. Assuming average transport lengths of 1.0 kilometre for geochemical anomalies (*cf.* Salminen and Hartikainen, 1985 and 10.0 kilometres for pebble lithologies (*cf.* Gillberg, 1967), the data collected in this study are adequate for a reconnaissance study. Follow-up sampling to test anomalies should proceed to a local scale of work (1 sample per square kilometre and better) and then down to property scale sample density (as much as one sample per linear 10 metres).

In any prospecting effort, follow-up exploration studies should rely on surficial geology to verify sample media and paleo-ice-flow directions. Exploration work should be restricted to sampling materials such as basal tills and certain colluvial facies. As a guide to further work, Drift Exploration Potential Maps (*cf.* Proudfoot *et al.*, 1995) have been generated and published for the entire region (see Meldrum and Bobrowsky, 1994a, 1994b). These 1:50 000 scale maps provide a guide for delimiting preferred sampling media based on those parameters which are known to influence the integrity of data and ease of interpretation (Table 3). Factors considered include: type of materials (*e.g.* till, colluvium, glaciofluvial, fluvial, lacustrine, etc.); drift thickness (1 m or 10 m); transport distance (*e.g.*, 10s of metres, 10s to 100s

TABLE 3
DRIFT EXPLORATION POTENTIAL MATRIX

POTENTIAL	I	II	III	IV	V
TERRAIN UNITS	R Cv/R Mv/R	Cb/R Cv/R Mb	CBV Mbv Combined	FG F Combine	L, LG, E, O, A, W, WG Combined
TOTAL SEDIMENT THICKNESS	< 1m	> 1m	> 10m	> 10 m	> 10m
TRANSPORT DISTRANCE	generally 10s metres	10s to 100s metres	10s to 100s metres	usually 100s metres but also 10s metres	often 100s to 1000s but also 10s metres
POST-EROSIVE DIAGENETIC INTERPRET	Very Easy	Easy	Moderate	Difficult	Very Difficult
DERIVATIVE PHASE	1st	1st	1st 2nd	2nd 3rd	3rd 4th
GEOCHEM/ PEBBLE SAMPLING INTERPRET	Very Easy	Easy	Moderate	Difficult	Very Difficult

of metres, 10s to 1000s of metres); diagenetic history and derivative phase (primary deposit, secondary, etc.).

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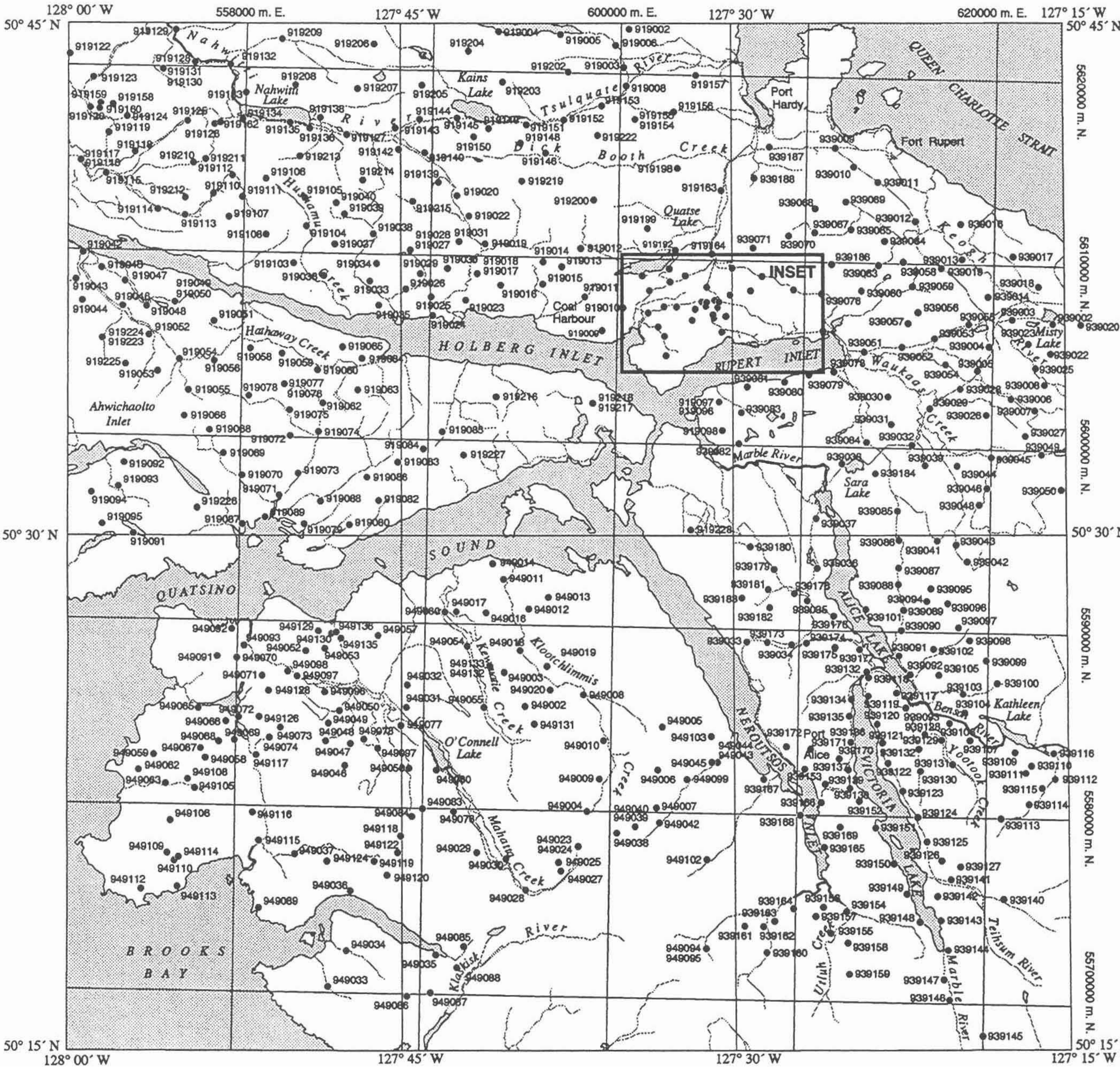
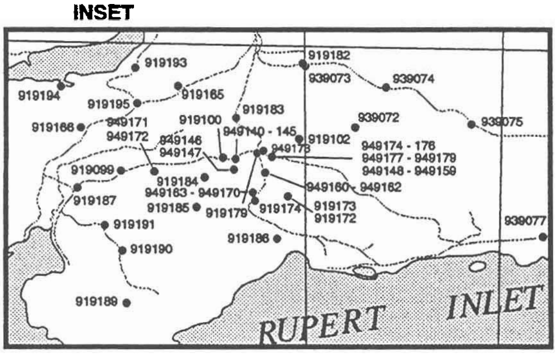
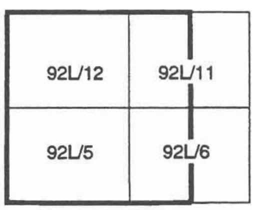
Sample Location Map (North Vancouver Island)



INSET





National Topographic System
Transverse Mercator Projection
NAD 1927
UTM Grid Zone 9

0 5 10 15

kilometres

• 939159 Sample location