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Ministry of Energy, Mines
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MINERAL RESOURCES DIVISION
Geological Survey Branch

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TILL GEOCHEMISTRY OF THE QUATSINO MAP AREA (92L/12)

By D.E. Kerr, S.J. Sibbick and W. Jackaman

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INTRODUCTION

Open File package 1992-21 presents the analytical results of the Quatsino (NTS 92L/12) drift exploration project, an evaluation of drift sampling as a regional mineral exploration tool. The Quatsino project is part of the British Columbia Geological Survey Branch's Drift Prospecting program and is designed to demonstrate the applicability of combined surficial geology-exploration geochemical methods in the search for drift-covered mineral deposits in areas of glaciated terrain. The Quatsino map sheet, centred over the North Island copper belt, represents an area of high mineral potential within a glaciated, coastal plateau setting.

Proper use of drift prospecting techniques is dependant upon an understanding of the regional surficial geology history, Quaternary stratigraphy and glacial ice-flow patterns. The relatively simple glacial stratigraphy in the Quatsino map area, reflecting a single glacial advance and retreat, makes this an ideal location for the application of drift prospecting, with only a single till sheet underlain by bedrock and locally overlain by glaciofluvial and glaciolacustrine sediments.

Till sediment samples were chosen as the preferred regional sampling media. Till is an unconsolidated nonsorted sediment (diamicton) carried and deposited directly by a glacier. It consists of a mixture of glacially-eroded bedrock fragments and any pre-existing surficial sediments (overburden). Till generally has a relatively dense sand-silt-clay matrix, with clasts ranging in size from pebbles to boulders which can be rounded to angular in shape. Locally-derived (<1 to 2 kilometres) bedrock clasts predominate in the tills within the Quatsino map area, although more distal (>5 kilometres) rock types may also be common.

Collected samples were analysed by instrumental neutron activation (INA) and inductively coupled plasma (ICP) methods. Included are data for 42 elements obtained by analysing surficial sediments collected in 1991 by the British Columbia Ministry of Energy, Mines and Petroleum Resources. Data obtained from this project can be used as a basis for detailed drift prospecting work in the area.

An orientation survey was conducted around the Island Copper mine to provide analytical guidelines as to which grain size fraction is best suited for mineral exploration in the Quatsino map area and in similar physiographic regions along British Columbia's West Coast.

SURVEY DESCRIPTION

PHYSIOGRAPHY AND CLIMATE

The Quatsino map sheet (Figure 1) covers an area of approximately 960 square kilometres within the Nahwitti Lowland, part of the Hecate Depression within the Coastal Trough (Holland, 1976). The map region can be further divided into two physiographic subunits; the northeast area is characterized by low plateau-like subdued relief below 300-450 metres elevation, whereas the remaining terrain north and south of Holberg Inlet consists of low rounded hills with isolated summits up to 600 metres in elevation. Parts of the extreme eastern margin of the map area belong to the Suquash Basin, which is defined by a gently rolling surface, rarely exceeding 300 metres in elevation.

Northern Vancouver Island is characterized by cool, wet winters and drier, warm summers, with 70 per cent to 80 per cent of precipitation occurring between October and March. The Quatsino map sheet is divided into two precipitation zones; in the region to the west of Nahwitti Lake, mean annual precipitation varies from 2300 millimetres to greater than 4000 millimetres, and to the east, mean annual precipitation varies from 1700 millimetres to 2200 millimetres (Howes, 1981).

SURFICIAL GEOLOGY

The surficial geology of the Quatsino area was mapped by Kerr (1992). Widespread deposits of glacial diamicton (till), generally locally derived, are common in the highlands north and south of Holberg Inlet, as well as in the lowlands in the northeastern map area. Thickness may attain tens of metres in certain valleys such as the Goodspeed, Clesklagh and the southernmost eastern and western tributaries of the Koprino River. Average till thickness, however, varies from 1 metre to 4 metres. Granulometric analysis of 21 till samples from the Quatsino map area (Figure 2) indicate the average till matrix consists of approximately 25.4 per cent granules, 34.7 per cent sand, 33.0 per cent silt and 6.9 per cent clay. Grain size distribution, however, can vary significantly within the same overburden unit, vertically as well as laterally, on both regional and local scales due to changes in depositional sedimentary environments. Glaciofluvial

outwash consisting of sand and gravel from 1 metre to 15 metres thick, is generally restricted to many valley bottoms including the Koprino River, Hathaway Creek, Nahwitti River and Hushamu Creek. Isolated pockets of silty clay glaciolacustrine sediments occur in valleys (Tsulquate River and Wanokana Creek) where glacial meltwaters were once ponded by stagnant lobes of ice. Glaciomarine and marine sediments along the coastal lowlands of Holberg and Rupert Inlets and Quatsino Sound are virtually non-existent or modified beyond recognition below the estimated marine limit of 30 metres elevation. Colluvium derived from till and weathered bedrock is found not only on steeper slopes, but as a ubiquitous veneer (less than 1 metre) or blanket (greater than 1 metre) which covers most other types of surficial sediment.

QUATERNARY HISTORY

The Quatsino map area was last glaciated during the Late Wisconsinan (Fraser glaciation) between $20\,600 \pm 330$ years B.P. (GSC-2505) and $12\,200 \pm 160$ years B.P. (GSC-24). Howes (1983) reported evidence for two glaciations based on the presence of two distinct tills in the north-central regions of Vancouver Island. However, subsequent mapping by Kerr (1992) provided evidence for only one glaciation within the study area. Directional ice-flow indicators (striae, grooves, crag and tail features, pebble fabrics) suggest that the regional ice direction during the last glaciation was generally toward the northwest (see Appendix A-3), probably originating from the Coast Mountains and crossing Queen Charlotte Strait. Fluted morainal landforms south of the Pemberton Hills parallel the glacial trend to the northwest. There is, however, considerable variation in glacier flow direction on a local scale as evidenced by glacial striae and till fabrics, notably south of Holberg Inlet. During the early stages of the glacial advance, individual tongues of ice followed preexisting valleys, some ice lobes flowing to the west (east of Koprino Harbour), southwest (east of Winter Harbour) and south (Koprino River valley). There is no evidence for any local ice sources in the Quatsino area.

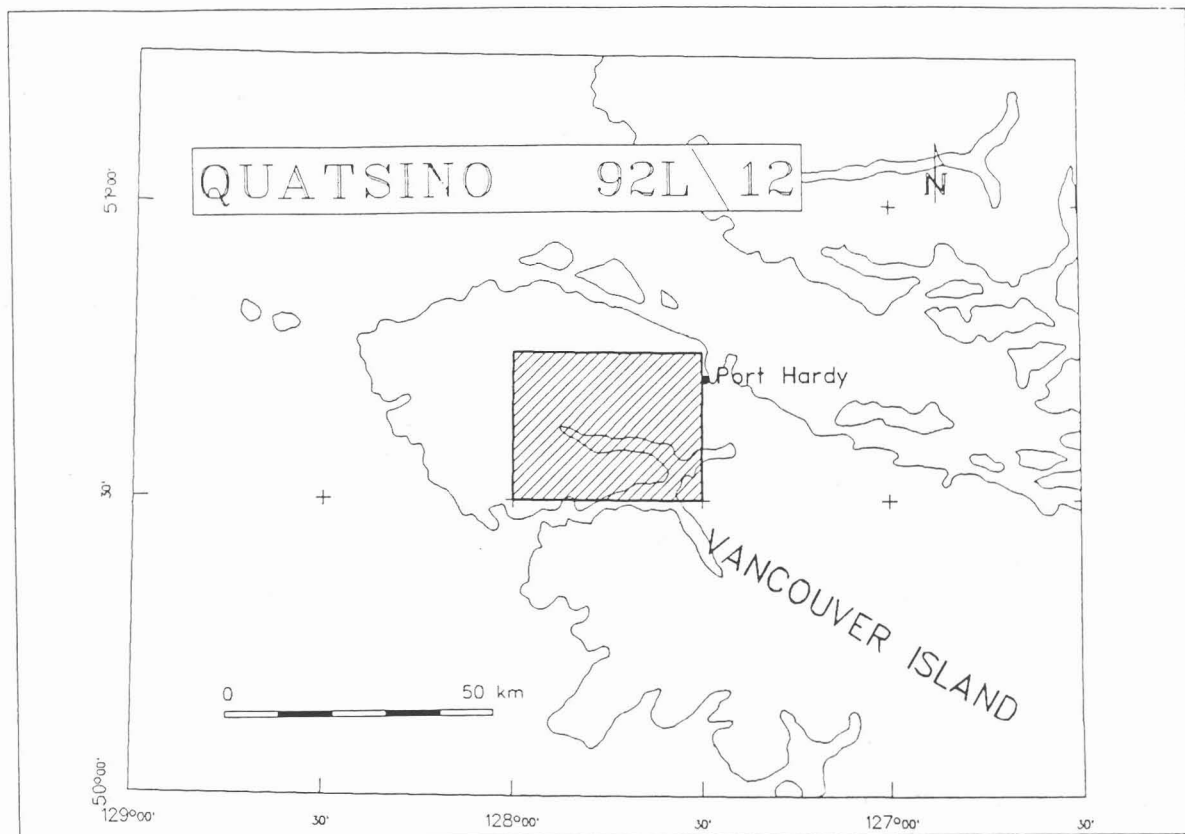


Figure 1 - Location of the Quatsino (NTS 92L/12) map area, northern Vancouver Island

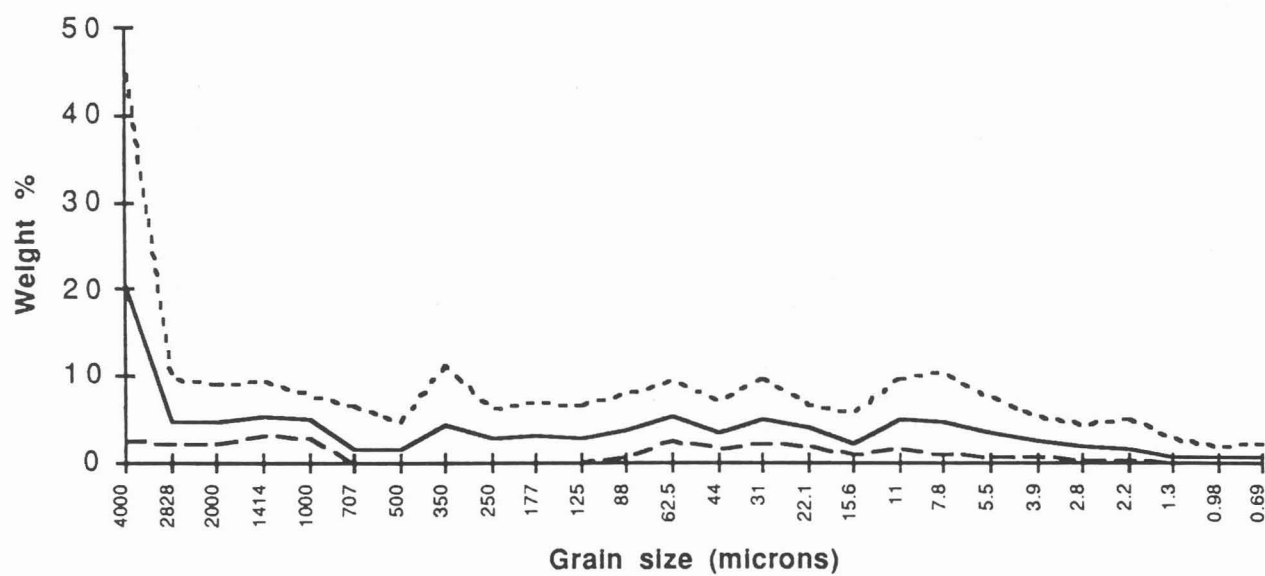


Figure 2 - Results of grain size analysis of 21 tills from the Quatsino map area. Solid line indicates mean value, dashed lines indicate maximum and minimum values

BEDROCK GEOLOGY

The Quatsino map area, underlain by rocks ranging from Lower Cretaceous to Upper Triassic in age, is part of the Wrangellia Terrane. Thick sequences of Upper Triassic (Vancouver Group) and Lower Jurassic (Bonanza Group) volcanic and sedimentary rocks were intruded during Jurassic time by granitic plutons, and are overlain by Cretaceous (Kyuquot and Queen Charlotte groups) sediments. Common rock types in the Vancouver Group are Karmutsen Formation basalt and tuff, Quatsino Formation limestone and Parson Bay Formation siltstone, shale and greywacke. Andesitic to rhyodacitic lava and tuff of the Bonanza Group are coeval with several Island Plutonic granodiorite stocks which intrude lower Mesozoic sequences (Massey and Melville, 1991). Muller *et al.*, (1974) described the major structural architecture of northern Vancouver Island as being dominated by fault-bound blocks each with essentially homoclinal southwesterly dipping strata. Northwest-trending faults may result from a late Cretaceous or Tertiary dextral transpressive regime (Massey and Melville, 1991).

MINERAL DEPOSITS

The diversity of rock types, magmatic activity, structural settings and the distribution of known metal mineralization in the project area suggest a high potential for a variety of mineral deposits. Fifty-eight mineral occurrences are known in the Quatsino map area, ranging from showings to past-producing mines (MINFILE 092L/102I, Vanderpohl and Hume, 1989): Table 1 lists their distribution by deposit type.

Known mineralization in the Quatsino area includes (Massey and Melville, 1991):

- Fe-Cu-Mo-Zn-Pb-Au skarns hosted in the upper Karmutsen and Quatsino formations.
- Cu-Mo-Au porphyry stockworks hosted by Bonanza Group volcanics.
- Pb-Zn mantos and Cu-Ag replacement bodies associated with Quatsino and Parson Bay limestones.
- Epithermal to mesothermal, shear-hosted quartz carbonate veins in Karmutsen Formation diabase and basalts hosting Au, Ag, As, Sb and Hg mineralization.

Further, the potential for epithermal gold deposits and sediment-hosted Carlin-type precious metal deposits has been suggested by a number of authors (Perello, 1987; Massey and Melville, 1991). The presence of Au-Ag-Cu bearing acid-sulphate deposits transitional between porphyry and epithermal systems has been suggested by Perello (1987) and Panteleyev (1992).

Deposit type	Commodities	Number
Vein	Cu, Pb, Zn, Ag	22
Skarn	Zn, Pb, Au, Ag, Fe, Cu	14
Porphyry	Cu, Au, Ag, Mo, Fe	6
Replacement	Cu, Ag, Au, Zn, Pb	5
Volcanogenic	Cu	1
Other/unknown	Cu, Fe	9

Table 1 - Mineral deposits of the Quatsino map area, by deposit type

GEOCHEMICAL ORIENTATION

INTRODUCTION

The goal of an orientation survey is to provide information which will maximize the effectiveness of a geochemical survey. The objective of this orientation study was to ascertain the size fraction which provided the maximum anomaly/background contrast for the detection of the principal deposit types known in the region.

The Island Copper Cu-Mo-Au porphyry deposit was selected as the site for the orientation survey. Although not representative of all the potential deposit types in the region, Cu-Mo-Au porphyries are the most sought after deposit type and have an extensive distribution throughout the map area. Located along the eastern border of the 92L/12 map sheet, the Island Copper mine began operation in 1971 with estimated reserves of 257 million tonnes averaging 0.52 % copper, 0.017 % molybdenum (Cargill *et al.*, 1976) and an average gold grade of 0.22 ppm (Perello *et al.*, 1989). Mineralization resulted from the intrusion of a rhyodacite porphyry body into the surrounding mid-Jurassic Bonanza Volcanics (Perello *et al.*, 1989). Pyrite, chalcopyrite and molybdenite are the principal sulphide minerals; sphalerite and galena occur erratically within and peripheral to the ore zone, whereas bornite has been observed in negligible quantities within the deposit (Cargill *et al.*, 1976). Generally, chalcopyrite occurs as veinlets, on slickenside surfaces and as disseminated grains, whereas molybdenite is found primarily on slickenside surfaces (Cargill *et al.*, 1976). Gold in the deposit occurs as particles averaging $1.5 \times 2.5 \mu\text{m}$ (microns) in size (Gabelman and Hanusiak, 1986) with approximately half the gold residing as inclusions in chalcopyrite, pyrite, molybdenite and silicates (Perello *et al.*, 1989).

Drift cover in the vicinity of the Island Copper mine consists primarily of a veneer of colluviated till overlying a blanket of till (Kerr and Sibbick, 1992). Thickness of these deposits is highly variable, ranging from one to seventy-five metres in thickness (Witherly, 1979). A geochemical soil survey carried out over the deposit reported copper values ranging from less than 10 ppm to over 1000 ppm (Witherly, 1979). Copper concentrations exceeding 200 ppm were found to overlie the approximate centre of the orebody in tills less than

nine metres in thickness (Cargill *et al.*, 1976). Several other anomalous zones exceeding 200 ppm copper were found to be associated with significant, but subeconomic, mineralization (Witherly, 1979).

METHODOLOGY

Till samples were obtained from the vicinity of the Island Copper mine during the regional sample collection program. In total, 36 samples were collected within an area which extends up to eight kilometres down ice (west) of the deposit. Samples collected from the 92L/12 map area were incorporated into the Quatsino survey dataset. Till samples were collected from roadcuts at an approximate density of one sample per square kilometre. To avoid contamination, the outer 20 centimetres of the roadcut was removed before sampling. Average sample depth was 240 centimetres. Collected samples, ranging from 3 to 10 kilograms in weight, were shipped to the Analytical Sciences Laboratory of the British Columbia Geological Survey Branch for further processing.

In the laboratory, samples were removed from their plastic bags and air dried at 30°C. After drying, each sample was disaggregated and a representative split taken for sieving. Each split was weighed then dry sieved to +4000 μm , -4000+2000 μm , -2000+250 μm , -250+125 μm , -125+63 μm and -63 μm size fractions. If sieving produced insufficient -63 μm material, additional splits were dry sieved to produce a minimum of 25 grams of -63 μm sediment. Several samples yielded considerably less than this amount. The +4000 μm , -4000+2000 μm and -2000+250 μm fractions were stored for future reference. The -250+125 μm and -125+63 μm fractions were wet sieved to remove any adhering fines, then dried at 30°C. After drying, the -250+125 μm fraction was ball milled in a tungsten-carbide ball mill. Representative splits of each of the three (-250+125 μm , -125+63 μm and -63 μm) size fractions were submitted for *aqua regia*-inductively coupled plasma emission spectroscopy (ICP-ES) and instrumental neutron activation (INA) analysis.

RESULTS AND DISCUSSION

Summary results of sieved fraction weights of the -2000 μm fraction are shown in Table 2. All fractions provided more than the desired 25 grams of sediment with the exception of four -63 μm fraction subsamples. The paucity of silt-clay material in these

	Weight (grams)			
	<2000+250	<250+125	<125+63	<63
Min	215.6	59.6	26.6	8.4
Max	645.5	340.6	119.7	98.1
Mean	344.4	155.1	71.3	43.9

	Weight (percent of total)			
	<2000+250	<250+125	<125+63	<63
Min	36.7	12.3	6.0	1.5
Max	77.8	38.9	18.2	15.0
Mean	56.8	24.6	11.5	7.2

Table 2 - Weight distribution by size fraction

samples is probably due to either a lack of fines in the original sample, or the tendency of silt-clay sized material to adhere to coarser fragments. Grain size distributions, calculated on the total <2000 μ m fraction weight, indicate that the proportion of material contributed by each fraction decreases with decreasing grain size (Figure 3). On average, the <2000+250 μ m fraction constitutes approximately 57 percent of the total sample weight whereas the <250+125 μ m fraction composes 25 percent, the <125+63 μ m fraction 11 percent and the <63 μ m fraction approximately 7 percent (Table 2). Based on the minimum yield weight of each sample size fraction, approximately 1700 grams of <2000 μ m material is required to insure a yield of 25 grams for each size fraction (Table 3).

The elements antimony, arsenic, barium, cadmium, copper, gold, lead, molybdenum and zinc were evaluated for the orientation survey. These elements were considered to represent the most prevalent forms of mineralization to be found within the Quatsino map area. Antimony, arsenic, barium, gold and molybdenum were analysed by instrumental neutron activation (INA) whereas cadmium, copper, lead and zinc were analysed by *aqua regia* - inductively coupled plasma emission spectrography (ICP-ES). Summary statistics of these results are shown in Table 4. Due to the small number of samples (n=36), median and quartile (25th and 75th percentiles) values were favoured over means and standard deviations as more reliable estimators of the dataset. Median element concentrations

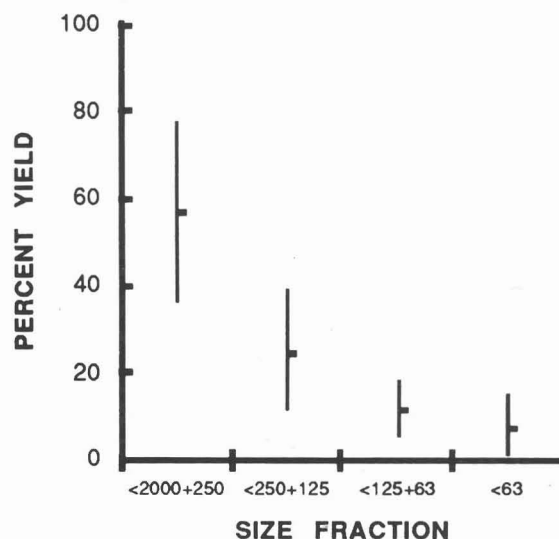


Figure 3 - Variation in proportion of till by size fraction. Mean value represented by tick, range by vertical line

are greatest within the <63 μ m fraction and generally lowest within the <125+63 μ m fraction. Median values are near or at detection limits for cadmium, gold and molybdenum in the <250+125 μ m fraction and for gold and molybdenum in the <125+63 μ m fraction. In the <63 μ m fraction, the median values for all elements were above detection limit with the exception of molybdenum.

Size Fraction	Minimum Weight	Total <2000 μ m weight	Percent Yield	Required <2000 μ m weight
<2000+250	215.6	516.0	36.7	59.8
<250+125	59.6	368.5	12.3	154.5
<125+63	26.6	426.4	6.0	400.2
<63	8.4	563.6	1.5	1681.0

Table 3 - Minimum weights of <2000 μ m material required to yield 25 grams of each size fraction

Contrast, a measure of the separation between anomalous and background populations, was estimated using a ratio of the 75th and 25th percentiles (Figure 4). Comparing each size fraction, contrast ratios are nearly identical for barium, copper and zinc. Of the remaining six elements, arsenic, gold, lead and molybdenum have higher contrast

	<250+125			<125+63			<63		
	Med	25%	75%	Med	25%	75%	Med	25%	75%
Sb	0.5	0.3	0.7	0.5	0.4	0.6	1.0	0.7	1.3
As	6.0	3.9	9.0	6.3	3.6	9.4	17.5	9.7	30.0
Ba	410	310	470	330	280	400	490	400	550
Cd	0.3	0.2	0.6	0.6	0.2	0.9	1.0	0.5	1.6
Cu	87	51	109	65	48	94	128	86	165
Au	2	2	4	2	2	3	11	4	20
Pb	6.5	3.0	13.0	6.5	4.0	13.0	15.0	9.0	40.0
Mo	1	1	1	1	1	1	1	1	2
Zn	69.0	51.0	112.0	58.5	48.0	112.0	94.0	69.0	147.0

Table 4 - Median (Med), 25th percentile (25%) and 75th percentile (75%) values for selected elements

ratios in the -63 μ m fraction, antimony in the -250+125 μ m fraction and cadmium in the -125+63 μ m fraction. In general, the -63 μ m fraction provides the best overall contrast.

Based on the results of this orientation survey, the -63 μ m fraction was selected as the medium for analysis. It affords the maximum contrast between anomalous and background concentrations while also providing higher overall concentrations than the -250+125 μ m and -125+63 μ m fractions. This is in agreement with till geochemistry studies carried out in eastern Canada, which suggest using the finest available fraction (either the -63 μ m or the -2 μ m fraction) to provide maximum anomaly contrast (Shelp and Nichol, 1987; Coker, 1991).

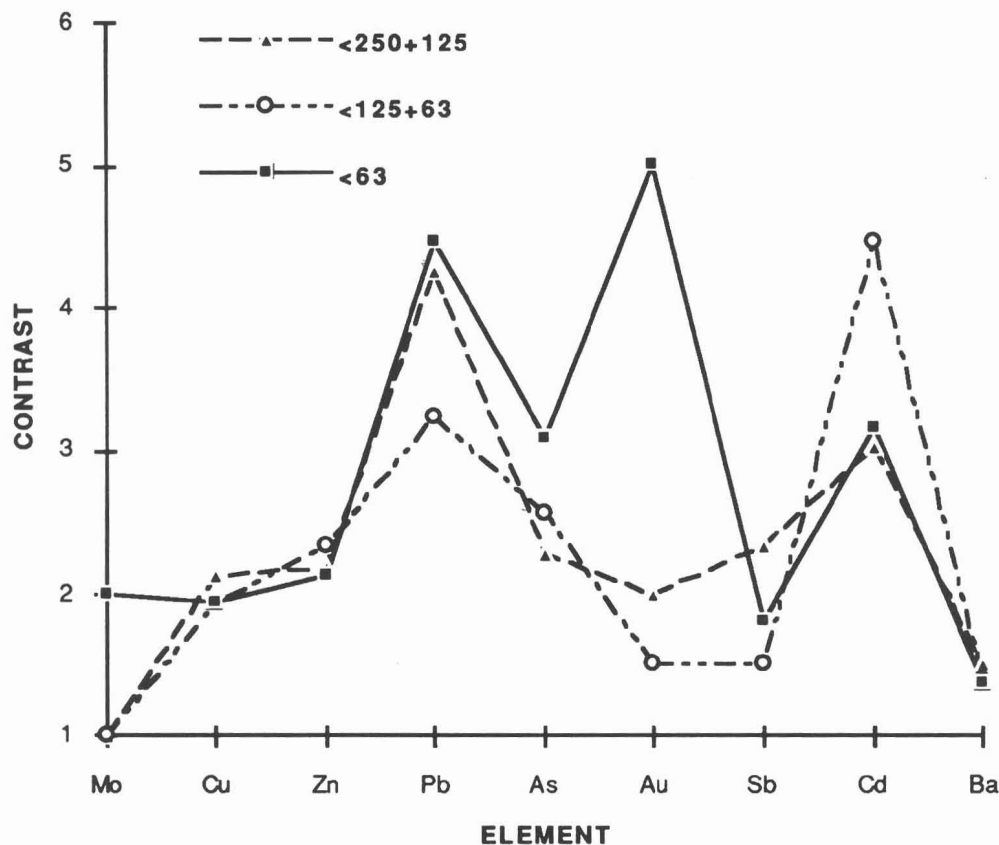


Figure 4 - Contrast ratios for selected elements, by size fraction

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

SAMPLE COLLECTION

Drift sample collection was carried out during the summer of 1991 over the 960 square kilometre survey area. Access was mainly by logging road, and by traverses on foot along streams which provided subsurface exposure. A helicopter was used to gain access to some isolated locations. Sampling for the Quatsino project consisted of 194 drift samples collected across the map area from road cuts, hand-dug pits and stream banks, at an approximate density of one sample per 5 square kilometres (see Appendix A-61). The unoxidized C-horizon, commonly 1 to 2 metres below the surface, was sampled where ever possible. Many till samples were taken at depths of 3 to 4 metres below the surface from stratigraphic sections in which till was overlain by colluvium or outwash.

SAMPLE PREPARATION

Till samples from the Quatsino map sheet were allowed to dry in the field and shipped to the Analytical Sciences Laboratory of the British Columbia Geological Survey Branch for further processing. All samples were removed from their plastic bags and air dried at 30°C. After drying, each sample was disaggregated and a quarter-split taken for sieving. Each quarter-split was weighed then dry sieved to +4000µm, -4000+250µm, -250+63µm and -63µm size fractions. If sieving produced inadequate amounts of -63µm material, additional quarter-splits were dry sieved to produce sufficient -63µm sediment for analysis. The +4000µm, -4000+2000µm and -2000+250µm fractions were stored for future reference. Representative splits of the -63µm fraction were taken for inductively coupled plasma emission spectroscopy (ICP-ES) and instrumental neutron activation (INA) analysis.

SAMPLE ANALYSIS

Subsamples for inductively coupled plasma emission spectroscopy (ICP-ES) were submitted to Acme Analytical Laboratories, Ltd. in Vancouver, B.C. and subjected to an aqua regia (3HCl:1HNO₃:2H₂O) digestion followed by analysis for aluminium, antimony, arsenic, barium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, gold, iron, lanthanum, lead, magnesium, manganese, molybdenum, nickel, phosphorous, potassium, silver, sodium, strontium, thorium, titanium, tungsten, uranium, vanadium, and zinc. Reported detection limits are shown in Table 5. Subsamples for instrumental neutron activation (INA) analysis were submitted to Activation Laboratories, Ltd. in Ancaster, Ontario for analysis of: antimony, arsenic, barium, bromine, calcium, cerium, cesium, chromium, cobalt, europium, gold, hafnium, iridium, iron, lanthanum, lutetium, mercury, molybdenum, neodymium, nickel, rubidium, samarium, scandium, selenium, silver, sodium, strontium, tantalum, terbium, thorium, tin, tungsten, uranium, ytterbium and zinc. Reported detection limits are shown in Table 5.

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Method			Method			Method			Method		
INA		ICP	INA		ICP	INA		ICP	INA		ICP
Sb	0.1	2	Co	1	1	Hg	1	na	Sr	500	1
Al	na	0.01%	Cu	na	1	Mo	1	1	Ta	0.5	na
As	0.5	2	Eu	0.2	nd	Nd	5	na	Tb	0.5	na
Ba	50	2	Fe	0.02%	0.01%	Ni	20	1	Th	0.5	2
Bi	na	2	Au	2 ppb	2	P	na	0.001%	Sn	100	na
B	na	2	Hf	1	na	K	na	0.01%	Ti	na	0.01%
Br	0.5	na	Ir	5 ppb	na	Rb	5	na	U	0.5	5
Cd	na	0.2	La	0.1	2	Sm	0.1	na	V	na	2
Ca	1%	0.01%	Pb	na	1	Sc	0.1	na	W	1	1
Ce	3	na	Lu	0.05	na	Se	5	na	Yb	0.2	na
Cs	1	na	Mg	na	0.01%	Ag	5	0.2	Zn	50	1
Cr	5	1	Mn	na	1	Na	0.01%	0.01%			

Table 5 - Detection limits by analytical method. na = not analysed

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