

ASPECTS OF STREAM-SEDIMENT AND WATER SURVEYS IN NORTHERN LABRADOR

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ABSTRACT

During 1991 and 1992, stream-sediment and stream-water follow-up surveys were conducted in selected areas of northern Labrador. The principal commodities targeted include gold, base metals, platinum-group elements (PGE), and granophile elements. Analytical data from the 1991 stream survey are discussed. Anomalous concentrations of several elements in sediment were found including gold, arsenic, chromium, copper, nickel and zinc, which are comparable to levels encountered elsewhere in mineralized areas. In many cases, stream-sediment and stream-water data yield different dispersion patterns for a given element, due in part to the contrasting effect of pH on mobility of elements in sediment and water. Data from the two media might be most useful when evaluated together. New sulphide mineralization was discovered and sampled during the field work. Several rock samples from these areas have anomalous levels of copper, nickel, cobalt and arsenic and high background levels of gold.

INTRODUCTION

This report presents some of the results of a two-year geochemical survey project in northern Labrador. Results of the 1991 program were released on open file (McConnell and Honarvar, 1993) and results of the entire project will be available later in 1993. Stream-sediment, panned-concentrate, stream-water and rock samples were collected in areas where previous reconnaissance-scale lake-sediment and stream-sediment surveys indicated elevated metal values, where detailed sampling had not been conducted and where, in the event of significant mineralization being discovered, access to coastal shipping seemed economically feasible. The project was undertaken to encourage mineral exploration in this little-explored area of the province by increasing our knowledge of geochemical dispersion patterns related to bedrock and mineralization. Mineral deposits targeted in the study include those of Au, Cu, Ni, Zn, W, Mo and platinum-group elements.

Field work was conducted in July and August of 1991 and 1992 and involved the collection of 630 stream-sediment, 378 water, 115 panned-concentrate and 75 rock samples. Analyses of the 1992 stream samples are presently underway. Geochemical results presented here are from the 1991 stream samples and from rock samples from both years.

LOCATION, ACCESS AND MINERAL-RIGHTS DISPOSITION

The survey area is shown in Figure 1. Sampling was done in the following NTS map areas: 14E (8, 9, 13 and 16), 14F

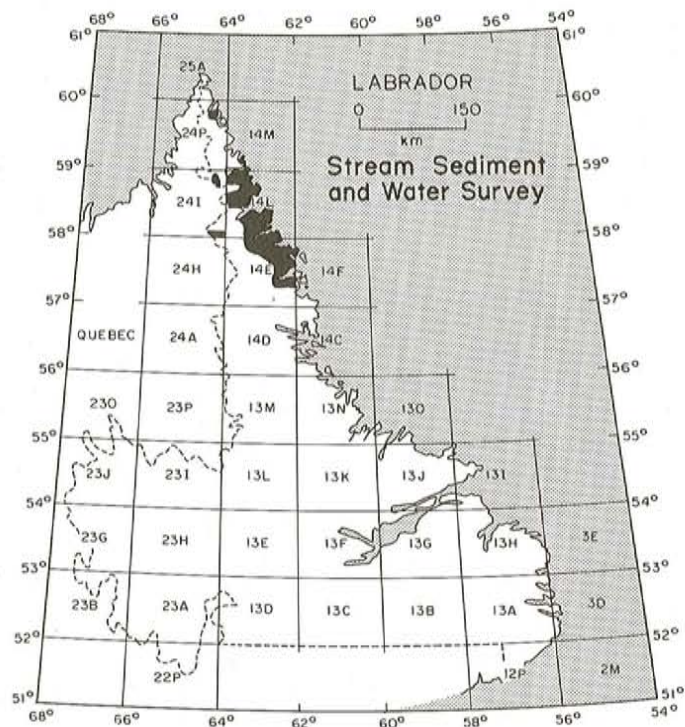


Figure 1. Index map of follow-up stream surveys.

(12 and 13), 14L (1, 2, 3, 4, 6, 7, 10, 12, 13, 14 and 15), 14M/3, 24I/1, 24I/16 and 24P/16.

The area is remote and access is more expensive than on the island portion of the province but can be moderated by advanced planning. The field project was helicopter-supported from base camps in Hebron Fiord and Ramah Bay (Steckler River). Happy Valley—Goose Bay is the closest major supply centre although Nain can provide essential foodstuffs and some equipment needs. Sea transportation (Marine Atlantic) to Nain from Goose Bay is inexpensive and generally begins in early July and runs to late October depending on ice conditions. An air strip suitable for fixed-wing use is located at the radar base in Saglek, which is central to the area. Permission to use it can be readily obtained from the Department of National Defence in Ottawa. Float plane, wheeled aircraft and helicopters are all available for charter in Goose Bay. Nain has regularly scheduled Twin-Otter service from Goose Bay. Fishing boats can be chartered in Nain to position fuel, campstuffs or personnel along the coast. The area normally is navigable from mid-July to late fall.

All of the area is crown land and most of it is available for prospecting. Exploration rights to land in this part of the province can be obtained easily and inexpensively by map staking.

PREVIOUS GEOCHEMICAL WORK

Geochemical surveys have been made in the area by both government and industry. The first recorded is a stream-sediment survey focussing on Zn mineralization conducted by Esso Minerals over most of the Ramah Group of supracrustal rocks in NTS map area 14L (MacLeod, 1984, 1985).

A reconnaissance lake-sediment and water survey was conducted by the Geological Survey of Canada in the southern part of the present follow-up area in 1985 (Hornbrook and Friske, 1986) encompassing NTS map areas 14M, 24P, 25A and the southern half of 14L and 24I. Sample density was one per 13 km². Sediment was analyzed for 17 elements plus loss-on-ignition. Analyses included Ag, As, Cd, Co, Cu, F, Fe, Hg, Mn, Mo, Ni, Sb, U, V and Zn. Lake water was analyzed for F, U and pH. In 1986, a reconnaissance geochemical survey using the same sample density was made in northern Labrador in which, because of the scarcity of lakes, samples of stream sediment and stream water were collected (Hornbrook and Friske, 1987). Stream sediment was analyzed for the same elements as lake sediment plus Au, Ba, Sn and W. As with lakes, stream waters were analyzed for F, U and pH. To facilitate comparison of results from the two sample media, both lake and stream samples were taken in the southern half of NTS map areas 14L and 24I.

DESCRIPTION OF FIELD AREA

Except for the extreme south, the area is above the tree line affording easy access. Outcrop is abundant particularly toward the coast. Relief is moderate to extreme. The most rugged topography is found in the central part of the survey

area particularly between Saglek and Nachvak fiords, where the Torngat Mountains reach their maximum elevations. The highest point is Cirque Mountain in NTS map area 14L/13, nearly a mile high at 5144 feet (1568 m). Till cover is thin to absent. The absence of glacial erratics at high elevations suggest that at least some of the higher mountains escaped glaciation. Generally, however, the area was subjected to continental glaciation with ice movement being predominantly from west to east.

Most of the sampling was done in the Nain Province and some in the Churchill Province. Rocks of the Nain Province are characteristically Archean quartzofeldspathic gneiss with lesser amounts of metavolcanic and meta-sedimentary supracrustal rocks and derivatives of mafic and ultramafic intrusives (Bridgewater *et al.*, 1978). Apebian diabase dykes intrude much of area. Metamorphic grade ranges from amphibolite in the east to granulite in the west. Basement rocks in sampled drainage basins of the Churchill Province are typically granulite-facies paragneiss and orthogneiss.

The stratigraphically similar Ramah and Mugford groups have been correlated by Smyth and Knight (1978). They consist of sedimentary and volcanic rocks preserved as remnants of a Lower Proterozoic cover sequence on the Nain Craton. The Ramah Group, metamorphosed to amphibolite facies (Knight and Morgan, 1981; Morgan, 1975) has been explored for sediment-hosted exhalative deposits particularly along an extensive bed of massive pyrite and chert (MacLeod, 1984, 1985). To the north of the area surveyed by Esso Minerals, a few streams in the northern Ramah Group that had anomalous zinc in the reconnaissance survey were re-sampled in more detail in the current survey. The lower Mugford Group consists predominantly of fine-grained siliciclastic sediments, carbonates and pyrite beds overlain by submarine and subaerial mafic volcanic rocks, all metamorphosed to greenschist facies. The group forms the Kaumajet Mountains—a rugged and spectacular landmass rising precipitously from the sea along much of its length. Results of the stream survey over the Kaumajet Mountains will be released in 1993.

SAMPLE COLLECTION

During the 1991 field season, 250 stream-sediment, 115 panned-concentrate, 71 water and 30 rock samples were collected from areas that were considered to have above-average potential for gold, base-metal and PGE mineralization. Panned concentrates were taken from areas with gold and PGE potential and waters from areas targeted for base metals. During 1992, 380 stream sediment, 307 water and 45 rock samples were collected. No panned concentrates were obtained as preliminary interpretation of the 1991 data indicated little additional benefit was gained from this medium.

Sediment was typically collected from several locations in the stream bed at a given site using a spade and sieved through a 3 mm aluminum screen. A kraft-paper waterproof sample bag of fine material was obtained as the active

sediment sample. At each of nine locations in 1991, a pair of samples was collected (site duplicates) to obtain a measure of chemical variability by site. Where a panned concentrate was collected, approximately 3 or 4 l of the fine material was reduced on-site to about 30 to 50 g of heavy-mineral concentrate by means of a conical pan. Water samples were collected by filling in mid-stream, a clean, rinsed, 250 ml nalgene bottle. Waters were typically clear, colourless and free of visible organic or suspended matter. Fresh samples of representative bedrock and grab samples of mineralized rocks were taken at several locations.

SAMPLE PREPARATION

Samples of active stream-sediment were air-dried in the field, then returned to the departmental geochemical laboratory and oven-dried at 60°C. One in 20 was selected as a laboratory duplicate and split in a riffle splitter. Each sample was then sifted in a stainless-steel sieve to < 63 µm. The panned heavy-mineral concentrates were pulverized in an alumina shatterbox prior to analysis. One in twenty was split for a laboratory duplicate.

Following field determination of pH and total dissolved solids, the water samples were filtered through 0.45 µm filter paper using a manual vacuum pump and acidified with 2 ml of nano-pure HNO₃.

Rock samples were pulverized to <100 µm in a tungsten-carbide shatterbox in preparation for analysis.

ANALYTICAL METHODS

Stream-Sediment, Panned-Concentrate and Rock Samples

These samples were analyzed by several methods (Table 1) for the following elements: Ag, As, Au, Ba, Br, Ce, Co, Cr, Cs, Cu, Dy, Eu, Fe, Ga, Hf, La, Li, Lu, Mn, Mo, Nb, Na, Ni, Pb, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, U, V, W, Y, Yb, Zn and Zr. Some elements, notably Ag, Ba, Cd, Ce, Co, Cr, Cu, Fe, La, Mo, Ni, Pb, Rb, Sc, Th, Zn and Zr were analyzed by more than one method. Where one method gives superior data to another for a particular element, this is indicated in the table by an asterisk. If one type of data is less satisfactory than another for any purpose, it is indicated by parentheses, '()'. In some applications, one type of data may be more satisfactory than another. For example, if total iron content of the sample is sought, Fe1 or Fe2 should be used, whereas if acid-leachable iron (likely in large part ferric iron, which frequently accounts for adsorption of some trace elements) is of interest, Fe4 should be used. The numeric suffix following the element name (e.g., Ba1) indicates the analytical method and is used consistently throughout the report. As a check on accuracy and precision, a standard sample of known composition and a sample duplicate (split) were included in each batch of 20 samples. Analyses for a selection of these elements are listed in the appendix. The entire suite of field and analytical data are available upon request as an ASCII file on floppy disk.

Instrumental neutron-activation data (suffix '1') represent total analyses. These were performed by Becquerel Laboratories Limited. Samples were prepared for analysis by adding sufficient material to fill a vial (generally 5 to 10 g), which was then weighed, shrink-wrapped and sent to the laboratory where it was irradiated, left for a specific time and the resultant gamma-ray spectrum counted. The detection limit for gold in most sample materials by this method is 2 ppb.

Digestion procedures for the ICP-ES and AA total analysis (suffix '2') are described by McConnell (1993). This method gives total solution for most elements except Cr in chromite, Zr in zirconium and Ba in BaSO₄.

Details of the atomic-absorption analytical procedures are described in Wagenbauer *et al.* (1983). The digestion for the AA partial analyses, HNO₃/HCl (suffix '4'), gives complete solution for oxide- and sulphide-bound elements but is partial for silicate-bound phases. Note that rock samples were analyzed only for Cu, Ni, Pb and Zn by this method.

A separate digestion (HNO₃) was used prior to the AA analysis of silver. To avoid loss of silver as a chloride precipitate, HCl was not used in the digestion. This mode of analysis is identified in Table 1 as suffix '6'.

Five rock samples were analyzed for platinum and palladium (detection limits 5 ppb and 2 ppb respectively) by ICP-atomic fluorescence spectrometry following fire-assay by Chemex Labs Limited, Vancouver.

Stream-sediment samples were analyzed for their organic content as estimated by loss-on-ignition (LOI) following controlled heating to 500°C. Details of the method are provided by McConnell (1993).

Water

Water samples were analyzed for pH, total dissolved solids (TDS) and Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Si, SO₄, Y and Zn by the four methods summarized in Table 2. The ICP methods are treated in detail by Finch (*this volume*). Problems with instrumentation in the field resulted in incomplete sets of analyses for pH and TDS. The following suffixes are affixed to the element name to distinguish analytical methods for water: 'w1' for ICP-ES and 'w2' for ICP-ES-USN.

RESULTS AND DISCUSSION

STATISTICAL ANALYSIS

Summary Statistics

Medians, means, standard deviations and ranges are tabulated for the geochemical analyses of stream sediments and waters in Tables 3 and 4, respectively. A number of observations can be made concerning the sediment data in

Table 1. Analytical methods for stream-sediment, panned-concentrate and rock samples

ELEMENTS	METHOD	DIGESTION/ PREPARATION
(Ag ₁), As ₁ , Au ₁ , Ba ₁ , Br ₁ , Cel, Co ₁ , Cr ₁ , Csl, Eul, Fel, Hfl, La ₁ , Lu ₁ , Mol, Na ₁ , Nil, Rb ₁ , Sbl, Scl, Sml, Tal, Tbl, Th ₁ *, U ₁ , W ₁ , Ybl, (Znl), (Zrl)	Neutron Activation Analysis (INAA)	5-10 g in shrink-wrapped vial. (total analysis)
Ba ₂ , Be ₂ , Ce ₂ , Co ₂ , Cu ₂ , Dy ₂ , Ga ₂ , La ₂ , Li ₂ , Mn ₂ , Nb ₂ , Ni ₂ , Pb ₂ , Sc ₂ , Sr ₂ , (Th ₂), Ti ₂ , V ₂ , Y ₂ , Zn ₂ , Zr ₂ *	Inductively Coupled Plasma Emission Spectroscopy (ICP-ES)	HF-CHIO ₄ -HCL (total digestion)
Cd ₂ , Cr ₂ , Mo ₂ , Rb ₂	Atomic Absorption Spectroscopy (AA)	HF-HCIO ₄ -HCL (total digestion)
Cd ₄ , Co ₄ , Cu ₄ , Fe ₄ , Mn ₄ , Ni ₄ , Pb ₄ , Zn ₄ *	Atomic Absorption Spectroscopy (AA)	HNO ₃ -HCL (3:1) (partial digestion)
Ag ₆ *	Atomic Absorption Spectroscopy (AA)	HNO ₃

* Indicates preferred method of analysis.
() indicates less favoured method of analysis; use alternative.

Table 2. Analytical methods for stream waters

ANALYSIS	METHOD	PREPARATION
pH	Corning combination pH electrode	None
Total dissolved solids	Corning conductivity/TDS sensor	None
Ca_w1, Fe_w1, K_w1, Mg_w1, Mn_w1, Na_w1, SiO ₂ w1, SO ₄ w1	ICP-ES	Filtration (0.45 μm) and HNO ₃ acidification in field
Co_w2, Cr_w2, Cu_w2, Mo_w2, Ni_w2, Y_w2, Zn_w2	ICP-ES-USN	Filtration (0.45 μm) and HNO ₃ acidification in field

Table 3. Six elements have less-than-detection-limit values for most samples: Ag, Au, Cd, Mo, Sb and W. Variations in results for different analytical methods can be noted for many elements. For the three elements Co, Fe and Ni analyzed by both neutron activation (INAA) and aqua regia/AA, the median values of the INAA analyses are higher, often substantially. Neutron activation is considered to give total analyses whereas aqua regia/AA yields partial analyses for most elements. A comparison of data for the eight elements analyzed by ICP-ES and aqua regia/AA gives mixed results. Medians and ranges of Cd and Cu are nearly identical by both methods. The medians and maximums are higher by ICP-ES for Co, Fe, Mn, Ni and Pb. For Zn, however, the median by ICP-ES is substantially higher but the maximums are nearly identical suggesting that the zinc in the highest concentration samples is nearly all present in easily soluble form—that is, either as oxides or sulphides. Finally, for most of the ten elements analyzed by both INAA and HF-

HClO₄-HCl/ICP-ES (or AA), the results are similar, with INAA data generally being marginally higher. The best agreement is for Ba, Co, Ni, Rb and Sc. For Fe and Cr, the median values compare well but analyses of the upper end of the data ranges are considerably higher in the INAA data. For the rare-earth elements Ce and La, both median and upper-range values are considerably greater in the INAA data, suggesting that the HF-HClO₄-HCl digestion only partially dissolves the host minerals.

From the list of medians in Table 4, it is noted that 7 elements of the 14 element suite of water analyses have less-than-detection-limit results for most samples. These include Co, Cr, Cu, Mn, Mo, Ni and Y. No water samples had detectable Cr despite some stream-sediment samples having more than 4000 ppm. This absence in water likely reflects the refractory nature of most chromium-bearing minerals including chromite. All other base metals analyzed do have

Table 3. Medians, geometric means, log₁₀ standard deviations and ranges of 1991 stream-sediment data. Data for LOI are arithmetic. Data are in ppm unless otherwise noted (*n*=232)

ELEMENT	MEDIAN	MEAN	STD. DEV.	RANGE	
Ag6	<0.1	<0.1	0.20	<0.1	0.8
As1	0.50	0.58	0.62	<0.50	225
Au1, ppb	<2.0	<2.0	0.34	<2.0	28
Ba1	610	575	0.20	95	1600
Ba2	548	525	0.20	55	1378
Be2	0.9	1.0	0.16	0.3	2.0
Cd2	<0.1	0.1	0.37	<0.1	3.8
Cd4	<0.1	0.1	0.26	<0.1	4.0
Ce1	96	93	0.21	14	579
Ce2	71	71	0.15	13	303
Co1	26	26	0.19	7	93
Co2	24	25	0.19	1	89
Co4	7	7.4	0.34	2	56
Cr1	200	224	0.28	72	4480
Cr2	175	191	0.25	63	2527
Cs1	0.33	0.42	0.36	0.20	3.2
Cu2	32	32	0.33	1	202
Cu4	31	32	0.29	5	185
Dy2	5.7	5.4	0.21	0.6	15.9
Eu1	1.40	1.23	0.26	0.25	3.20
Fe1, %	7.9	7.9	0.14	2.9	24.1
Fe2, %	7.70	7.59	0.16	0.34	17.8
Fe4, %	1.36	1.41	0.22	0.48	8.34
Ga2	24	34	0.16	5	54
Hf1	14.0	14.8	0.29	1.8	101.0
La1	47	48	0.21	7	301
La2	34	34	0.16	6	132
Li2	14.2	16.2	0.20	4.7	79.1
Mn2, %	0.11	0.11	0.15	0.01	0.24
Mn4	83	83	0.38	17	621
Mo1	<5	<5	0.19	<5	58.5
Mo2	4	4.3	0.24	2	69
Na1, %	1.75	1.74	0.14	0.47	3.31
Nb2	7	8.3	0.38	1	80
Ni1	43	48	0.54	5	1880
Ni2	43	55	0.45	1	1756
Ni4	25	32	0.41	4	1060
Pb2	9	8.5	0.28	1	82
Pb4	1	2.1	0.37	1	73
Rb1	47	44	0.21	2	91
Rb2	42	41	0.15	14	93
Sb1	<0.05	<0.05	0.45	<0.05	7.98
Sc1	26.5	26.3	0.14	10.8	74.7
Sc2	26.6	26.3	0.15	1.9	58.4
Sm1	8.2	8.1	0.19	1.5	38.3
Sr2	213	200	0.18	40	446
Ta1	1.3	1.4	0.32	0.24	10.0
Tb1	1.1	1.1	0.21	0.33	4.1
Th1	14.8	14.8	0.33	2.5	211
Ti2	5740	6166	0.27	730	43470
U1	1.9	2.0	0.24	0.5	13.2
V2	144	155	0.19	13	736
W1	<2.0	<2.0	0.16	<2.0	7.2
Y2	33	31	0.23	4	90
Yb1	3.1	3.0	0.28	0.20	13.0
Zn2	116	117	0.16	16	775
Zn4	35	39	0.28	11	780
Zr2	135	132	0.20	18	590
LOI, %	1.9	2.1	1.14	0.4	8.1

Table 4. Medians, geometric means, log₁₀ standard deviations and ranges of analytical data from stream water samples. Data are in ppb unless otherwise noted (*n*=66)

ELEMENT	MEDIAN	MEAN	STD. DEV.	RANGE	
Ca_w1, ppm	0.55	0.68	0.44	0.15	33.06
Co_w2	<1	1	0.26	<1	4
Cr_w2	<1	<1	-	<1	<1
Cu_w2	<1	1	0.37	<1	11
Fe_w1	5	6	0.49	<5	102
K_w1,	100	200	0.53	<100	13500
Mg_w1,	204	269	0.46	61	19370
Mn_w1	<2	1	0.26	<2	8
Mo_w2	<1	<1	0.22	<1	3
Na_w1, ppm	0.83	0.81	0.30	0.16	4.77
Ni_w2	<2	2	0.44	<2	35
SiO ₂ _w1, ppm	1.1	1.2	0.32	0.2	8.2
Si_w1, ppm	0.51	0.56	0.32	0.09	3.84
SO ₄ _w1, ppm	1.0	1.5	0.44	0.4	152.2
Y_w2	<0.5	<0.5	0.05	<0.5	0.5
Zn_w2	5.1	5.5	0.20	2.0	40

a reasonable range of values particularly Zn, and even Cu and Ni have detectable concentrations in sufficient samples to be of use.

Summary statistics for the 115 panned-concentrate samples are not included here but the trends and analytical comparisons described above for the sediment data are very similar (McConnell, 1993). The data in the upper ranges of values of heavy-mineral elements (e.g., As, Au, Cr, Fe, REEs, W, etc.) are generally two- to ten-fold higher in the concentrates than the sediments.

Correlation Analysis

Spearman (ranked) correlation analysis was performed on all stream-sediment data. A matrix of correlation coefficients of elements of exploration interest is given in Table 5. Three types of relationships are worth noting. The first type is the one between the same element by two analytical methods. Three elements, Cu, Ni and Fe are analyzed by two methods. Correlation coefficients between Cu2 and Cu4 (0.96) and Ni2 and Ni4 (0.92) are very strong, particularly for copper, indicating either type of data will give similar patterns. However, there is no significant correlation between Fe2 and Fe4 (0.08).

The significance of the lack of correlation between Fe2 and Fe4 is apparent in the second type of relationship, i.e., that between the trace elements and Fe4, LOI and Mn4, or what might be considered environmental factors. The ability of (hydr)oxides of Fe and Mn to scavenge trace elements has been well documented and is apparent in these data. Several elements are moderately to strongly correlated with Fe4 (i.e., >0.4): As1, Co4, Cu2, Cu4, Ni2, Ni4, Pb4 and Zn4. Correlations of these elements with Mn4 are similar although coefficients of Co4, Ni2 and Ni4 with Mn4 are considerably stronger and coefficients of As1, Cu2, and Cu4 are

Table 5. Spearman correlation coefficients of selected 1991 stream sediment data ($N=232$)

ELEMENT	As1	Au1	Co4	Cr1	Cu2	Cu4	Fe2	Fe4	LOI	Mn4	Mo2	Ni2	Ni4	Pb4	Sb1	Zn4
As1	1.00	0.30	0.38	0.00	0.50	0.51	0.07	0.47	0.35	0.31	0.33	0.26	0.32	0.42	0.49	0.36
Au1	0.30	1.00	-0.04	-0.07	0.38	0.41	0.30	0.16	0.07	-0.09	0.33	-0.10	0.00	0.07	0.12	-0.01
Co4	0.38	-0.04	1.00	0.32	0.49	0.52	-0.09	0.79	0.33	0.93	0.11	0.83	0.86	0.59	0.40	0.87
Cr1	0.00	-0.07	0.32	1.00	0.06	0.04	0.10	0.20	-0.12	0.34	-0.24	0.53	0.54	0.27	-0.09	0.16
Cu2	0.50	0.38	0.49	0.06	1.00	0.96	0.20	0.61	0.27	0.36	0.45	0.36	0.48	0.43	0.32	0.50
Cu4	0.51	0.41	0.52	0.04	0.96	1.00	0.23	0.65	0.25	0.38	0.49	0.34	0.48	0.43	0.32	0.53
Fe2	0.07	0.30	-0.09	0.10	0.20	0.23	1.00	0.08	-0.34	-0.17	0.37	-0.24	-0.07	-0.03	-0.03	-0.12
Fe4	0.47	0.16	0.79	0.20	0.61	0.65	0.08	1.00	0.36	0.74	0.38	0.61	0.64	0.51	0.37	0.79
LOI	0.35	0.07	0.33	-0.12	0.27	0.25	-0.34	0.36	1.00	0.35	0.16	0.47	0.37	0.23	0.23	0.54
Mn4	0.31	-0.09	0.93	0.34	0.36	0.38	-0.17	0.74	0.35	1.00	-0.00	0.84	0.79	0.57	0.41	0.84
Mo2	0.33	0.33	0.11	-0.24	0.45	0.49	0.37	0.38	0.16	-0.00	1.00	-0.12	0.01	0.21	0.15	0.13
Ni2	0.26	-0.10	0.83	0.53	0.36	0.34	-0.24	0.61	0.47	0.84	-0.12	1.00	0.92	0.50	0.31	0.76
Ni4	0.32	0.00	0.86	0.54	0.48	0.48	-0.07	0.64	0.37	0.79	0.01	0.92	1.00	0.53	0.30	0.77
Pb4	0.42	0.07	0.59	0.27	0.43	0.43	-0.03	0.51	0.23	0.57	0.21	0.50	0.53	1.00	0.43	0.54
Sb1	0.49	0.12	0.40	-0.09	0.32	0.32	-0.03	0.37	0.23	0.41	0.15	0.31	0.30	0.43	1.00	0.43
Zn4	0.36	-0.01	0.87	0.16	0.50	0.53	-0.12	0.79	0.54	0.84	0.13	0.76	0.77	0.54	0.43	1.00

Note: Coefficients $> |0.15|$ are significant at the 99% confidence level.

considerably stronger with Fe4. All of these elements have weak or no correlations with total iron (Fe2). LOI has weaker correlations with the trace elements than do Fe4 and Mn4, the strongest being 0.54 with Zn4.

The third type of relationship is between pairs of trace elements where several elements have moderate to strong positive correlations. Much of this is attributable to mutual correlation with Fe4 and Mn4 described above. For example, the modest 0.38 correlation between As1 and Co4 is likely due largely to both elements being strongly correlated with Fe4. However, stronger correlations such as Co1-Ni4 (0.54) and Cu4-Mo2 (0.49) likely reflect primary metal associations. One intriguing correlation is Au1-Cu4 (0.41) suggesting that higher gold concentrations may occur in areas with higher background levels of copper.

Spearman coefficients between selected stream-sediment data with stream water data and pH in water with stream-water data are given in Table 6. In general, there is either no correlation or only a negative correlation between a given element in sediment and in water. For example, the following are coefficients between aqua regia/AA analyses in sediment and the same element in water: Co (-0.49), Cu (0.04), Fe (0.19), Mn (-0.49), Ni (-0.32) and Zn (-0.06). This lack of correlation between the two media may be explained in part by the effect of pH. The elements with negative auto-correlations (Co, Mn, Ni and Zn) have negative correlations with pH in water data and positive correlations with pH in sediment data as shown in Figure 2. Thus, a pH that favours precipitation in sediment also discourages solution in water. As a result, one would not expect to find similar distribution patterns for one of these elements in the different sample media. This is shown elsewhere in the case of Ni (McConnell, 1993). Sediments from streams draining ultramafic lenses

north of Saglek Fiord have high Ni4 values but the corresponding water values are below detection limit. However, clastic dispersion of weathering sulphides might yield Ni anomalies in sediment while at the same time producing acidic stream waters, hence mobile conditions for Ni in water. Thus, a sulphide deposit might be distinguished geochemically from a silicate source by the presence of anomalies in both media.

Regression Analysis

In an effort to remove the effects of the strong correlations of some elements in the stream-sediment data with Fe4, Mn4 and LOI, linear-regression analysis was performed on the base metals Cu4, Ni4 and Zn4 (SPSS Inc., 1988) using \log_{10} transformed data. Since Fe4 and Mn4 are themselves strongly correlated ($r=0.74$), Mn4 was not included in the regression analysis. Loss-On-Ignition correlates only weakly with Cu4 ($r=0.25$) thus was not included in the regression analysis for Cu4. Standardized residuals were calculated and are plotted and discussed more fully elsewhere (McConnell, 1993). Generally, the patterns of the raw data and residual data are similar and are best evaluated in conjunction with each other rather than relying exclusively on either type of distribution pattern. The lack of knowledge of mineral resources, or bedrock metal contents in the area, inhibits an empirical evaluation of the effectiveness of the regression analyses in reflecting mineralization.

Site Duplicates

Nine pairs of site duplicate samples were collected in 1991. A comparison of the analytical results of these duplicates indicates that most elements have very similar concentrations

Table 6. Spearman correlation coefficients between selected 1991 stream sediment and water data and pH and water data

ELEMENT	pH	TDS	Ca_w1	Co_w2	Cu_w2	Fe_w1	K_w1	Mg_w1	Mn_w1	Mo_w2	Na_w1	Ni_w2	SiO ₂ _W	SO ₄ _w1	Zn_w2
As1	0.34	0.44	0.48	-0.26	-0.08	0.14	0.47	0.33	-0.30	0.04	0.29	-0.18	-0.12	0.12	-0.05
Au1	-0.15	0.65	0.27	0.10	0.13	-0.10	0.02	0.26	0.22	0.16	0.13	0.30	0.27	0.47	0.28
Ba1	-0.53	-0.17	-0.28	0.47	0.25	0.04	-0.61	-0.09	0.39	-0.13	-0.33	0.41	0.41	0.22	-0.00
Cd4	0.20	0.58	0.46	-0.15	-0.23	0.07	0.38	0.42	-0.06	0.26	0.30	-0.06	0.01	0.36	0.13
Ce1	-0.46	-0.23	-0.19	0.44	0.49	-0.06	-0.46	-0.07	0.41	-0.31	-0.26	0.51	0.37	0.12	0.11
Co4	0.71	0.20	0.46	-0.49	-0.39	0.19	0.68	0.31	-0.46	0.19	0.39	-0.58	-0.42	-0.14	-0.04
Cr1	0.52	-0.30	0.31	-0.14	0.09	0.05	0.31	0.20	-0.04	-0.11	0.32	-0.09	-0.12	-0.05	0.13
Cu2	0.06	0.39	0.34	-0.04	0.07	-0.29	0.15	0.30	0.05	0.10	0.28	0.14	-0.03	0.27	0.21
Cu4	0.08	0.37	0.34	-0.04	0.04	-0.28	0.17	0.29	0.04	0.12	0.29	0.11	-0.05	0.26	0.21
Fe1	0.15	0.36	0.24	0.17	0.26	0.07	-0.03	0.36	0.30	-0.11	0.10	0.40	0.45	0.41	0.11
Fe4	0.67	0.38	0.47	-0.40	-0.38	0.19	0.61	0.30	-0.40	0.16	0.31	-0.55	-0.34	-0.10	-0.08
LOI	0.23	0.36	0.35	-0.17	-0.21	0.05	0.37	0.18	-0.16	0.10	0.18	-0.21	-0.14	0.07	-0.08
Mn4	0.68	0.35	0.51	-0.55	-0.39	0.19	0.74	0.33	-0.49	0.22	0.45	-0.61	-0.41	-0.11	-0.06
Mo2	0.50	0.40	0.59	0.02	-0.04	0.31	0.40	0.60	-0.09	0.21	0.47	-0.12	0.22	0.44	0.02
Ni2	0.72	0.12	0.52	-0.45	-0.35	0.17	0.73	0.31	-0.42	0.12	0.42	-0.53	-0.43	-0.15	0.01
Ni4	0.66	0.16	0.52	-0.33	-0.20	0.13	0.58	0.38	-0.30	0.04	0.38	-0.32	-0.26	0.00	0.04
Pb2	-0.08	0.47	0.33	0.25	0.24	0.03	0.00	0.35	0.26	0.09	0.09	0.32	0.40	0.48	0.10
Pb4	0.57	0.40	0.58	-0.38	-0.14	0.07	0.63	0.46	-0.26	0.13	0.52	-0.31	-0.21	0.13	0.09
Sb1	0.08	0.55	0.41	-0.11	-0.10	0.05	0.29	0.42	-0.14	0.16	0.41	-0.07	0.02	0.28	0.13
Sc2	-0.37	-0.09	-0.23	0.37	0.44	-0.13	-0.50	-0.06	0.40	-0.25	-0.19	0.59	0.52	0.28	0.08
U1	-0.39	0.45	0.10	0.19	0.13	-0.21	-0.21	0.30	0.34	0.13	0.24	0.43	0.29	0.47	0.26
W1	0.27	0.37	0.23	-0.15	-0.11	-0.06	0.16	0.23	0.07	0.03	0.14	0.05	0.00	0.18	0.05
Yb1	-0.48	0.50	-0.08	0.38	0.40	-0.08	-0.43	0.07	0.42	-0.24	-0.23	0.65	0.58	0.41	0.03
Zn2	-0.06	0.44	0.28	0.09	0.28	-0.05	0.02	0.34	0.19	0.03	0.11	0.39	0.37	0.48	0.11
Zn4	0.62	0.36	0.46	-0.38	-0.28	0.10	0.61	0.31	-0.42	0.13	0.34	-0.45	-0.28	-0.02	-0.06
pH_w	1.00	N.D.	0.52	-0.39	-0.28	0.41	0.72	0.41	-0.44	0.04	0.54	-0.52	-0.17	-0.07	-0.16

Note: For all coefficients except those with pH and TDS, N=69 and values $> |0.28|$ are significant at the 99% confidence level.

For pH, N=39 and coefficients $> |0.37|$ are significant at the 99% confidence level.

For TDS, N=31 and coefficients $> |0.42|$ are significant at the 99% confidence level.

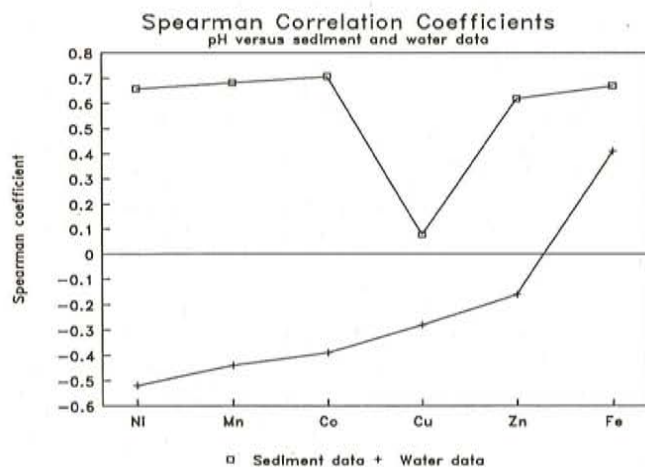


Figure 2. Correlation coefficients of pH with sediment and water data.

in both samples. An important exception is gold, which has no significant correlation among the nine pairs. This lack of reproducibility, despite using a very fine fraction ($< 63 \mu\text{m}$), is due to the 'nugget effect' and is particularly pronounced in stream-sediment data in comparison with results from lake sediment (McConnell and Davenport, 1989) or even soil (McConnell and Honarvar, 1990). Scatterplots of the site duplicate data for Au1, Cu4, Ni4, Zn4, Fe4 and

Mn4 are shown in Figure 3. The Spearman correlation coefficients are also shown.

Cumulative Frequency Plots

Figure 4 illustrates the distribution of Au1, Cr1, Cu4, Ni4 and Zn4 in stream sediment. Inflection points in the curves separate sub-populations. There appear to be distinct populations for Au > 8 ppb, Cr1 > 900 ppm, Cu4 > 120 ppm and Zn4 > 200 ppm. The distributions of Cu, Ni and Zn and SO₄ in the 66 water samples are also shown as cumulative frequency plots in Figure 4.

It is somewhat risky to compare absolute values in one area with those in another. Nonetheless, the highest values in stream sediment for some elements are of comparable magnitude to those found elsewhere in mineralized areas. These elements and highest values include As1 (225 ppm), Au1 (28 ppb), Cr1 (4480 ppm), Cu4 (185 ppm), Mo1 (59 ppm), Ni4 (1060 ppm) and Zn4 (780 ppm).

New Mineralization

During stream sampling, outcrops and boulders were prospected for sulphide mineralization. Mineralized samples were collected during both field seasons and analyzed for a variety of elements. Table 7 lists all samples meeting the following analytical criteria: As1 > 1000 ppm, Au1 > 20

SITE DUPLICATES

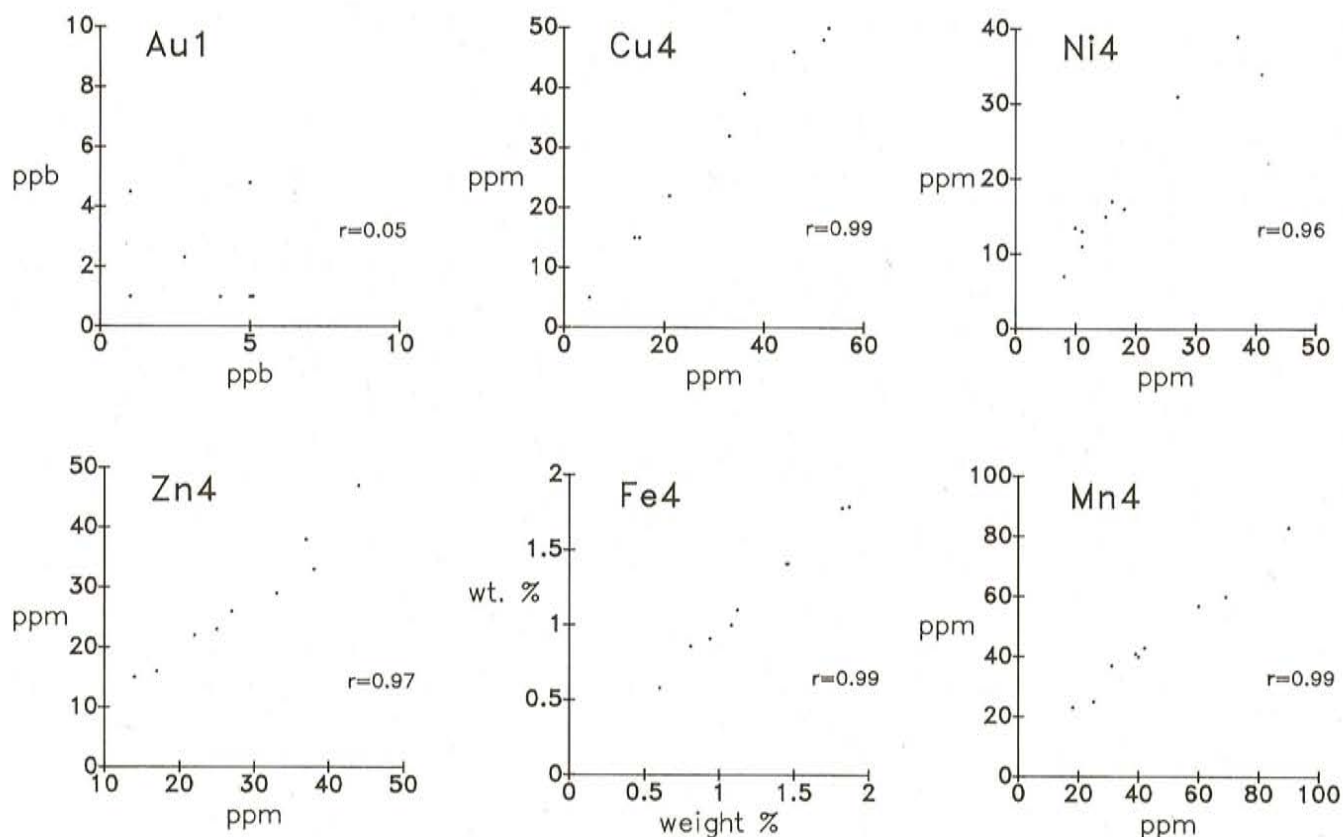


Figure 3. Scatterplots of analyses of nine site duplicates for Au, Cu4, Ni4, Zn4, Fe4 and Mn4.

ppb, Co1 >500 ppm, Cr1 >2000 ppm, Cu4 >1000 ppm, Mo2 >100 ppm and Ni4 >2000 ppm. Samples 6242005 and 6242010 were from one of the most visually impressive showings—a zone of disseminated to semi-massive sulphides outcropping for a strike length of about 200 m with a thickness of 1 to 1.5 m. The mineralization is located in paragneiss in the NTS map area 14L/02 just to the south of the mouth of Hebron Fiord. Sample 6242020 is from a similar mineralized zone about 1.5 km to the northwest. Another interesting sample is 6240016—a specimen of massive sulphides from the NTS map area 24I/16 in the Churchill Province. The sample is from an outcrop of unknown strike extension with a thickness of about 1.5 m.

Stream-Sediment-Data Presentation

As examples, the results of Au1 and Ni4 analyses of stream sediments from 60 sites from five follow-up anomalies sampled in 1991 in the Saglek area are shown as catchment-basin maps in Figures 5 and 6. More complete sets of maps of all the 1991 samples have been released previously (McConnell, 1993). The sediment analysis from a basin is depicted by pattern filling, the density of which, is proportional to the element level. The highest values are noted next to the basins. The two southernmost areas are Au anomalies, the small area northeast of Saglek Fiord is a

Au–Ni anomaly, the northeasternmost area was sampled because of high Ni contents in the east half and high gold values in the west half and the three basins in the north of the map were sampled for Au. The area of unpatterned basins in the northwest was sampled in 1992; sediment analyses from these are not available at the time of writing.

Only two of the five areas confirmed the anomalous gold analyses in the original reconnaissance samples (Figure 5). The highest gold analysis in the reconnaissance stream-sediment survey (50 ppb) was from the area to the south of Saglek Fiord from which no samples in the detailed survey returned detectable gold analyses. A 0.5-m-thick quartz vein was found outcropping in the stream near the original 50 ppb stream sample but no evidence of mineralization was seen. The area west of Saglek Fiord, underlain by Churchill Province gneisses, and the area north of Saglek Fiord, underlain by Nain Province gneisses and ultramafic rocks, both have several samples with detectable gold values including three of 8.9, 10 and 11 ppb.

Several follow-up samples from the reconnaissance nickel anomaly in Figure 6 have high Ni4 analyses (229 to 1060 ppm). These are almost certainly due to the presence of ultramafic rocks observed in the area. No sulphide mineralization was noted during the stream sampling.

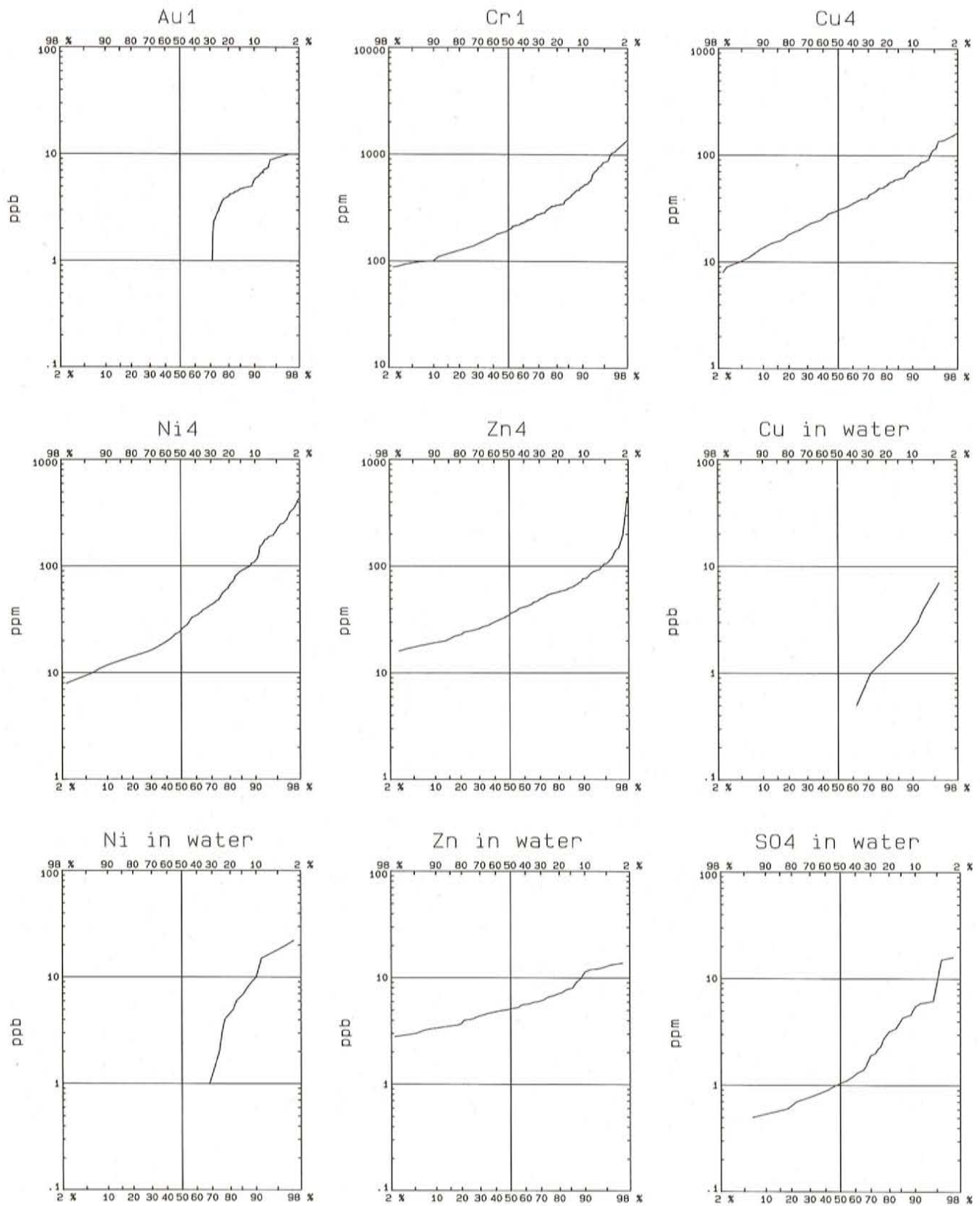


Figure 4. Cumulative frequency plots of Au1, Cr1, Cu4, Ni4 and Zn4 in stream sediment and Cu, Ni, SO₄ and Zn in stream water.

Table 7. Selected rock sample locations and analyses. Gold data in ppb, all others in ppm

SAMPLE NUMBER	NTS	UTM EAST	UTM NORTH	AsI	AuI	CoI	CrI	Cu4	Mo2	Ni4	Zn4	ROCK TYPE
6242005*	14L02	523550	6436740	.5	3.9	59	410	2657	7	170	71	Sulphide-bearing schist
6242010*	14L02	523550	6436740	.2	1.0	624	86	720	6	2023	78	Sulphide-bearing schist
6242015	14L02	523550	6436740	2.5	1.0	110	4820	23	6	869	45	Ultramafic pod
6242020*	14L02	522440	6438120	.2	8.3	140	60	1411	7	374	63	Sulphide-bearing schist
6242026	14L02	526960	6436890	.2	1.0	150	1900	13	3	2923	24	Ultramafic pod
6242034	14L02	501900	6437000	.2	1.0	45	2010	32	5	832	26	Carbonatized ultramafic
6242041	14L02	542470	6438200	.2	1.0	130	1800	3	4	2484	31	Ultramafic
6242042	14L02	542360	6441580	3440	18.0	94	640	369	6	635	112	Sulphide bearing gneiss
6240007	14L03	472600	6441200	.2	14.0	94	560	1148	4	461	11	Sulphide bearing gneiss
6240011	14L14	501350	6518510	.2	2.2	140	2210	12	1	2567	29	Ultramafic pod
6240014	14M03	474050	6544030	3.0	1.0	1	8	391	2	10	876	Probable quartz vein
6240015	14M03	474050	6544030	64.0	39.0	1	160	6	88	7	6	Graphitic schist
6240023	14M03	482750	6540500	.9	1.0	1	24	7201	1	5	9	Sulphide-bearing sandstone
6242039	14M03	542450	6565450	.2	1.0	120	1400	3	3	2007	43	Altered ultramafic
6240016	24I16	441590	6531150	2.9	39.0	170	77	59	143	467	11	Massive sulphides
6240032	24P16	421660	6643030	.2	1.0	100	2700	3	3	748	19	Ultramafic

* Samples 6242005, -10 and -20 are from extensive mineralized zones.

SUMMARY AND CONCLUSIONS

The highest values of some elements in the 1991 stream sediment data are comparable to those found elsewhere in mineralized areas. These include AsI (225 ppm), AuI (28 ppb), CrI (4480 ppm), Cu4 (185 ppm), Ni4 (1060 ppm) and Zn4 (780 ppm).

The usefulness of the water data suffers from the low-dissolved element concentrations resulting in less-than-detection-limit analyses for most samples for 7 of the 14 analyses performed. However, Cu, Ni, Zn and SO₄ all yielded a reasonable range of values.

Correlation analysis of stream-sediment data indicates that there is significant scavenging of the mobile species of the trace elements As, Co, Cu, Ni, Pb and Zn by hydroxides of Fe and Mn. Interpretation of these data may be enhanced by determining their residual values after regression against Fe and Mn. There is no positive correlation between analyses of an element in sediment and in water, due probably in large part to the effects of pH on solubility. Thus, one would not expect to find similar element patterns in the two media. An exception might be in the case of clastic dispersion of weathering sulphides that could produce both a stream-sediment anomaly as well as acidic waters that could give rise to a stream-water anomaly.

Several areas of sulphide mineralization were encountered during the follow-up stream sampling. Although 'ore grade' analyses were not obtained from grab samples, no thorough evaluation of mineralized zones was made and the new stream-sediment and water data may reflect additional mineralization.

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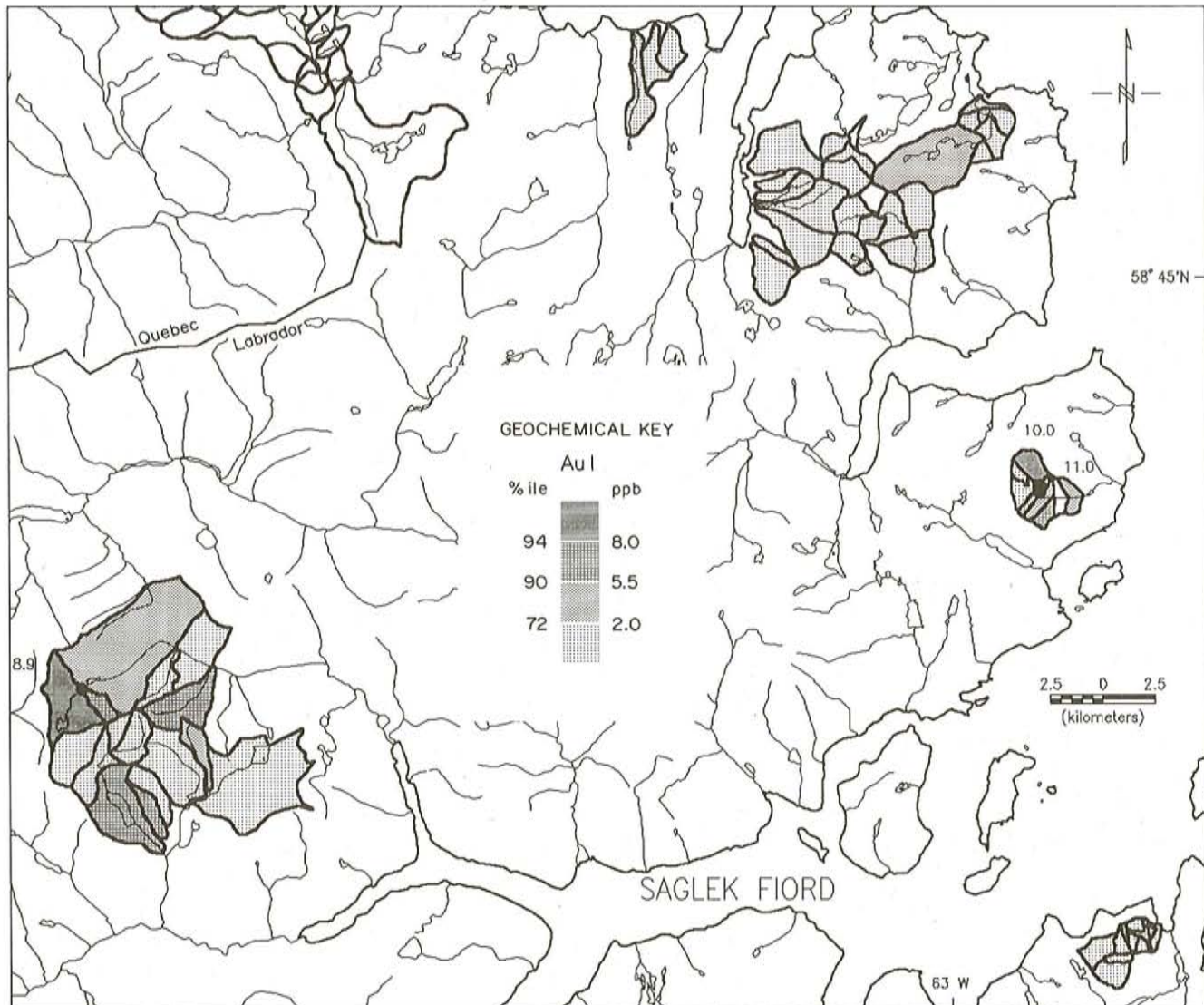


Figure 5. Gold (Au) in stream sediment in Saglek Fiord area.

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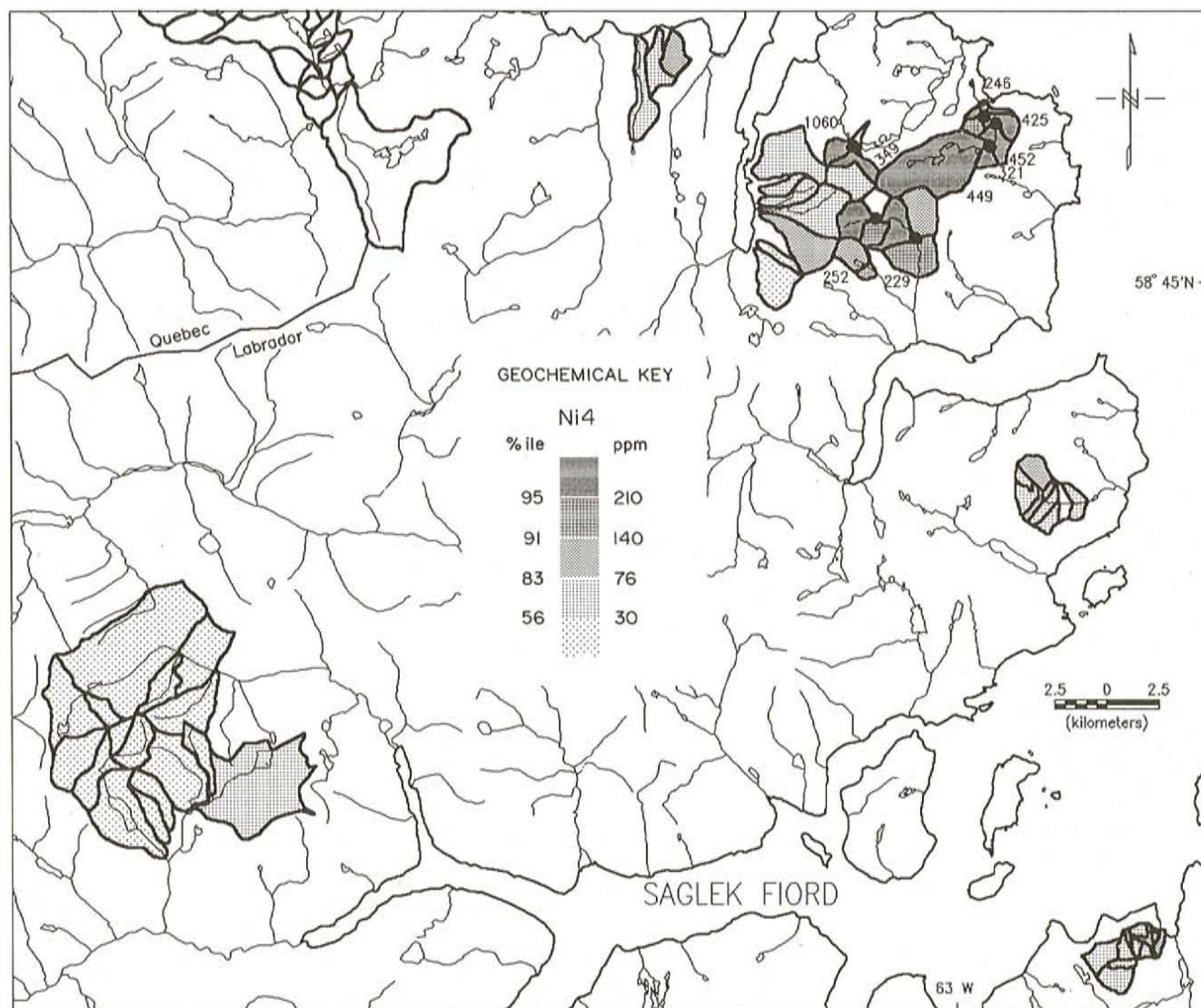


Figure 6. Nickel (Ni4) in stream sediment in Saglek Fiord area.

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