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SOIL AND STREAM GEOCHEMISTRY OF THE FLORENCE LAKE GREENSTONE BELT, LABRADOR

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ABSTRACT

During the summer of 1995, follow-up geochemical surveys, employing soil, stream water and stream sediment as sample media, were conducted over parts of the Archean Florence Lake greenstone belt in the Hopedale Block of the Nain Province. Previous regional lake-sediment surveys had identified areas having anomalous base-metal and gold values associated with portions of the belt. Earlier mineral exploration in the area had also found numerous minor sulphide showings and a few Ni–Cu occurrences. The follow-up survey was designed to identify areas with good mineral potential and conversely rule out areas with little potential. Soil samples were collected from approximately 650 sites, stream-water samples from 148 sites and stream-sediment samples from 41 sites. As part of the study, an orientation survey was conducted over the best known Ni mineralization in the area, the Baikie showing, to provide a demonstration of dispersion characteristics in the area. In addition, one day was spent in an area underlain by the Ballet Pond schists, to the east of the greenstone belt itself. Results of the survey indicate the presence of elevated values of Cu, Ni, Ag and As in soil samples. Some of these anomalies are remote from known mineralization. Anomalous values of base metals are also found in both stream-water and stream-sediment data, however, base-metal scavenging in the sediments by Mn and Fe (hydr)oxides is widespread and pronounced and makes data interpretation problematic. Follow-up studies over some of the soil anomalies are recommended.

INTRODUCTION

A geochemical follow-up survey (*see* McConnell, 1996) was conducted over most of the southern portions of the Florence Lake greenstone belt (Figures 1 and 2). The project was part of a multidisciplinary study to assess and document the mineral potential of the region. Bedrock mapping (James *et al.*, 1996a, b), mineral deposit studies (Miller, 1996) and Quaternary mapping (Batterson, 1996) were conducted during the same period. The objective of the multidisciplinary project is to provide the exploration industry with additional geoscience data to aid in focusing base-metal and gold exploration. The geochemical survey component of the project is designed to map the geochemical expression of most of the area underlain by rocks of the Florence Lake greenstone belt. In addition, a few soil and stream samples were collected from over the nearby Aphebian age Ballet Pond schists and metavolcanic rocks of the Makkovik Province. This latter area has several strong Cu anomalies in lake sediments.

PREVIOUS WORK

The first geochemical survey conducted in the Florence Lake area was a soil survey for Cu, Zn, U and Mo (Hansuld, 1959). He reported anomalous Cu values in the Knee Lake area. A stream-sediment and soil survey over portions of the greenstone belt was reported by Bondar (1963). Cold-extractable total heavy metals were analyzed on all samples, and cold-extractable Cu, Mo and Ni were analyzed for some samples. Highlights of the stream survey included Ni and Cu anomalies in the Schist Lakes (Benny and Klotz lakes) and Knee Lake areas. A further stream-sediment program in 1964 (Earthrowl, 1964) failed to define any strongly anomalous base-metal targets.

The Geological Survey of Canada, as part of a complete reconnaissance lake-sediment–water survey of Labrador, sampled the area in 1983 (Friske *et al.*, 1993a). They identified areas with anomalous base metals and subsequently included the NTS map areas 13K/10 and 13K/15 as part of a high density "in-fill" follow-up lake-sediment survey in 1992 (Friske *et al.*, 1993b). This survey confirmed, and gave further definition to, anomalous areas.

GEOLOGY

The most recent regional-scale (1:100 000) mapping of the area was reported on by Ermanovics (1993). He describes the area as being underlain by rocks of the Florence Lake greenstone belt consisting of Archean metavolcanic and meta-

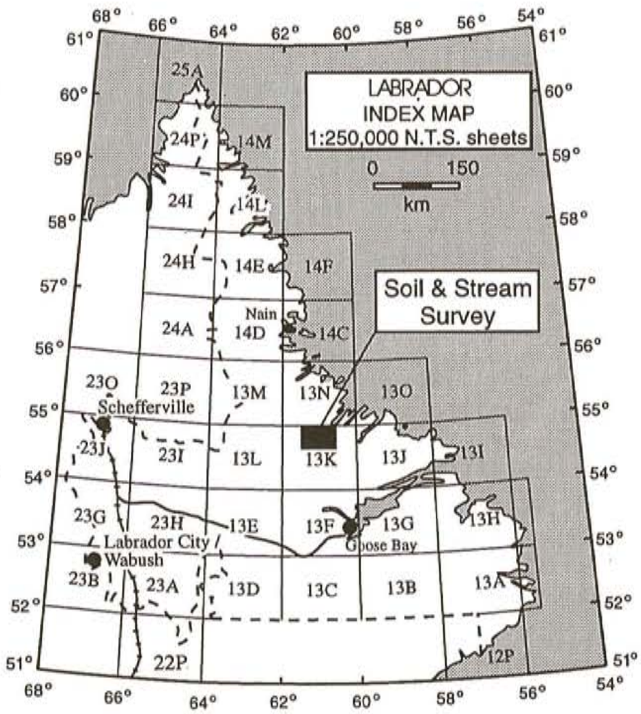


Figure 1. *Index map of study area.*

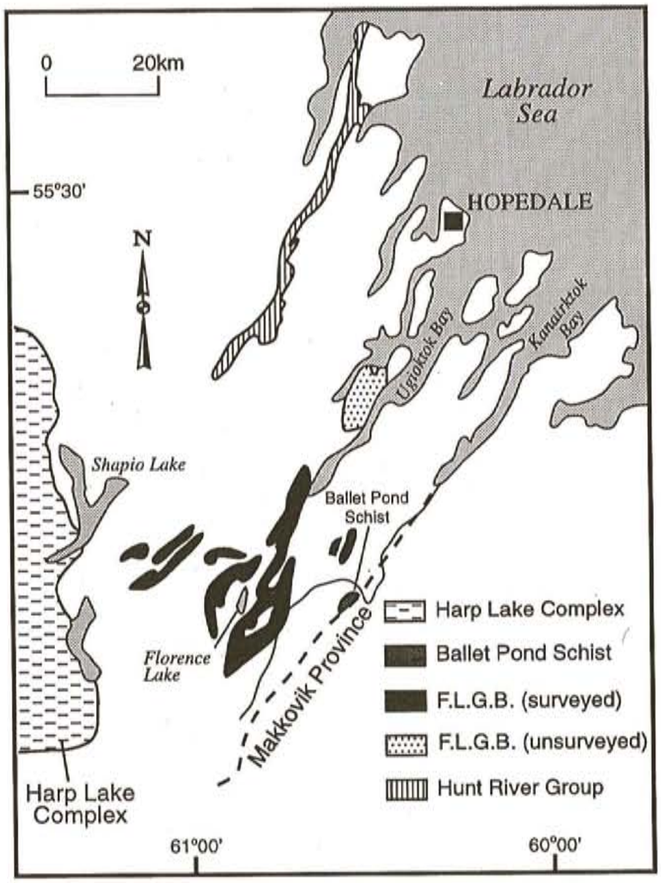


Figure 2. *Location of Florence Lake greenstone belt and site of the geochemical survey. (FLGB–Florence Lake greenstone belt.)*

sedimentary supracrustal rocks that are enclosed by predominantly felsic to intermediate intrusive rocks. The enclosing rocks are both older and younger than the greenstone belt rocks. More recently, the central and eastern parts of the belt have been re-mapped at scales of 1:25 000 and 1:10 000 (James *et al.*, 1996b) and (Miller, 1996). Working collaboratively, they have abandoned the nomenclature of Ermanovics (*op. cit.;* and the term Florence Lake group), and have subdivided the greenstone belt into five sub-belts and ten lithologic units. James *et al.* (1996a) describe the rocks as consisting primarily of greenschist- to amphibolite-facies mafic and ultramafic rocks, and lesser amounts of felsic and intermediate volcanic and volcaniclastic sedimentary rocks. The ultramafic rocks commonly occur as composite units that are interlayered with felsic and mafic volcanic rocks and local volcaniclastic sediments. The composite nature of these units and their stratigraphic continuity suggest they are extrusive in origin. Due to the polydeformed nature of the rocks, James *et al.* (*op. cit.*) were unable to define volcanic stratigraphy.

MINERALIZATION

The history of mineral exploration in this area extends back, at least, to 1959. Work through 1989 is well summarized by Brace (1990) and subsequent work by Miller (1996). Exploration activities have included stream and soil geochemistry, geophysics, diamond drilling and prospecting. The principal target has been Ni–Cu mineralization but others include asbestos, Cu–Fe, Cu–Zn, PGE and Au. Numerous examples of base-metal sulphide mineralization have been found. In addition to Ni and Cu, anomalous values of Pd–Pt have been reported from the Baikie showing (Reusch, 1987). The locations of mineral occurrences known prior to 1983 in the NTS map area 13K have been compiled at 1:250 000 scale by Harris and O'Driscoll (1983). Wilton (1996) makes brief mention of some mineral occurrences in the Florence Lake greenstone belt. Miller's (1995) work, although focusing on the plentiful distribution of ultramafic rocks in the sub-belts and their mineral potential, has up-to-date maps of all types of sulphide mineralization. He recognizes two principal groupings; Ni–Cu associated with ultramafic rocks and Fe–Cu (± Zn) associated with felsic volcanic rocks and volcanogenic sediments. He concludes that the ultramafic rocks in the Florence Lake greenstone belt exhibit many features characteristic of komatiitic flows similar to those found in the Kambalda nickel district of Australia. With particular reference to the Baikie showing, Miller (*op. cit.*) notes that Ni–Cu mineralization is found in altered ultramafic rocks, possibly komatiitic flows, with nearby sulphidic sediments– analogous to the Kambalda model. Sulphide mineralization consists of pyrrhotite–pyrite–pentlandite ± chalcopyrite. Grab samples assay 0.84 to 2.65% Ni and 0.01 to 0.07% Cu (Sutton, 1970; Brace and Wilton, 1990). Results of recent exploration drilling at the Baikie showing include intersections of 7.9 m assaying 2.02% Ni and 5.2 m assaying 2.35% Ni, 0.13% Cu and 0.05% Co.

SURFICIAL ENVIRONMENT

Regional surficial geological reports and maps have been published by Klassen and Thompson (1988, 1989, 1993) and Thompson and Klassen (1986). Working within this context and as part of the multidisciplinary approach to the Kanairiktok project, Batterson (1996) prepared 1:50 000-scale maps from aerial photographs with follow-up field checks; his report describes the ice-flow directions and Quaternary geology history.

During the Late Wisconsinan the surveyed area was completely covered by ice. Ice flow during this period was toward the northeast. In much of the area, a thin and discontinuous till cover overlies bedrock. The exceptions are the major river valleys that contain thick deposits of gravel, sand and mud of fluvial, glaciofluvial or marine origin. Marine limit in the study area is about 125 m asl. However, some areas below marine limit may have remained ice covered. Glacial sediments in these areas were not reworked by the sea. The landscape around Florence Lake, for example, contains no marine sediments despite being below this critical elevation. Over till-covered areas, glacial dispersal patterns are relatively simple with dispersal trains linear toward the northeast. In these areas, conventional drift-exploration techniques should be effective. Batterson (1996) cautions, however, that exploration within the major valleys requires consideration of a fluvial system where dispersal may be unrelated to ice-flow directions and transport distances greater. Drift exploration should be avoided in areas below marine limit that contain marine muds and near shore sand and gravel.

SAMPLE COLLECTION

Geochemical sampling was designed to identify areas of Florence Lake greenstone belt rocks enriched in base metals or gold. Approximately 650 soil, 148 stream-water, 41 stream-sediment and 28 rock samples were collected. Glacial flow from the southwest is likely to have developed geochemical dispersion trains trending northeasterly from any mineralized zones. Where possible, soil sampling was conducted along lines oriented at approximately right angles to glacial flow to maximize the likelihood of intersecting any dispersion trains. In several areas where the volcanic belts are very narrow and oriented nearly parallel to ice flow, this sampling strategy was impossible and sampling was conducted along the belt-axis or along what was regarded as the down-ice margin. Generally, soil samples were collected from the B-horizon at 200 m intervals along lines spaced 1 km apart. Additional high-density sampling was done over an area of known nickel mineralization (Baikie showing) to provide orientation data. Stream waters were collected in acid-washed, 250 ml nalgene bottles, particularly in areas unsuitable for soil sampling due to lack of till cover or extreme topographic relief. In some instances, stream sediment was sampled at the same site. Outcrops of typical bedrock as well as sulphide mineralization discovered during the field work were also sampled.

SAMPLE PREPARATION AND ANALYSES

Preparation

Soil and sediment samples were air dried in the field, then returned to the Geological Survey's 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 <180 μm. In the field, water samples were analyzed for conductivity, filtered through 0.45 μm filter paper using a manual vacuum pump and acidified with 2 ml of nano-pure HNO_3. Samples were then returned to St. John's for further analysis. Rock samples were pulverized to <100 μm in a tungsten–carbide shatterbox in preparation for analysis. As a check on quality control, a laboratory standard of known composition and a split of a sample were included within each batch, and were added to every batch of 20 rock, soil and sediment samples for quality control.

Analyses

Soil, stream-sediment and rock samples were analyzed for 43 elements plus loss-on-ignition. These elements and methods of analyses are tabulated in Table 1. Note that several elements (e.g., Cu, Fe, Pb, etc.) have been analyzed by more than one method. The reader should note whether the method is "partial" or "total" and then select the element/method combination desired.

Stream-water samples were analyzed for 21 elements, SO_4, conductivity and pH. These methods are summarized in Table 2.

DESCRIPTION AND DISCUSSION OF RESULTS

STATISTICAL ANALYSIS

Summary Statistics

To give an appreciation of the range and distribution characteristics of individual elements, tables are presented for soil (Table 3), stream-sediment (Table 4) and stream-water

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

ELEMENTS	METHOD	DIGESTION/ PREPARATION
(Ag), As, Au, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Ni, Rb, Sb, Sc, Sm, Ta, Tb, Th, U, W, Yb, (Zn), (Zr)	Neutron Activation Analysis (INAA)	5 to 10 g in shrink-wrapped vial (total analysis)
Ba, Be, Ce, Co, Cu, Dy, Ga, La, Li, Mn, Nb, Ni, Pb, Sc, Sr, Ti, V, Y, Zn, Zr*	Inductively Coupled Plasma Emission Spectroscopy (ICP-ES)	$HF-HClO_4-HCl$ (total digestion)
Cr, Mo	Atomic Absorption Spectroscopy (AA)	$HF-HClO_4-HCl$ (total digestion)
Cd, Co, Cu, Fe, Mn, Ni, Pb, Zn*	Atomic Absorption Spectroscopy (AA)	HNO_3-HCl (3:1) (partial digestion)
Ag*	Atomic Absorption Spectroscopy (AA)	HNO_3

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

To enable the user to readily distinguish the method of analysis for a given element, a suffix is attached to the element symbol when used in statistical summaries and appendices. The key to the suffixes is as follows:

1. Neutron activation analysis (INAA).
2. ICP-ES/after $HF-HClO_4-HCl$ digestion.
2. AA/after $HF-HClO_4-HCl$ digestion.
4. AA/after HNO_3-HCl (3:1) digestion.
6. AA/after HNO_3 digestion.

Thus, Zn4 is zinc analyzed by AA/HNO_3-HCL whereas Zn1 is zinc analyzed by INAA.

Table 2. Analytical methods for stream-water samples

ANALYSIS	METHOD	PREPARATION
pH	Corning combination pH electrode	None
Conductivity	Corning conductivity sensor	None
Ca, Fe, K, Mg, Mn, Na, Si, SO_4	ICP emission spectroscopy	Filtration (0.45 µm) and HNO_3 acidification in field
Al, Ba, Be, Co, Cr, Cu, Li, Mo, Ni, P, Sr, Ti, Y, Zn	ICP ultrasonic nebulizer	Filtration (0.45µm) and HNO_3 acidification in field

Table 3. Summary statistics, soil data for regional and Baikie samples (N=560 and N=82 respectively)

ELEMENT	MEDIAN		MEAN (Arithmetic)		MEAN (Geometric)		STANDARD DEVIATION		MINIMUM		MAXIMUM	
	Regional	*Baikie*	*Regional*	*Baikie*	*Regional*	*Baikie*	*Regional*	*Baikie*	*Regional*	*Baikie*	*Regional*	*Baikie*
Ag6	0.05	0.05	0.08	0.06	0.07	0.06	0.05	0.02	0.05	0.05	0.7	0.1
As1	1.5	3.2	4.2	31.4	1.6	4.7	15.4	150	0.2	0.7	185	1160
Au1, ppb	<1.0	<1.0	1.44	1.13	1.15	1.10	3.04	0.39	<1.0	<1.0	67	3
Ba1	470	510	485	538	468	525	110	127	25	260	1100	1100
Ba2	463	503	468	513	457	501	98	96	51	269	868	808
Be2	1	1	1.0	1.1	1.0	1.1	0.26	0.15	0.1	0.8	3.1	1.7
Br1	34	4.3	39.9	49.9	32.4	38.9	26.2	38.4	3.2	5.4	205	219
Cd4	<0.1	<0.1	0.1	0.1	0.1	0.1	0.05	0.00	<0.1	<0.1	0.6	0.1
Ce1	39	43	41.5	46.9	38.9	45.7	16.2	13.3	2	26	240	110
Ce2	40	40	42.2	43.2	39.8	42.7	16.2	10.3	6	32	271	100
Co1	10	10	11.0	11.5	10.2	11.0	4.78	4.00	2	4.8	38	26
Co2	11	11	11.4	12.0	10.5	11.5	4.88	3.97	1	7	48	27
Co4	5	5	5.9	5.5	5.1	4.9	3.48	2.86	1	2	27	17
Cr1	69	99	82.0	104	74.1	102	50.9	25.1	5	64	650	200
Cr2	54	78	62.1	82.2	56.2	81.3	39.0	18.7	2	51	537	167
Cs1	1	1	1.0	1.1	0.8	1.0	0.47	0.31	0.25	0.25	4.7	1.8
Cu2	14	20	18.0	27.2	14.8	21.9	14.9	22.0	3	7	120	133
Cu4	12	17	15.5	23.2	12.3	18.2	13.6	19.7	2	5	111	112
Dy2	2.1	2.1	2.1	2.2	2.0	2.1	0.62	0.45	0.1	1.5	7.6	4.3
Eu1	1.3	1.2	1.3	1.2	1.3	1.2	0.40	0.37	0.25	0.25	2.5	3.1
Fe1, wt. %	3.7	3.6	3.8	3.8	3.6	3.7	0.93	1.00	0.1	2.1	10	8.8
Fe2, wt. %	3.60	3.3	3.7	3.8	3.6	3.7	0.87	0.77	0.07	2.19	9.74	6.09
Fe4, wt. %	1.59	1.7	1.7	1.7	1.6	1.7	0.63	0.59	0.06	0.61	6.91	3.88
Ga2	18	18	18.4	18.2	18.2	19.1	4.33	3.35	1	12	38	32
Hf1	7.9	8.1	8.3	8.3	7.9	8.1	2.46	2.22	0.5	3.5	17	18
La1	19	19	19.5	19.9	18.6	19.5	6.19	5.52	1	12	97	49
La2	18	19	18.9	19.6	18.2	19.1	6.21	4.14	1	14	112	42
Li2	12	12.6	12.2	13.0	11.5	12.6	4.43	3.04	0.1	8	45.5	22.8
LOI	11.7	13.3	13.5	14.8	11.5	12.9	9.26	8.04	1.7	3.2	96.9	39.4
Mn2	431	460	442	468	427	457	154	112	11	285	3077	1179
Mn4	80	97	95.0	109	81.3	98	118	71	9	42	2530	625
Mo1	0.5	1	0.73	1.09	0.44	0.91	1.19	0.58	<0.2	<0.2	19	3.2
Mo2	<0.5	<1.0	0.61	0.55	0.54	0.52	0.74	0.32	<0.5	<0.5	14	3
Na1, wt. %	2.3	2.2	2.3	2.2	2.3	2.1	0.37	0.40	0.1	1.5	4.3	4.7
Nb2	8	8	8.5	8.6	8.1	8.3	2.23	1.71	1	4	24	14
Ni1	23	35	31.7	41.7	24.0	35.5	38.2	30.3	5	5	390	250
Ni2	20	29	27.5	37.7	21.4	32.4	33.3	30.9	4	14	347	261
Ni4	13	15	18.5	21.3	13.2	17.4	27.1	20.1	1	6	337	152
Pb2	9	9	9.1	9.5	8.1	9.3	5.20	2.10	1	6	81	18
Pb4	3	2	3.8	2.2	2.8	1.9	4.78	1.19	1	<1	80	7
Rb1	45	46	43.1	46.6	40.7	45.7	13.1	10.5	2	18	110	84
Sb1	0.1	0.1	0.11	0.08	0.05	0.05	0.21	0.07	<0.02	<0.02	2.9	0.41
Sc1	11.8	12.3	11.9	12.4	11.5	12.3	2.40	1.96	0.3	10	26.3	26.4
Sc2	10.2	10.9	10.3	11.0	10.0	11.0	1.99	0.95	0.2	9.3	24.9	13.6
Sm1	3.5	3.8	3.7	4.0	3.5	3.8	1.19	1.11	0.1	2.4	16.6	8.7
Sr2	233	222	238	225	234	224	48.6	36.9	20	124	393	305
Ta1	0.71	0.81	0.72	0.81	0.69	0.79	0.21	0.16	0.1	0.33	1.7	1.3
Tb1	<0.25	<0.25	0.36	0.36	0.33	0.32	0.18	0.18	<0.25	<0.25	1.7	1
Th1	4.1	4.4	4.3	4.8	4.1	4.7	1.37	1.30	0.2	2.8	10.3	11.2
Ti2	5176	5029	5265	5033	5129	5012	1100	779	68	3130	12437	6894
U1	1.2	1.2	1.2	1.3	1.1	1.3	0.93	0.35	0.1	0.8	19.8	3
V2	82	83	84.3	82.1	81.3	81.3	20.0	12.4	1	58	187	131
W1	<0.25	<0.25	0.27	0.30	0.26	0.27	0.23	0.28	<0.25	<0.25	4.9	2.4
Y2	12	12	12.7	13.0	12.3	12.9	3.33	2.47	1	9	43	26
Yb1	1.4	1.9	1.5	2.0	1.4	1.9	0.68	0.56	0.2	1.2	6.5	4.6
Zn2	42	41	43.3	44.6	41.7	42.7	13.3	18.20	19	28	150	180
Zn4	25	23	27.3	25.8	25.7	23.4	11.8	16.48	8	10	137	150
Zr1	230	320	241	317	219	295	98.7	99.4	50	50	670	650
Zr2	104	108	107	108	102	107	29.3	21.2	1	53	263	168

Note: data in ppm unless otherwise indicated.

Table 4. Summary statistics, stream-sediment data (N=39)

ELEMENT	MEDIAN	MEAN (Arithmetic)	MEAN (Geometric)	STANDARD DEVIATION	MINIMUM	MAXIMUM
Ag6	<.05	0.06	0.06	0.02	0.05	0.1
As1	5.6	101	6.92	321	0.59	1730
Au1, ppb	<1	1.66	1.32	1.65	1	8.5
Ba1	390	466	427	277	220	1700
Ba2	384	472	417	321	198	1908
Be2	1.1	1.2	1.15	0.3	0.8	2.1
Br1	22	23.8	19.1	14.2	3.6	51
Cd4	0.1	1.12	0.22	3.6	0.1	16.1
Ce1	33	47.8	40.7	39.5	17	240
Ce2	42	57.0	47.9	53.0	24	328
Co1	25	55.5	30.2	86.8	10	438
Co2	29	62.7	36.3	95.5	11	466
Co4	19	46.2	24.0	73.0	4	338
Cr1	140	159	132	113	32	680
Cr2	111	139	115	112	28	604
Cs1	1.3	1.51	1.32	0.85	0.25	4.1
Cu2	33	61.5	36.3	72.3	5	301
Cu4	31	53	30.9	62.8	4	252
Dy2	2.7	3.74	3.02	4.32	1.8	26.6
Eu1	1.3	1.19	1.00	0.56	0.25	2.2
Fe1, wt. %	5.6	5.91	5.37	2.55	2.3	12.1
Fe2, wt. %	6.76	6.81	6.31	2.83	2.65	15.63
Fe4, wt %	3.79	3.76	3.24	2.09	0.63	11.1
Ga2	20	18.6	19.5	6.73	1	28
Hf1	8.3	7.74	6.76	3.15	0.5	15
La1	19	20.8	19.5	7.21	10	36
La2	19	20.5	19.5	6.38	11	38
Li2	25.8	31.6	28.2	17.77	11.3	84.5
Mn2	1114	7799	1820	22941	555	126990
Mn4	407	6253	759	19758	74	107000
Mo1	2.0	5.12	1.32	8.18	0.2	34
Mo2	3.0	5.33	2.45	7.37	0.5	28
Na1, wt. %	2.4	2.41	2.29	0.65	0.46	4.31
Nb2	8	7.95	7.24	3.54	2	21
Ni1	56	92.2	61.7	114	5	645
Ni2	57	86.4	63.1	96.6	17	553
Ni4	38	63.9	42.7	86.4	10	503
Pb2	17	24.4	17.0	32.3	4	204
Pb4	12	20.6	12.6	32.0	2	202
Rb1	45	47.9	42.7	19.0	2	98
Sb1	0.15	0.35	0.17	0.60	0.02	2.9
Sc1	16	16.8	15.8	5.60	8.4	30.9
Sc2	14.2	15.5	14.8	5.32	6.2	31.1
Sm1	3.5	3.91	3.72	1.27	2.1	6.6
Sr2	222	208	195	64.3	67	333
Ta1	0.78	0.75	0.65	0.41	0.1	2.7
Tb1	0.50	0.47	0.41	0.23	0.25	0.92
Th1	3.5	3.92	3.63	1.6	1.7	7.4
Ti2	5269	5369	5012	1704	1009	8633
U1	2.7	4.23	2.95	4.72	0.9	26
V2	136	136	129	37.6	63	223
W1	0.25	0.37	0.30	0.37	0.25	1.9
Y2	15	16	15.5	4.39	7	27
Yb1	1.5	1.61	1.45	0.66	0.2	3.5
Zn2	116	202	129	314	45	1628
Zn4	81	180	95.5	337	23	1700
Zr1	190	193	155	112	50	450
Zr2	91	90.3	81.3	38.1	30	178

Note: data in ppm unless otherwise indicated.

data (Table 5). Because the population of many elements is more nearly log-normal than arithmetic, the geometric (log) mean as well as the arithmetic mean is given.

Correlation Analysis

Correlation coefficients for selected elements in the regional soil data are given in Table 6. Correlations for all

Table 5. Summary statistics, stream-water data (N=148, except N=98 for pH)

ELEMENT	MEDIAN	MEAN (Arithmetic)	MEAN (Geometric)	STANDARD DEVIATION	MINIMUM	MAXIMUM
Al	83	92.30	83.18	43.94	23	260
Ba	<2	2.99	2.63	2.07	1	16
Be	<0.05	0.05	0.05	0.02	<0.05	0.2
Ca, ppm	3.5	3.75	2.88	2.44	0.58	10.7
Co	0.5	0.65	0.60	0.29	0.5	2
Cr	0.5	0.65	0.62	0.23	0.5	1
Cu	2	1.97	1.66	1.29	1	7
Fe	26	33.39	26.30	25.76	5	154
K, ppm	0.3	2.34	0.33	17.47	0.1	209.5
Li	<0.5	0.61	0.51	1.36	<0.5	17
Mg, ppm	0.31	0.51	0.35	0.74	0.10	6.08
Mn	2	2.93	2.19	2.15	1	10
Mo	1	0.83	0.78	0.35	0.5	3
Na, ppm	0.78	0.91	0.83	0.98	0.47	12.44
Ni	<1	2.18	1.51	3.1	<1	30
P	5	50.74	4.90	426.83	2	5111
Si, ppm	0.8	1.01	0.79	0.71	0.1	3.1
SO_4, ppm	1.2	1.39	1.23	1.4	0.5	17.2
Sr	5.5	6.54	5.62	4.06	1.5	26.2
Ti	<0.5	0.62	0.56	0.43	<0.5	5
Y	<0.2	0.20	0.20	0.02	<0.2	0.4
Zn	1.3	1.75	1.35	1.74	0.2	13.7
pH	6.51	6.52		0.33	5.06	7.01
Conductivity, μS	27.0	31.40	26.92	17.39	7.2	97.9

Note: element data in ppb unless otherwise noted.

Table 6. Spearman correlation coefficients for regional soil data (N=560)

	Ag6	As1	Au1	Co4	Cr1	Cu2	Cu4	La1	Li2	Mo2	Ni2	Ni4	Pb4	Sb1	Y2	Zn4
Ag6	**1.00**	0.05	-0.05	-0.03	0.02	-0.10	-0.12	-0.03	0.05	0.07	0.00	-0.05	0.19	0.10	-0.02	-0.03
As1	0.05	**1.00**	0.20	0.51	0.57	0.47	0.46	0.16	0.66	0.03	0.53	0.50	0.28	0.70	0.32	0.43
Au1	-0.05	0.20	**1.00**	0.22	0.19	0.23	0.22	0.02	0.22	-0.02	0.24	0.24	-0.11	0.21	0.14	0.15
Co4	-0.03	0.51	0.22	**1.00**	0.42	0.54	0.53	0.12	0.66	-0.03	0.71	0.80	-0.11	0.44	0.39	0.62
Cr1	0.02	0.57	0.19	0.42	**1.00**	0.35	0.33	0.05	0.51	0.01	0.77	0.68	0.19	0.39	0.13	0.39
Cu2	-0.10	0.47	0.23	0.54	0.35	**1.00**	0.97	0.32	0.53	0.10	0.44	0.49	-0.01	0.29	0.48	0.47
Cu4	-0.12	0.46	0.22	0.53	0.33	0.97	**1.00**	0.33	0.48	0.08	0.40	0.47	-0.02	0.24	0.46	0.47
La1	-0.03	0.16	0.02	0.12	0.05	0.32	0.33	**1.00**	0.25	0.10	-0.01	-0.01	0.17	0.11	0.78	0.15
Li2	0.05	0.66	0.22	0.66	0.51	0.53	0.48	0.25	**1.00**	0.08	0.63	0.58	0.21	0.49	0.48	0.61
Mo2	0.07	0.03	-0.02	-0.03	0.01	0.10	0.08	0.10	0.08	**1.00**	0.03	-0.01	0.13	0.02	0.09	0.08
Ni2	0.00	0.53	0.24	0.71	0.77	0.44	0.40	-0.01	0.63	0.03	**1.00**	0.93	0.04	0.42	0.23	0.54
Ni4	-0.05	0.50	0.24	0.80	0.68	0.49	0.47	-0.01	0.58	-0.01	0.93	**1.00**	-0.05	0.38	0.22	0.59
Pb4	0.19	0.28	-0.11	-0.11	0.19	-0.01	-0.02	0.17	0.21	0.13	0.04	-0.05	**1.00**	0.23	0.03	0.17
Sb1	0.10	0.70	0.21	0.44	0.39	0.29	0.24	0.11	0.49	0.02	0.42	0.38	0.23	**1.00**	0.26	0.28
Y2	-0.02	0.32	0.14	0.39	0.13	0.48	0.46	0.78	0.48	0.09	0.23	0.22	0.03	0.26	**1.00**	0.28
Zn4	-0.03	0.43	0.15	0.62	0.39	0.47	0.47	0.15	0.61	0.08	0.54	0.59	0.17	0.28	0.28	**1.00**

Note: Correlations >|0.13| are significant at the 99.9% confidence level.

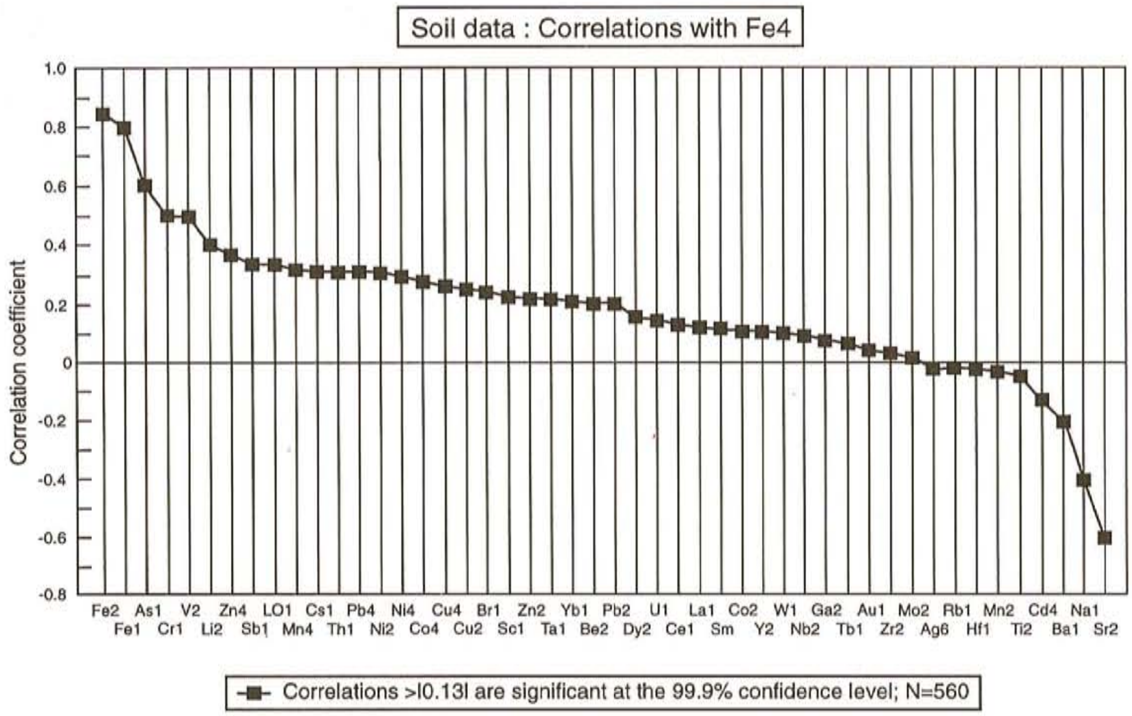


Figure 3. *Correlation of soil data with iron (Fe4).*

soil data with the environmental factors Fe4 and Mn4 are shown in Figures 3 and 4, respectively. In Table 6, As correlates strongly with Sb and moderately with Cr, Ni, Cu and Zn. Gold shows weak correlations but is strongest with Ni, Cu, Sb and As. Nickel correlates strongly with Cr and Co. Aqua regia soluble iron (Fe4) shows only weak to moderate correlations with most elements (Figure 3). The strongest are with As, Cr and V and strongly negative with Sr. Correlations of elements with Mn are considerably stronger than with Fe (Figure 4) – Co4, Ni4, Zn4 and Li2 show this in particular. Correlations with loss-on-ignition (not shown) are generally weak to moderate; exceptions include Br (0.75), Fe (0.35), Rb (−0.42) and Na (−0.60). These observations suggest that, with the possible exception of scavenging of Co, Ni and Zn by Mn hydroxides, interpretation of soil anomalies need not correct for environmental factors.

Correlation coefficients for selected elements in the stream-sediment data plus Cu, Ni and Zn in stream water are given in Table 7. Generally, correlations are much stronger here than are found in the soil data. Note, however, that there are many fewer samples in the sediment population. In particular, correlations between iron (Fe1 and Fe4) and As1, Co4, Sb1 and Zn4 are very strong. The correlations between manganese (Mn4) and these same elements are even stronger in most cases with that of Co4 (0.97) being the most extreme. Examples of these strong correlations are shown as scatter-plots of As1 with Fe4 (Figure 5), Co4 with Mn4 (Figure 6) And Ni4 with Mn4 (Figure 7). In the case of cobalt, almost all of the variation in Co4 may be attributed to the abundance of manganese, almost certainly present as Mn (± Fe) hydroxides. In contrast, Figure 7 shows the correlation of Ni and Mn (0.59) to be weaker. For values of Mn <3,000 ppm, the correlation is very weak and variation in Ni content may closely reflect the actual, unscavenged Ni content of the catchment basin. Nonetheless, the application of stream-sediment geochemistry in this area for elements having strong correlations with Fe and Mn, appears to be of limited usefulness.

Generally, the sediment–water correlations are weak to moderate although the strongest show an interesting correlation of Cu in water with As, Cu and Sb in sediment. Correlation coefficients for most of the stream-water data are given in Table 8.

ELEMENT DISTRIBUTION IN SOIL

Regional Samples

The project focuses on the area's potential for gold and base-metal mineralization. The distribution of Au and the distribution of As (which correlates weakly with Au, Table 6) are shown as symbol plots superimposed on bedrock geology and 1:1 000 000-scale drainage data in Figures 8 and 9. The data have been grouped into intervals on the basis of inflection points on the respective cumulative frequency curves included with the figures. Most of the gold population falls below the 1 ppb detection limit and above this, the curve is linear until about 3.8 ppb where there is a sharp break suggesting a distinct population. Data falling in this upper range are coded as orange and red. The distributions of these anomalous samples are largely confined to the Schist Lakes sub-belt, the north half of the Knee Lake sub-belt, the central portion of the Baikie sub-belt and to two adjacent samples in the Ugjoktok sub-belt. The highest individual sample (67 ppb) is from the Schist Lakes sub-belt. The distribution of gold in soils is notoriously prone to the "nugget effect". This, com-

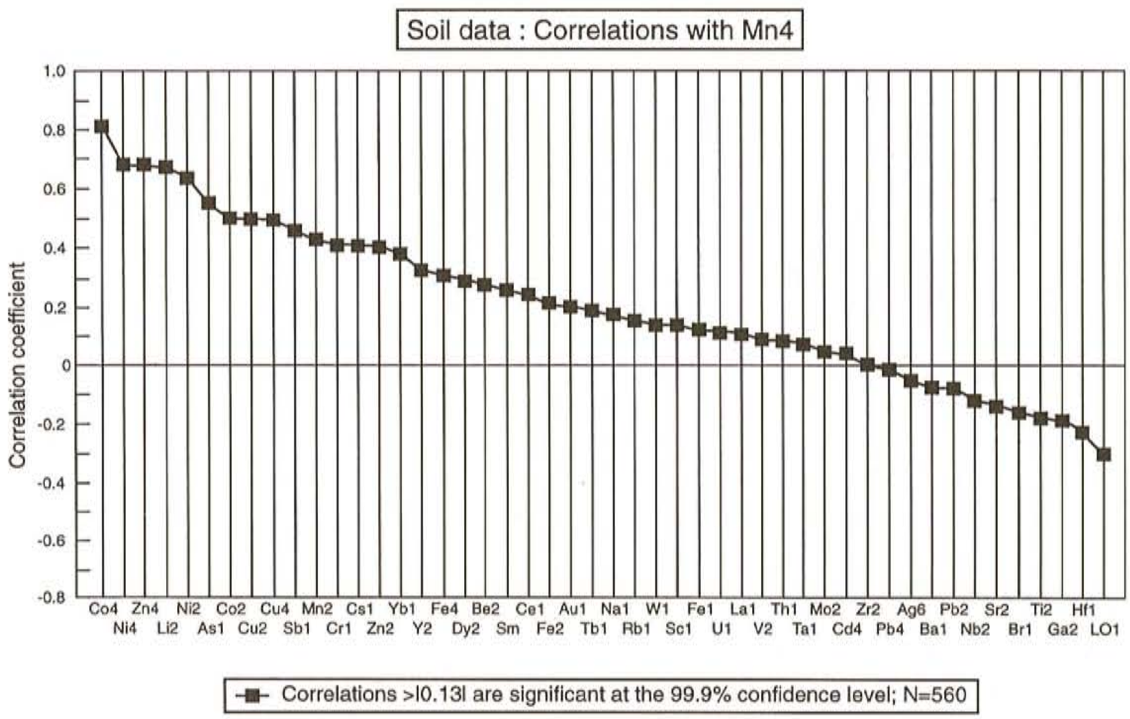


Figure 4. *Correlation of soil data with manganese (Mn4).*

Table 7. Spearman correlation coefficients for selected stream-sediment and water data (N=39)

	As1	Au1	Co4	Cr1	Cu4	Fe1	Fe4	La2	Mn4	Ni4	Pb4	Sb1	Zn4	CuW2	NiW2	ZnW2
As1	**1.00**	0.02	0.81	0.20	0.64	0.83	0.86	0.28	0.85	0.69	0.50	0.81	0.81	0.37	0.14	-0.17
Au1	0.02	**1.00**	-0.14	0.14	0.11	-0.29	-0.20	-0.13	-0.15	0.12	-0.39	-0.01	0.01	0.44	0.06	0.13
Co4	0.81	-0.14	**1.00**	0.07	0.61	0.85	0.87	0.21	0.97	0.69	0.64	0.68	0.84	0.18	0.19	-0.12
Cr1	0.20	0.14	0.07	**1.00**	0.09	0.20	0.14	-0.20	0.03	0.52	-0.21	0.39	0.06	0.07	-0.23	-0.09
Cu4	0.64	0.11	0.61	0.09	**1.00**	0.49	0.51	0.30	0.58	0.52	0.46	0.51	0.78	0.26	0.21	-0.15
Fe1	0.83	-0.29	0.85	0.20	0.49	**1.00**	0.94	0.24	0.86	0.61	0.58	0.72	0.68	0.13	0.08	-0.14
Fe4	0.86	-0.20	0.87	0.14	0.51	0.94	**1.00**	0.25	0.87	0.60	0.57	0.69	0.75	0.15	0.12	-0.12
La2	0.28	-0.13	0.21	-0.20	0.30	0.24	0.25	**1.00**	0.15	0.27	-0.03	0.32	0.28	0.01	0.35	0.10
Mn4	0.85	-0.15	0.97	0.03	0.58	0.86	0.87	0.15	**1.00**	0.59	0.71	0.68	0.79	0.20	0.18	-0.20
Ni4	0.69	0.12	0.69	0.52	0.52	0.61	0.60	0.27	0.59	**1.00**	0.18	0.73	0.69	0.29	0.08	-0.08
Pb4	0.50	-0.39	0.64	-0.21	0.46	0.58	0.57	-0.03	0.71	0.18	**1.00**	0.23	0.50	-0.10	0.00	-0.39
Sb1	0.81	-0.01	0.68	0.39	0.51	0.72	0.69	0.32	0.68	0.73	0.23	**1.00**	0.62	0.40	0.17	-0.08
Zn4	0.81	0.01	0.84	0.06	0.78	0.68	0.75	0.28	0.79	0.69	0.50	0.62	**1.00**	0.33	0.26	-0.03
Cu_water	0.37	0.44	0.18	0.07	0.26	0.13	0.15	0.01	0.20	0.29	-0.10	0.40	0.33	**1.00**	0.10	0.21
Ni_water	0.14	0.06	0.19	-0.23	0.21	0.08	0.12	0.35	0.18	0.08	0.00	0.17	0.26	0.10	**1.00**	0.19
Zn_water	-0.17	0.13	-0.12	-0.09	-0.15	-0.14	-0.12	0.10	-0.20	-0.08	-0.39	-0.08	-0.03	0.21	0.19	**1.00**

Note: Correlations >|0.47| are significant at the 99.9% confidence level.

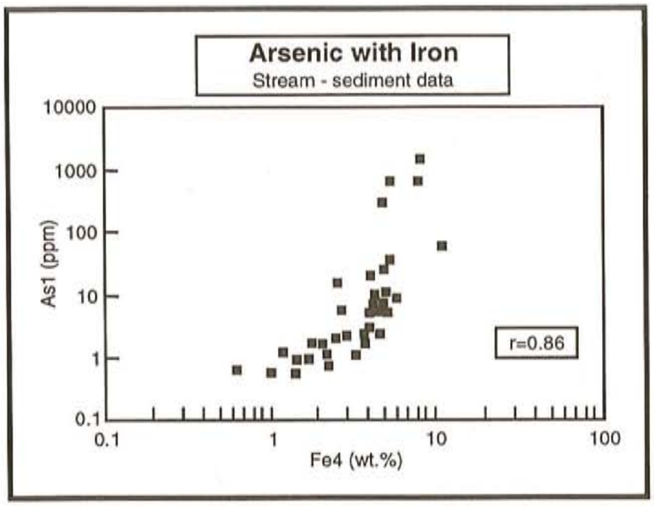


Figure 5. *Scatterplot of arsenic with iron in stream sediment.*

pounded by analytical uncertainty because of the detection limit problem, makes rigorous comparisons between samples difficult. The overall gold distribution pattern may be more significant than the individual values. The distribution of As (Figure 9) reveals very strong patterns when symbols are grouped by inflection points on the cumulative frequency curve. Except for a small break at 1 ppm, the population curve is nearly linear up to about 2.8 ppm. Most values <1 ppm (black symbols) are found in the outlying western and north-central greenstone belts. Most of the values >1 and <2.8 ppm (blue) occur in the south half of the Baikie sub-belt and the southern and eastern portions of the Knee Lake sub-belt. Conversely samples with high levels of As (>6.0 ppm) are primarily restricted to the north half of the Baikie sub-belt, the central portion of the traverse across the Ugjoktok sub-belt, the northeastern Knee Lake sub-belt and the eastern side of

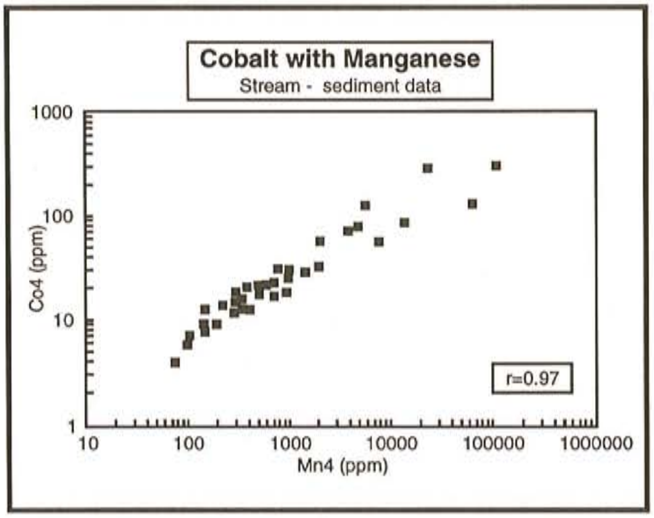


Figure 6. *Scatterplot of cobalt with manganese in stream sediment.*

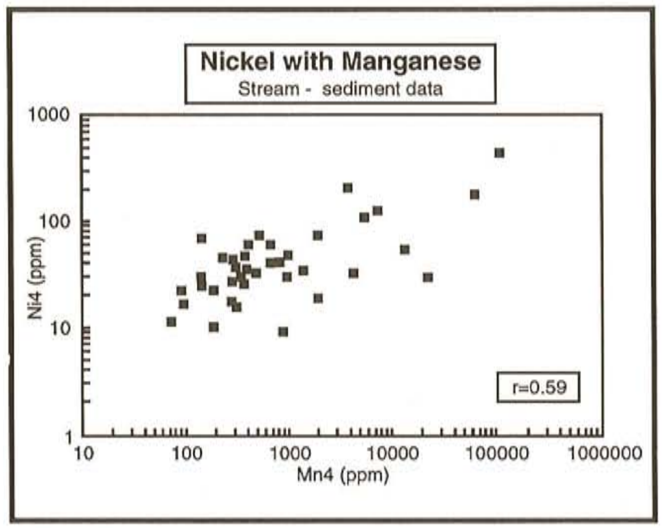


Figure 7. *Scatterplot of nickel with manganese in stream sediment.*

Table 8. Spearman correlation coefficients for stream-water data (N=144, except N=98 for pH)

	Al	Ca	Co	Cr	Cu	Fe	K	Mg	Na	Ni	P	Si	SO4	Sr	Zn	Conductivity
Al	**1.00**	-0.42	-0.03	0.14	-0.04	0.50	0.12	-0.36	0.20	-0.02	0.08	0.12	-0.33	-0.26	0.06	-0.50
Ca	-0.42	**1.00**	0.10	-0.05	0.28	-0.20	-0.18	0.75	-0.10	0.21	-0.02	0.37	0.61	0.71	0.00	0.92
Co	-0.03	0.10	**1.00**	-0.23	0.18	-0.15	-0.20	0.07	-0.11	0.57	-0.19	0.12	0.05	0.09	0.34	0.10
Cr	0.14	-0.05	-0.23	**1.00**	-0.32	0.01	-0.18	0.04	0.06	0.04	-0.18	0.04	0.08	-0.05	-0.20	0.01
Cu	-0.04	0.28	0.18	-0.32	**1.00**	0.05	0.21	-0.03	-0.27	-0.03	0.43	0.16	-0.02	0.14	0.47	0.13
Fe	0.50	-0.20	-0.15	0.01	0.05	**1.00**	0.21	-0.03	0.16	-0.06	0.19	-0.09	-0.14	-0.14	0.24	-0.22
K	0.12	-0.18	-0.20	-0.18	0.21	0.21	**1.00**	-0.17	0.12	-0.24	0.53	0.01	-0.16	-0.18	0.21	-0.21
Mg	-0.36	0.75	0.07	0.04	-0.03	-0.03	-0.17	**1.00**	0.22	0.24	-0.01	0.25	0.65	0.64	-0.06	0.81
Na	0.20	-0.10	-0.11	0.06	-0.27	0.16	0.12	0.22	**1.00**	0.04	0.08	0.39	0.22	0.19	0.05	0.06
Ni	-0.02	0.21	0.57	0.04	-0.03	-0.06	-0.24	0.24	0.04	**1.00**	-0.26	0.21	0.16	0.32	0.19	0.27
P	0.08	-0.02	-0.19	-0.18	0.43	0.19	0.53	-0.01	0.08	-0.26	**1.00**	-0.03	-0.11	-0.00	0.27	-0.06
Si	0.12	0.37	0.12	0.04	0.16	-0.09	0.01	0.25	0.39	0.21	-0.03	**1.00**	0.14	0.59	0.02	0.34
SO4	-0.33	0.61	0.05	0.08	-0.02	-0.14	-0.16	0.65	0.22	0.16	-0.11	0.14	**1.00**	0.38	0.03	0.65
Sr	-0.26	0.71	0.09	-0.05	0.14	-0.14	-0.18	0.64	0.19	0.32	-0.00	0.59	0.38	**1.00**	0.00	0.72
Zn	0.06	0.00	0.34	-0.20	0.47	0.24	0.21	-0.06	0.05	0.19	0.27	0.02	0.03	0.00	**1.00**	-0.03
Conductivity	-0.50	0.92	0.10	0.01	0.13	-0.22	-0.21	0.81	0.06	0.27	-0.06	0.34	0.65	0.72	-0.03	**1.00**
pH	-0.22	0.38	-0.05	0.00	0.09	-0.06	-0.05	0.21	-0.24	0.02	-0.01	0.02	0.23	0.23	-0.18	0.37

Note: Correlations >|0.25| are significant at the 99.9% confidence level.

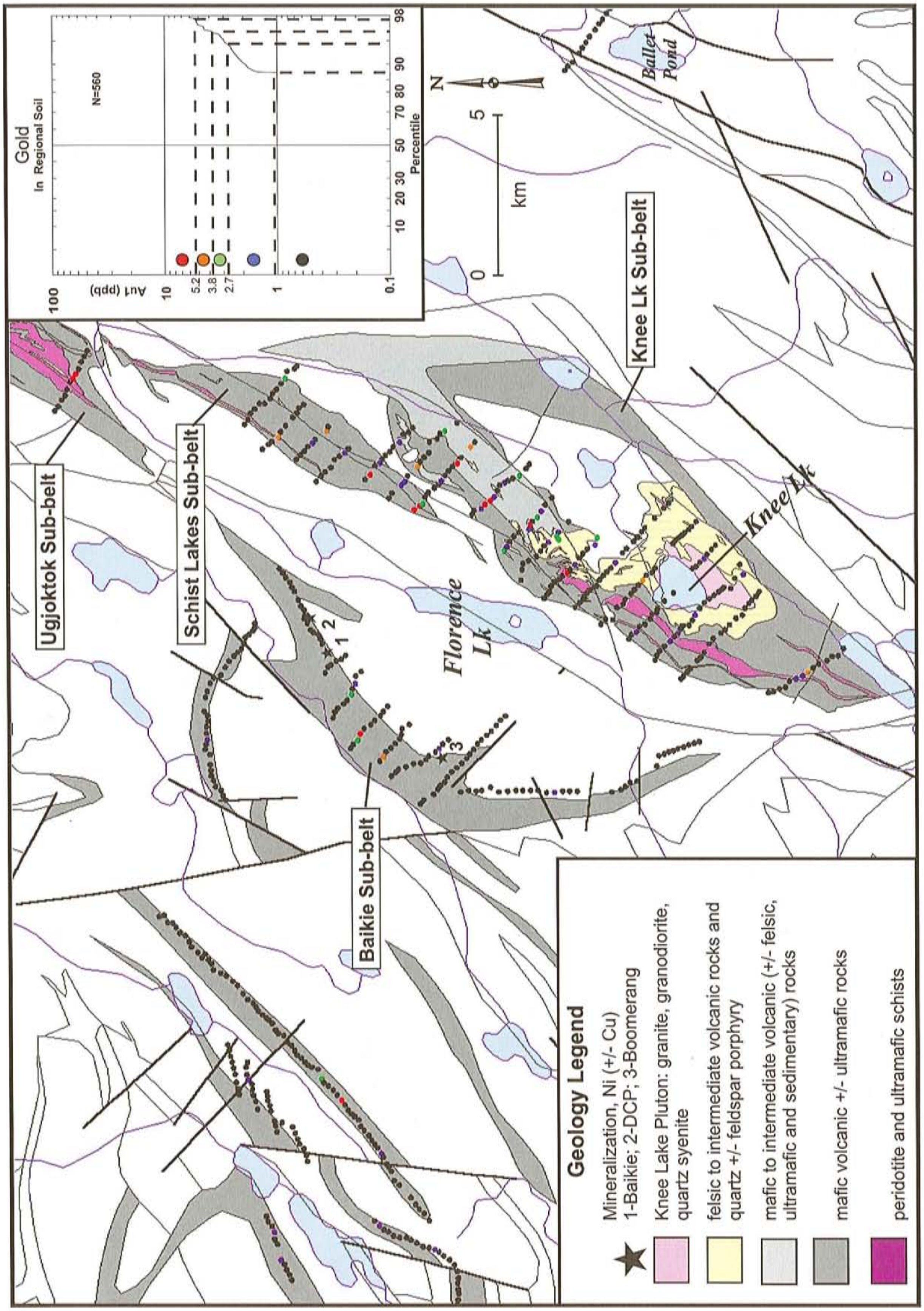


Figure 8. *Gold in regional soil samples (geology after Ermanovics, 1993 and James* et al., *1996b).*

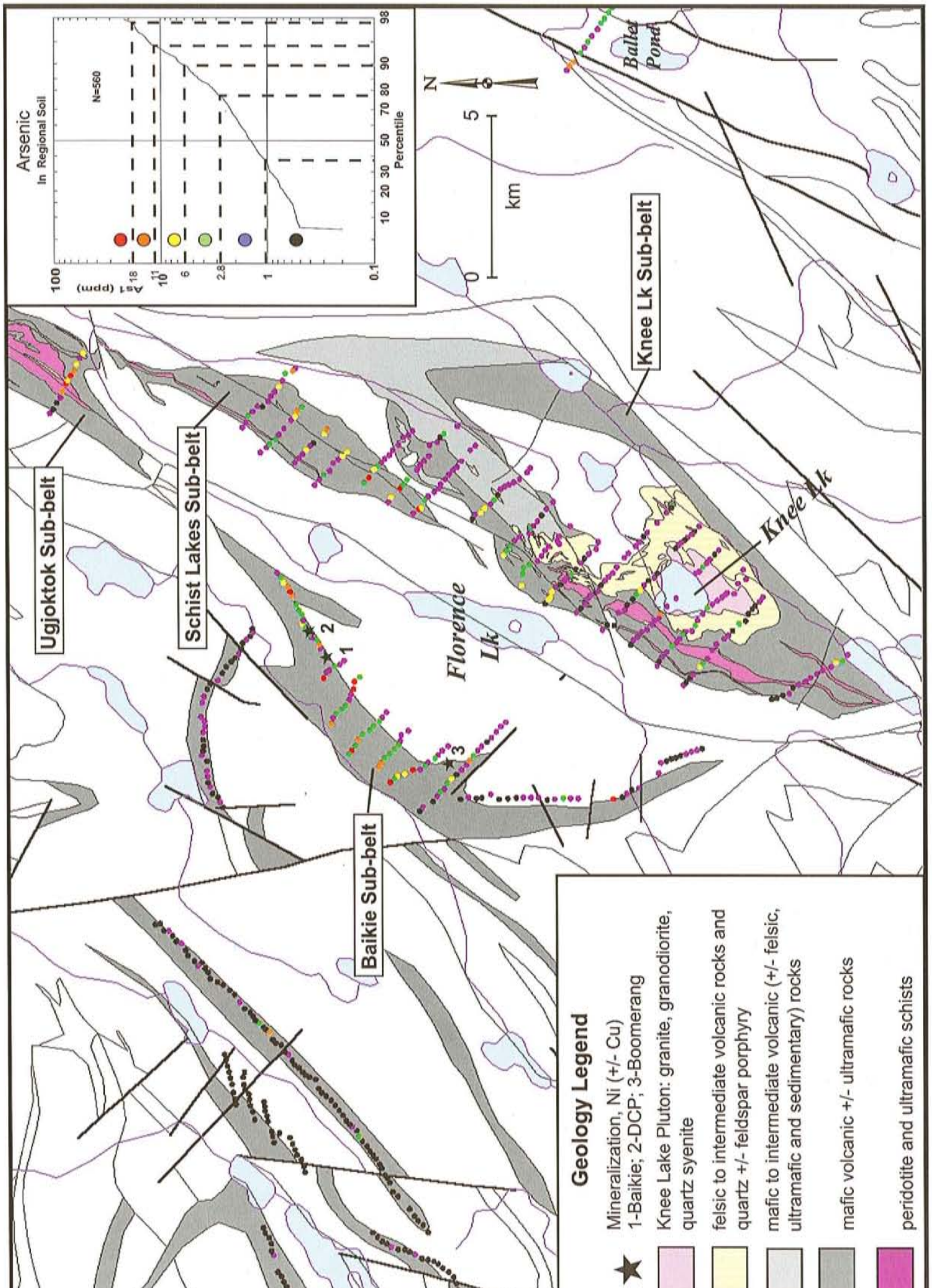


Figure 9. *Arsenic in regional soil samples (geology after Ermanovics, 1993 and James* et al., *1996b).*

the Schist Lakes sub-belt. The distribution of high As values in the Schist Lakes sub-belt forms a narrow north-northeast-trending pattern similar to that shown by gold. The highs are partially coincident with a fault zone mapped by James *et al.* (1996b). The zone of high As in the Ugjoktok belt also coincides with two high gold samples. The area is underlain by talc schist of ultramafic origin.

The distribution of nickel (*aqua regia* soluble) in the regional soil data is presented in Figure 10. Because there are very few samples with high nickel values from the sites to the west and north, only the central part of the survey centred on Florence Lake is shown. Most of the anomalous values (orange and red) are associated with areas underlain by ultramafic rocks, particularly in the Knee Lake sub-belt. Nickel is a good indicator of differentiation in igneous rocks generally ranging from low to high in the felsic to mafic sequence, thus the high Ni values over the ultramafic units are to be expected. Similarly, the low values over the granitic Knee Lake pluton are also reasonable. These observations also indicate that the soil and its parent till material have not undergone significant glacial transport. More surprising are the numerous elevated values of Ni over the predominantly felsic volcanic terrane to the north and east of the pluton suggesting that there may be more mafic rocks in the unit than the bedrock mapping indicates.

Orientation Survey over the Baikie Showing

A detailed soil survey was conducted over the Baikie showing to provide orientation information as to the nature of dispersion in soil from known mineralization. The Baikie showing at surface consists of a small outcrop of ultramafic rock exposed in poorly drained ground containing stratabound pyrrhotite–pyrite–pentlandite ± chalcopyrite. Grab samples assay 0.84 to 2.65% Ni and 0.01 to 0.07% Cu (Sutton, 1970; Brace and Wilton, 1990). Eighty-two samples of B and B–C horizon soil were collected from a grid with lines running at 135°, approximately at right angles to both the average regional ice-flow direction and to the strike of local bedrock units. Lines were spaced at 50 m and sample sites at 12.5 m in the vicinity of the showing and at 100 and 25 m respectively for more distal samples. The till coverage in the area is estimated at 90 to 95 percent and is generally thin, commonly less than a metre. The grid was designed with most sites located down-ice of the mineralization so as to identify dispersion in that direction. Batterson (1996) has identified ice-flow direction in the Florence Lake area to have ranged between 35 and 75°.

The distributions of Ni and Cu (*aqua regia* digestion) in soil are shown in Figure 11. The cumulative frequency curve for Ni shows three distinct inflection points at 30, 43 and 64 ppm and a less distinct break at 19 ppm. Plotting the samples according to these inflection points shows that most of the highest samples occur within about 50 m of mineralization although what appears to be a fan of elevated Ni spreads to the north of the showing for about 150 m. A high Ni sample about 30 m up-ice of the showing may be reflecting sub-cropping mineralization or possibly just the associated ultramafic host rock. What appears as an isolated high Ni sample in the north-central area is not explained. It also has a high Cu concentration. The distribution of Cu is broadly similar to that of Ni. Its cumulative frequency curve has only three inflection points – at 20, 31 and 66 ppm. As with Ni, most of the dispersion seems to be local with a tail to the north. The pattern is less uniform than that of Ni and at least one anomalous sample to the southeast seems unrelated to the Baikie showing.

ELEMENT DISTRIBUTION IN STREAMS

The distributions of sediment data are not shown, in part because there are few samples, but more significantly, because the very strong association of base metals with Mn and Fe makes interpretation difficult or impossible. Of the base-metal water data, Cu shows the most interesting patterns. The catchment basins have been digitized, colour-filled according to Cu content and plotted on Figure 12. The 1:250 000-scale drainage features are shown in blue. Most of the highest Cu sites are from streams draining the Baikie sub-belt and seem to have some spatial correlation with the known Ni mineralization. The reasons for the cluster of high values in this area are not apparent. The distribution does not simply reflect bedrock geology as mapped nor is the pattern echoed in the distribution of Cu in soil (not shown); however, the drainage basins of all streams with high Cu values do represent possible follow-up exploration targets.

CONCLUSIONS

This survey reinforces the belief that the Florence Lake greenstone belt is a prospective target for base-metal and gold mineralization. The data from both the soil and stream samples point to new areas for detailed exploration. In particular, the distributions of gold and arsenic in soil suggest that the potential for gold mineralization is highest in the northern part of the Knee Lake sub-belt, the Schist Lakes sub-belt, possibly in association with north-northeast faulting, the central and northern parts of the Baikie sub-belt and over ultramafic portions of the Ugjokok sub-belt. The highest Ni values in soil are found in proximity to the concentration of ultramafic rocks in the Knee Lake sub-belt with some high values found over the central Baikie sub-belt. Note, however, that the Baikie nickel showing is not strongly reflected in the regional sampling but is delineated clearly at the detailed scale. The distribution of Cu in stream water highlights the Baikie sub-belt. Although the source of the water-borne copper is not known, there is a spatial association of known Ni–Cu mineralization and high values of Cu in water.

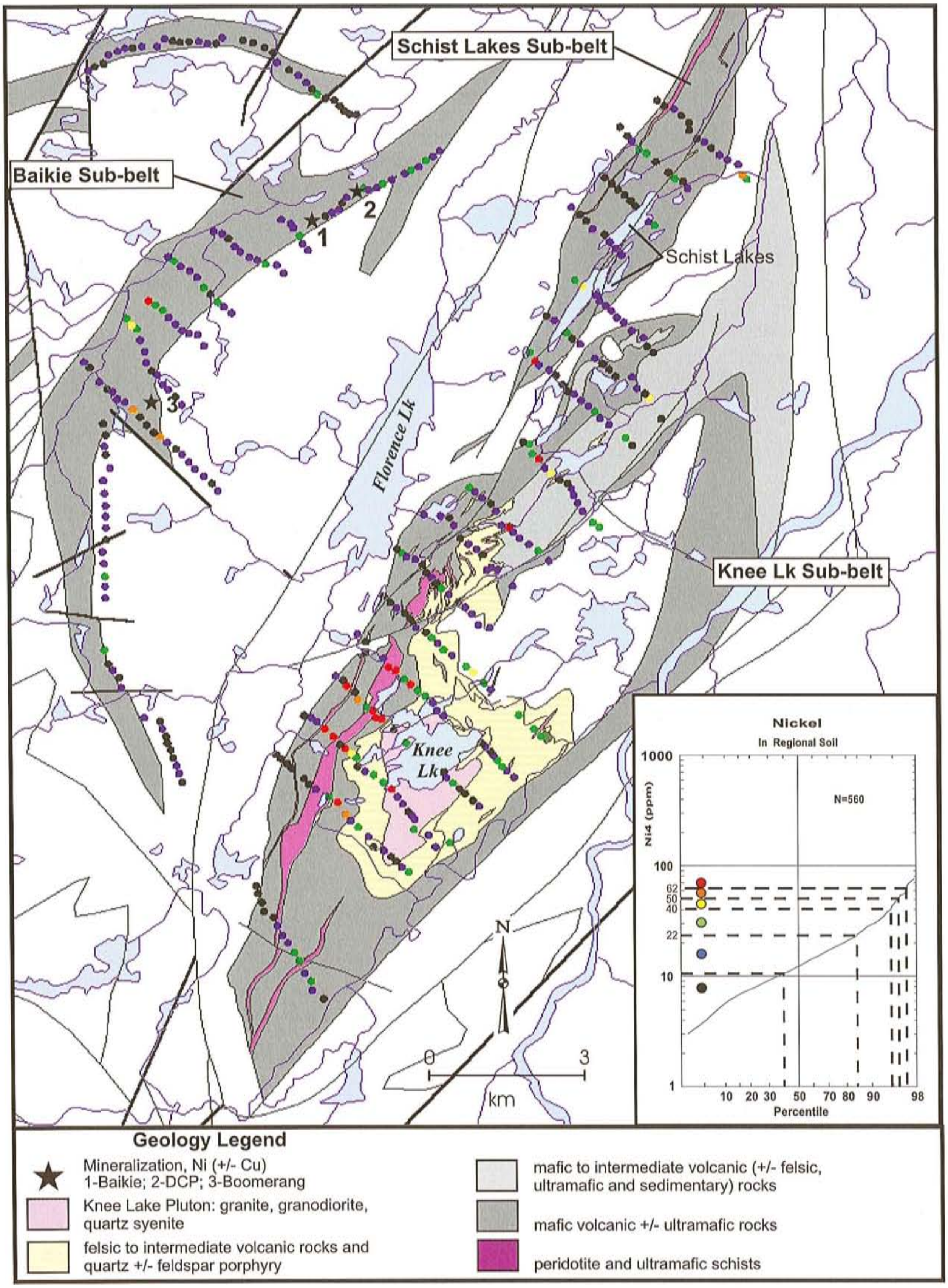
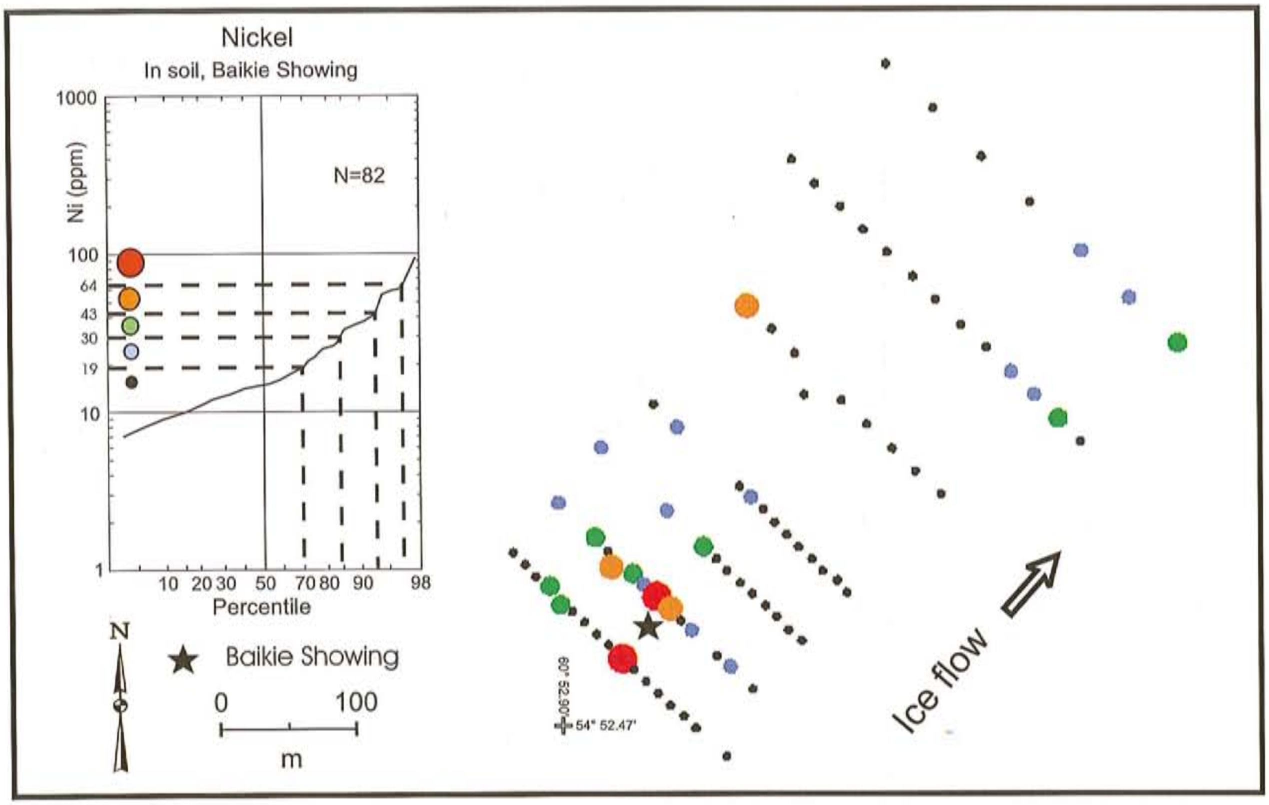


Figure 10. *Nickel (Ni_4) in regional soil samples (geology after Ermanovics, 1993 and James* et al.*, 1996b).*



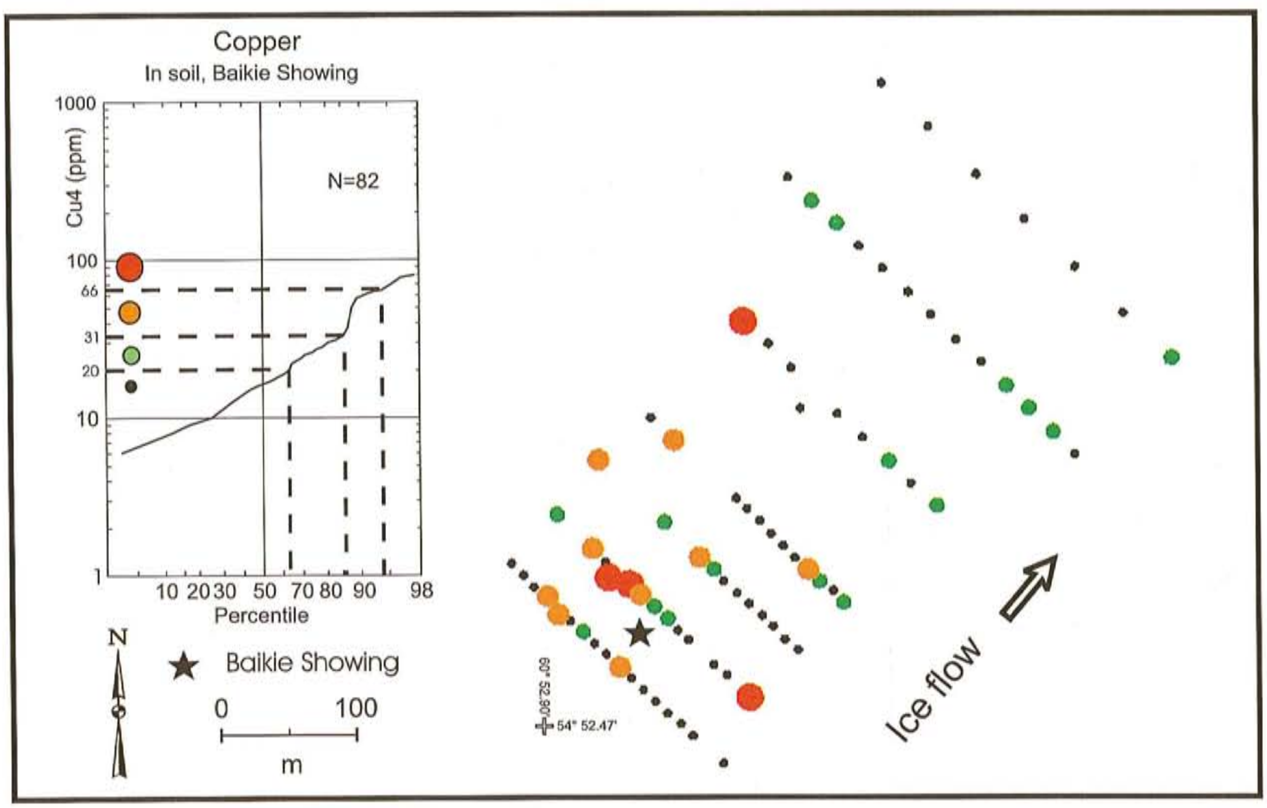


Figure 11. *Nickel (top) and copper (bottom) in soil, Baikie showing.*

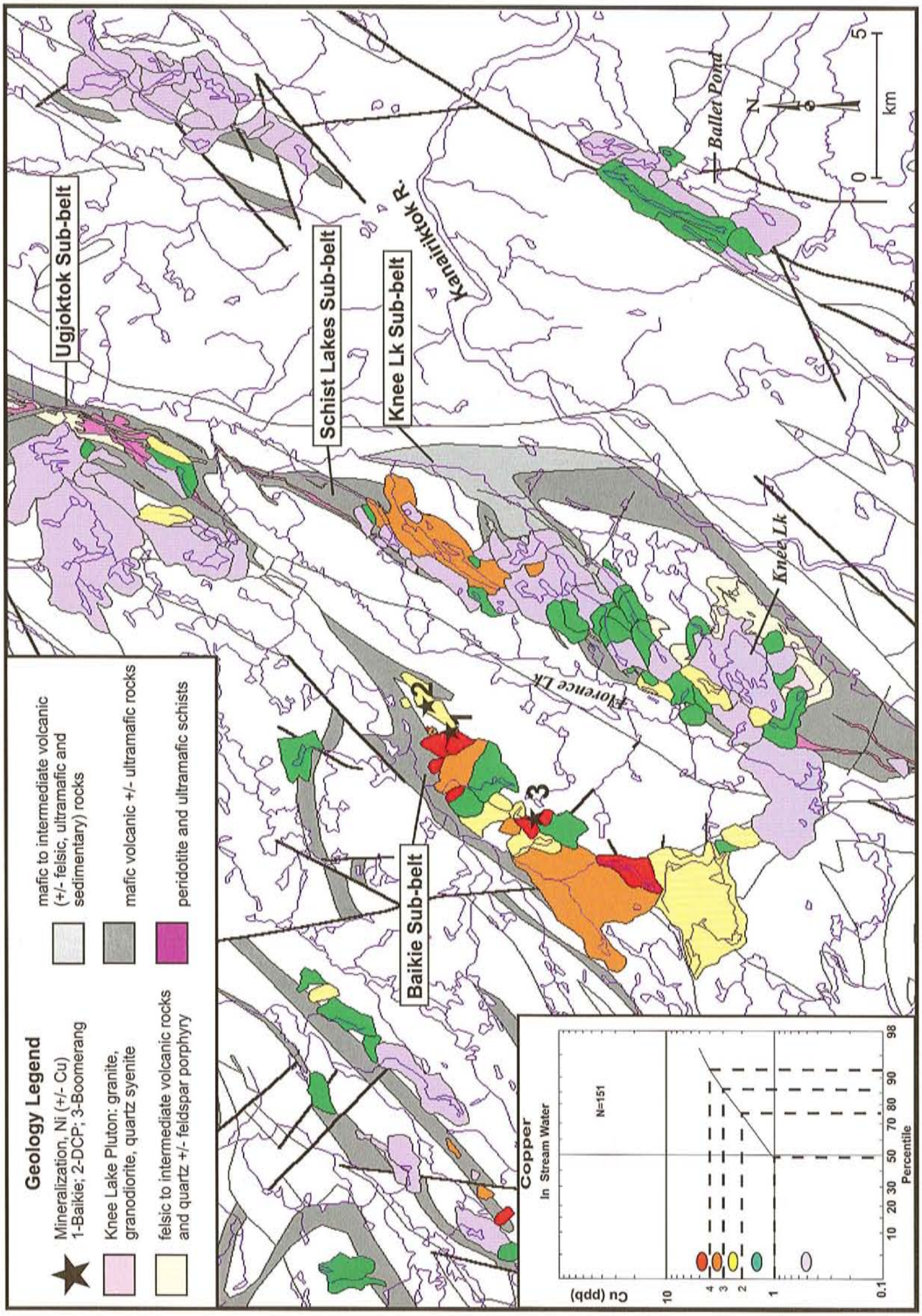


Figure 12. *Copper in stream water (geology after Ermanovics, 1993 and James* et al., *1996b).*

The survey results, together with the parallel Quaternary geology study of Batterson (1996), indicate that most of the area is suitable for soil–till or stream-water geochemistry, although the widespread and pronounced scavenging of base metals by (hydr-)oxides of manganese and iron in stream sediment make the application of stream-sediment geochemistry for base metals problematical. The consistent ice-flow direction to the northeast and the relatively local provenance of the till simplify the problems of data interpretation and provide the explorationist with suitable sampling material.

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