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NEW ICP-ES GEOCHEMICAL DATA FOR REGIONAL LABRADOR LAKE-SEDIMENT AND LAKE-WATER SURVEYS

J.W. McConnell and C. Finch

Open File LAB/1602

St. John's, Newfoundland
October, 2012

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Cover photo: Hunt Lake, central Labrador circa 1985.

Newfoundland Labrador

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ABSTRACT

The report provides new inductively coupled plasma-emission spectrographic (ICP-ES) data for lake-sediment samples, as well as the original analytical and field data for reconnaissance-scale lake-sediment and water surveys conducted in Labrador by the Geological Survey of Canada between 1977 and 1984. Some 19 836 samples were obtained from 18 706 sites. The ICP-ES analyses were performed by the Geochemical Laboratory of the Newfoundland and Labrador Department of Natural Resources. These data are particularly suitable for displaying in a geographic information system or for performing statistical analyses.

The report contains descriptions of the ICP-ES analytical procedures, comments on data quality, statistical summaries of all data and individual symbol maps of the geographic distributions of the ICP-ES elements. The field and descriptive data, the ICP-ES analytical data as well as previously determined analytical data are provided.

INTRODUCTION

This report provides additional lake-sediment geochemical data to supplement previous data released by the Geological Survey of Canada (GSC), for the regional lake-sediment and water geochemical surveys conducted in Labrador, as part of the National Geochemical Reconnaissance Program. Samples collected during the GSC surveys have been further analyzed by the Geochemical Laboratory of the Newfoundland and Labrador Department of Natural Resources. Samples were analyzed for 30 elements using inductively coupled plasma-emission spectrometry (ICP-ES). The elements are: aluminum (Al), barium (Ba), beryllium (Be), calcium (Ca), cerium (Ce), cobalt (Co), chromium (Cr), copper (Cu), dysprosium (Dy), iron (Fe), gallium (Ga), potassium (K), lanthanum (La), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), niobium (Nb), nickel (Ni), phosphorus (P), lead (Pb), scandium (Sc), strontium (Sr), thorium (Th), titanium (Ti), vanadium (V), yttrium (Y), zinc (Zn) and zirconium (Zr).

The report outlines the history of the GSC surveys and their products and describes the analytical procedures employed for the ICP-ES analyses, the quality control methods used and their results, statistical analyses of the data, histograms, cumulative frequency curves and coloured symbol maps of each element showing the relationship of element values to geology. For data completeness, all previous data, as well as the new ICP-ES data, are included in the discussions of data quality, the table of correlation coefficients, statistical summaries and the appended database.

LOCATION AND SURVEY DESCRIPTIONS

All of Labrador was surveyed by lake-sediment and water sampling with the exception of the northern part, where a scarcity of lakes precluded such work. Figure 1 shows the NTS map areas sampled in the surveys. Note that for areas along the Québec border, only the Labrador portions were sampled. The northern area was surveyed by reconnaissance-scale stream-sediment and water sampling. The work was carried out under the direction of the Geological Survey of Canada (GSC) during the period 1977–1984 as part of the National Geochemical Reconnaissance Program.

The results of the surveys were published as 18 open-file reports (Hornbrook and Friske, 1989; Friske *et al.*, 1992a, b, 1993a–j and 1994a–e). Approximately 18 706 sites were sampled; of these, 1130 were sampled in duplicate giving a total of 19 836 samples.

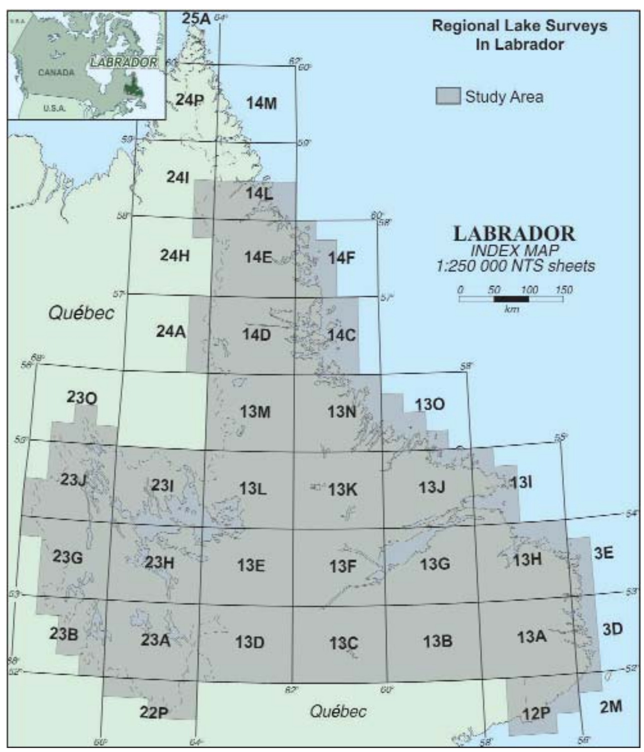

Figure 1. *Locations of the surveyed areas.*

Sediment samples were analyzed by the GSC for 35 unique elements and loss-on-ignition. An additional nine analytical procedures were applied to eight of these elements giving a total analytical suite of 43 elemental analyses. Some analyses were only performed on part of the sample set, notably arsenic by hydride generation atomic absorption spectrometry and by colorimetry, cadmium by atomic absorption spectrometry, antimony by hydride generation atomic absorption spectrometry, vanadium by aqua regia digestion – atomic absorption spectrometry and tungsten by colorimetry after $K_2S_2O_7$ fusion. With the exception of cadmium and vanadium however, these elements were analyzed by other methods for the entire sample set. The 35 elements analyzed are: silver (Ag), arsenic (As), gold (Au), barium (Ba), bromine (Br), cadmium (Cd), cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), copper (Cu), europium (Eu), fluorine (F, as the fluoride ion), iron (Fe), hafnium (Hf), mercury (Hg), lanthanum (La), lutetium (Lu), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), lead (Pb), rubidium (Rb), antimony (Sb), scandium (Sc), samarium (Sm), tantalum (Ta), terbium (Tb), thorium (Th), uranium (U), vanadium (V), tungsten (W), ytterbium (Yb) and zinc (Zn).

SAMPLE COLLECTION AND PREPARATION PROCEDURES

Sediment collection was under the supervision of the Geological Survey of Canada. Sampling involved landing a float-equipped helicopter on the lake and dropping a weighted tubular sampler fitted with a nylon rope for retrieval. A butterfly valve in the bottom of the tube opened upon impact with the sediment and closed upon retrieval, trapping the contained sediment. Samples were stored in water-resistant Kraft paper bags and were partially air-dried in the field prior to shipping them to Ottawa for sample preparation. Markings on the rope permitted determination of the sample depth. Other observations made during sampling included noting the location of the site on a 1:250 000-scale topographic map, sediment colour and the presence of any source of contamination. Preparation included final air-drying, crushing and ball-milling. The −80 mesh fraction (177 micron) was obtained by sieving and used for analysis.

DESCRIPTION OF ICP-ES ANALYTICAL PROCEDURE

INSTRUMENTATION

Trace element analysis on this dataset of 30 elements was undertaken using a Fisons Instruments Maxim III fully simultaneous Inductively Coupled Plasma-Emission Spectrometer (ICP-ES) and Thermo Instruments Iris High Resolution ICP-ES. Table 1 lists all elements, spectral lines and detection limits for this method. Samples were typically analyzed unattended using a Gilson 222 auto sampler and the analytical data collected were later corrected and calculated off-line.

DISSOLUTION

One gram of lake sediment was weighed in a porcelain crucible and was ashed at 500°C for four hours, to ensure that organic material was completely burned off before digestion. After the four hours, the samples were removed from the oven, cooled and transferred to 100 ml Teflon beakers. Five ml of concentrated hydrochloric acid, 15 ml of concentrated hydrofluoric acid and

Table 1. Spectral lines and detection limits for elements analyzed by ICP-ES

Reporting Name	Wavelength	Method Detection Limit
Al2	396.152	0.01%
Ba2	455.397	1 ppm
Be2	313.077	0.1 ppm
Ca2	422.673	0.01%
Ce2	418.673	1 ppm
Co2	228.617	1 ppm
Cr2	205.561	1 ppm
Cu2	324.574	1 ppm
Dy2	353.170	0.1 ppm
Fe2	271.441	0.01%
Ga2	294.364	1 ppm
K2	766.488	0.01%
La2	408.670	1 ppm
Li2	670.784	0.1 ppm
Mg2	279.077	0.01%
Mn2	403.447	1 ppm
Mo2	202.031	1 ppm
Na2	588.995	0.01%
Nb2	319.497	1 ppm
Ni2	231.605	1 ppm
P2	213.617	1 ppm
Pb2	220.355	1 ppm
Sc2	361.383	0.1 ppm
Sr2	407.771	1 ppm
Th2	283.73	1 ppm
Ti2	307.864	1 ppm
V2	310.231	1 ppm
Y2	371.027	1 ppm
Zn2	213.857	1 ppm
Zr2	343.822	1 ppm

5 ml of 1:1 perchloric acid was added to each sample. All acids were reagent grade or better. The samples were placed on a hotplate at 200°C and evaporated to dryness, after which the beakers were half-filled with 10% hydrochloric acid and returned to the hot plate at 100°C. When the residue was completely dissolved the samples were removed, cooled and transferred to 50 ml volumetric flasks. One ml of 50 g/l boric acid was added to each sample to complex any residual hydrofluoric acid. The samples were made to volume and analyzed by ICP-ES (Lichte, 1987). Standard reference materials (LKSD-1, LKSD-2, LKSD-3 and LKSD-4) were placed in each sample batch at a frequency of 1:20 samples. Both analytical and sampling duplicates were distributed at the same frequency throughout the dataset.

DATA QUALITY

To ensure the reliability of the analytical data, three means of determining data accuracy and/or precision were employed. First, during sample collection, pairs of sediment samples were obtained from every sequence of twenty lakes. Analyses of these site duplicates give an appreciation of within-lake data variation. Second, at the analytical stage, a standard of known composition was inserted within every batch of 20 samples. These consisted of four international reference standards composed of lake-sediment material: LKSD-1, LKSD-2, LKSD-3 and LKSD-4. The results of these standards (Table 2) were monitored to ensure analytical accuracy and precision. Third, a sample split to produce a laboratory duplicate, was included in every batch of 20 samples. These duplicates were compared to ensure adequate precision.

Site duplicates are useful because they give an appreciation of overall data variance occurring at both the sampling and analytical stages. As they consist of samples from the survey itself, they may reveal limitations in the data that are specific to the region and which may not show up in the reference standards. Table 3, listing Spearman correlation coefficients for all elements analyzed in the survey, provides a ready way of assessing the variance of data and comparing the reproducibility of analyses of a given element done by two different methods. Scatter plots of the thirty elements analyzed by ICP-ES along with the Spearman correlation coefficient (r) are

Table 2. Control standards: recommended and average values, standard deviations, number of analyses and percent recovery

CONTROL LKSD-1	A12	Ba2	Be2	Ca2	Ce2	Co2	Cr2	Cu2	Dy2	Fe2	K2	La2	Li2	Mg2
recommended	4.1	430	1.1	7.7	27	11	31	44	3.4	2.8	0.95	16	7	1.04
average	4.1	356	0.7	7.8	26	12	26	44	3	2.8	0.95	17	8.1	0.98
std. deviation	0.2	73.52	0	0.3	4.78	0.82	5.81	2.48	0.3	0.1	0.03	2.64	0.5	0.05
N	142	142	142	142	142	142	142	142	142	142	142	142	142	142
recovery (%)	99.00	82.70	66.50	101.20	98.00	105.20	85.30	99.00	89.70	100.40	100.10	107.90	115.50	94.10
LKSD-2	**A12**	**Ba2**	**Be2**	**Ca2**	**Ce2**	**Co2**	**Cr2**	**Cu2**	**Dy2**	**Fe2**	**K2**	**La2**	**Li2**	**Mg2**
recommended	6.5	780	2.5	1.6	108	17	57	37	7.3	4.3	2.19	68	20	1.01
average	6.8	777	1.8	1.5	112	20	50	38	6.2	4.3	2.16	68	24.1	0.97
std. deviation	0.8	21.54	0.1	0.1	11.68	0.86	6.37	2.32	0.4	0.2	0.09	2.62	2.5	0.05
N	137	137	137	137	137	137	137	137	137	137	137	137	137	137
recovery (%)	105.10	99.60	70.70	91.70	104.00	116.60	87.20	102.20	84.30	100.90	98.50	100.20	120.60	96.40
LKSD-3	**A12**	**Ba2**	**Be2**	**Ca2**	**Ce2**	**Co2**	**Cr2**	**Cu2**	**Dy2**	**Fe2**	**K2**	**La2**	**Li2**	**Mg2**
recommended	6.6	680	1.9	1.6	90	30	87	35	4.9	4	1.84	52	25	1.2
average	6.9	689	1.5	1.5	92	35	74	36	4.3	4.1	1.85	51	30.4	1.13
std. deviation	0.9	23.25	0.1	0.1	10.36	1.58	4.85	2.35	0.3	0.1	0.07	1.86	2.9	0.05
N	143	143	143	143	143	143	143	143	143	143	143	143	143	143
recovery (%)	104.70	101.30	81.10	96.80	102.00	115.60	84.70	102.10	88.60	103.00	100.60	98.50	121.70	94.40
LKSD-4	**A12**	**Ba2**	**Be2**	**Ca2**	**Ce2**	**Co2**	**Cr2**	**Cu2**	**Dy2**	**Fe2**	**K2**	**La2**	**Li2**	**Mg2**
recommended	3.1	330	1	1.3	48	11	33	31	3.7	2.8	0.68	26	12	0.56
average	3.2	336	0.8	1.2	48	12	30	32	3.4	3	0.7	27	14.6	0.5
std. deviation	0.3	22	0	0.1	6	0.6	2.6	3.4	0.3	0.2	0	1.9	2.3	0
N	129	129	129	129	129	129	129	129	129	129	129	129	129	129
recovery (%)	101.70	101.90	77.60	95.20	100.70	113.10	91.60	104.60	91.10	106.30	98.10	105.40	121.80	94.00

Table 2. Continued

CONTROL LKSD-1	Mn2	Mo2	Na2	Nb2	Ni2	P2	Pb2	Sc2	Sr2	Ti2	V2	Y2	Zn2	Zr2
recommended	700	10	1.48	7	16	698	82	9	250	3010	50	19	331	134
average	711	9	1.5	6	14	678	81	7.9	266	2886	51	21	321	39
std. deviation	35.99	0.63	0.1	1.07	3.17	20.91	3.6	0.3	8.61	141.43	2.12	0.97	9.55	2.57
N	142	142	142	142	142	142	142	142	142	142	142	142	142	142
recovery (%)	101.50	94.70	101.60	86.10	86.20	97.20	99.00	87.30	106.40	95.90	102.60	111.20	97.00	28.70
LKSD-2	**Mn2**	**Mo2**	**Na2**	**Nb2**	**Ni2**	**P2**	**Pb2**	**Sc2**	**Sr2**	**Ti2**	**V2**	**Y2**	**Zn2**	**Zr2**
recommended	2020	-5	1.43	8	26	1222	44	13	220	3460	77	44	209	254
average	2129	1	1.41	9	24	1282	43	12.3	240	3284	78	40	206	107
std. deviation	110.97	0.72	0.06	0.68	3.71	47.05	3.23	0.6	6.83	154.02	3.15	1.41	6.96	5.07
N	137	137	137	137	137	137	137	137	137	137	137	137	137	137
recovery (%)	105.40	-29.00	98.50	108.30	91.50	104.90	97.60	94.80	109.20	94.90	101.70	90.60	98.70	42.00
LKSD-3	**Mn2**	**Mo2**	**Na2**	**Nb2**	**Ni2**	**P2**	**Pb2**	**Sc2**	**Sr2**	**Ti2**	**V2**	**Y2**	**Zn2**	**Zr2**
recommended	1440	-5	1.72	8	47	1091	29	13	240	3330	82	30	152	178
average	1524	1	1.69	8	45	1047	31	12.1	255	3137	82	27	145	97
std. deviation	79.47	0.47	0.06	0.7	2.61	34.66	3.99	0.5	7.4	116.74	3.3	0.97	5.1	3.52
N	143	143	143	143	143	143	143	143	143	143	143	143	143	143
recovery (%)	105.90	-24.30	98.30	105.30	95.00	96.00	105.40	92.90	106.10	94.20	99.60	90.30	95.30	54.30
LKSD-4	**Mn2**	**Mo2**	**Na2**	**Nb2**	**Ni2**	**P2**	**Pb2**	**Sc2**	**Sr2**	**Ti2**	**V2**	**Y2**	**Zn2**	**Zr2**
recommended	500	-5	0.54	9	31	1440	91	7	110	2270	49	23	194	105
average	550	2	0.6	4	30	1468	92	7.2	130	1922	49	22	191	38
std. deviation	62.1	0.3	0.1	0.6	2.2	53.9	4	0.3	5.9	87.3	2.6	0.9	8	2.2
N	129	129	129	129	129	129	129	129	129	129	129	129	129	129
recovery (%)	110.00	-37.00	108.20	43.30	97.70	101.90	100.80	103.10	118.60	84.70	100.10	97.80	98.40	36.30

Table 3. Spearman correlation coefficients (r) of site duplicates for all sediment and water analyses. N>1000 for most variables

Variable	Correlation Coefficient (r)	Variable	Correlation Coefficient (r)
Sediment			
Ag3_ppm	0.52	Mn2_ppm	0.95
Al2_pct	0.95	Mn3_ppm	0.95
As19_ppm	0.77	Mo1_ppm	0.89
As1_ppm	0.84	Mo2_ppm	0.90
As21_ppm	0.44	Mo5_ppm	0.86
Au1_ppb	0.15	Na1_pct	0.94
Ba1_ppm	0.92	Na2_pct	0.93
Ba2_ppm	0.92	Nb2_ppm	0.91
Be2_ppm	0.96	Ni1_ppm	0.65
Br1_ppm	0.91	Ni2_ppm	0.97
Ca2_pct	0.92	Ni3_ppm	0.97
Cd3_ppm	0.57	P2_ppm	0.96
Ce1_ppm	0.97	Pb2_ppm	0.90
Ce2_ppm	0.97	Pb3_ppm	0.77
Co1_ppm	0.90	Rb1_ppm	0.85
Co2_ppm	0.94	Sb19_ppm	0.44
Co3_ppm	0.92	Sb1_ppm	0.76
Cr1_ppm	0.83	Sc1_ppm	0.95
Cr2_ppm	0.97	Sc2_ppm	0.95
Cs1_ppm	0.68	Sm1_ppm	0.97
Cu2_ppm	0.96	Sr2_ppm	0.92
Cu3_ppm	0.96	Ta1_ppm	0.61
Dy2_ppm	0.95	Tb1_ppm	0.88
Eu1_ppm	0.56	Th1_ppm	0.97
F9_ppm	0.93	Th2_ppm	0.59
Fe1_pct	0.94	Ti2_ppm	0.94
Fe2_pct	0.94	U1_ppm	0.97
Fe3_pct	0.93	U8_ppm	0.96
Ga2_ppm	0.83	V2_ppm	0.96
Hf1_ppm	0.88	V5_ppm	0.94
Hg18_ppm	0.91	W13_ppm	0.72
K2_pct	0.94	W1_ppm	0.54
La1_ppm	0.97	Y2_ppm	0.97
La2_ppm	0.97	Yb1_ppm	0.83
Li2_ppm	0.95	Zn2_ppm	0.93
LOI_pct	0.91	Zn3_ppm	0.92
Lu1_ppm	0.90	Zr2_ppm	0.95
Mg2_pct	0.94		
Water			
Fw9_ppb	0.92	Uw10_ppb	0.62
pHw	0.95	Uw11_ppb	0.75

Note: Coefficients are significant at the 0.000 confidence level for all variables shown in Figures 2 and 3. The greater the absolute value of r, the better the correlation with ± 1.00 representing a perfect correlation.

STATISTICAL ANALYSIS

SUMMARY STATISTICS

To quantify the range and distribution characteristics of the element populations, summary statistics have been calculated for the all sediment data (Table 4). Analyses of the second sample of site-duplicate pairs are excluded. Statistics tabulated include the median, arithmetic mean, geometric mean, arithmetic standard deviation, logarithmic standard deviation and minimum and maximum. Because the distributions of most element populations are more log-normal than normal, the geometric means as well as arithmetic means are given.

HISTOGRAMS AND CUMULATIVE FREQUENCY CURVES

Histograms of the lake-sediment and water variables are included in the symbol plot maps showing the distributions of the variables. These figures show the shape of the population distributions and may be useful when interpreting the distribution maps of these variables. Cumulative frequency curves are also incorporated into these maps. The curves show the percentage of data accounted for by the progressive range of variable values.

DATA PRESENTATION

Symbol plot images of 29 of the 30 elements analyzed by ICP-ES were prepared in ArcMap™. Thorium had only about 2200 analyses and is not plotted. For most elements, the data were divided into six intervals using the Jenks natural breaks optimization method, which seeks to minimize the average deviation from the group mean for each group, while maximizing the deviation from the means of the other groups.

The element divisions were inspected visually, and in some instances the intervals were manually adjusted to emphasize the highest value samples. The dot layers were sorted sequentially so that the lowest value symbols (black) plotted on the bottom and the highest value symbols (red) plotted on top to ensure none of the higher value symbols were obscured.

The elements are presented as pdf files in Figures 4–33. This format permits areas of interest to be examined in detail by zooming to the most appropriate scale while still retaining high resolution.

DATA

The data are described in Appendix 1 and are available on the web and CD as Appendix 2 in .csv format.

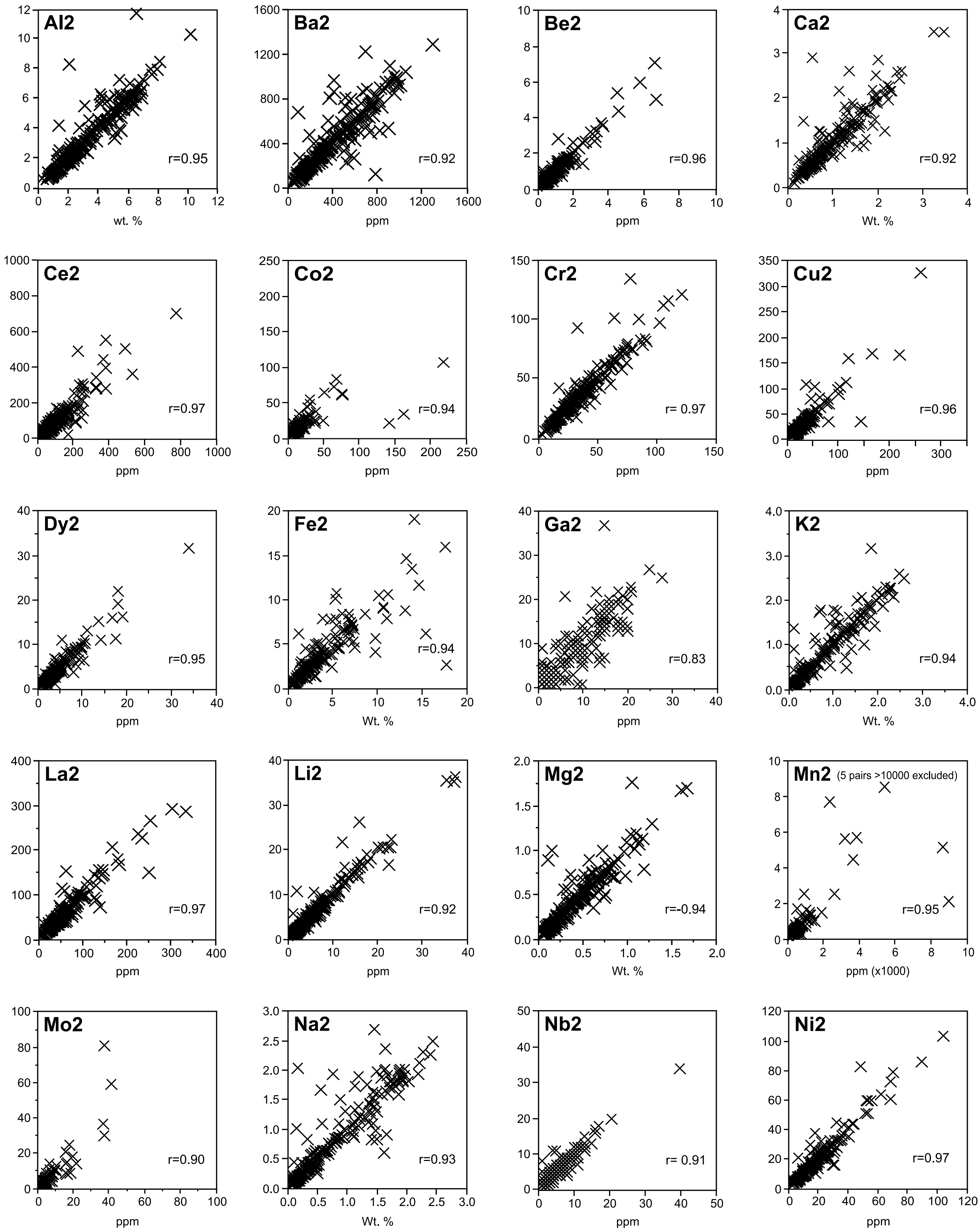

Figure 2. *Scatterplots and Spearman correlation coefficients of ICP-ES site-duplicate data: Al2, Ba2, Be2, Ca2, Ce2, Co2, cr2, Cu2, Dy2, Fe2, Ga2, K2, La2, Li2, Mg2, Mn2, Mo2, Na2, Nb2 and Ni2.*

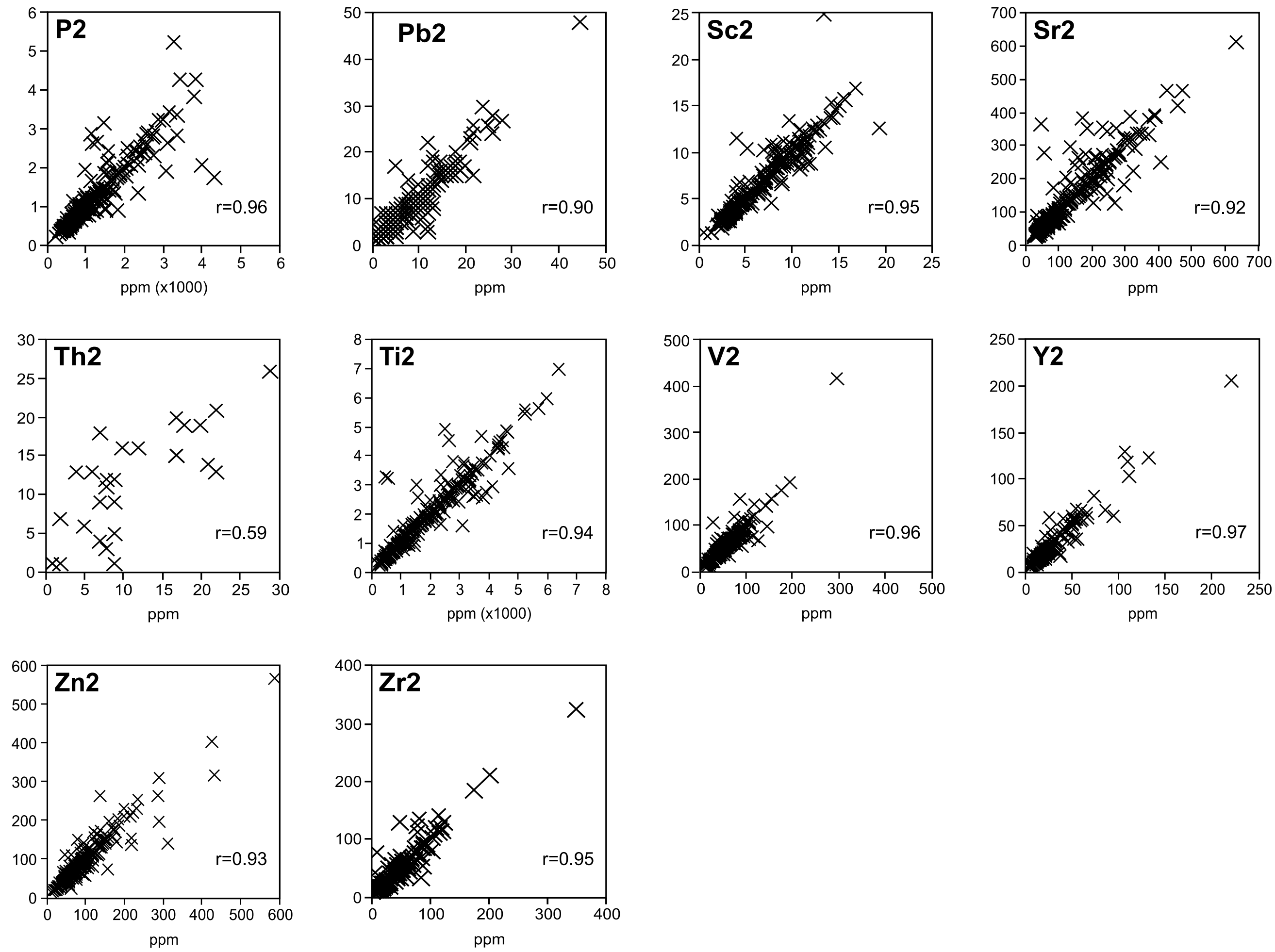

Figure 3. *Scatterplots and Spearman correlation coefficients of ICP-ES site-duplicate data: P2, Pb2, Sc2, Sr2, Th2, Ti2, V2, Y2, Zn2 and Zr2.*

Table 4. Summary statistics for all lake-sediment and water data

Variable	No. Samples	Median	Mean (Arithmetic)	Mean (Geometric)	Standard Deviation (Arithmetic)	Standard Deviation (Logarithmic)	Minimum	Maximum
Sediment								
Ag3_ppm	18693	<0.1	0.1	0.1	0.1	0.18	0.1	2.2
Al2_pct	18292	3.36	3.64	3.01	2.03	0.29	0.08	12
As19_ppm	18697	<0.5	1.5	0.8	4.9	0.52	0.3	335
As1_ppm	14251	<1.0	2	0.8	5.9	0.35	0.2	336
As21_ppm	4373	<1.0	0.7	0.6	0.6	0.18	0.5	11
Au1_ppb	18697	<2.0	1.5	1.2	1.5	0.22	1	57
Ba1_ppm	18697	300	420	297	349	0.38	25	4800
Ba2_ppm	18292	337	412	331	269	0.3	1	3158
Be2_ppm	18292	0.9	1.1	0.8	1.6	0.35	0.1	77.1
Br1_ppm	18697	21	26.1	20.5	21.4	0.31	0.2	721
Ca2_pct	18292	0.83	1.03	0.84	0.71	0.28	0.01	35.82
Cd3_ppm	9697	<0.2	0.2	0.1	0.6	0.25	0.1	48
Ce1_ppm	18697	86	114	84	104	0.35	1	1690
Ce2_ppm	18292	78	106	80	98	0.33	1	1442
Co1_ppm	18694	11	14	8	17	0.55	1	470
Co2_ppm	18292	11	14	10	15	0.36	1	441
Co3_ppm	18693	7	10	7	12	0.38	1	370
Cr1_ppm	18697	39	47	33	40	0.39	8	670
Cr2_ppm	18292	31	38	30	28	0.31	1	402
Cs1_ppm	18696	0.2	0.6	0.4	0.7	0.37	0.2	13
Cu2_ppm	18292	21	28	21	27	0.34	1	508
Cu3_ppm	18693	20	26	20	24	0.31	1	450
Dy2_ppm	18292	3.4	4.6	3.5	4.9	0.29	0.1	164.3
Eu1_ppm	18695	1	1.3	1	1.1	0.29	0.5	26
F9_ppm	18534	180	210	167	143	0.31	20	1640
Fe1_pct	18696	3	3.9	2.7	3.6	0.4	0.1	69.2
Fe2_pct	18292	2.84	3.52	2.52	3	0.38	0.01	41.02
Fe3_pct	18693	1.9	2.72	1.85	2.68	0.39	0.01	42
Ga2_ppm	14320	9	9.6	6.9	6.5	0.41	1	112
Hf1_ppm	18697	2	3.4	2	3.7	0.46	0.5	50
Hg18_ppb	18570	70	82	69	53	0.26	5	900
K2_pct	18292	0.53	0.76	0.48	0.66	0.45	0.01	4.89
La1_ppm	18695	41	54	40	50	0.34	1	971
La2_ppm	18292	43	57	44	51	0.32	1	905
Li2_ppm	18292	5.1	7.1	4.8	6.6	0.42	0.1	98.3
LOI_pct	18685	27.8	27.4	22.9	14.1	0.3	0.5	98.5
Lu1_ppm	18697	0.3	0.4	0.3	0.5	0.38	0.1	18
Mg2_pct	18292	0.32	0.43	0.31	0.34	0.36	0.01	5.11
Mn2_ppm	18291	379	765	362	2561	0.47	1	136408
Mn3_ppm	18693	165	518	193	2102	0.5	9	99999

Table 4. Continued

Variable	No. Samples	Median	Mean (Arithmetic)	Mean (Geometric)	Standard Deviation (Arithmetic)	Standard Deviation (Logarithmic)	Minimum	Maximum
Mo1_ppm	18696	1	4	2	7	0.4	1	216
Mo2_ppm	18292	2	4	2	7	0.4	1	203
Mo5_ppm	18693	2	4	2	7	0.38	1	244
Na1_pct	18695	0.57	0.9	0.54	0.84	0.48	0.02	8.75
Na2_pct	18292	0.55	0.79	0.51	0.67	0.45	0.01	4.32
Nb2_ppm	18292	4	5	4	4	0.33	1	50
Ni1_ppm	18696	5	17	10	22	0.4	5	620
Ni2_ppm	18292	15	20	15	20	0.31	1	522
Ni3_ppm	18693	12	17	12	19	0.34	1	550
P2_ppm	18292	1013	1257	1037	842	0.27	1	12520
Pb2_ppm	18292	7	9	7	8	0.34	1	392
Pb3_ppm	18693	1	2	2	5	0.31	1	365
Rb1_ppm	18696	17	27	14	27	0.55	2	260
Sb1_ppm	18697	<0.1	0.12	0.08	0.26	0.32	0.05	16.1
Sc1_ppm	18696	6.7	7.8	6.3	4.8	0.29	0.1	47.5
Sc2_ppm	18292	6.6	7.2	6.2	7	0.25	0.1	804
Sm1_ppm	18697	6.4	7.9	6.2	6.8	0.31	0.1	204
Sr2_ppm	18292	116	153	119	109	0.31	1	865
Ta1_ppm	18695	0.2	0.4	0.3	0.3	0.26	0.2	3.8
Tb1_ppm	18696	0.7	0.9	0.6	0.9	0.37	0.2	32
Th1_ppm	18697	5	6	4	4	0.35	0.1	68
Th2_ppm	2070	9	10	8	7	0.38	1	46
Ti2_ppm	18292	1666	1944	1518	1286	0.33	1	13738
U1_ppm	18697	1.8	3.8	1.9	11.3	0.48	0.1	1030
U8_ppm	18703	1.9	3.8	2	10.7	0.46	0.1	926
V2_ppm	18292	56	59	50	32	0.28	1	369
V5_ppm	9697	40	48	40	29	0.27	2	370
W1_ppm	18696	1	1	1	1	0.08	1	19
Y2_ppm	18292	20	27	21	31	0.29	1	969
Yb1_ppm	18697	1	2.2	1.4	2.9	0.38	0.5	100
Zn2_ppm	18292	85	98	83	87	0.24	1	7062
Zn3_ppm	18693	73	89	73	124	0.27	2	13500
Zr2_ppm	18292	30	39	27	34	0.39	1	606
depth_m	18681	5	8.3	4.8	10.95	0.45	0	192
Water								
pHw	18706	6.3	6.3	1	0.52		3.5	8.4
Fw9_ppb	18706	28	35	27	36	0.29	10	980
Uw10_ppb	14393	<0.02	0.02	0.01	0.04	0.24	0.01	2.55
Uw11_ppb	14825	<0.02	0.035	0.011	0.09	0.56	0.005	3.2

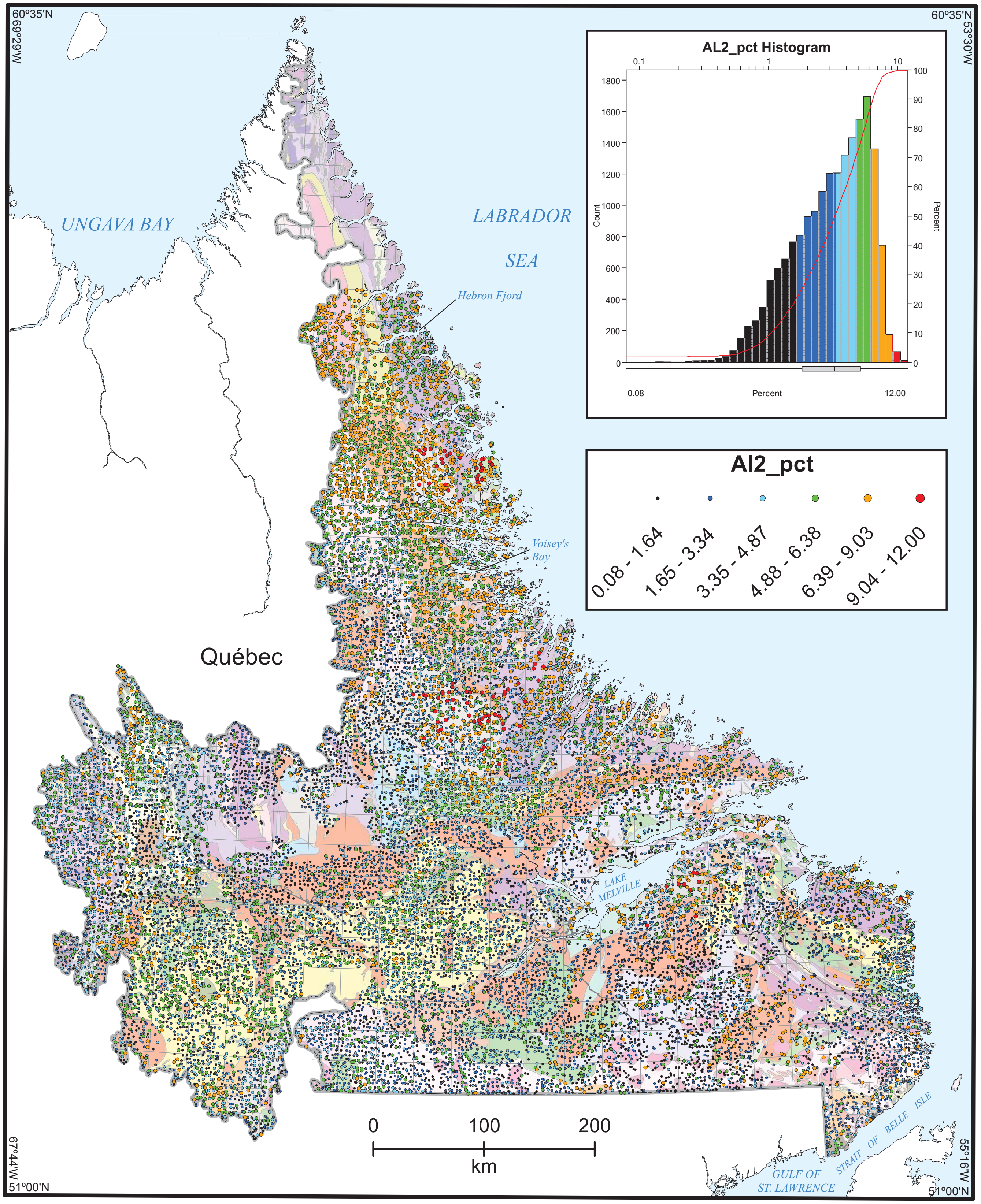

Figure 4. *Aluminum (A12_pct) in lake sediment.*

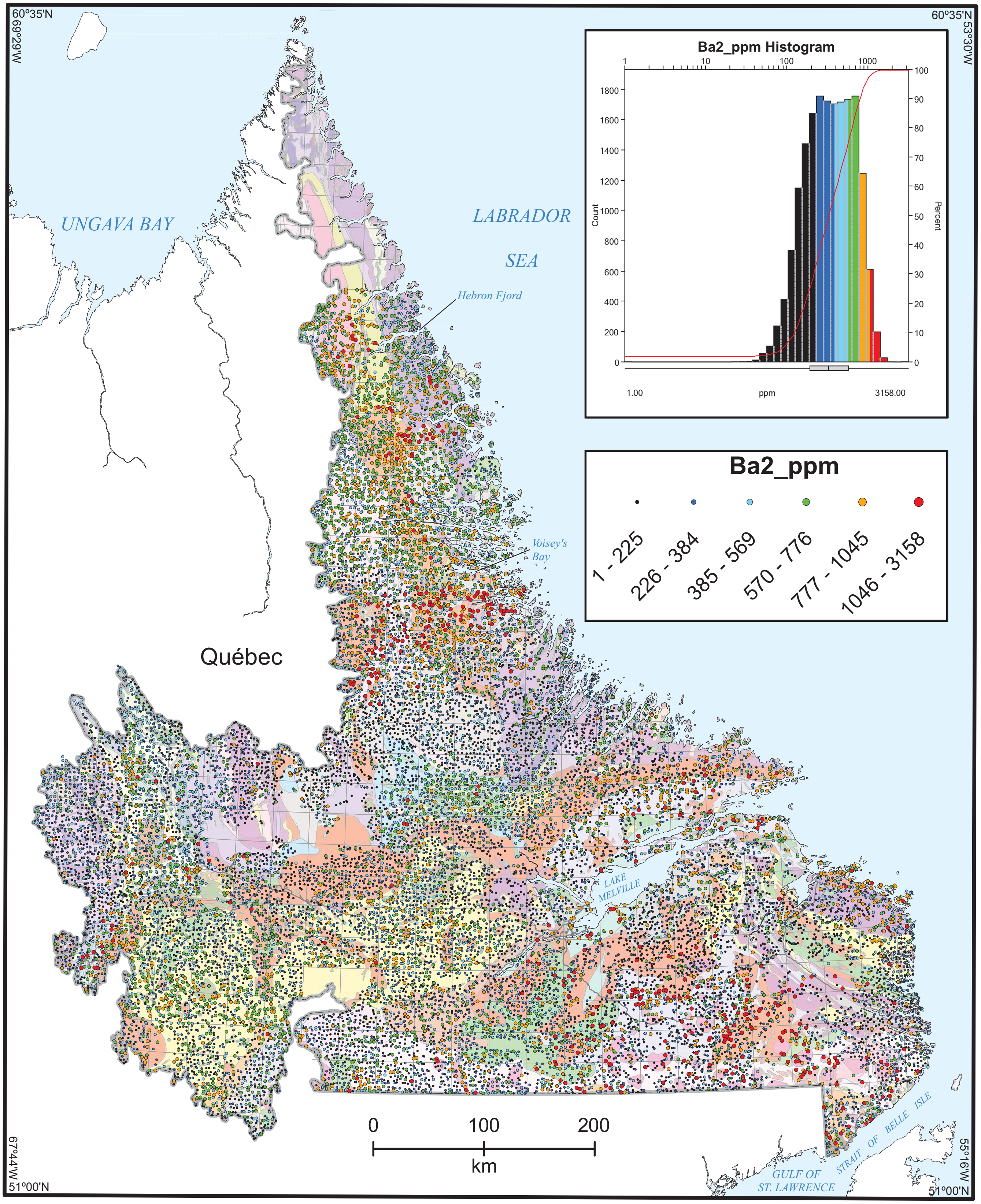

Figure 5. *Barium (Ba2_ppm) in lake sediment.*

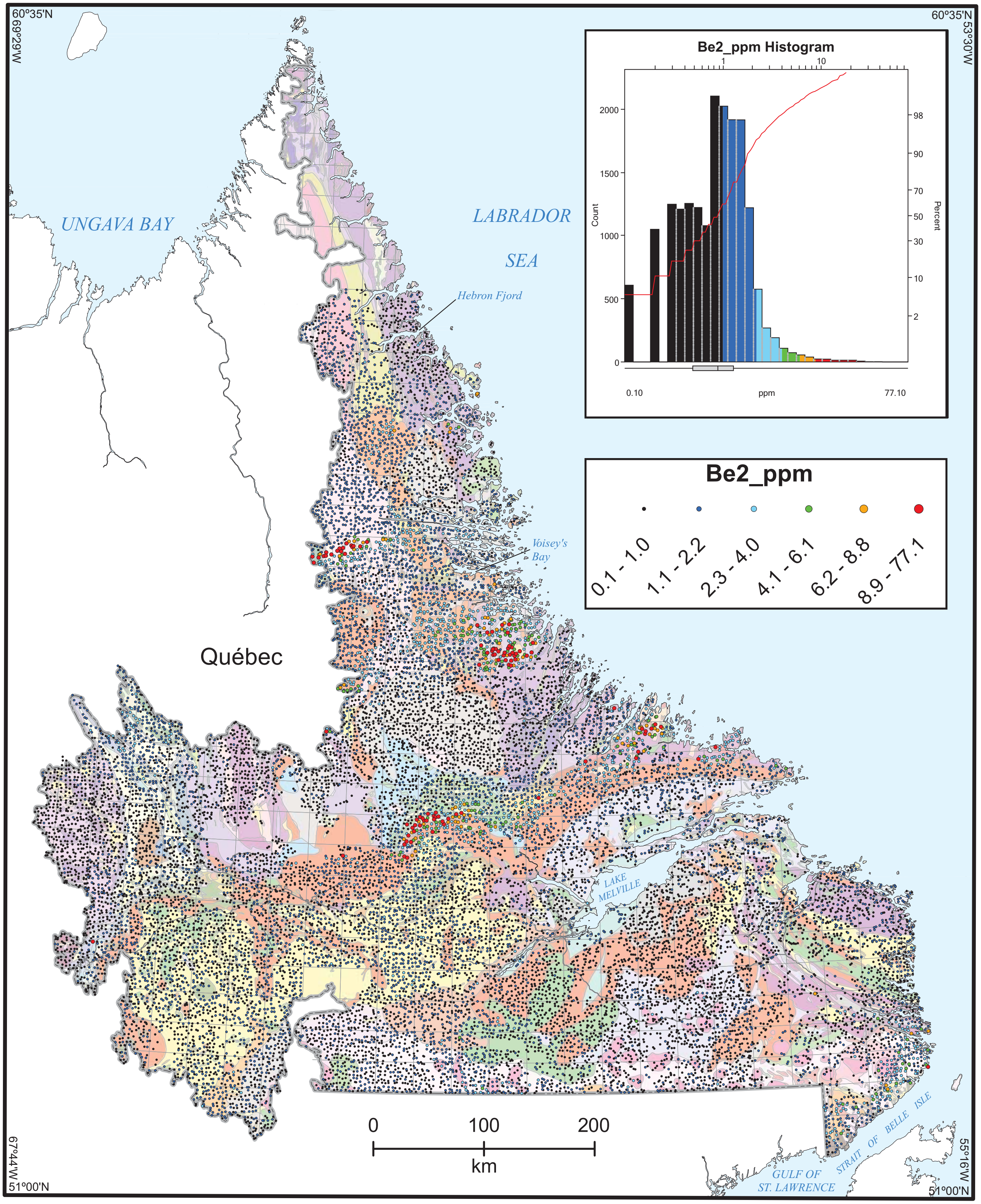

Figure 6. *Beryllium (Be2_ppm) in lake sediment.*

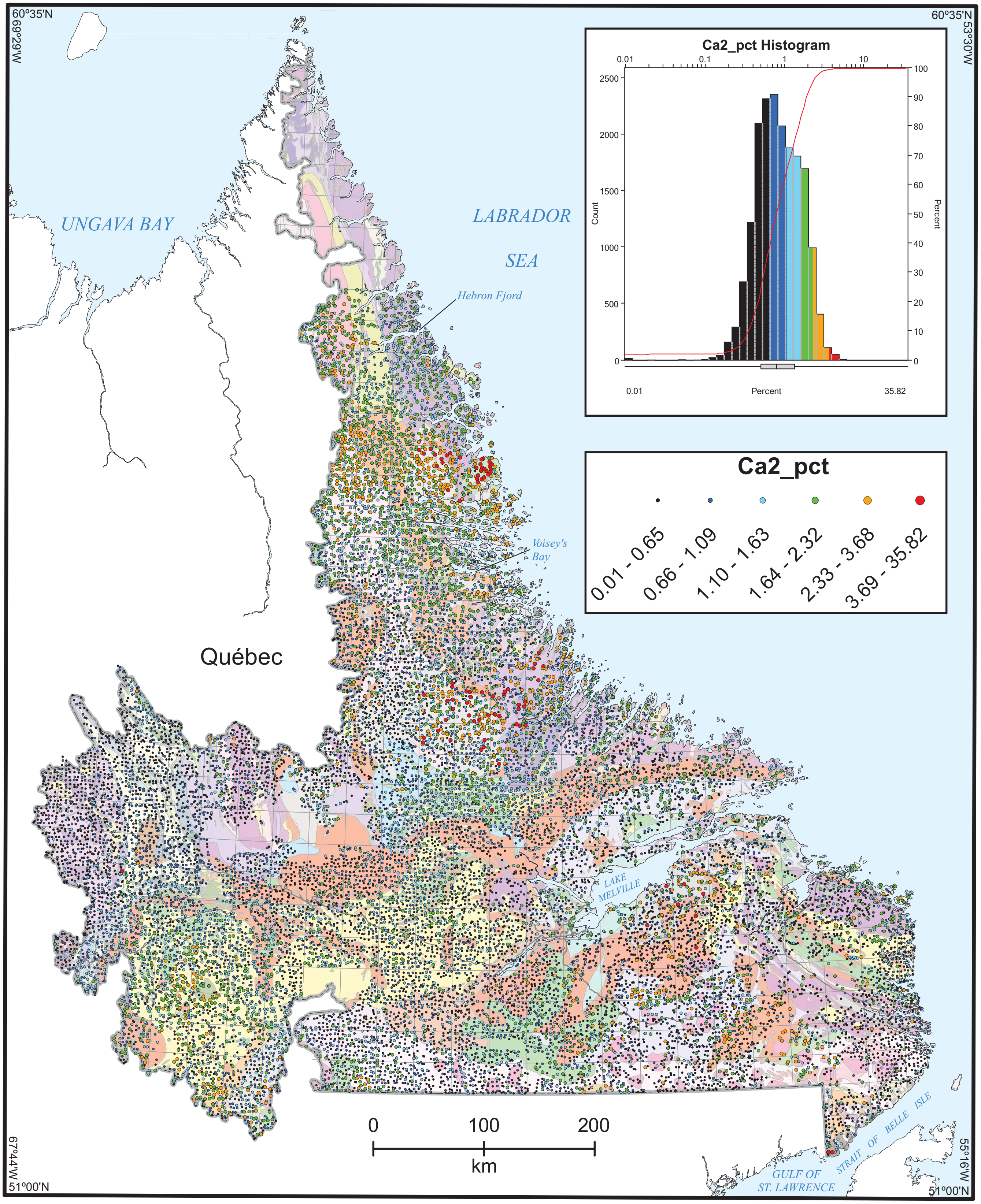

Figure 7. *Calcium (Ca2_pct) in lake sediment.*

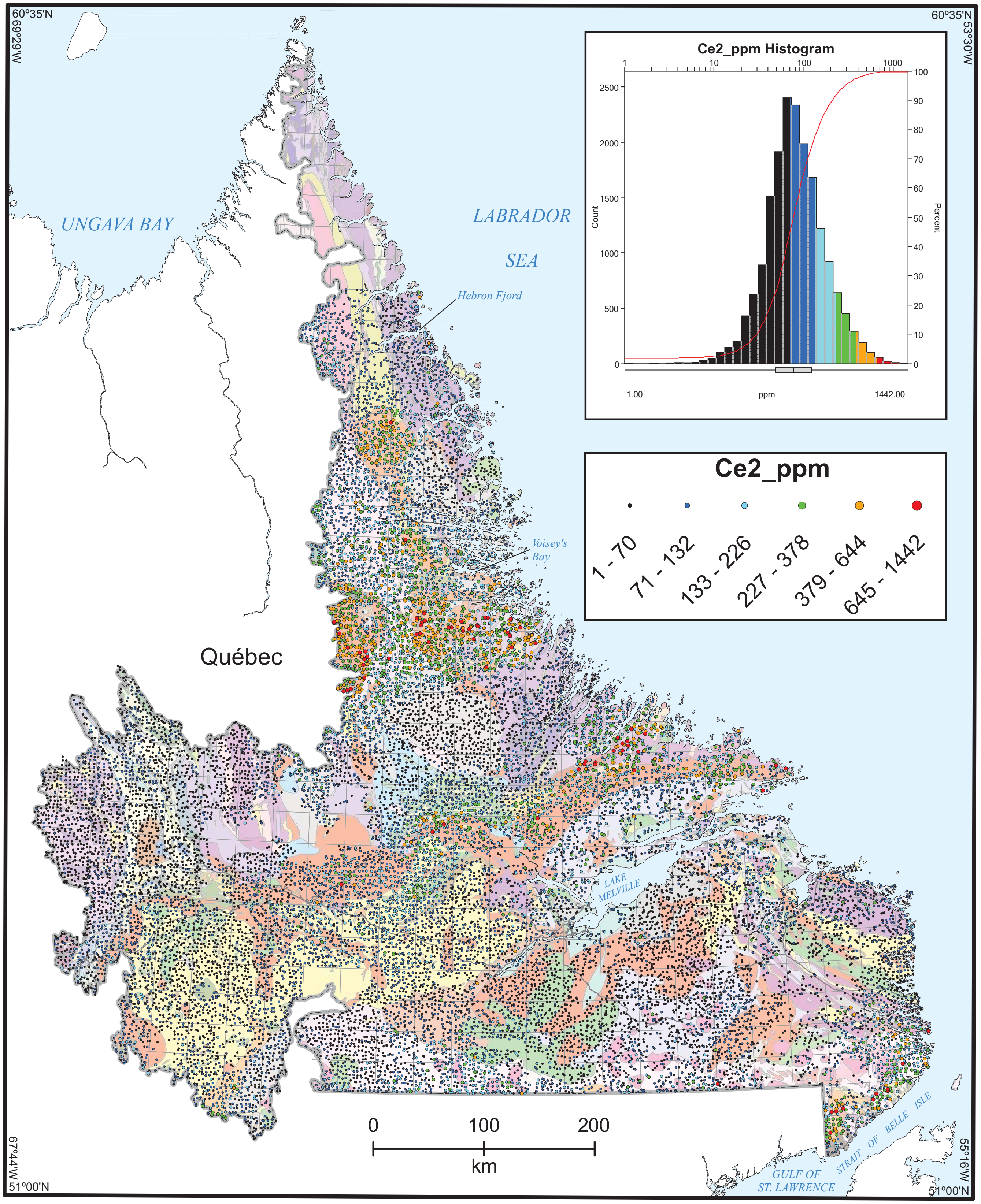

Figure 8. *Cerium (Ce2_ppm) in lake sediment.*

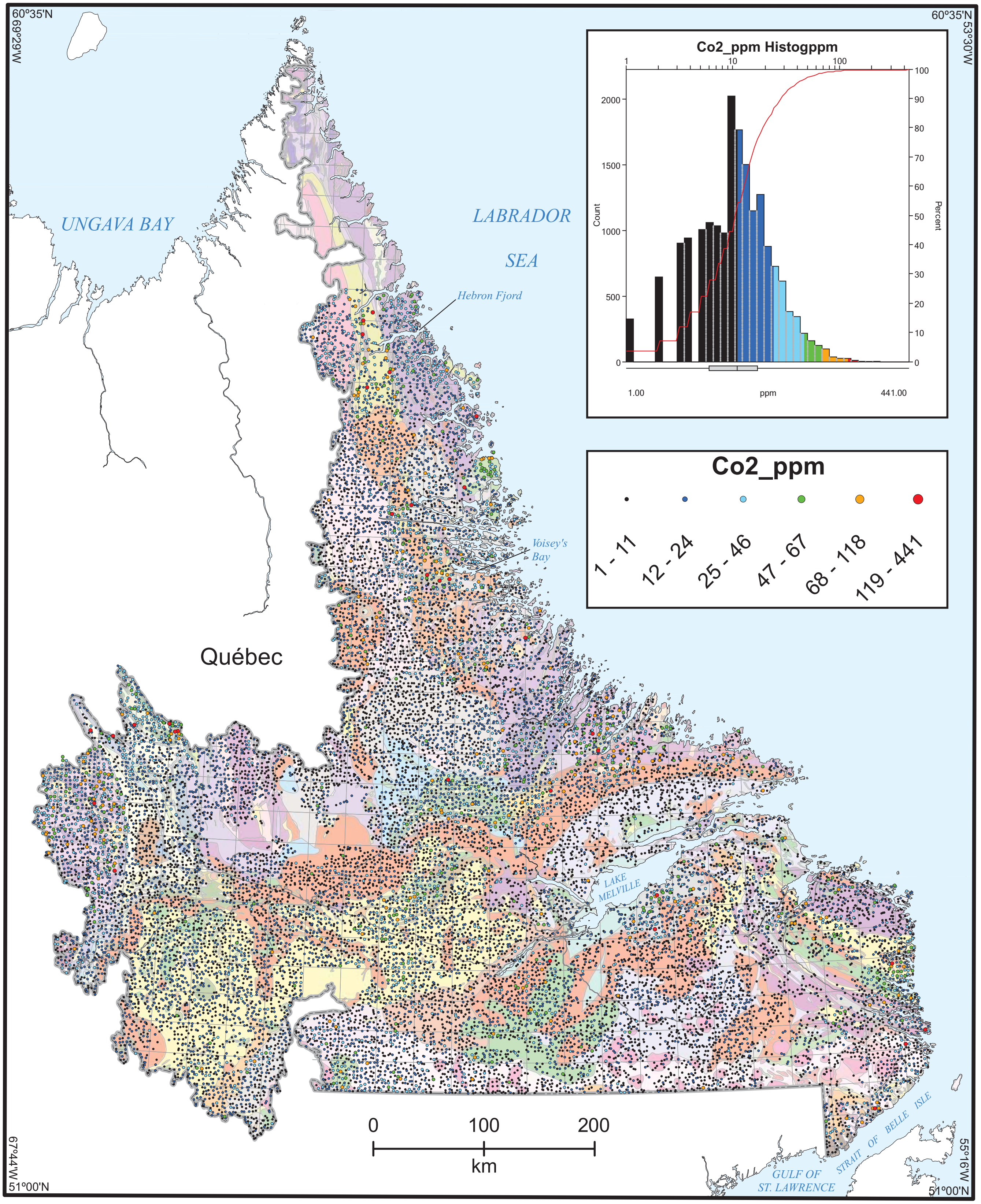

Figure 9. *Cobalt (Co2_ppm) in lake sediment.*

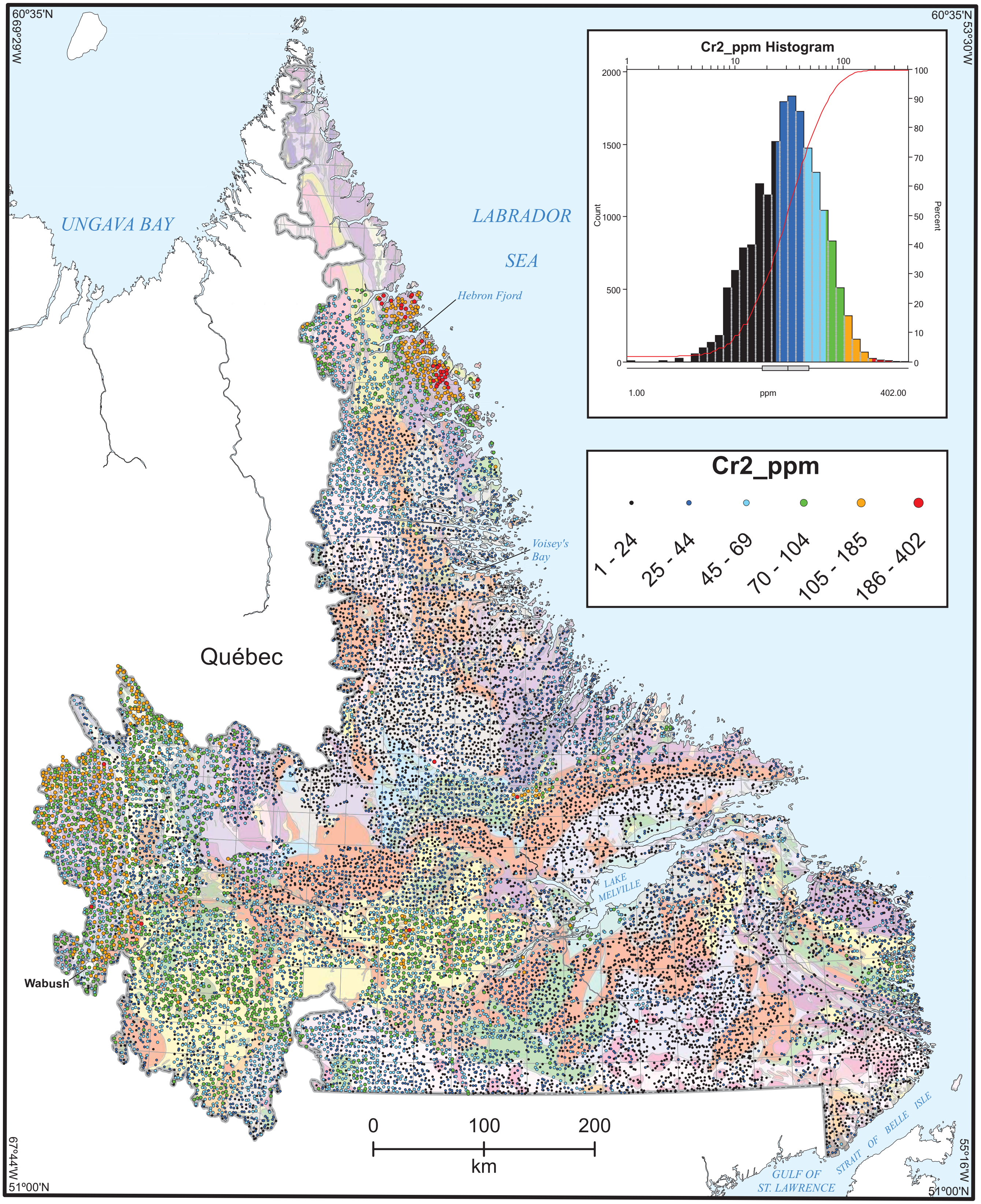

Figure 10. *Chromium (Cr2_ppm) in lake sediment.*

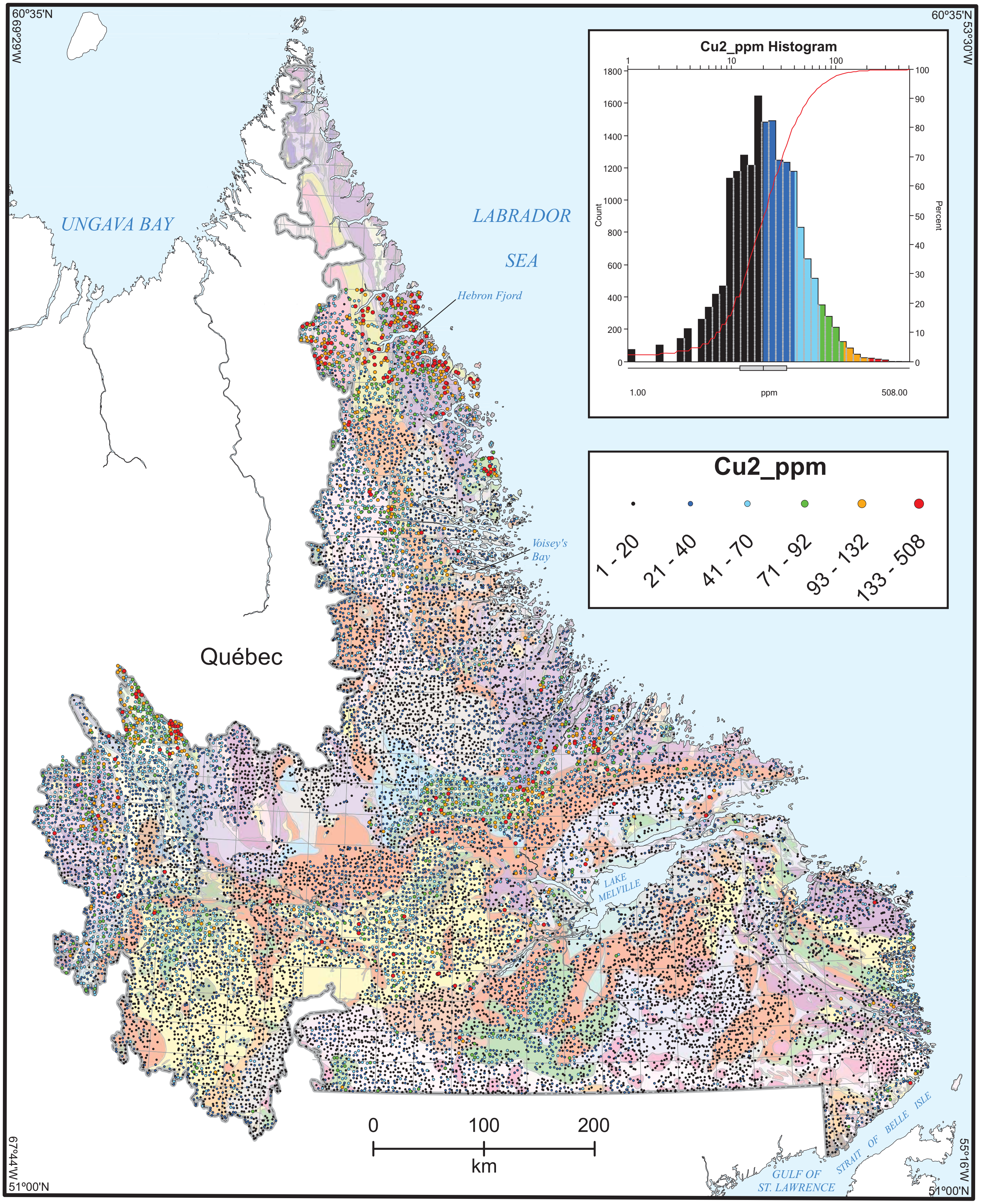

Figure 11. *Copper (Cu2_ppm) in lake sediment.*

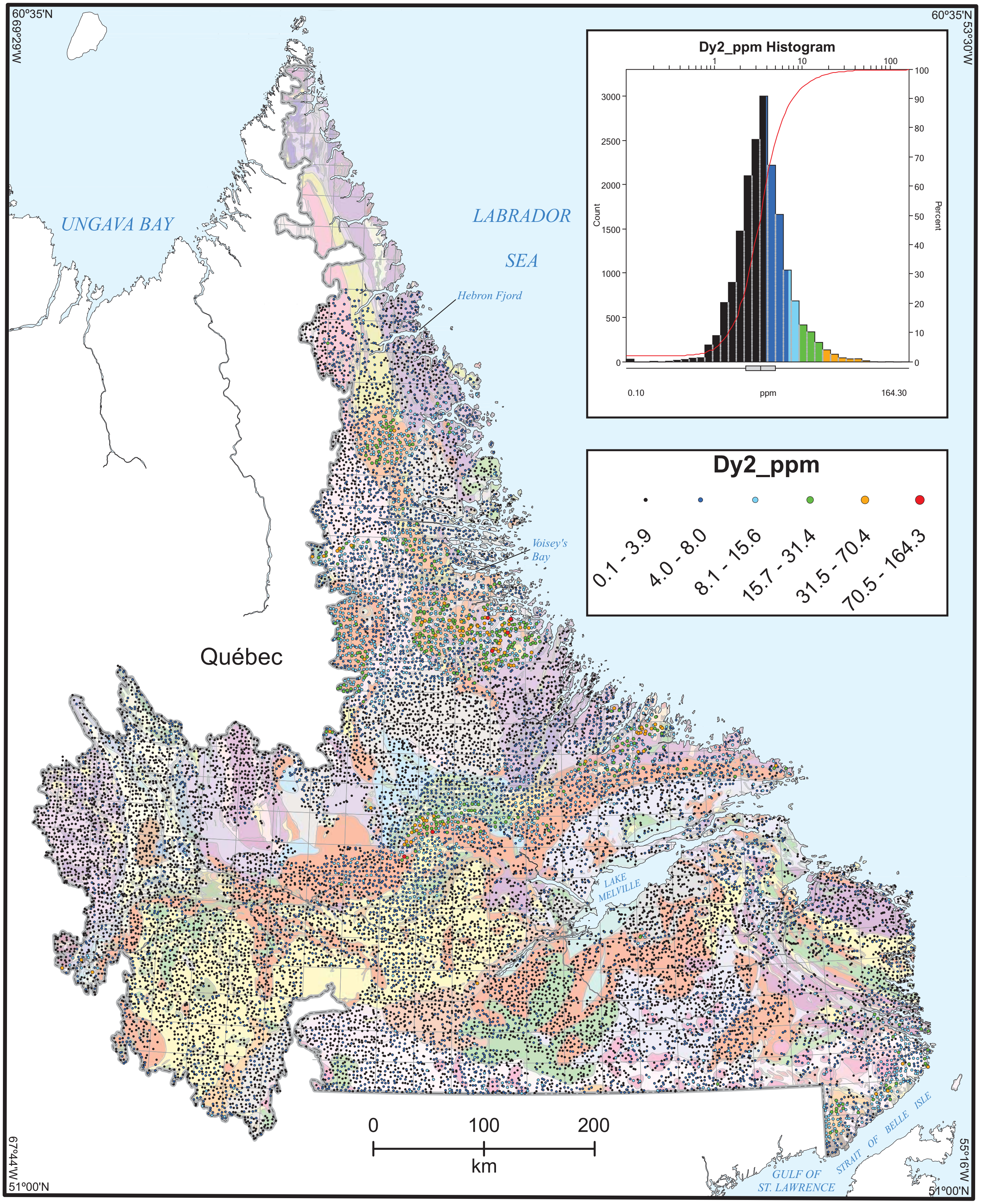

Figure 12. *Dysprosium (Dy2_ppm) in lake sediment.*

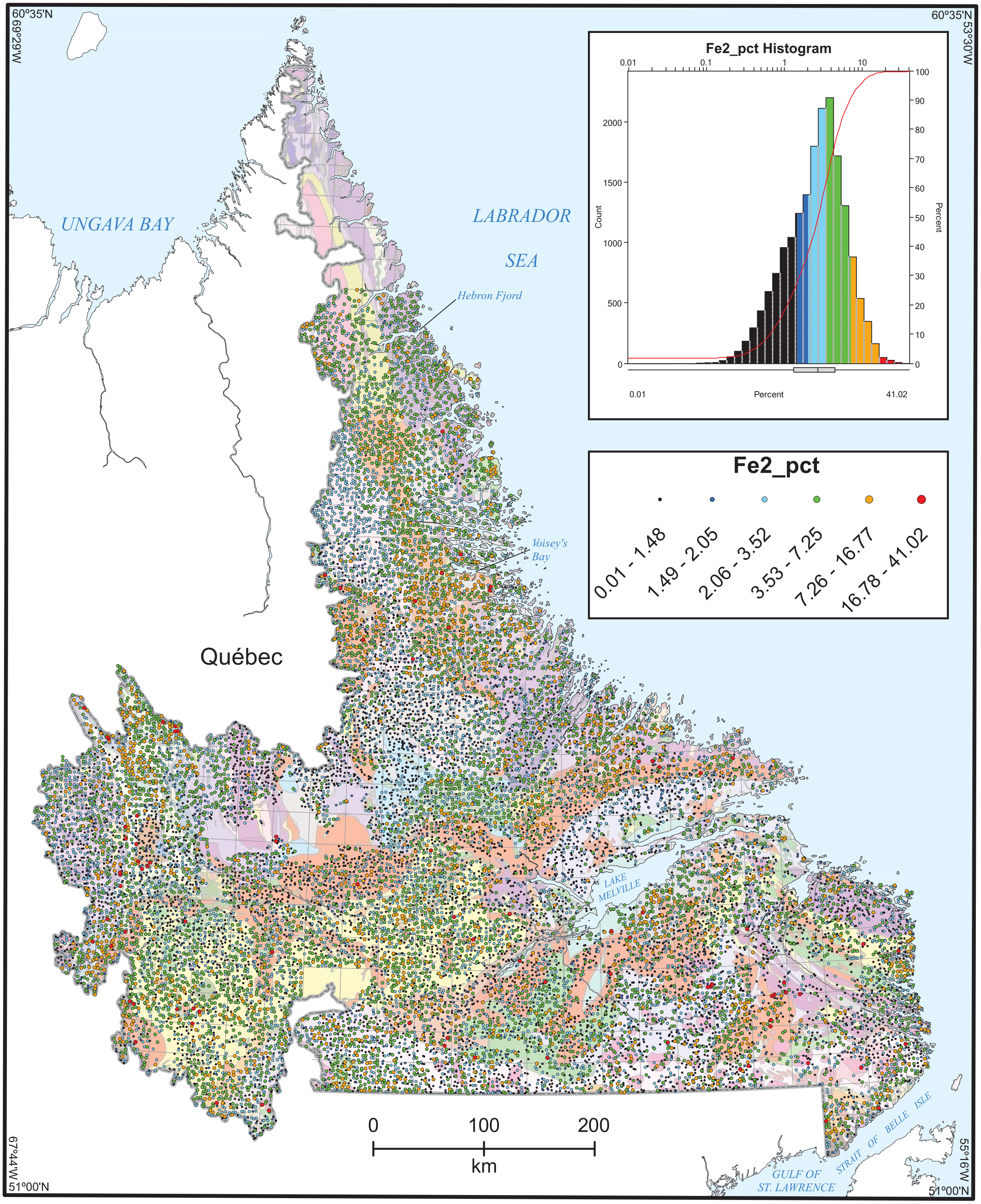

Figure 13. *Iron (Fe2_pct) in lake sediment.*

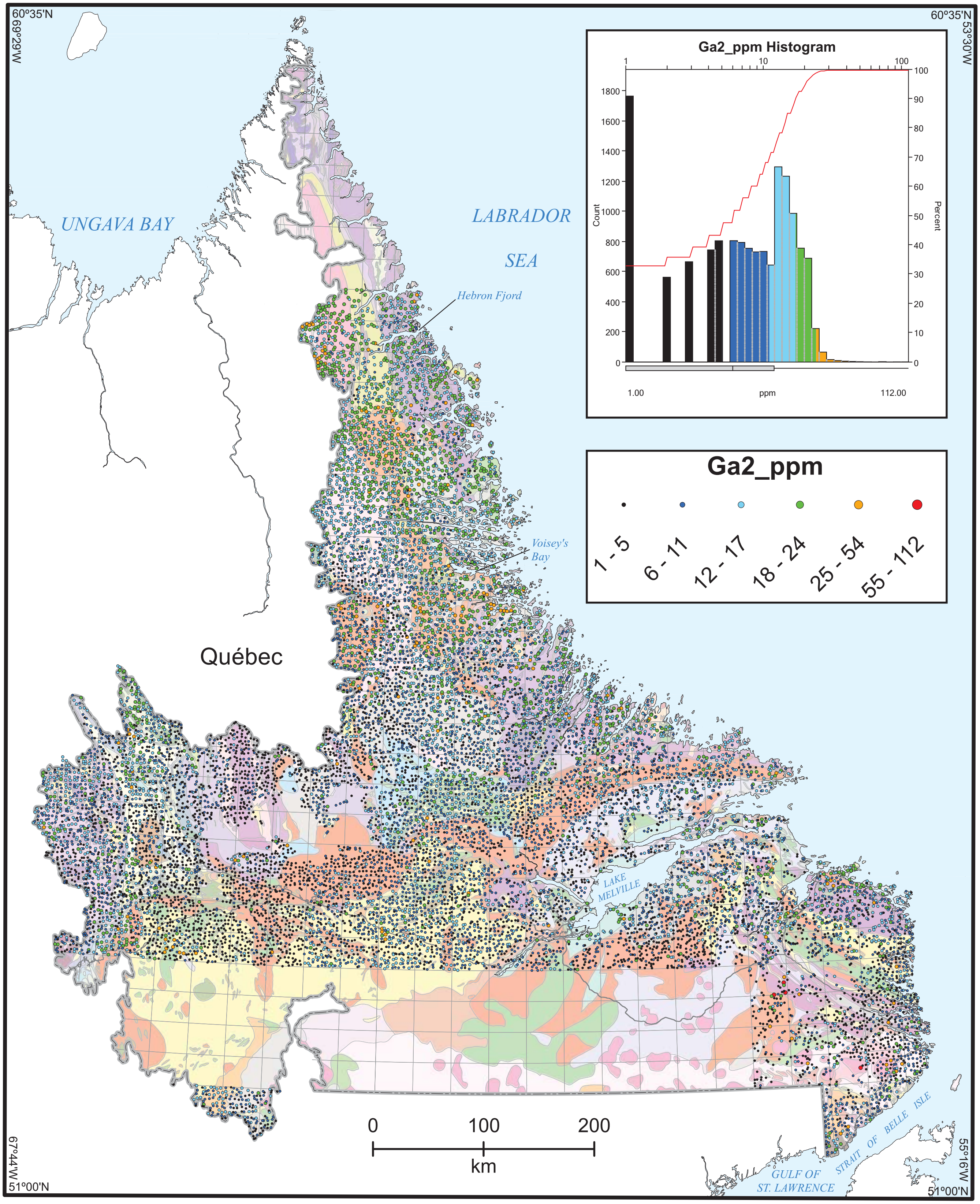

Figure 14. *Gallium (Ga2_ppm) in lake sediment.*

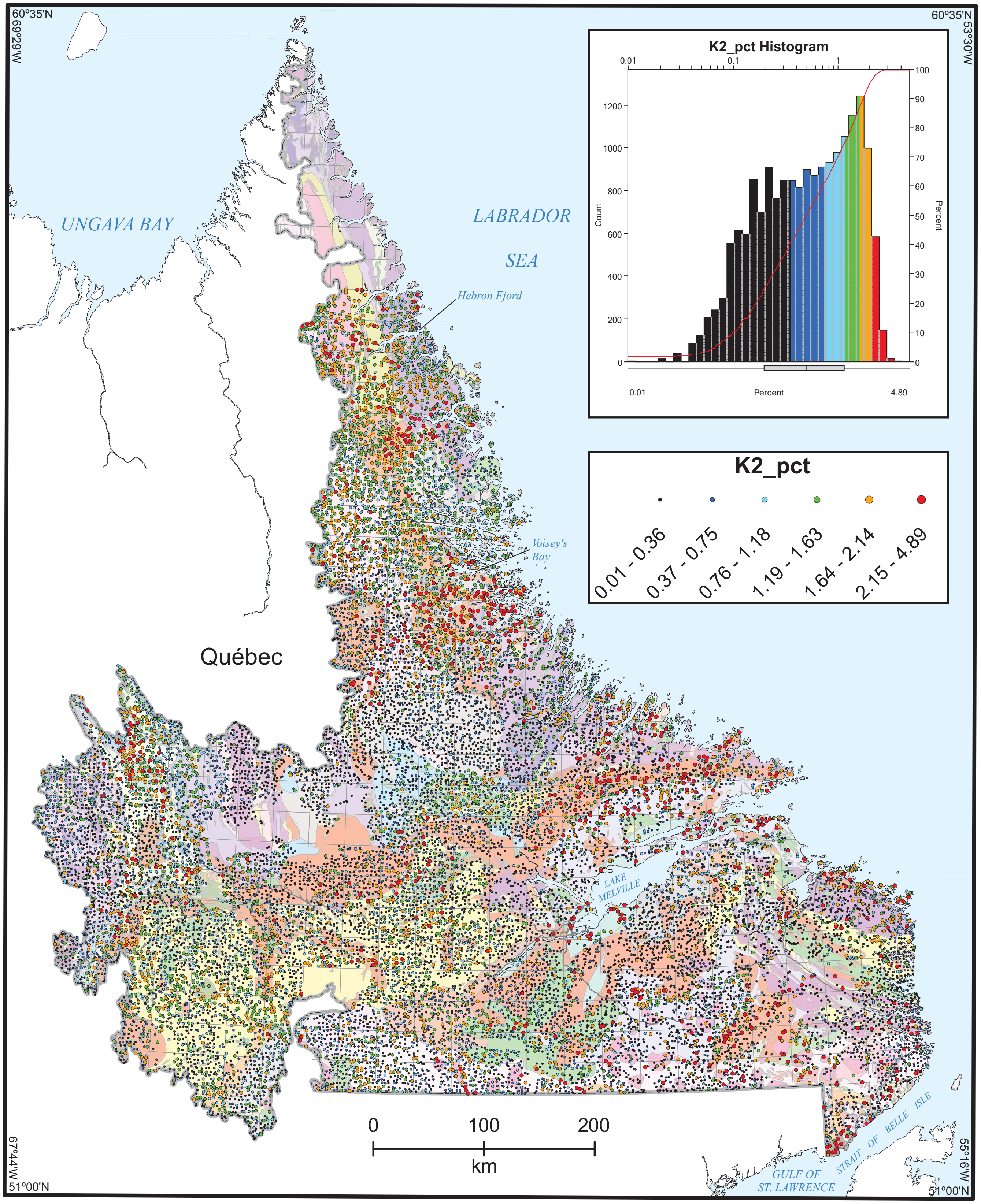

Figure 15. *Potassium (K2_pct) in lake sediment.*

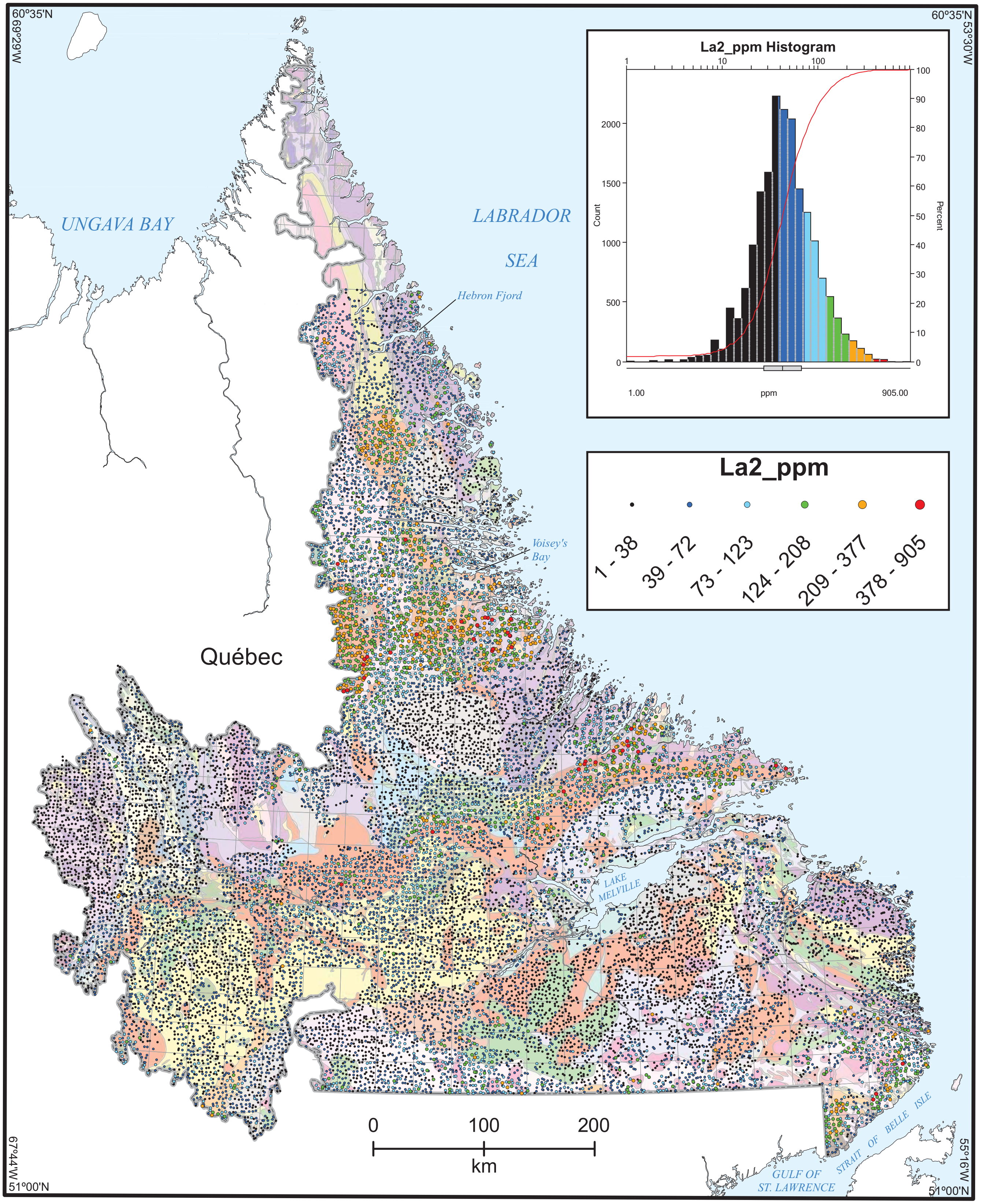

Figure 16. *Lanthanum (La2_ppm) in lake sediment.*

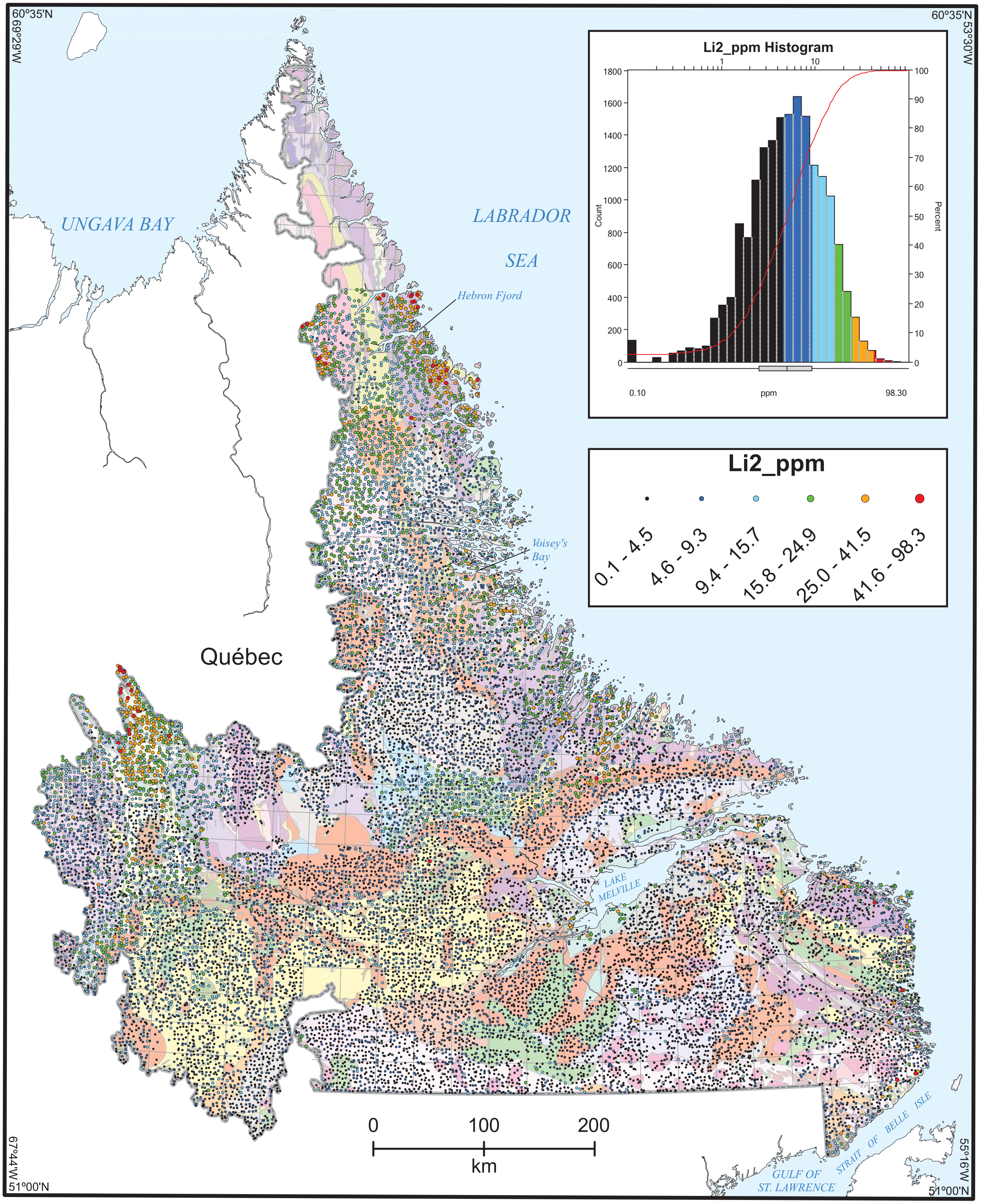

Figure 17. *Lithium (Li2_ppm) in lake sediment.*

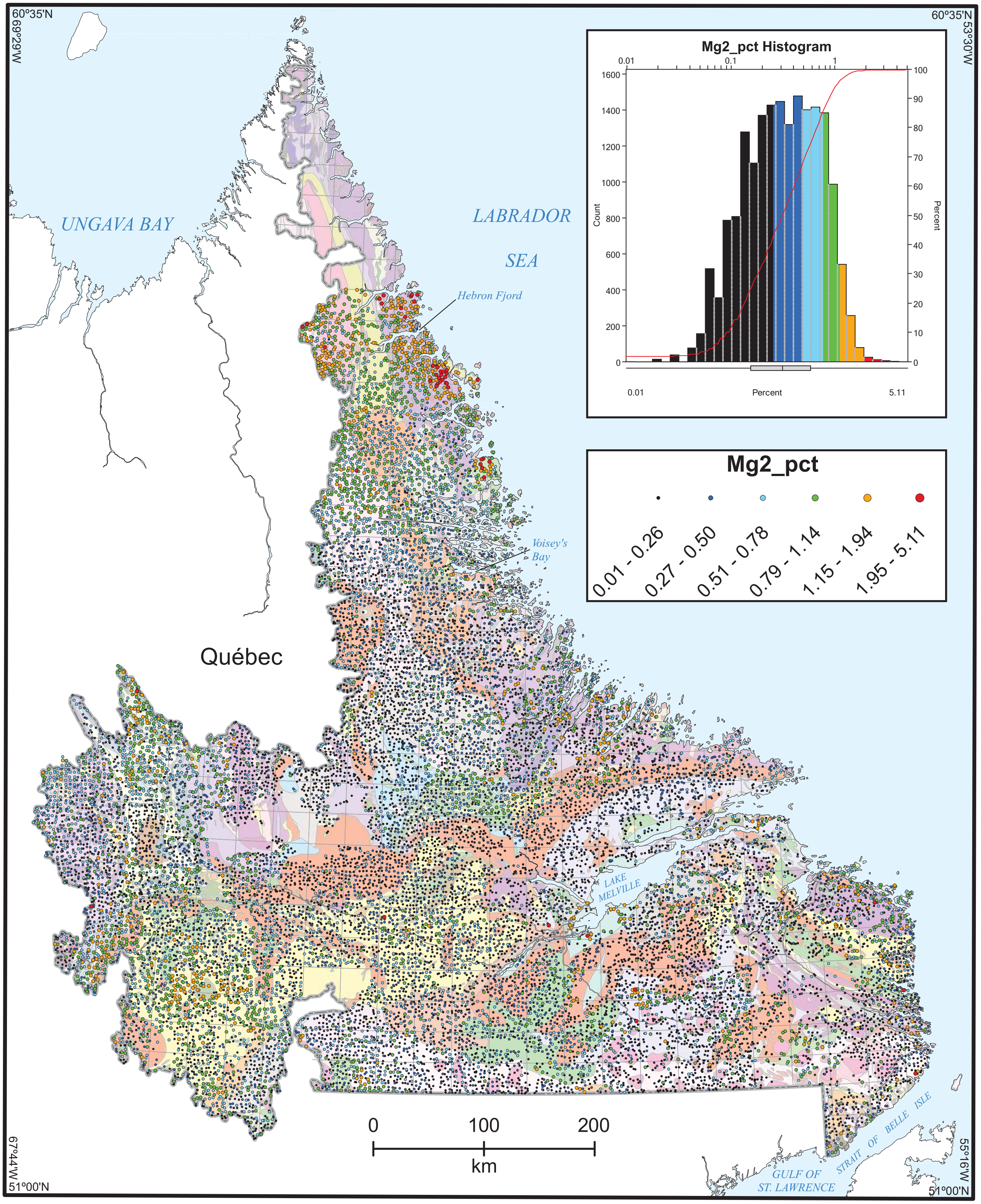

Figure 18. *Magnesium (Mg2_pct) in lake sediment.*

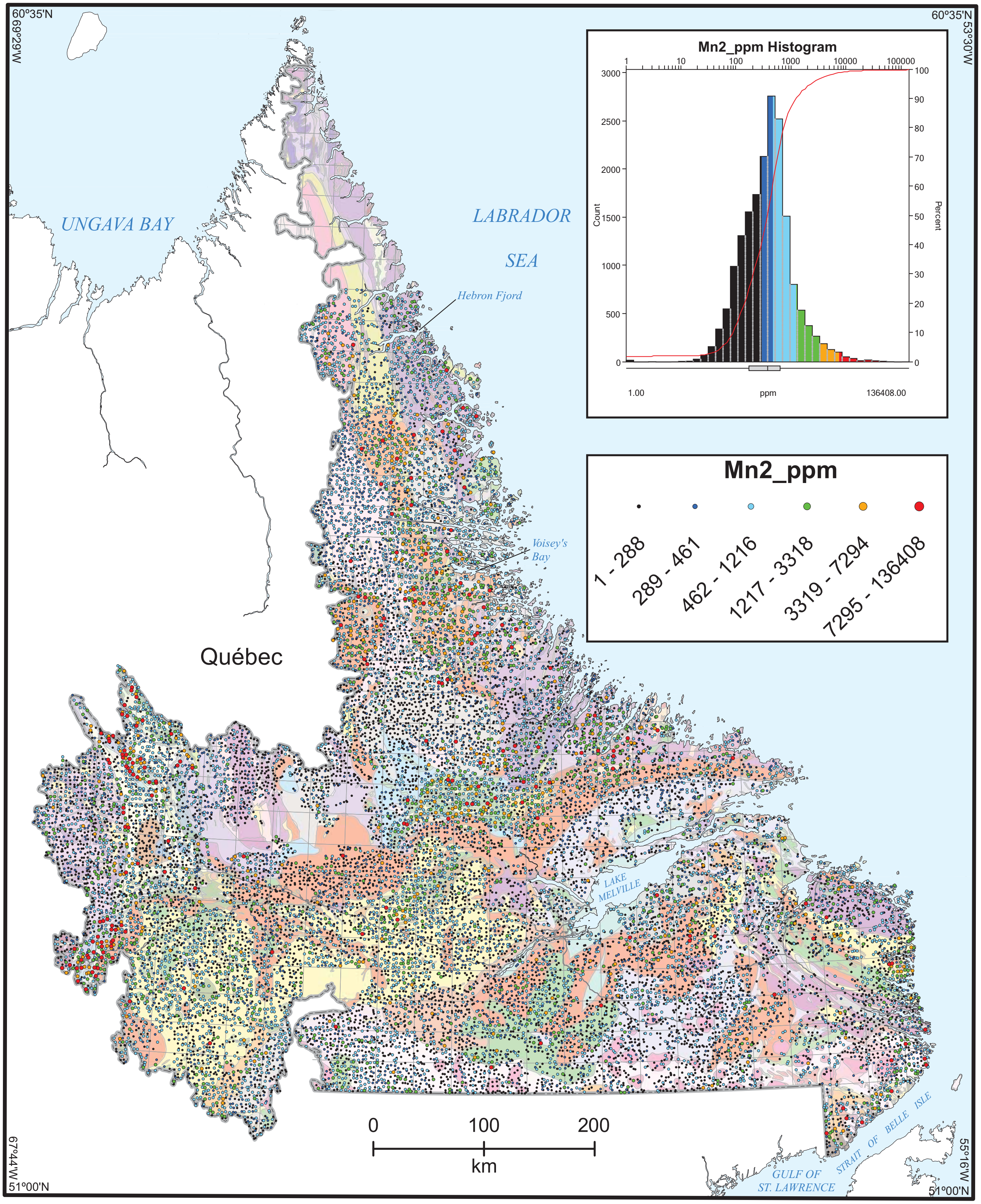

Figure 19. *Manganese (Mn2_ppm) in lake sediment.*

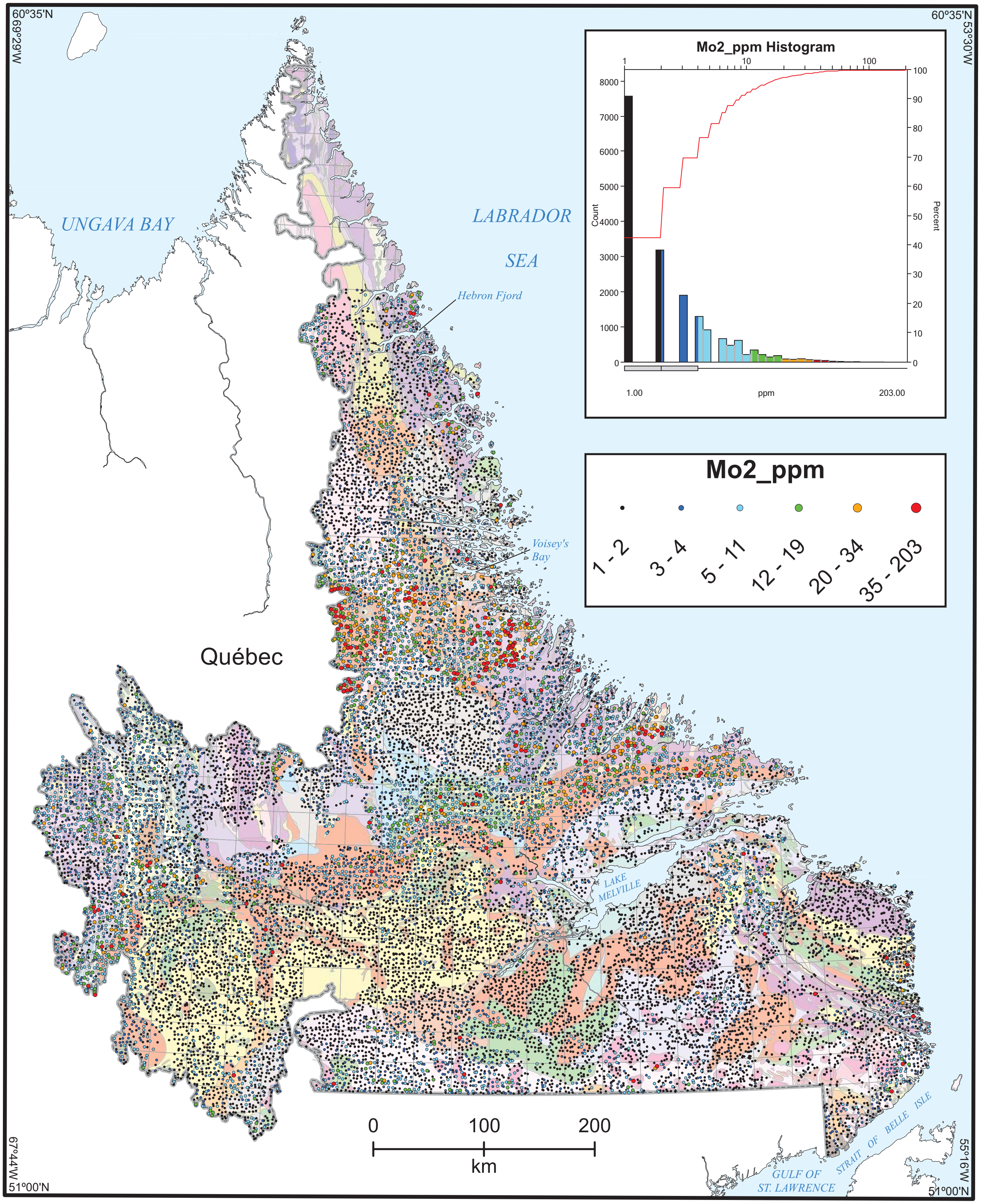

Figure 20. *Molybdenum (Mo2_ppm) in lake sediment.*

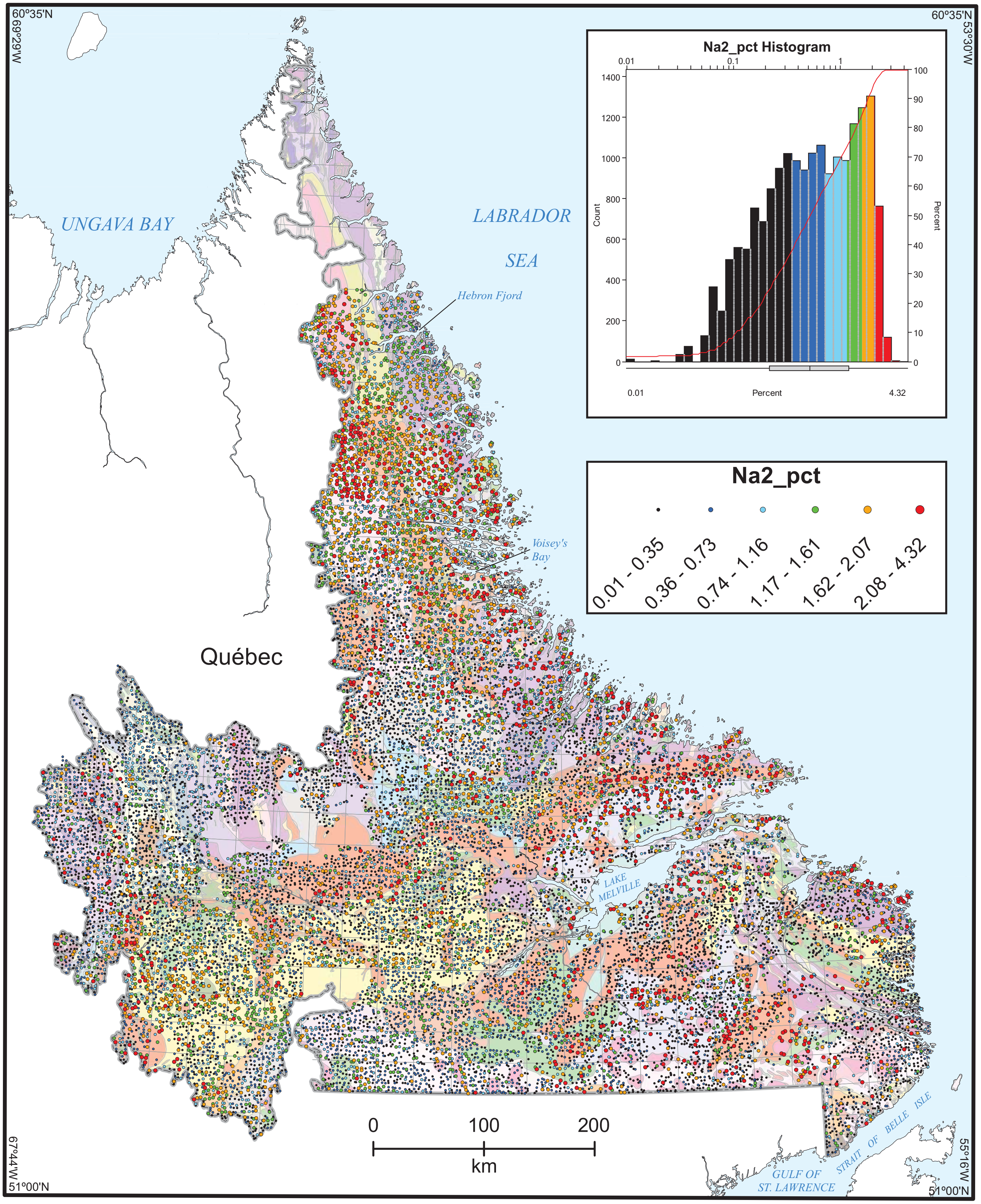

Figure 21. *Sodium (Na2_pct) in lake sediment.*

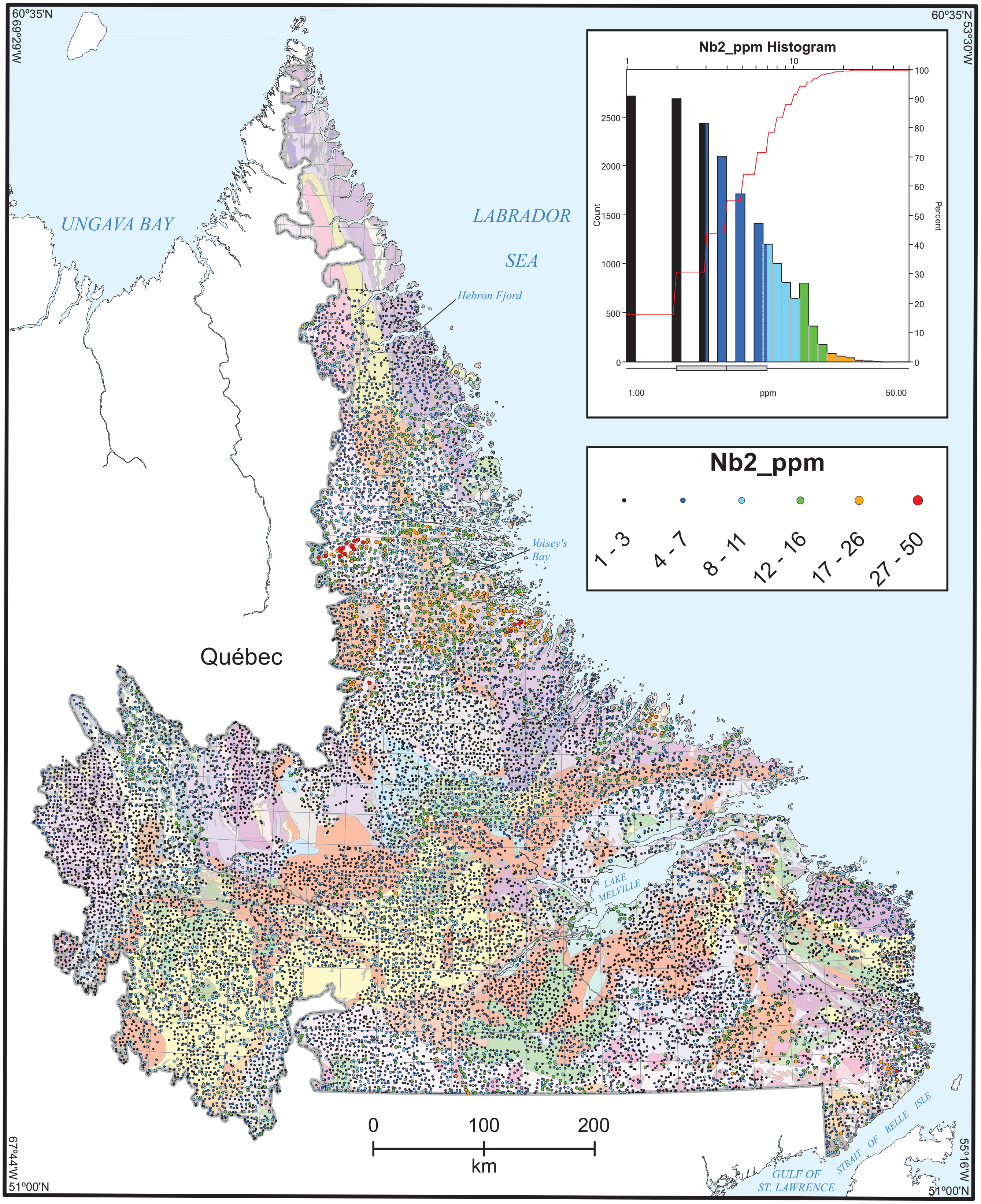

Figure 22. *Niobium (Nb2_ppm) in lake sediment.*

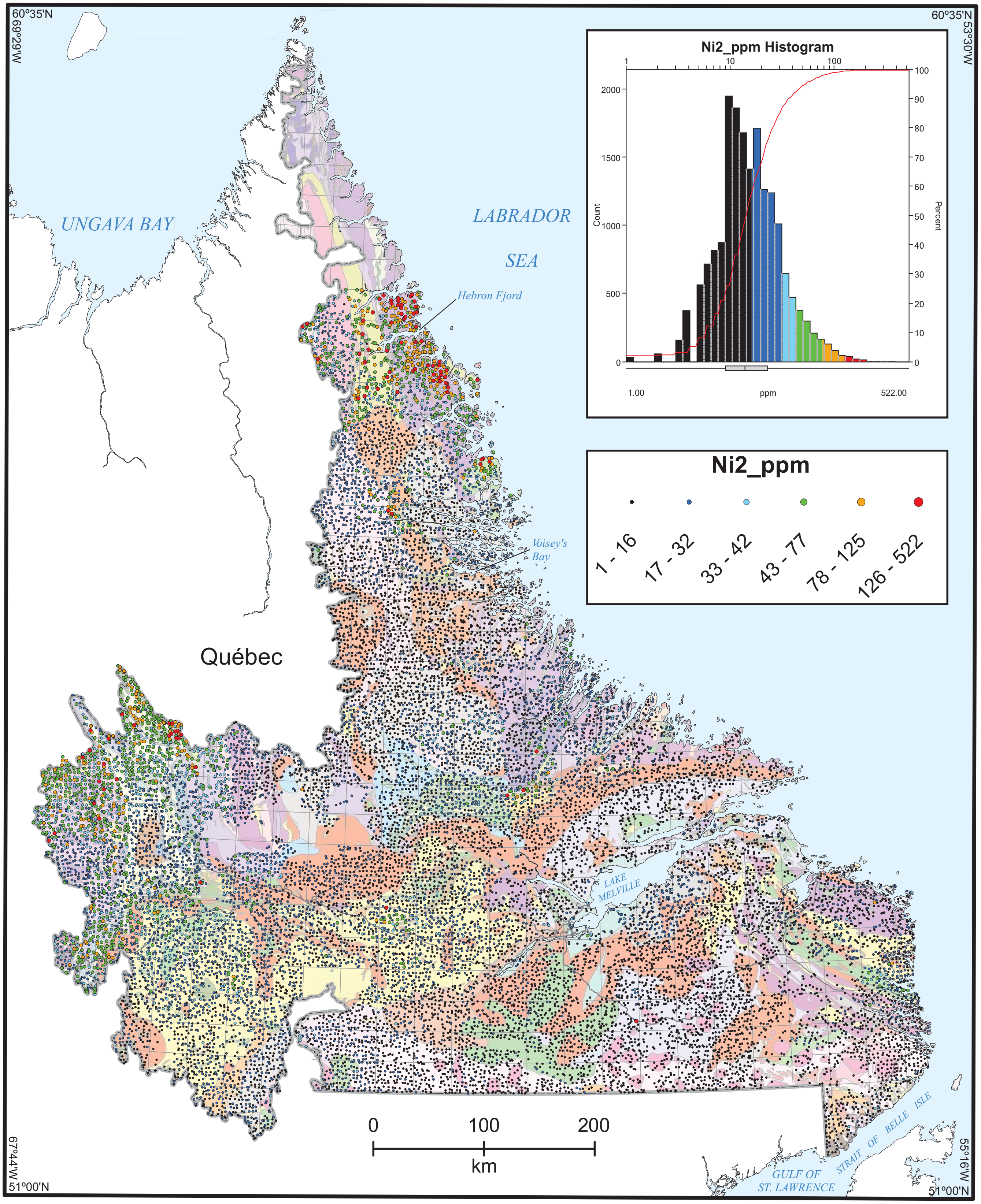

Figure 23. *Nickel (Ni2_ppm) in lake sediment.*

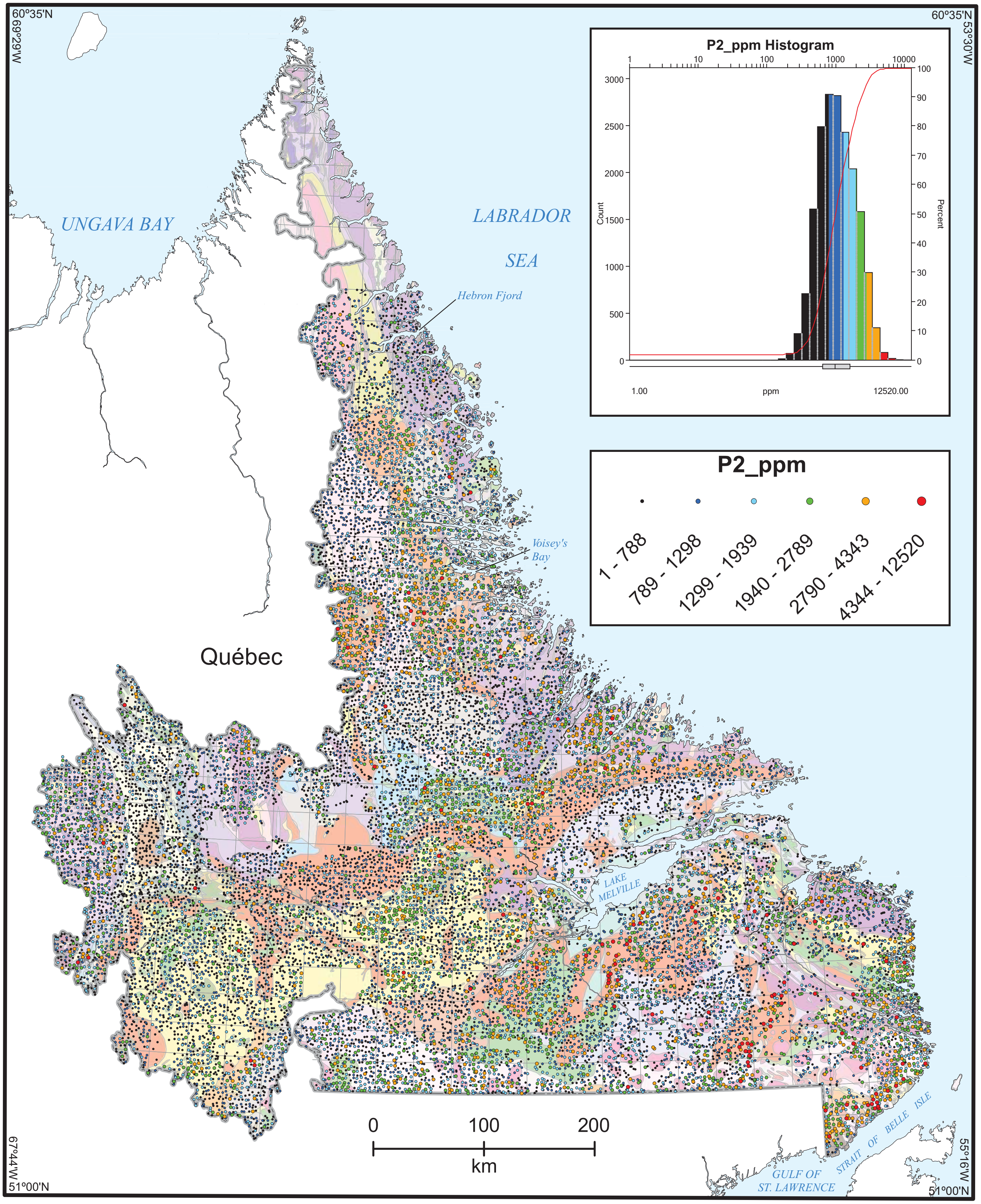

Figure 24. *Phosphorus (P2_ppm) in lake sediment.*

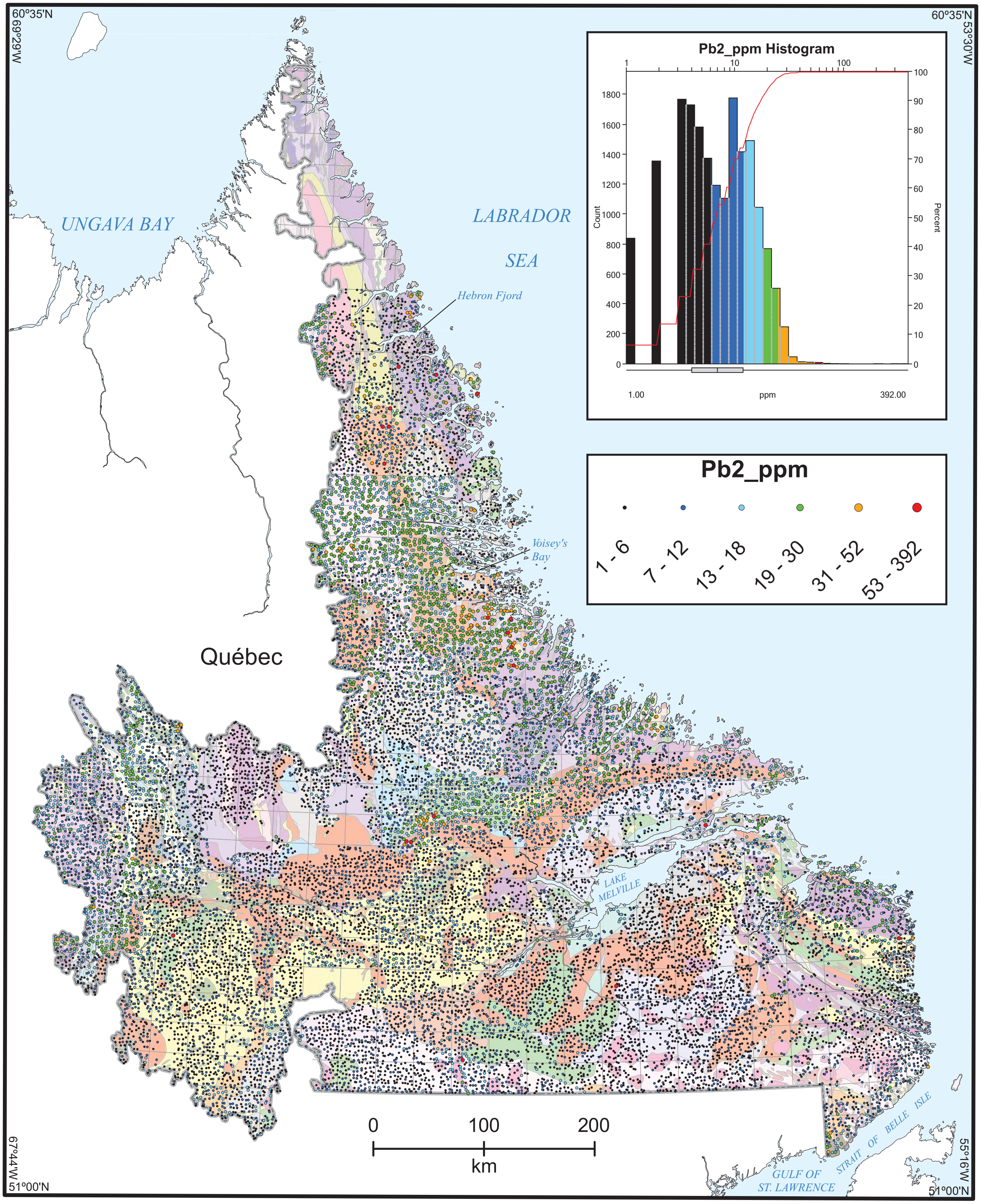

Figure 25. *Lead (Pb2_ppm) in lake sediment.*

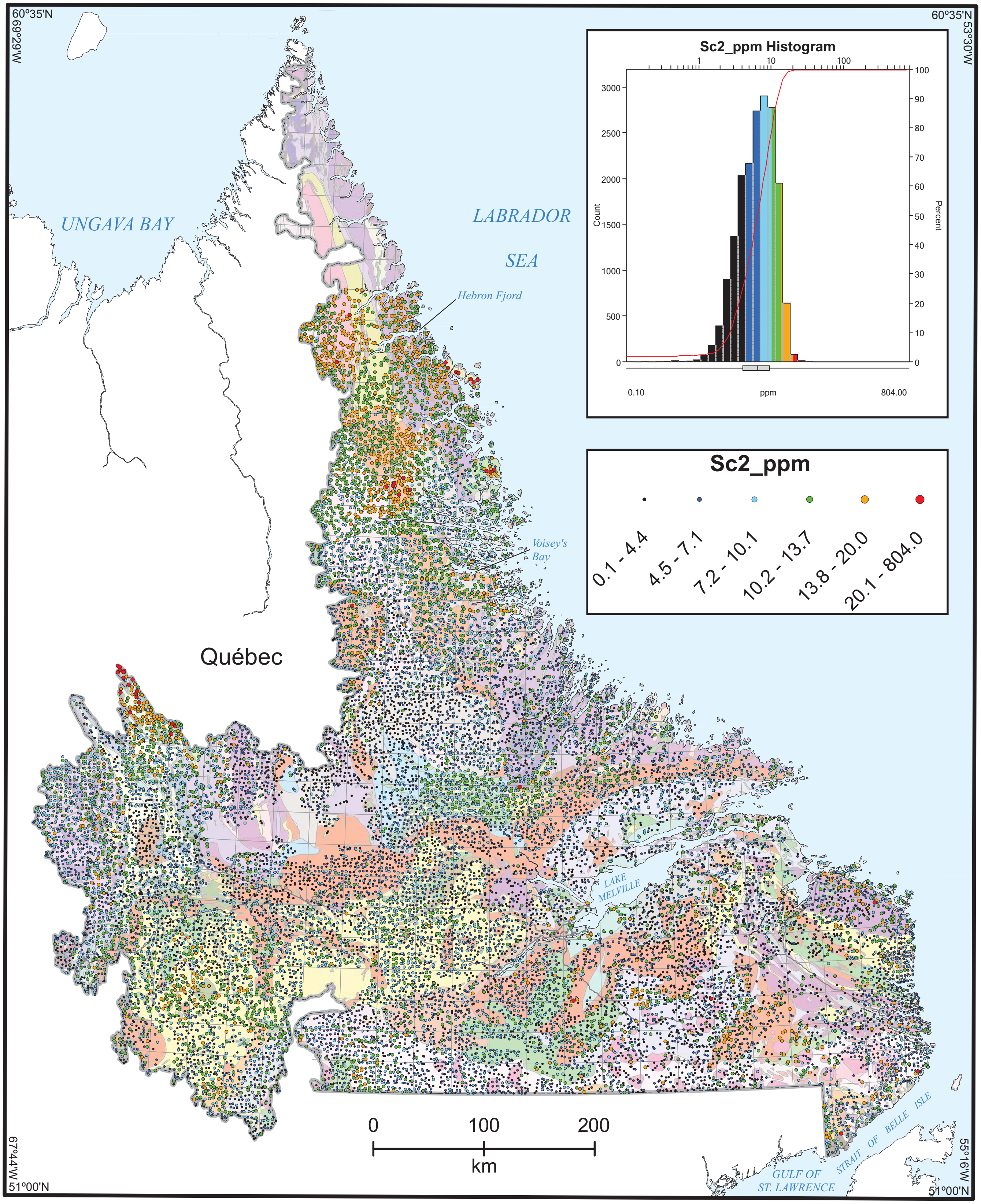

Figure 26. *Scandium (Sc2_ppm) in lake sediment.*

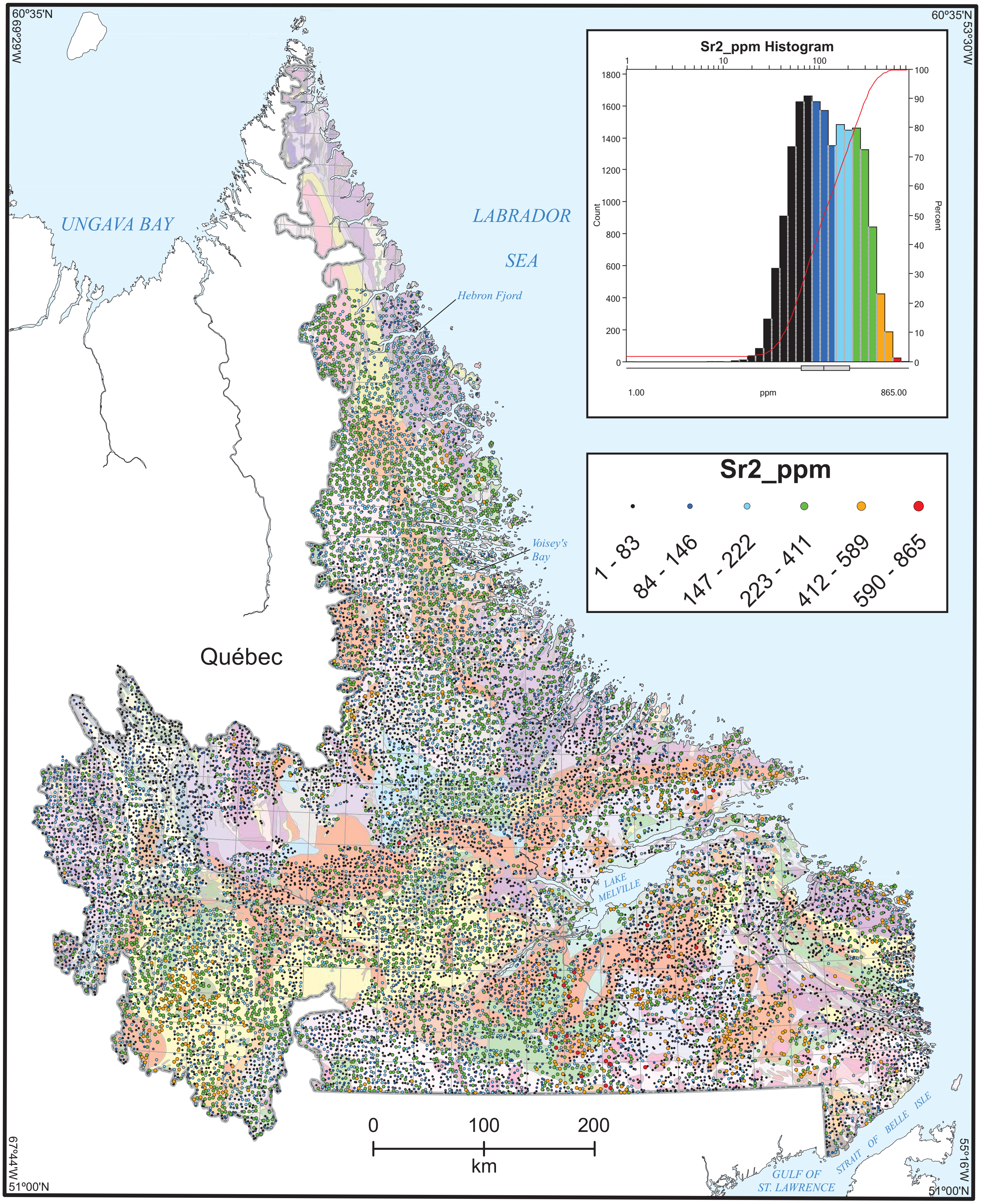

Figure 27. *Strontium (Sr2_ppm) in lake sediment.*

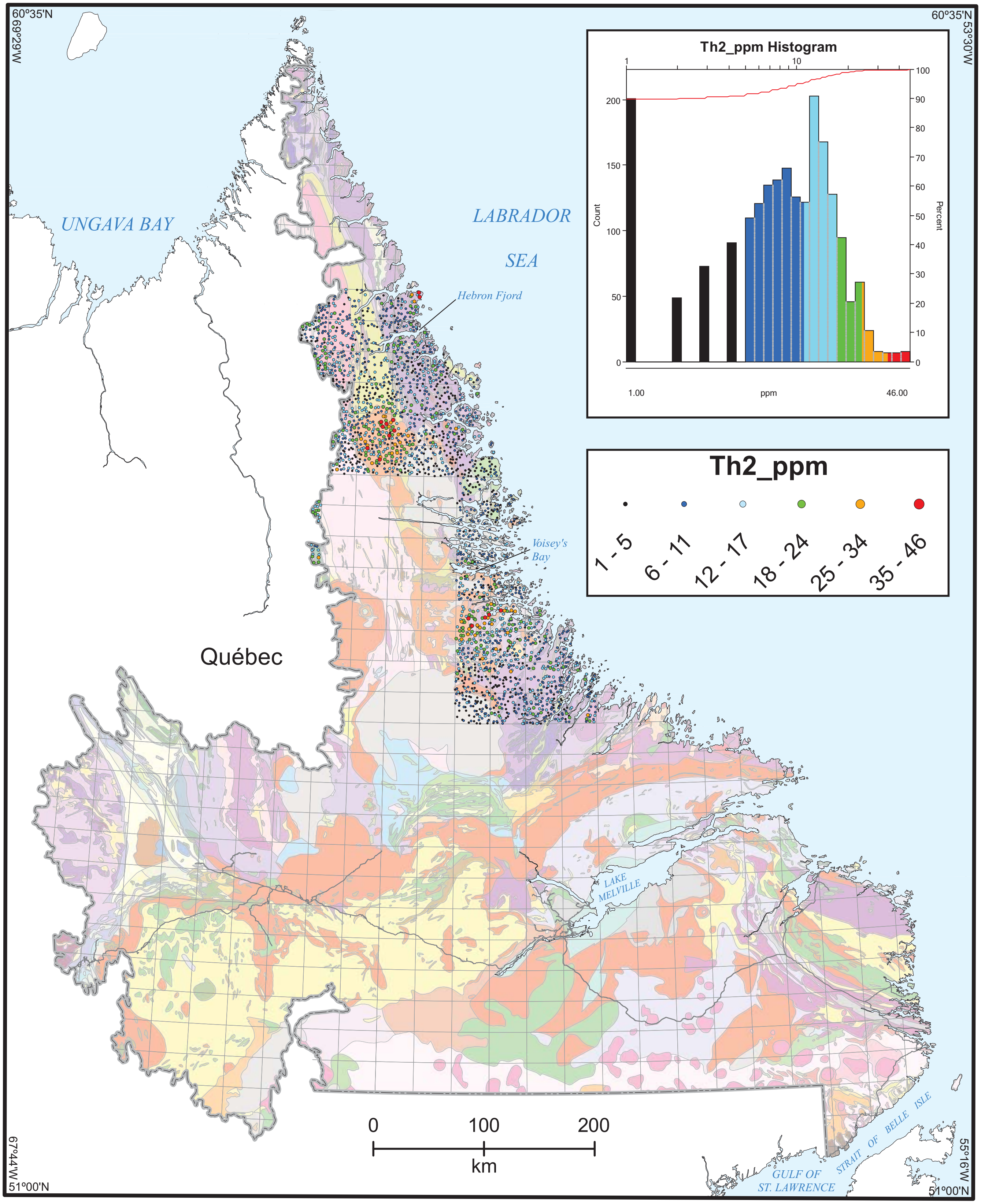

Figure 28. *Thorium (Th2_ppm) in lake sediment.*

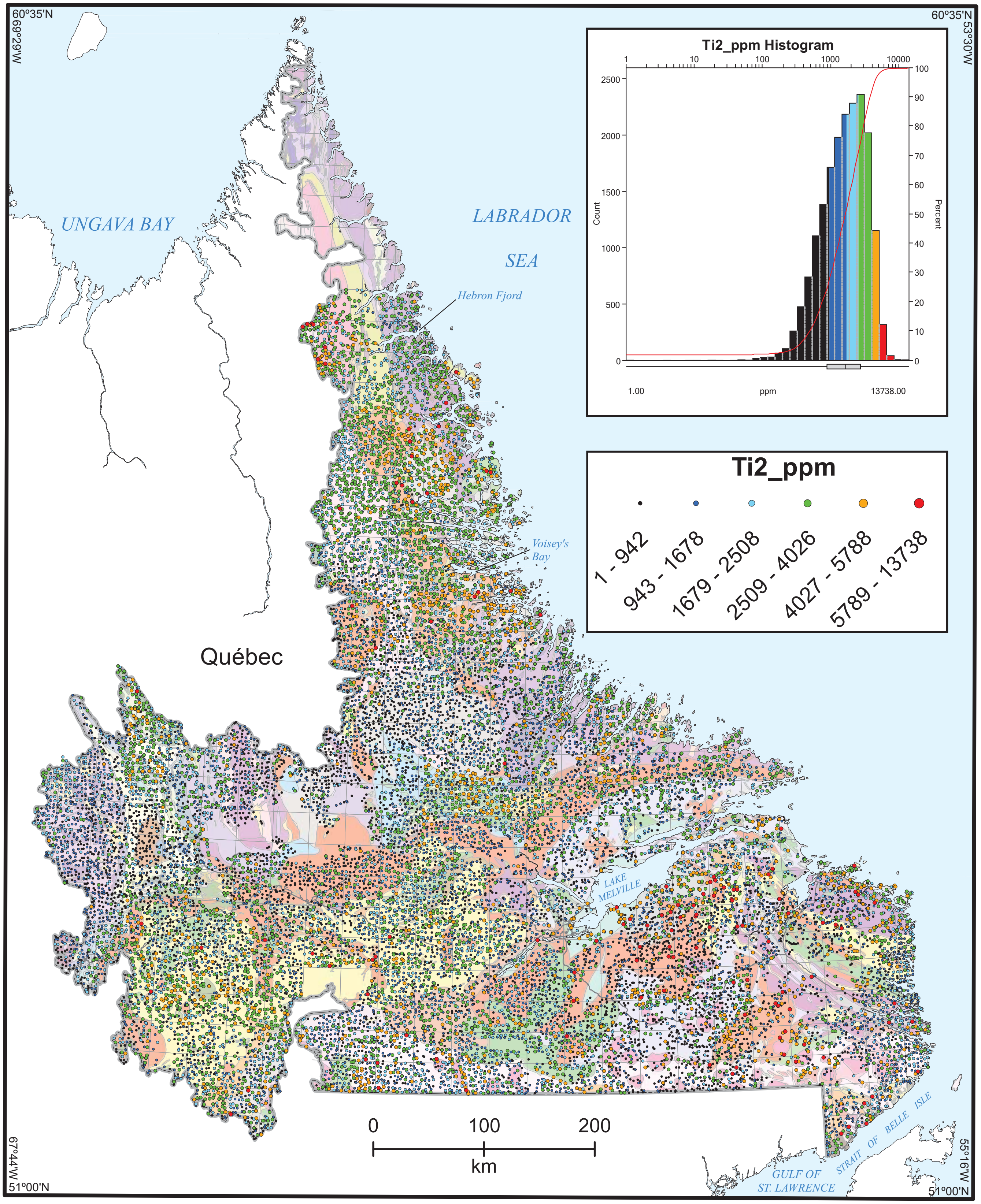

Figure 29. *Titanium (Ti2_ppm) in lake sediment.*

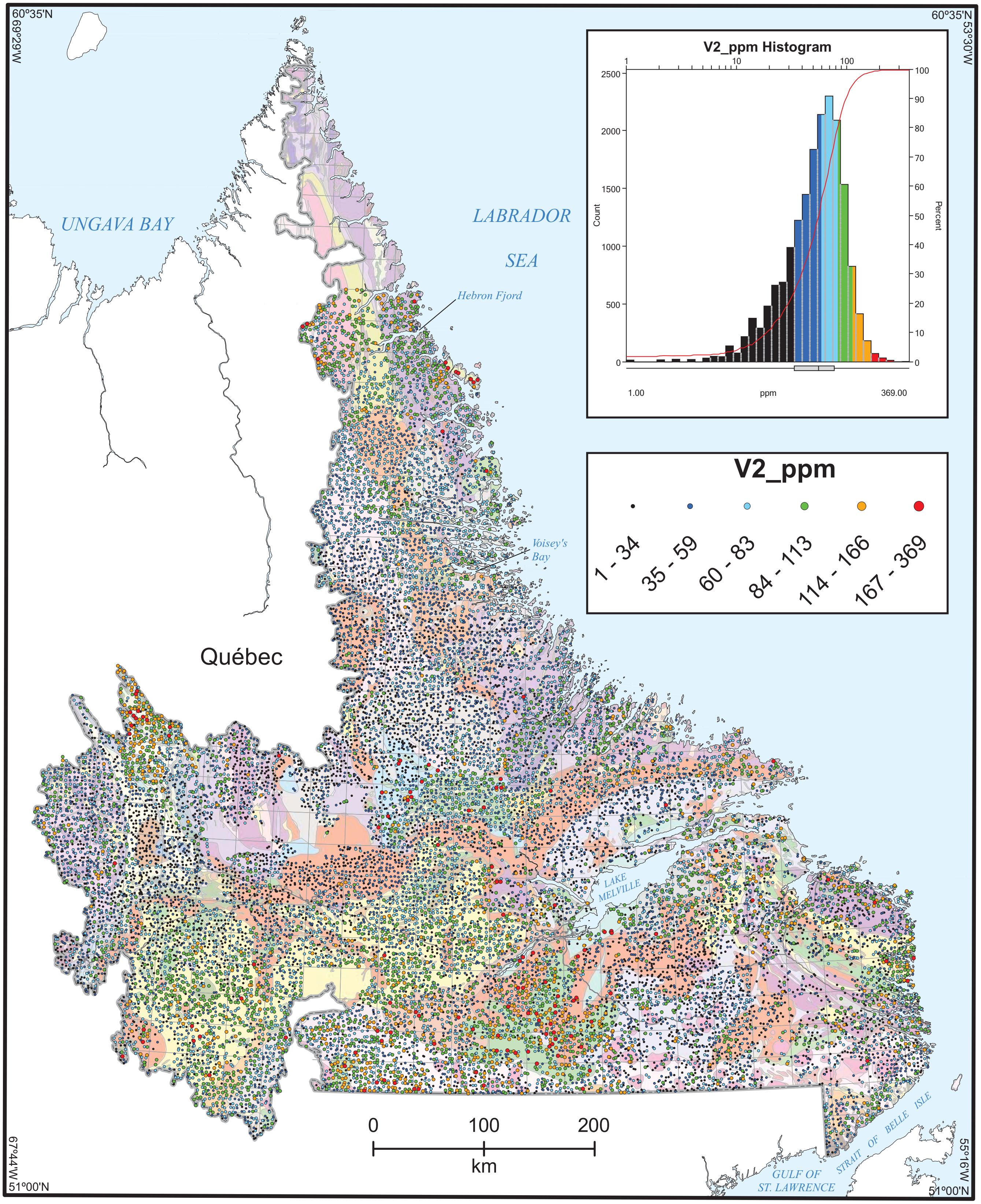

Figure 30. *Vanadium (V2_ppm) in lake sediment.*

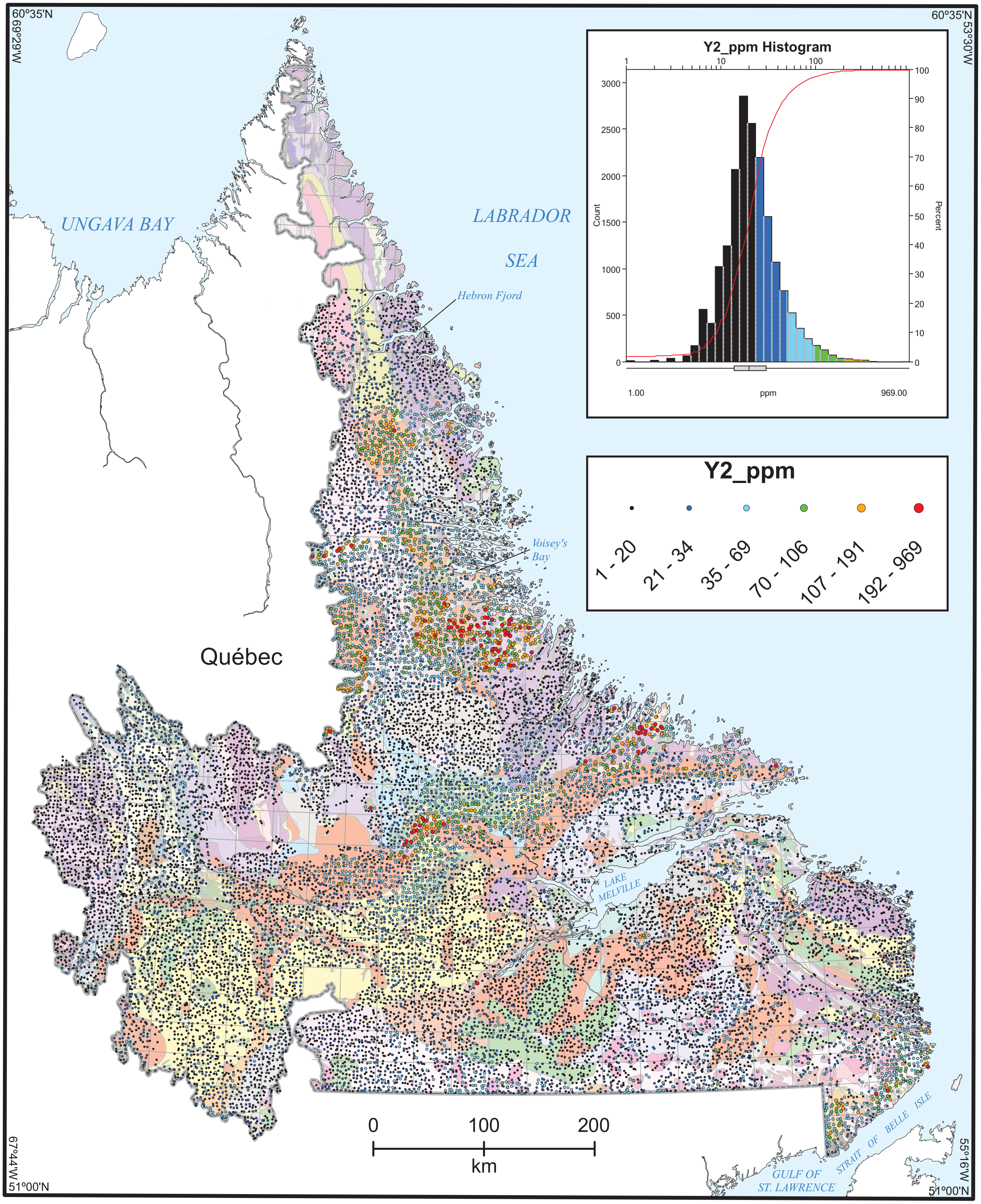

Figure 31. *Yttrium (Y2_ppm) in lake sediment.*

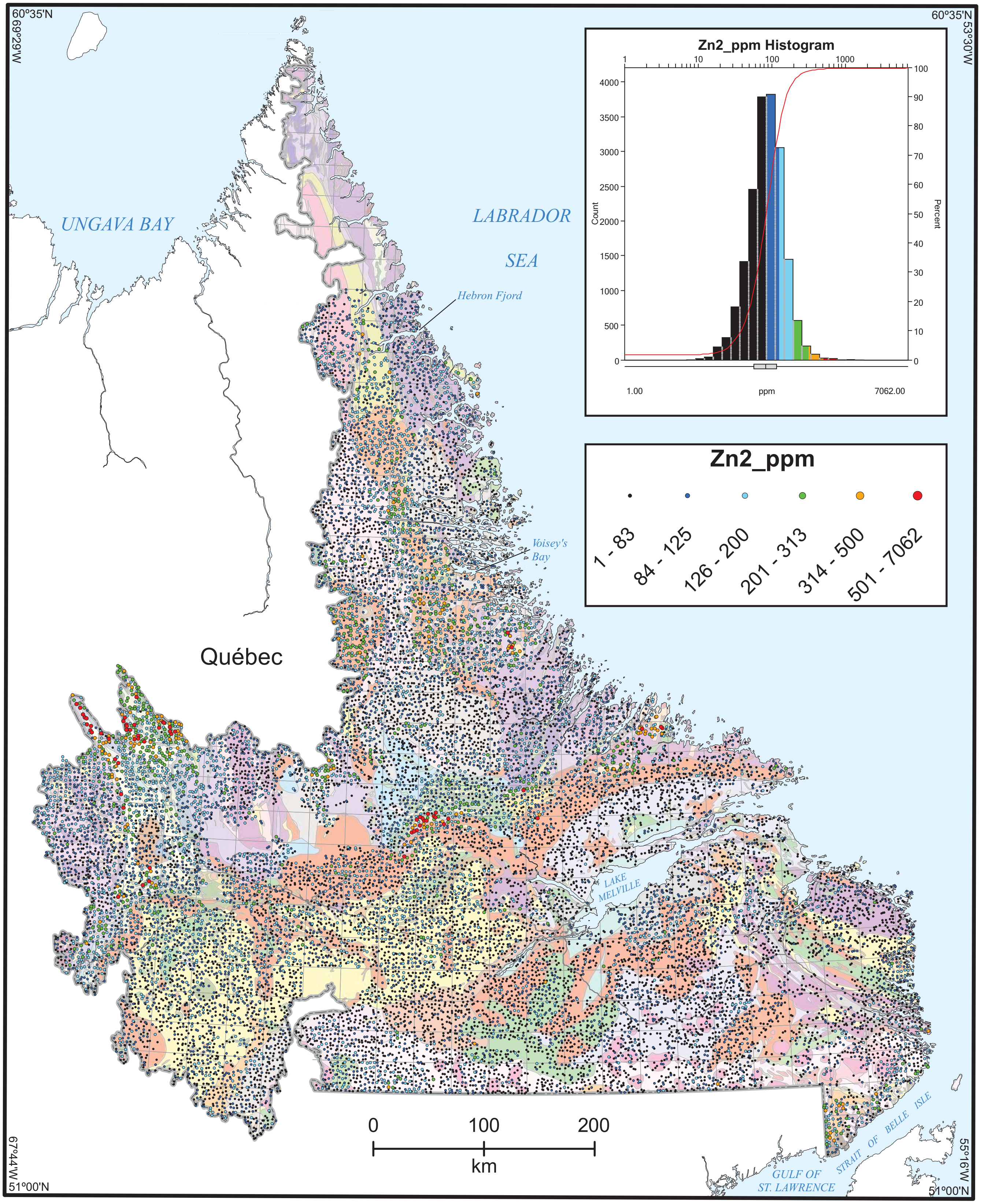

Figure 32. *Zinc (Zn2_ppm) in lake sediment.*

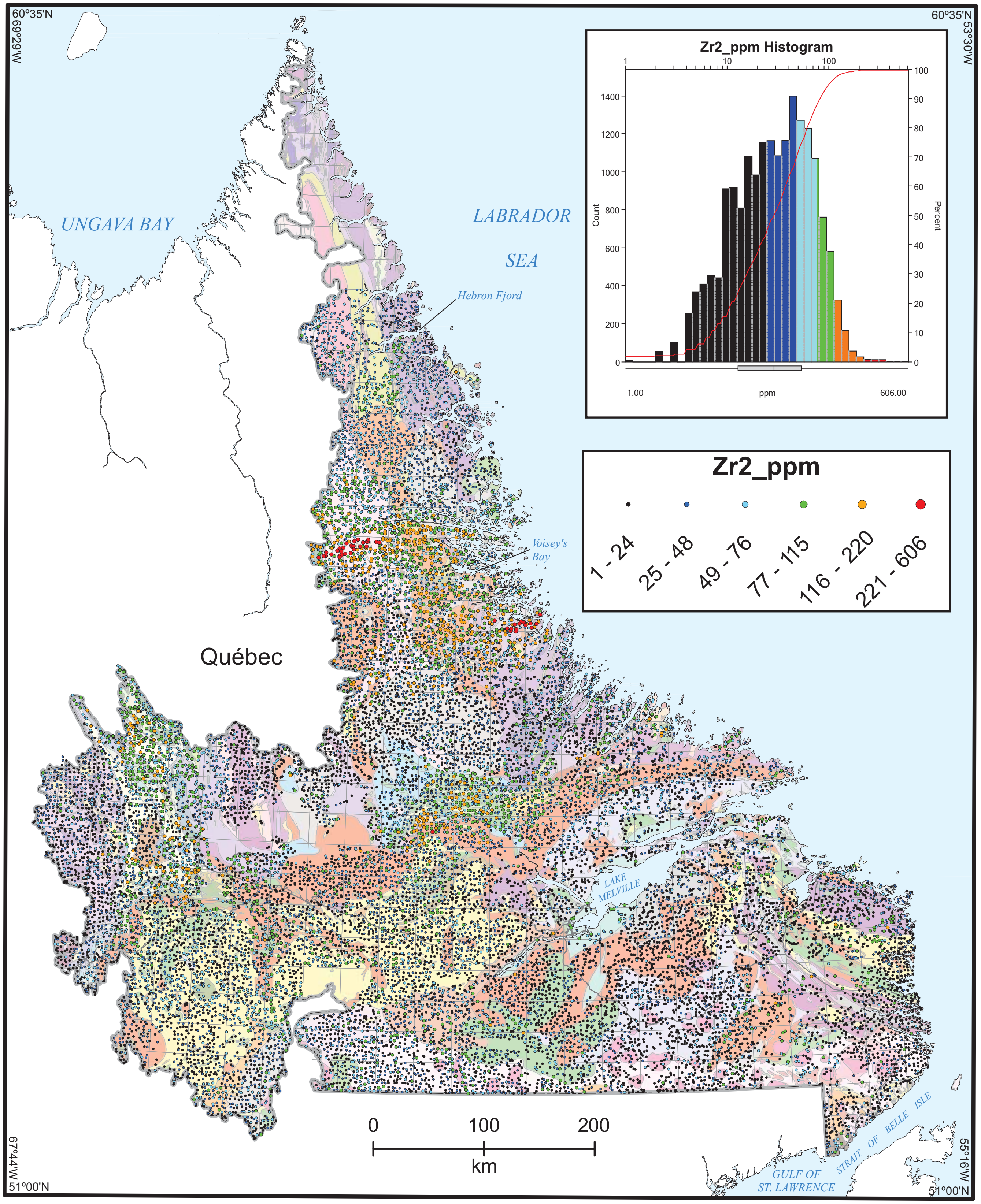

Figure 33. *Zirconium (Zr2_ppm) in lake sediment.*

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APPENDIX 1

Descriptions and Formats of Field, Descriptive and Analytical Variables

A. Variable Descriptions

FIELD AND DESCRIPTIVE VARIABLES

Variable	Position	Description/Analytical Method	Key to Numeric Variables
NTS	1	1:250,000 NTS map	
number	2	Sample number	
NTS_number	3	Concatenation of “number” and “NTS”; uniquely identifies sample	
utmzone	4	UTM zone number	
utmeast	5	UTM easting in metres	
utmnorth	6	UTM northing in metres	
Long_NAD27	7	Longitude in decimal degrees	
Lat_NAD27	8	Latitude in decimal degrees	
sampyear	9	Year of sample collection	
depth_m	10	Water depth in metres	
lakesize	11		
contam	12	Possible site contamination	0 absent 1 present
colour	13	Sediment colour	
relief	14	Topographic relief	
suspension	15	Quantity of suspended matter in water	
sitedup	16	Site duplicate	0 routine sample 1 first of site pair 2 second of site pair
inaawt_g	17	Sample weight for INAA in grams	
openfile1	18	Original GSC open file Number	
openfile2	19	NGR open file number with INAA data	

ANALYTICAL VARIABLES

Variable	Position	Element	Analytical Method
Ag3_ppm	20	Silver	4M HNO_3 1M HCl; AAS
Al2_pct	21	Aluminum	$HClO_4$-HF-HCl; ICP
As19_ppm	22	Arsenic	Hydride AAS
As1_ppm	23	Arsenic	INAA; Becquerel
As21_ppm	24	Arsenic	6M HCl, colorimetry
Au1_ppb	25	Gold	INAA; Becquerel
Ba1_ppm	26	Barium	INAA; Becquerel
Ba2_ppm	27	Barium	$HClO_4$-HF-HCl; ICP
Be2_ppm	28	Beryllium	$HClO_4$-HF-HCl; ICP
Br1_ppm	29	Bromine	INAA; Becquerel

Ca2_pct	30	Calcium	$HClO_4$-HF-HCl; ICP
Cd3_ppm	31	Cadmium	4M HNO_3 1M HCl; AAS
Ce1_ppm	32	Cerium	INAA; Becquerel
Ce2_ppm	33	Cerium	$HClO_4$-HF-HCl; ICP
Co1_ppm	34	Cobalt	INAA; Becquerel
Co2_ppm	35	Cobalt	$HClO_4$-HF-HCl; ICP
Co3_ppm	36	Cobalt	4M HNO_3 1M HCl; AAS
Cr1_ppm	37	Chromium	INAA; Becquerel
Cr2_ppm	38	Chromium	$HClO_4$-HF-HCl; ICP
Cs1_ppm	39	Cesium	INAA; Becquerel
Cu2_ppm	40	Copper	$HClO_4$-HF-HCl; ICP
Cu3_ppm	41	Copper	4M HNO_3 1M HCl; AAS
Dy2_ppm	42	Dysprosium	$HClO_4$-HF-HCl; ICP
Eu1_ppm	43	Europium	INAA; Becquerel
F9_ppm	44	Fluoride	Na_2CO_3-KNO_3 fusion; ISE
Fe1_pct	45	Iron	INAA; Becquerel
Fe2_pct	46	Iron	$HClO_4$-HF-HCl; ICP
Fe3_pct	47	Iron	4M HNO_3 1M HCl; AAS
Ga2_ppm	48	Gallium	$HClO_4$-HF-HCl; ICP
Hf1_ppm	49	Hafnium	INAA; Becquerel
Hg18_ppb	50	Mercury	HNO_3-HCl plus Al solution; AAS
K2_pct	51	Potassium	$HClO_4$-HF-HCl; ICP
La1_ppm	52	Lanthanum	INAA; Becquerel
La2_ppm	53	Lanthanum	$HClO_4$-HF-HCl; ICP
Li2_ppm	54	Lithium	$HClO_4$-HF-HCl; ICP
LOI_pct	55	Loss-on-ignition	gravimetric
Lu1_ppm	56	Lutetium	INAA; Becquerel
Mg2_pct	57	Magnesium	$HClO_4$-HF-HCl; ICP
Mn2_ppm	58	Manganese	$HClO_4$-HF-HCl; ICP
Mn3_ppm	59	Manganese	4M HNO_3 1M HCl; AAS
Mo1_ppm	60	Molybdenum	INAA; Becquerel
Mo2_ppm	61	Molybdenum	$HClO_4$-HF-HCl; ICP
Mo5_ppm	62	Molybdenum	Aqua Regia; AAS
Na1_pct	63	Sodium	INAA; Becquerel
Na2_pct	64	Sodium	$HClO_4$-HF-HCl; ICP
Nb2_ppm	65	Niobium	$HClO_4$-HF-HCl; ICP
Ni1_ppm	66	Nickel	INAA; Becquerel
Ni2_ppm	67	Nickel	$HClO_4$-HF-HCl; ICP
Ni3_ppm	68	Nickel	4M HNO_3 1M HCl; AAS
P2_ppm	69	Phosphorus	$HClO_4$-HF-HCl; ICP
Pb2_ppm	70	Lead	$HClO_4$-HF-HCl; ICP
Pb3_ppm	71	Lead	4M HNO_3 1M HCl; AAS
Rb1_ppm	72	Rubidium	INAA; Becquerel
Sb19_ppm	73	Antimony	Hydride AAS
Sb1_ppm	74	Antimony	INAA; Becquerel

Sc1_ppm	75	Scandium	INAA; Becquerel
Sc2_ppm	76	Scandium	$HClO_4$-HF-HCl; ICP
Sm1_ppm	77	Samarium	INAA; Becquerel
Sr2_ppm	78	Strontium	$HClO_4$-HF-HCl; ICP
Ta1_ppm	79	Tantalum	INAA; Becquerel
Tb1_ppm	80	Terbium	INAA; Becquerel
Th1_ppm	81	Thorium	INAA; Becquerel
Th2_ppm	82	Thorium	$HClO_4$-HF-HCl; ICP
Ti2_ppm	83	Titanium	$HClO_4$-HF-HCl; ICP
U1_ppm	84	Uranium	INAA; Becquerel
U8_ppm	85	Uranium	Direct Neutron Activation
V2_ppm	86	Vanadium	$HClO_4$-HF-HCl; ICP
V5_ppm	87	Vanadium	HNO_3-HCl plus Al solution; AAS
W13_ppm	88	Tungsten	$K_2S_2O_7$ fusion, colorimetry
W1_ppm	89	Tungsten	INAA; Becquerel
Y2_ppm	90	Yttrium	$HClO_4$-HF-HCl; ICP
Yb1_ppm	91	Ytterbium	INAA; Becquerel
Zn2_ppm	92	Zinc	$HClO_4$-HF-HCl; ICP
Zn3_ppm	93	Zinc	4M HNO_3 1M HCl; AAS
Zr2_ppm	94	Zirconium	$HClO_4$-HF-HCl; ICP
Fw9_ppb	95	Fluoride in water	Ion Selective Electrode
pHw	96	pH of water	glass-calomel electrode; pH meter
Uw10_ppb	97	Uranium in water	Scintrex UA-3
Uw11_ppb	98	Uranium in water	Fission Track

B. Data Formats of Descriptive, Field and Analytical Variables

Variable	**Variable Type**	**Width**	**Number of Decimals**
NTS	String	3	
number	Number	6	0
NTS_number	String	9	
utmzone	Number	2	0
utmeast	Number	8	0
utmnorth	Number	8	0
Long_NAD27	Number	10	6
Lat_NAD27	Number	9	6
sampyear	Number	4	0
depth_m	Number	3	0
lakesize	String	8	
contam	Number	1	0
colour	String	5	
relief	String	3	

suspension	String	5	
sitedup	Number	1	0
inaawt_g	Number	5	2
openfile1	String	8	
openfile2	String	8	
Ag3_ppm	Number	4	1
Al2_pct	Number	6	2
As19_ppm	Number	4	1
As1_ppm	Number	5	1
As21_ppm	Number	4	1
Au1_ppb	Number	3	0
Ba1_ppm	Number	4	0
Ba2_ppm	Number	6	0
Be2_ppm	Number	5	1
Br1_ppm	Number	5	1
Ca2_pct	Number	6	2
Cd3_ppm	Number	4	1
Ce1_ppm	Number	3	0
Ce2_ppm	Number	6	0
Co1_ppm	Number	3	0
Co2_ppm	Number	6	0
Co3_ppm	Number	3	0
Cr1_ppm	Number	4	0
Cr2_ppm	Number	6	0
Cs1_ppm	Number	4	1
Cu2_ppm	Number	6	0
Cu3_ppm	Number	3	0
Dy2_ppm	Number	5	1
Eu1_ppm	Number	6	1
F9_ppm	Number	3	0
Fe1_pct	Number	5	1
Fe2_pct	Number	5	2
Fe3_pct	Number	5	2
Ga2_ppm	Number	6	0
Hf1_ppm	Number	6	1
Hg18_ppb	Number	3	0
K2_pct	Number	5	2
La1_ppm	Number	3	0
La2_ppm	Number	6	0
Li2_ppm	Number	7	1
LOI_pct	Number	4	1
Lu1_ppm	Number	4	1
Mg2_pct	Number	5	2
Mn2_ppm	Number	6	0
Mn3_ppm	Number	5	0

Mo1_ppm	Number	3	0
Mo2_ppm	Number	6	0
Mo5_ppm	Number	2	0
Na1_pct	Number	5	2
Na2_pct	Number	6	2
Nb2_ppm	Number	6	0
Ni1_ppm	Number	3	0
Ni2_ppm	Number	6	0
Ni3_ppm	Number	3	0
P2_ppm	Number	6	0
Pb2_ppm	Number	6	0
Pb3_ppm	Number	2	0
Rb1_ppm	Number	3	0
Sb19_ppm	Number	4	1
Sb1_ppm	Number	6	2
Sc1_ppm	Number	4	1
Sc2_ppm	Number	5	1
Sm1_ppm	Number	4	1
Sr2_ppm	Number	6	0
Ta1_ppm	Number	6	1
Tb1_ppm	Number	4	1
Th1_ppm	Number	4	1
Th2_ppm	Number	6	0
Ti2_ppm	Number	6	0
U1_ppm	Number	4	1
U8_ppm	Number	4	1
V2_ppm	Number	6	0
V5_ppm	Number	3	0
W13_ppm	Number	2	0
W1_ppm	Number	2	0
Y2_ppm	Number	6	0
Yb1_ppm	Number	6	1
Zn2_ppm	Number	6	0
Zn3_ppm	Number	5	0
Zr2_ppm	Number	6	0
Fw9_ppb	Number	3	0
pHw	Number	3	1
Uw10_ppb	Number	5	2
Uw11_ppb	Number	5	3

APPENDIX 2

Field and Stream-sediment and Water Data

Available as separate file online and on the CD