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LAKE SEDIMENT AND WATER GEOCHEMICAL SURVEYS FOR RARE-METAL MINERALIZATION IN LABRADOR

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ABSTRACT

A study was undertaken, a) to determine the feasibility of applying new analytical procedures for determining elements of the rare-metal suite to conventional lake sediment—water surveying and, b) to identify new prospecting targets. Four areas were selected for surveying using available reconnaissance lake sediment data for elements commonly associated with rare-metal mineralization, such as fluorine, zinc and lead. The presence of rare-metal mineralization was also a factor for selecting the Strange Lake and Letitia Lake areas. A total of 444 pairs of sediment and water samples were collected from a 2080-km² area and analyzed for up to 38 elements. All sediment samples were analyzed by Inductively Coupled Plasma Emission Spectrometry (ICP) for: Ba, Ce, Ga, La, Nb, Sr, Th, Y, and Zr, and by Atomic Absorption Spectrometry (AA) for Ag, Be, Cd, Co, Cu, Fe, Mn, Mo, Ni, Pb and Zn. Fluoride was determined by ion-selective electrode and loss-on-ignition as an estimate of organic content. Samples from the Strange Lake area were also analyzed by direct Neutron Activation Analysis (NA) for: As, Au, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Ni, Rb, Sb, Sc, Sm, Ta, Th, U, W, Yb, Zn, and Zr. All lake waters were analyzed for F, Zn and pH. Those from the Letitia lake area were also analyzed for Y and water samples from the Strange Lake area were analyzed for Be.

The use of correlation analysis, principal components analysis and simple statistics helped in recognizing associations of elements in each area. Cumulative frequency curves are employed to recognize and separate component populations and to define contour intervals for contoured data maps of Be, Yb and Y in sediment, and F in water. The rare-metal suite and associated elements (e.g., REE, Be, F, Nb, Pb, Th, Y, Zn and Zr) give clearly defined dispersion patterns upward of 40 km in length at Strange Lake, which can be linked to areas of known mineralization. In addition, several anomalies in areas that have received little or no exploration, present new targets for exploration. Contoured data for F, Zn and Y in water, show dispersion patterns that can be linked with mineralization and/or areas of alkaline bedrock.

INTRODUCTION

This paper summarizes data and observations contained in a recently published open file report (McConnell, 1988) on the results of field work during 1983 and 1985, following the discovery of the Strange Lake (Lac Brisson) rare-metal deposit in Labrador. This type of deposit is receiving exploration attention from industry, with the expectation that demand for these commodities could rapidly increase in the near future. The study characterizes the nature of geochemical dispersion into the surficial environment; the emphasis being on lake sediment and water geochemistry. It also assesses the mineral potential of four areas with known or suspected rare-metal mineralization, and identifies several elements, not previously analyzed in lake sediment, as useful guides to mineralization. These include the rare-earth elements, Be, Nb, Y and Zr. Analyses of Y in water are also easily performed by ICP and correlate with yttrium mineralization.

The Strange Lake and Letitia Lake areas, where rare-metal mineralization is present, were sampled. A 50-million-tonne deposit of Zr—Y—Be—Nb—REE is contained within an alkaline intrusion at Strange Lake (Miller, 1988) and several smaller Nb—Be and Zr occurrences are located in the Letitia Lake area, generally in association with peralkaline rocks (Miller, 1988). The Letitia Lake area has anomalous levels of F and Zn (Geological Survey of Canada, 1983). The two other areas studied, referred to here as Michikamats and 13L, were not known to be mineralized but were surveyed because the presence of very high levels of F in the reconnaissance data (Geological Survey of Canada, 1978a,b, 1983) suggested the occurrence of specialized or possibly mineralized granitoids. The locations of these four areas is shown in Figure 1.

PREVIOUS GEOCHEMICAL WORK

The earliest work is that of Brummer (1957, 1960), who described stream sediment surveys for base metals in the Letitia Lake area that led to the discovery of the Mann Nb—Be deposits. In 1977, the Geological Survey of Canada released the first of a series of open file reports of reconnaissance lake sediment and water survey data for Labrador. The samples were not analyzed for any of the rare-metal suite ore elements, but did include elements commonly associated with such deposits including F, Pb, U and Zn. The surveys involved the collection of samples at a density of about 1 per 17 km². Subsequent open file reports (Geological Survey of Canada, 1978a,b) included the Strange Lake area, the Michikamats area and the 13L areas, and highlighted several areas with

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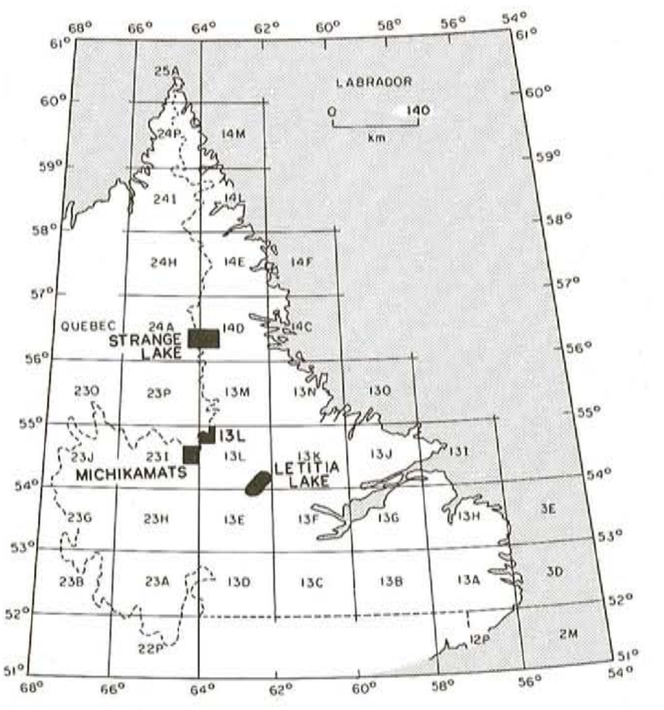

Figure 1. *Location of survey areas.*

anomalous concentrations of F, Pb, U and Zn. One of the anomalies was instrumental in leading to the discovery of the Strange Lake deposit. In 1983, reconnaissance coverage was extended to the Letitia Lake area, in which anomalies in Pb, F and Zn were identified. Work by McConnell and Batterson (1987) on the geochemistry of tills, stream and lake sediments and waters in the Strange Lake area indicated the presence of strong linear anomalies in all sampled environments, extending for tens of kilometres down-ice from the deposit. The lake data in the report did not include analyses of such diagnostic elements as rare earths, Nb, Th, U, Y or Zr, a gap which is filled in this report.

AREA DESCRIPTIONS

Strange Lake Area

The area is located on the Labrador–Quebec border and is accessible only by air. The regional geology of the area has been mapped by Ryan *et al.* (1988) and the deposit occurs in the Helikian Strange Lake alkaline complex, the lithology and mineralogy of which has been comprehensively described by Miller (1986). The alkaline complex, which intrudes Aphebian gneiss and a Helikian quartz monzonite body, has an ovoid surface exposure. The most intensely mineralized phase has a surface exposure of about 1.5 km^2. The ore mineralogy in the 50-million-tonne deposit is complex and consists primarily of such unusual minerals as elpidite (Na–Zr silicate), gittinsite (Ca–Zr silicate), pyrochlore (Ca niobate), and gadolinite (Y–Be silicate).

The surveyed area is located above the tree-line and has a low to moderate topographic relief. Eastward-flowing glacial ice of the Laurentide ice-sheet, which covered the area in the Late Wisconsinan period (Shilts *et al.*, 1979; Batterson *et al.*, 1985), eroded the upper portion of the alkaline complex and deposited till over 60 percent of the area, ranging in thickness from a veneer to 16 m. The remainder of the surface is covered with glaciofluvial deposits, organic accumulations and scattered outcrops (McConnell and Batterson, 1987).

Letitia Lake Area

This area is readily accessible by air from Goose Bay, Labrador. Bedrock mapping by Thomas and Hibbs (1983) and Thomas *et al.* (1983) resulted in a five-fold division of the rocks in the survey area; the oldest of which is the Aphebian Disappointment Lake gneiss. This is intruded by the dioritic to granitic North Pole Brook intrusive suite. Overlying these are felsic volcanic and subvolcanic rocks and associated sedimentary rocks of the Letitia Lake Group, which have peralkaline affinities (Thomas, 1981). These, in turn, have been intruded by the Red Wine alkaline intrusive suite. Finally, the four older rock units are unconformably overlain by sedimentary, mafic volcanic and intrusive rocks of the Seal Lake Group.

Most of the known Be–Nb–REE mineralization in the vicinity of Letitia Lake is associated with peralkaline syenite of the Red Wine alkaline intrusive suite (Miller, 1987). Miller reports that the principal Nb–Be-bearing minerals are barylite (Be), eudidymite (Be), niobophyllite (Nb) and pyrochlore (Nb). The most notable occurrences are the Mann #1 and Mann #2 deposits (Be–Nb–Th), and the Two Tom Lake occurrence (Be–Y–Nb–REE). The Mann #1 deposit is estimated to contain 6.8-million tonnes of BeO (Gaines, 1977). Widespread, but apparently minor, Zr mineralization is found south of Letitia Lake in eudialyte-bearing pegmatites, also thought to be associated with the Red Wine alkaline intrusive suite (R. Miller, personal communication, 1988).

Work by Batterson and LeGrow (1986) indicated that at least three major glacial flow events occurred during the Wisconsinan. The earliest trends 046°; the second ranges from 096° in the south, to 114° in the north. The third and last event, however, is the major flow in terms of controlling the present glacial dispersion patterns of both geochemistry and lithic clasts. Its flow direction ranges from 074° in the north, to 080° in the south. Most of the area is underlain by locally derived till, which is generally < 4-m thick. Other locally significant Quaternary deposits mapped by Batterson and LeGrow (1986) include glaciofluvial outwash and bog.

Michikamats Area

This area is accessible by float plane or helicopter from Goose Bay or Schefferville. The geology in the area has been mapped at 1:250,000 scale by Emslie (1963), and is summarized here.

The oldest rocks, which are located in the northwest, are fine- to medium-grained, foliated granite and granodiorite. Massive, medium- to coarse-grained, pink to white granite and syenite underlie most of the central part of the area. A subcircular, 10-km diameter of clinopyroxene-bearing syenite represents a distinct phase of this unit. The youngest rocks consist of flat-lying, unmetamorphosed conglomerate, arkose and siltstone and are poorly exposed in the southeast. No mineralization of economic interest was noted by Emslie (1963) during the regional mapping.

Detailed Quaternary mapping has not been done in the Michikamats area. Emslie (1963) noted during the course of his bedrock mapping that drumlins, striae, and crag and tail features indicate that the last glacial advance was east to east-southeast. He also noted rare striae, which he thought recorded an earlier northeast advance. Boulder till covers most of the area and outcrops are restricted mainly to hilltops and along lake shores. Several eskers are present in the area trending southeast and cross-cutting the dominant striae direction. One of these eskers traverses the syenite phase described above and passes over the sedimentary terrane. It appears to play a significant role in the dispersal and localization in lake sediments and waters of some elements derived from the syenite.

13L Area

The 13L area formed a small part of the region, mapped at 1:250,000 by Emslie (1964). The oldest rocks underlie the central survey area and consist of granitic and/or syenitic gneiss metamorphosed to granulite facies. The granitic gneiss terrane in the south is a porphyritic granitic gneiss and, in fact, may be a phase of the previous unit (Emslie, 1964). Greene (1970) regarded the first unit as Aphebian and the porphyritic rock as Paleohelikian. The youngest rocks are massive, medium- to coarse-grained, granitic rocks (Emslie, 1964). Scintillation counts over this last unit average 1.5 to 3 times those found in other granitoid terranes (McConnell, 1986). No mineralization has been reported from the area.

The only Quaternary geology observations reported are those of Emslie (1964), and are included in the marginal notes of his geology map. He describes abundant glacial striae throughout the map area, which indicate the latest ice-flow direction to have been easterly, however, within the present survey area only a single ice-striation having a 100° trend is recorded.

SAMPLING AND ANALYTICAL METHODS

Lake sediment and water samples were collected by means of a float-equipped helicopter; 444 samples, including 5 percent site duplicates were obtained from 407 lakes in the four survey areas. Sample density was 1 site per 4.7 km±The sampled lakes have a mean (geometric) area of 0.11 km±and a mean ± 2 standard deviation range of 0.01 km±to 2.88 km± Details of sample collection and sample preparation are described in McConnell (1988). Sediments were dried, sieved through a 180 μm mesh size and analyzed for up to 38 elements.

Inductively coupled plasma emission spectroscopy (ICP) was used to analyze all sediment samples for Ba, Ce, Ga, La, Nb, Sr, Th, Y, and Zr. The analyte was prepared by digesting one gram of sample overnight in 15 mL concentrated HF, 5 mL concentrated HCl and 5 mL of 50 percent HClO#. This solution was evaporated to dryness at 200° C. Ten mL of concentrated HCl and 40 mL of water were then added. This mixture was redigested at 100° C for 2 hours, brought to volume by adding 20 percent HCl and centrifuged to remove any remaining solids. The solution was then analyzed by ICP. This digestion gives complete solution of all elements determined except, in some cases, Zr.

Samples were prepared for atomic absorption spectrometry (AA) as follows: 1 g was added to 6 mL of 4 M HNO^a and 1 M HCl, allowed to remain overnight, then mixed and digested for two hours at 90° C, cooled, and finally, made up to 20 mL by adding de-ionized water. This solution was then analyzed for Ag, Be, Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn. This digestion typically extracts 80 to 100 percent of these elements (Davenport, 1988). The preparation and analysis of Mo by AA is described in Wagenbauer *et al.* (1983).

Fluoride was determined by ion-selective electrode, and loss-on-ignition was measured as an estimate of organic content. Samples from the Strange Lake area were also analysed by direct Neutron Activation Analysis (NA) for: As, Au, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Ni, Rb, Sb, Sc, Sm, Ta, Th, U, W, Yb, Zn, and Zr. All the lake water samples were analyzed for F, Zn and pH. Those from the Letitia Lake area were also analyzed for Y by ICP. Waters from the Strange Lake area were analyzed for Be by AA, although nearly all samples were below the 10 μg/L detection limit.

RESULTS

A variety of interpretation procedures were used to obtain statistics for inter-area comparisons and to determine correlations between elements. These aided in the identification of environmental factors that affect the compositions of sediment, enabled overlapping geochemical populations to be separated into their components, and facilitated the recognition of distinct groups of elements associated with rare-metal mineralization. Cumulative frequency plots are of particular help in defining threshold levels for sediment concentrations derived from mineral occurrences. Other procedures include the computation of basic statistics (means, standard deviations and ranges), histograms, Pearson correlations, regression analysis and principal components analysis.

Principal components analyses is a multivariate statistical technique that defines groups of variables (elements) that are mutually correlated, and, for each group, defines a 'factor' that is a linear combination of its variables that accounts for most of its variance. In geochemistry, it is particularly useful in identifying groups of associated elements that are separated into factors. The strength, or contribution, of an element within a given factor is given by its 'factor loading'. A 'factor score' for a given sample can be calculated by determining the sum of these weighted contributions given by each element.

Table 1. Pearson correlation coefficients (x 100) of selected lake sediment data, Strange Lake area. Values between ± 40 are shown by *

	Be	Cd	Ce	Eu	F	Hf	La	Lu	Nb	Pb	Sm	Tb	Th	U	Y	Yb	Zn	Zr	Fe	Mn	LOI
Cd	*																				
Ce	66	*																			
Eu	64	53	78																		
F	42	*	57	57																	
Hf	45	*	*	46	64																
La	62	51	94	78	41	*															
Lu	86	48	78	85	53	54	76														
Nb	54	*	43	46	73	88	*	54													
Pb	79	40	67	71	55	51	61	81	60												
Sm	79	56	88	91	53	44	89	94	45	78											
Tb	87	52	80	88	53	52	79	98	52	83	97										
Th	61	*	63	65	55	47	40	69	57	74	69	69									
U	*	44	*	*	*	*	48	*	*	*	*	*	*								
Y	89	49	80	82	48	48	79	96	50	81	95	99	67	*							
Yb	87	43	76	85	57	61	72	98	62	81	93	98	69	*	97						
Zn	42	66	60	62	*	*	67	53	*	51	62	56	*	53	53	47					
Zr	54	*	46	55	68	96	*	64	91	63	54	62	54	*	59	71	*				
Fe	*	*	*	*	41	*	*	*	*	*	*	*	*	*	*	*	41	*			
Mn	*	*	*	*	51	*	*	*	*	*	*	*	*	*	*	*	*	*	63		
LOI	*	*	*	*	-60	-70	*	*	-73	*	*	*	*	42	*	*	*	-69	*	*	
	Be	Cd	Ce	Eu	F	Hf	La	Lu	Nb	Pb	Sm	Tb	Th	U	Y	Yb	Zn	Zr	Fe	Mn	LOI

Contoured data plots were made of selected data using PLOTGEN, a software package designed by the U.S. Geological Survey, specifically for geochemical data (Evenden and Botbol, 1985). The program was run on the Department of Mines' HP-9000 mini computer. The resulting output is similar to hand-contoured plots, although depending on the selection of various parameters in the package, a certain degree of data smoothing can be obtained. In some instances, this results in individual data points plotting outside their expected contour fields.

From these analyses and data plots it is evident that each area has suites of elements that show enrichments relative to background populations. Histograms and cumulative frequency plots are often effective tools for recognizing and classifying anomalous populations and for selecting threshold values for contoured data maps. A contour map, histogram and cumulative frequency plot for one element from each of the four survey areas, which is representative of that area's rare-metal suite, are presented and discussed below.

Strange Lake Area

Results of the correlation and principal components analyses and of the contoured data maps (McConnell, 1988) indicate that the elements Y, Be, the heavy rare earths, Th, Zr, and Pb and ratios of HREE/LREE in lake sediment reflect the mineralization, and fluoride in water distinguishes the entire peralkaline intrusion. Water samples from the Strange Lake area have less than detection limit concentrations (10 $\mu g/L$) of Be, despite their proximity to Be mineralization.

As an illustration of element correlations, a matrix of the Pearson correlation coefficients of the rare-metal suite elements and the environmental variables (Fe, Mn and LOI) are given in Table 1. In general, the REE elements correlate strongly with each other and with Be and Pb. The group Zr, Nb and Hf are strongly correlated with each other, but not with the REE. The elements Zn and U, despite being enriched in the deposit, do not correlate strongly with other elements of the rare-metal suite. The environmental variables, Fe and Mn, correlate moderately with F and Zn, but not with the other members of the suite. LOI has strong negative correlations with F, Nb and Zr, which may explain, in part, why data distribution maps of these elements do not show mineralization dispersion patterns as clearly as do other elements of the suite.

Principal components analysis using a varimax rotation was applied to 36 elements, using logged values. A range of factor models was evaluated, but in each case the first factor was composed of similar elements and included mostly those known to occur in anomalous concentrations in the deposit. The factor loadings (> 0.7) of the elements for the first factor of the three-factor model are given in Table 2. These elements correspond in large part to those associated with the rare-metal deposit. A contour plot of the factor scores of this factor (McConnell, 1988), reveal a very clear down-ice dispersion pattern from the deposit. It is notable that one of the probable ore-elements, niobium, in the Strange Lake deposit, has a rather low-factor loading (0.5). Correspondingly, a contour plot of Nb (McConnell, 1988) gives only a fair dispersion pattern in contrast with those elements with higher loadings.

Table 2. Factor loadings (> 0.70) of mineralization-related factors for a three-factor model of principal components analysis. Lake sediment and water data from Strange Lake and Letitia Lake areas.

Strange Lake	Letitia Lake
Tb (.99)	Y (.93)
Y (.98)	La (.93)
Sm (.97)	Be (.85)
Lu (.97)	Ce (.85)
Yb (.97)	Pb (.84)
La (.88)	Zn (.77)
Th (.87)	Cd (.76)
Be (.87)	
Eu (.87)	
Ce (.86)	
Pb (.86)	
Fw (.81)	

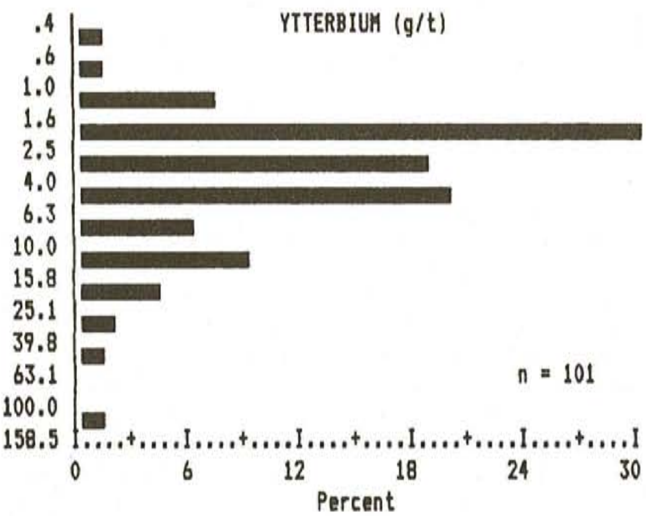

Figure 2. *Histogram of ytterbium distribution in lake sediment, Strange Lake area.*

Ytterbium, a heavy rare-earth element, typifies the distribution in lake sediment of the rare-metal suite associated with the Strange Lake deposit. A histogram (Figure 2) and the cumulative frequency curve (Figure 3) of the log10 Yb distribution, depict the multi-population character of the data. In Figure 2, a population break is apparent between 6.3 and 10 g/t Yb. Moreover, the upper population appears strongly skewed to the right. In the cumulative frequency curve, the population breaks are considerably easier to identify. A pronounced break occurs between 12 and 25 g/t ('A' in Figure 3), which can be seen on the accompanying contour map of Yb (Figure 4) to correspond to sediment values from samples adjacent to, or immediately down-ice from, the main mineralized zone. These are enclosed by the highest contour line of 24.8 g/t. The 6.3 to 10 g/t break seen in the histogram is more clearly defined on the cumulative freqency curve as occurring between 6 and 7 g/t ('B' on Figure 3). This corresponds approximately to the 5 g/t contour line in Figure 4, which encloses samples reflecting dispersion from the entire peralkaline complex. The down-ice dispersion as defined by the contour lines bracketing this population, can be traced for at least 40 km.

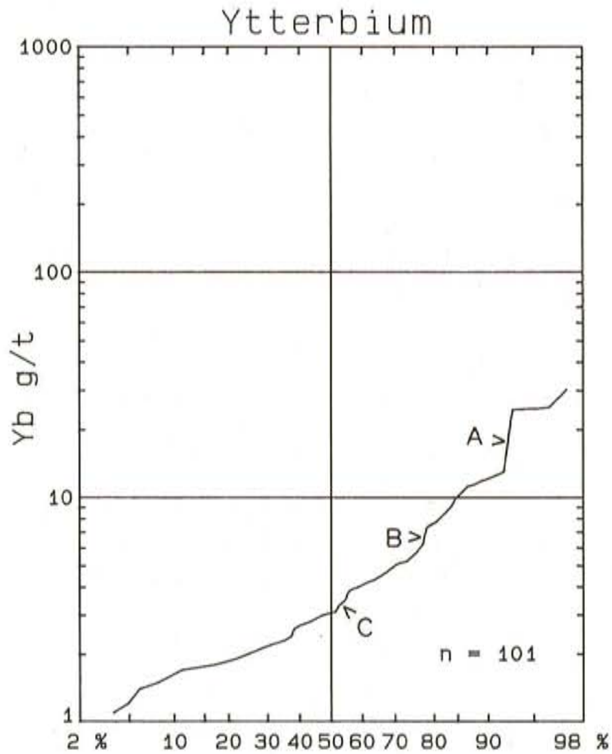

Figure 3. *Cumulative frequency curve of ytterbium distribution in lake sediment, Strange Lake area.*

A third population break, 'C' in Figure 3, occurs at about 3 g/t. Samples in Figure 4, which fall between the 3 and 5 g/t contour lines, are located over and down-ice of the quartz monzonite intrusion. Finally, a fourth population, as defined by the cumulative frequency curve, is composed of those samples falling below 3 g/t. On the contoured data map, these correspond to the area of gneiss terrain to the north of the peralkaline and quartz monzonite dispersion trains, and represent the background population.

Thus, at Strange Lake, four populations (mineralization, peralkaline complex, quartz monzonite and gneiss) can be distinguished by means of a cumulative frequency curve, and these values can then be used to separate samples spatially by provenance on the contoured data map.

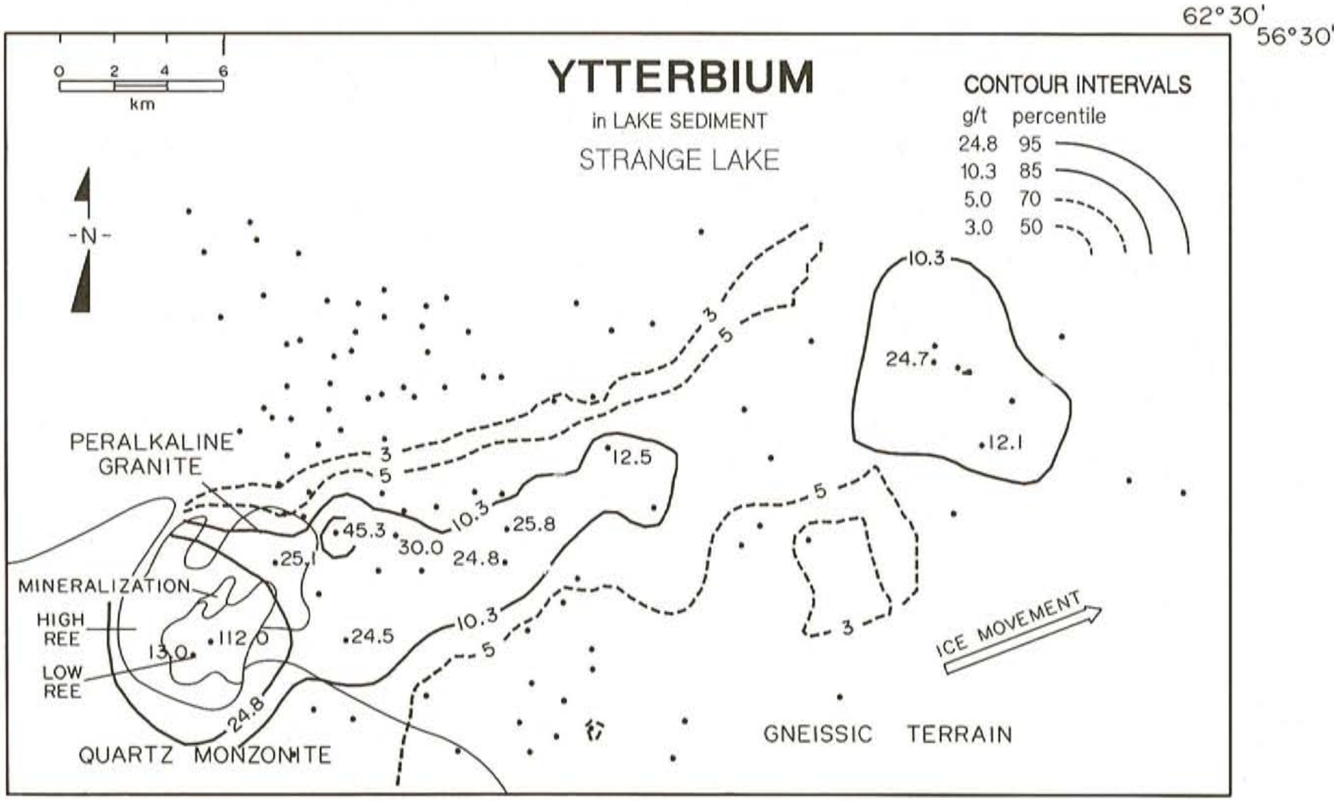

Figure 4. *Contour map of ytterbium in lake sediment, Strange Lake area; (geology from Miller, 1986).*

Letitia Lake Area

The Mann #2 and Two Tom Lake rare-metal occurrences are identified in lake sediment by Zn and Be, and, to a lesser degree, by Nb. Zinc, Y and F in lake waters also highlight the mineralized areas. In addition, unexplored areas are identified, which have Zn, Be, Zr and Nb lake sediment anomalies of equal intensity to those in proximity to mineralization. The Mann #1 occurrence is poorly situated to give rise to a lake sediment anomaly.

Principal components analysis of 24 elements was run and three-, four-, and five-factor models were computed. In each instance, the first factor generated had high loadings on a suite of elements associated with rare-metal mineralization. The elements with the highest loadings (> 0.7) in the first factor of the three-factor model are listed in Table 2. From this, one can see that the elements are similar to the Strange Lake suite shown in Table 2. Note that some of the elements in the Strange Lake factor (i.e., Yb, Tb, Sm, Lu and Eu) were not analyzed in the Letitia survey. A contour plot of this factor (McConnell, 1988) shows that the areas with the highest values are in proximity to the Mann #2 Deposit, the Two Tom Lake occurrence and an area in the south-central part of the survey underlain by rocks of the Red Wine alkaline intrusive suite. This last area is also a beryllium (Be) anomaly and is described in more detail below.

The distribution of Be is discussed as representative of the rare-metal suite in the Letitia Lake area. A histogram of the Be distribution (Figure 5) and a cumulative frequency curve (Figure 6) are presented. In both figures, population breaks are discernible but are not as obvious as with the corresponding figures for Yb at Strange Lake. The histogram appears generally log-normal with a small subpopulation above 63 g/t. The cumulative frequency curve indicates that an inflection point occurs somewhere between 40 and 70 g/t ('A' in Figure 6) separating the highest population from the rest of the data. This break is represented on the contoured data map of Be (Figure 7) by the 46 g/t contour line. Sample sites within this contour include those in the vicinities of the Mann #2 deposit and the Two Tom Lake occurrence. In addition, a large anomaly is outlined in the south of the survey area centred over a portion of the Red Wine alkaline intrusive suite. A fourth anomaly, represented by a single sample (69 g/t), is located 9 km southwest of Mann #2.

Two inflection points on the cumulative frequency curve are denoted by 'B' and 'C' in Figure 6. The 'C' inflection at about 23 g/t corresponds to the second highest contour line in Figure 7. Most of the samples enclosed by this contour are from an area extending up-ice from the Two Tom Lake occurrence and from an area surrounding the southern anomaly. In the first area, these samples suggest that either there is an area of bedrock enrichment surrounding the Two

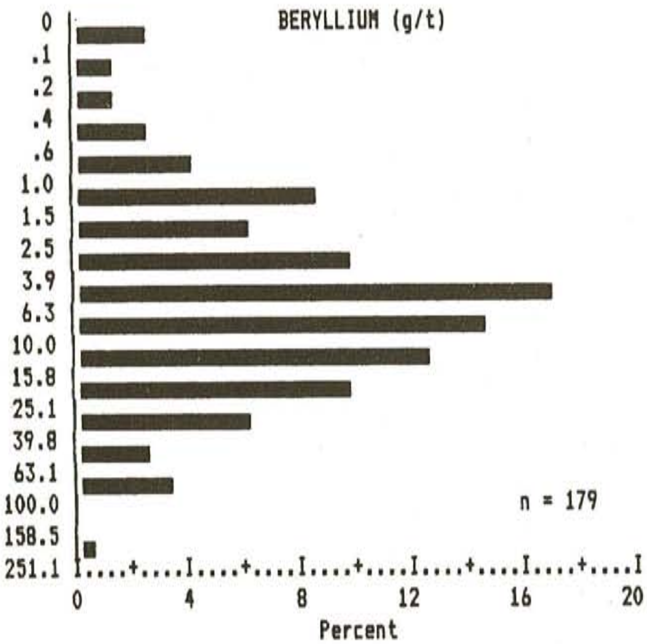

Figure 5. *Histogram of beryllium distribution in lake sediment, Letitia Lake area.*

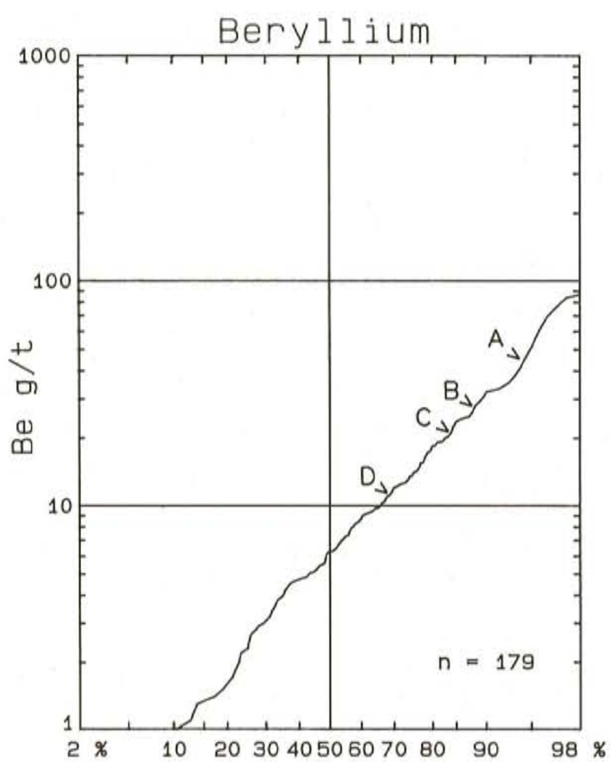

Figure 6. *Cumulative frequency curve of beryllium distribution in lake sediment, Letitia Lake area.*

Tom mineralization or that there is additional mineralization not yet recognized. In the second area, the samples extend the size of the as-yet unexplained anomaly.

A final minor inflection point, 'D' at about 11 to 12 g/t Be, corresponds to the lowest contour line in Figure 7. This contour line roughly outlines the extent of Letitia Lake Group rocks in the north and also expands the southern anomaly.

Michikamats Area

There are anomalies present in F, Ce and La similar in magnitude to those associated with mineralization at Strange Lake and Letitia Lake. However, the concentrations of the elements Y, Nb and Be are substantially lower than in the mineralized areas. No HREE data are available for this area, but since the chemical behaviour of HREE is similar to that of Y, levels are not likely to be high. The dispersion pattern of F in water (Fw) is similar to those of Be, Y and La and is discussed here as a representative element.

The histogram of Fw (Figure 8) has an irregular shape. The cumulative frequency curve (Figure 9) shows several distinct breaks separating at least 5 component populations. However, the contour levels chosen for the map (Figure 10), only correspond in part to these breaks. The highest break ('A' at about 550 to 580 μg/L) is a minor one and does correspond to the highest contour level in Figure 10. This encloses only a single sample, 1867 μg/L. The other six samples with values $>$ 580 μg/L are surrounded by samples with somewhat lower Fw contents, whose influence prevents the higher samples from being separately contoured.

A second break, 'B', occurs at about 350 to 400 μg/L. This is approximately equivalent to the second contour line at 300 μg/L, which delineates two centres of high Fw concentrations that are also reflected by Be, Y and La (McConnell, 1988). The lowest contour (224 μg/L) does not correspond to an inflection point but, rather, occurs midway between the two points 'B' and 'C'. The sample sites enclosed by it are associated with the northern anomaly. A break at 60 μg/L, 'D', separates the lowest 15 to 20 percent of the data that are not identified on the contour map.

13L Area

Results from the 21 samples in this small area indicate an area of enrichment in Y and F similar in magnitude to element levels associated with mineralization at Strange Lake and Letitia Lake. Levels of Be and Ce are also moderately high, whereas those of Zr and Nb are not.

A bimodal distribution of Y is apparent in the histogram (Figure 11) and the cumulative frequency curve (Figure 12) with a break ('C') occurring between 25 and 60 g/t. Lesser inflection points occur at 170 g/t ('B') and at 220 g/t ('A').

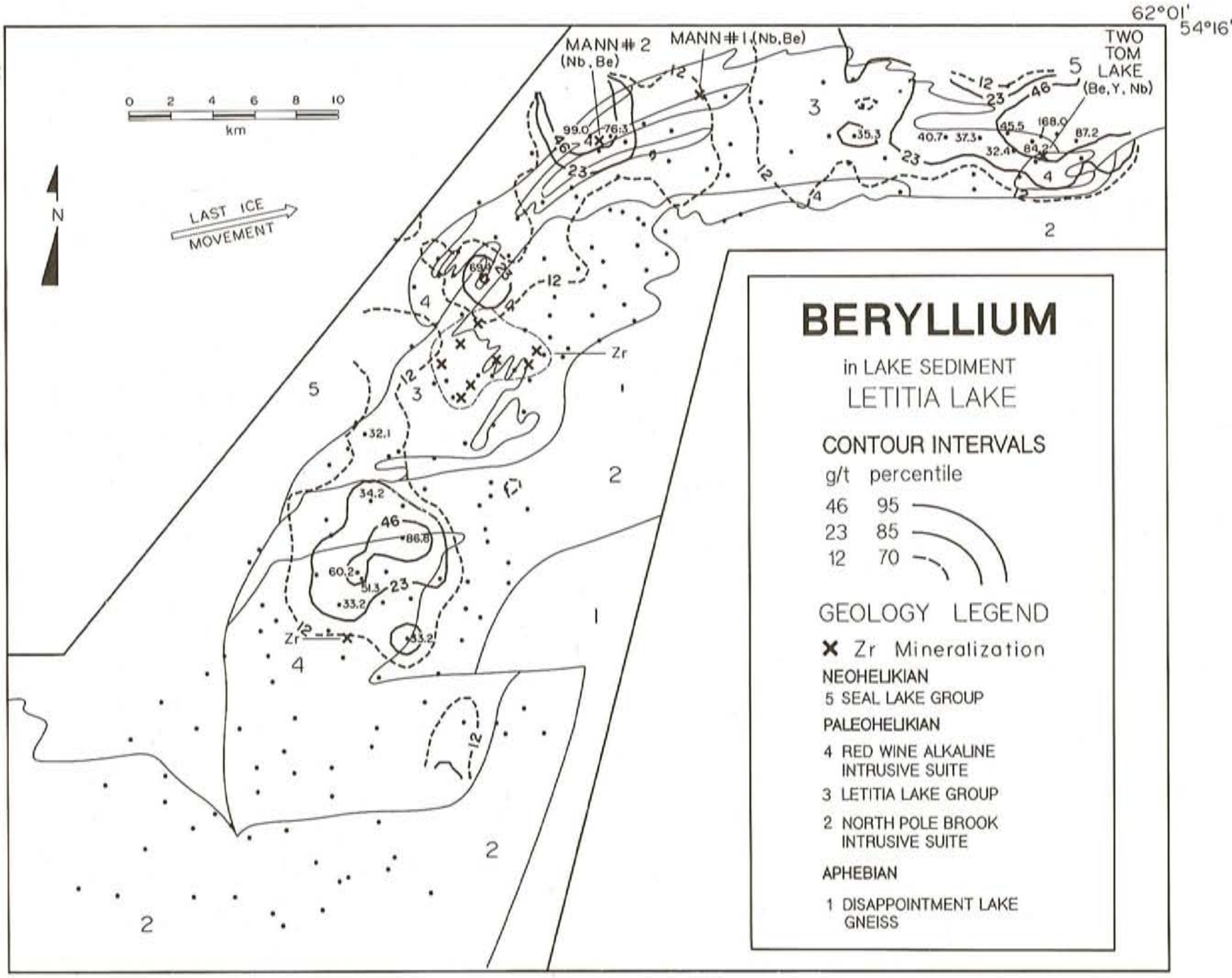

Figure 7. *Contour map of beryllium in lake sediment, Letitia Lake area (geology after Thomas et al., 1983 and Thomas and Hibbs, 1983).*

The upper point is similar to the upper contour line (Figure 13) of 210 g/t. A pair of sample sites are grouped within this contour. The next lower contour, 189 g/t, includes only 2 samples and 1 sample of 191 g/t falls outside the line. The delineation of the dispersion pattern would be improved by replacing the 189 g/t contour with 170 g/t. Similarly, replacing the 140 g/t line with a 40 g/t line might better resolve the pattern in terms of underlying bedrock. Regardless, there is distinct multi-sample anomaly centred in the southeast portion of the survey area.

CONCLUSIONS

The following conclusions can be drawn from this study:

1) Many elements in the rare-metal suite are present in samples of lake sediment and water from mineralized areas in concentrations that are considerably higher than in samples from non-mineralized areas. Thus, these media provide a potent prospecting method. In sediment, these elements include Be, F, Hf, Nb, Pb, REE, Th, Y, Zn and Zr. In water, they comprise F, Y and Zn. The ability of an element to disperse into lake sediment depends partly upon the stability of the source minerals in the weathering environment.

2) Two methods of analysis, ICP and direct neutron activation, are particularly valuable in providing these data.

3) Principal components analysis offers a practical technique for recognizing element associations diagnostic of rare-metal mineralization. This is particularly useful in areas where knowledge of the chemical character of the target mineralization is lacking.

4) Environmental factors encountered within the lake such as organic content (LOI), pH of water, and adsorption by Fe and Mn oxides, do not appear to have a large influence on the distribution of REE in lake sediment. The distributions of F, Hf, Nb and Zr, however, have moderate to strong

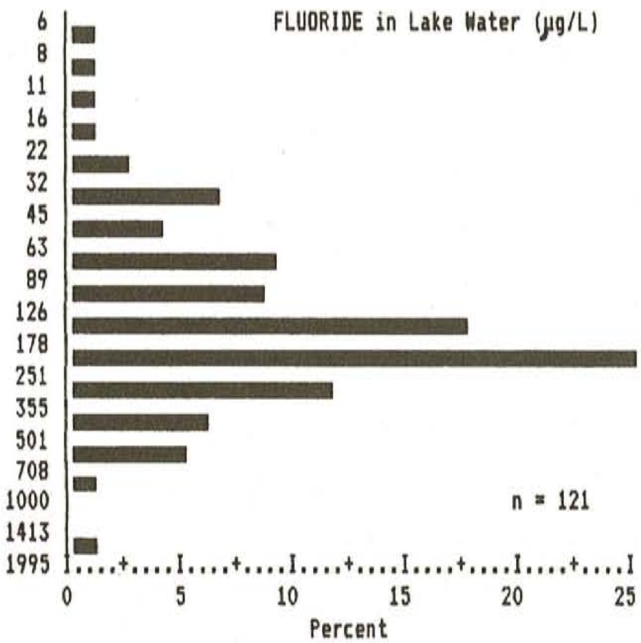

Figure 8. *Histogram of fluoride distribution in lake water, Michikamats area.*

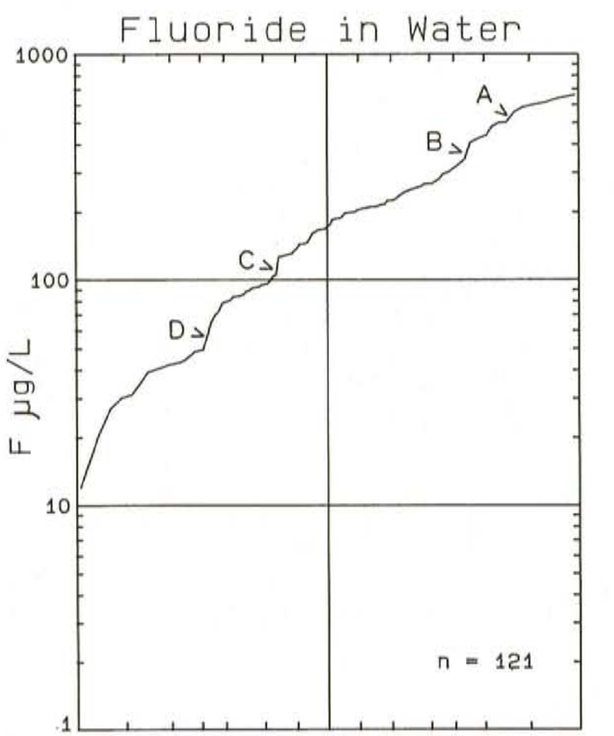

Figure 9. *Cumulative frequency curve of fluoride distribution in lake water, Michikamats area.*

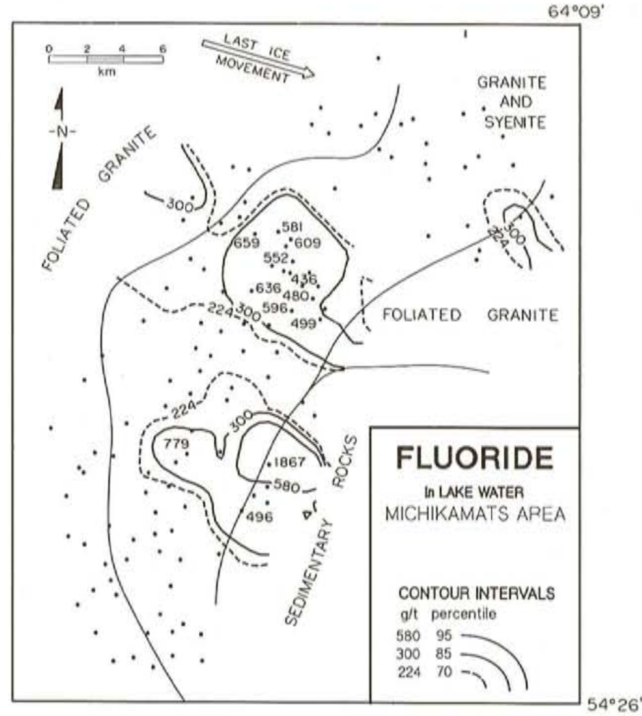

Figure 10. *Contour map of fluoride in lake water, Michikamats area; (geology from Emslie, 1963).*

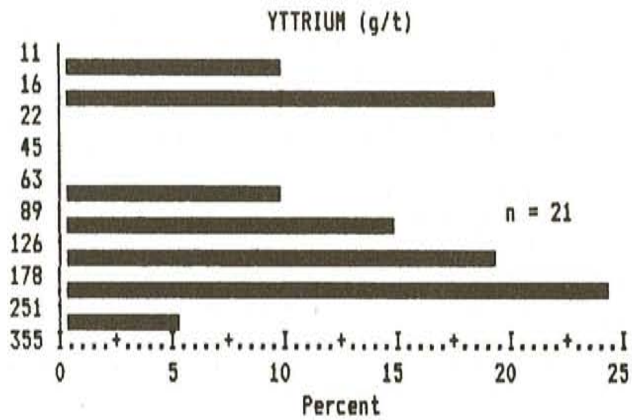

Figure 11. *Histogram of yttrium distribution in lake sediment, 13L area.*

negative correlations with LOI in most areas. The interpretation of dispersion patterns of such elements may be enhanced by the use of regression analysis to calculate residual values.

5) The shape and areal extent of geochemical dispersion fans vary broadly and are products of the erosional and depositional regimes active during glaciation. In the Strange Lake area, these processes produced a geochemical fan identifiable for up to 40 km down-ice from the deposit. By contrast, glacial smearing is much less evident in the other three areas where maximum anomaly displacement from source is on the order of 2 to 4 km.

6) Several unexplained anomalies are present in areas that have received little or no exploration in the Letitia Lake,

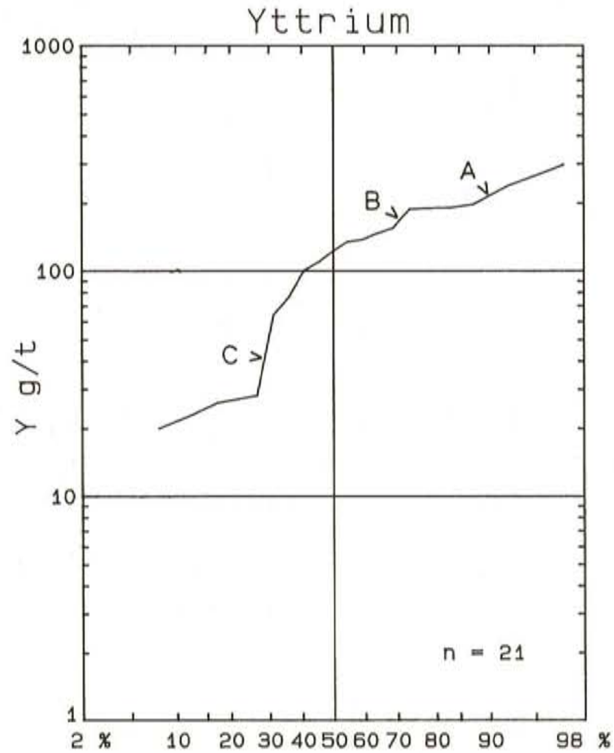

Figure 12. *Cumulative frequency curve of yttrium distribution in lake sediment, 13L area.*

Michikamats and 13L areas. These targets are potential sites of undiscovered rare-metal mineralization.

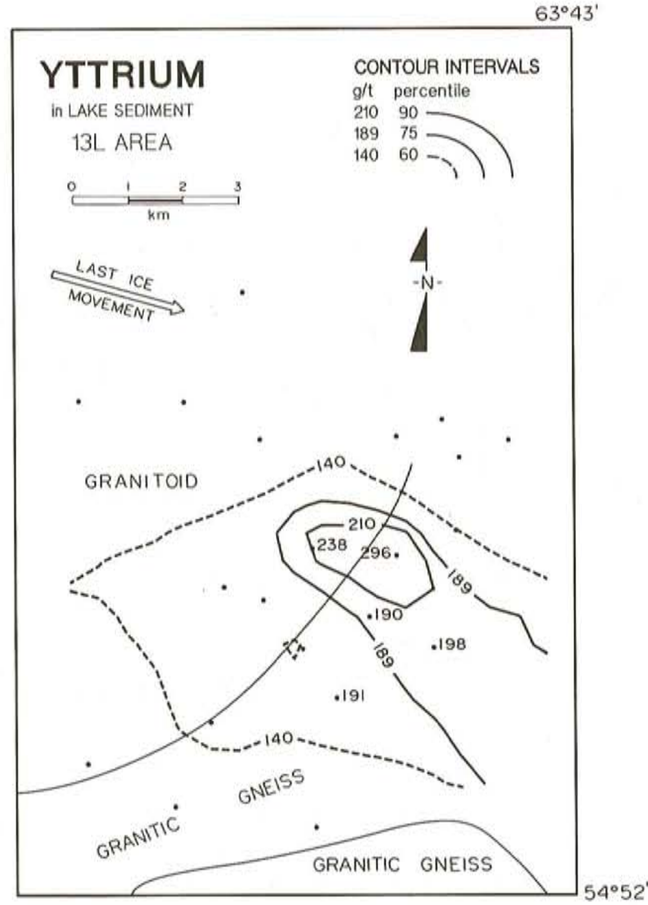

Figure 13. *Contour map of yttrium in lake sediment, 13L area; (geology from Greene, 1970).*

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