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AQUATIC CHARACTERIZATION FOR RESOURCES AT RISK IN EASTERN CANADA

by

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Executive Summary

The risk assessment analysis for aquatic resources in eastern Canada has required extensive evaluation of watershed data for the Province of Quebec. Identification and selection of target watersheds representing similar aquatic chemistry and geological factors, and contrasting them with those of differing geology and soil characteristics has formed a quantitative base for model formulation.

Aquatic effects have been shown for regions in the far eastern area of the Province of Quebec where localized anthropogenic factors are minimal. Although these areas exhibit soft water characteristics the excess proportion of sulphate in the system can be related to long range transport.

Résumé administratif

Pour procéder à l'évaluation des risques qui menacent les ressources aquatiques de l'est du Canada, il a fallu faire une analyse poussée des données sur des bassins versants dans la province de Québec. Nous avons rassemblé des données quantitatives qui serviront de base à l'élaboration d'un modèle en identifiant et en sélectionnant des bassins versants dont l'eau présentait des caractéristiques chimiques et géologiques semblables, et en comparant ces bassins versants à ceux dont la géologie et le sol étaient différents.

On a découvert des cours d'eau contaminés dans des régions situées complètement à l'est du Québec, là où les effets anthropiques localisés sont négligeables. Ces régions sont caractérisées par des eaux douces, mais les quantités excessives de sulfate qu'elles contiennent indiquent une relation avec le transport à grande distance des polluants atmosphériques.

ABSTRACT

To ascertain quantitative estimates of resources at risk for eastern Canada, linkage must be made between geological terrain sensitivity to acid deposition and water chemistry. An evaluation has been made of watershed areas principally in the Province of Quebec to identify and characterize factors related to LRTAP effects. The watershed areas are geographically located within the bounds of the high sulphate deposition zone of the continental plume. To identify specific test watersheds for detailed analysis, alkalinity frequency distributions were computed. A selection of watersheds has been made that spans the Pre-Cambrian shield region of the Laurentian highlands, the St. Lawrence lowlands and the Gaspe Peninsula. There is evidence that areas in the far eastern areas of Quebec, removed from strong anthropogenic sources may be considered as approaching critical levels of alkalinity. Ionic composition for selected watersheds display similar chemical characteristics for regions of diverse geology and soil characteristics. These differences have been assessed in light of the common effects of sulphate deposition.

RÉSUMÉ

Pour vérifier la valeur des données quantitatives sur les ressources menacées dans l'est du Canada, il faut établir la relation entre les caractéristiques géologiques des sols et leur sensibilité aux dépôts acides et à la composition chimique de l'eau. On a étudié certaines régions des bassins versants surtout dans la province de Québec, afin d'identifier et de classer les facteurs relatifs au TGDPA. Ces régions sont géographiquement situées à l'intérieur des limites de la zone à haute teneur en sulfate du panache continental. On a ressemblé des données sur la distribution des zones à alcalinité élevée afin d'identifier les bassins versants spécifiques les plus représentatifs aux fins de cette analyse. Les bassins versants choisis couvrent le bouclier précambrien de la région des hautes terres des Laurentides, la plaine littorale du Saint-Laurent et la péninsule de la Gaspésie. Il semble que dans certaines régions complètement à l'est du Québec, éloignées de toutes source anthropique marquée, l'alcalinité approche du niveau critique. On remarque les mêmes caractéristiques chimiques dans la composition ionique de bassins versants choisis dans des régions dont la géologie et la nature du sol sont différentes. Ces différences ont été évaluées en se basant sur les effets courants des dépôts de sulfate.

INTRODUCTION

The region of eastern Canada south of latitude 52°N lies within the proscribed region of the continental pollution plume. The southern part of the Province of Quebec receives an estimated sulphate deposition, when considering both wet and dry contributions of between 10 and 30 kg ha^{-1} yr^{-1} (Barrie and Hales, 1984). Characterization of the aquatic resources within this region will lead to projected estimates, with confidence intervals of the total aquatic resource at risk.

Investigations into the aquatic effects of acidic deposition in southern Quebec have centred on the documentation and clarification of the chemical relationships of importance in rivers and lakes under stress from acid deposition (Jones et al., 1983). Significant insights into the chemical dynamics and of chemical relationships in 177 lakes in the region between between the Ottawa River and the Saguenay River have been produced (Bobée et al., 1983).

In light of the common problems experienced in regions impacted by large scale deposition of sulphur and nitrogen oxides, as described by Henriksen (1980), Lachance et al. (1985), and the general sensitivity of the bedrock and derived soils of the Laurentian Shield discussed by Shilts (1981), a detailed analysis of the entire available data set for the Province of Quebec to clearly identify in quantitative terms the aquatic risk has been undertaken.

MATERIALS AND METHODS

The basic geographic unit of the study was the watershed designation based upon the Water Survey of Canada map of the Province of Quebec hydrometric stations (Figure 1). Data were subgrouped into watershed areas and all further analyses were conducted under the watershed restriction.

The data base used in this study is contained on the NAQUADAT system maintained by Environment Canada (Demayo, 1970). A subset of all the available data for lakes between 1967 and 1982 which were of interest were evaluated for data precision and representativeness. Numerous problems were encountered, particularly with reference to missing data. The primary variable which was missing was the alkalinity. To solve the data availability situation an editing process of alkalinity estimation was devised.

To estimate alkalinity the average value of two methods was selected. The first method was to compute the alkalinity in μeq/L based upon an ion balance in which alkalinity was the only missing variable (Equation 1).

$$[Ca^{+2}] + [Mg^{+2}] + [Na^{+}] + [K^{+}] - [SO_4^{-2}] - [Cl^{-}] - [HCO_3^{-}] = 0 \qquad (1)$$

(units in μeq/L).

The second method was to compute the alkalinity as in Equation 2.

$$\log\left[HCO_3^-\right] = -7.8 + \log\left[P_{CO_2}\right] + pH \qquad (2)$$

This latter equation is dependent upon $\left[P_{CO_2}\right]$, the partial pressure of carbon dioxide in surface waters. An examination of the pH/CO_2 relationship in surface waters showed considerable variance but in general a value of $10^{-2.5}$ atm. was acceptable (Figure 2). This is in good agreement with the findings of the cation denudation rate model proposed by Thompson (1982).

To begin the characterization of the available lake data, a method to represent large amounts of data in an easy to read form was selected. Ion rosettes which graphically depict the relative contribution to the total ionic content of a sample for each of the major cations and anions were chosen. This technique, first developed by Maucha (1932), was applied to all 57 watersheds under study for the period of record.

It should be noted that some of the regions are located near marine systems and as such sea salt ratio corrections have been applied where appropriate.

RESULTS AND DISCUSSION

Regionally, the ion rosettes represent five distinct geographical and geological regions (Figure 3). Mt. Tremblant displays an ionic composition which is well buffered with calcium bicarbonate dominating the system. However, a high level of sulphate (SO_4^{-2}) shows the presence of acidic stress upon the system. This can be compared to the Natachquan, a system under marine influence located in the far eastern region of Quebec on the north shore of the St. Lawrence River. Note the similarity in the ionic composition. Although the Natachquan basin is a relatively soft water system, the dominance of the sulphate component of the ion balance clearly shows that the system is under stress. The St. Maurice watershed shows an episode of strong acid load wherein the bicarbonate component has been overloaded and eliminated through normal stoichiometric processes. This system, however, has sufficient buffering capacity to re-establish a more normal ionic composition through weathering processes over time. Nevertheless, such acid shocks can have disasterous effects upon the biotic communities within such systems (Jefferies et al., 1979).

Geographical factors dominate the aquatic effects observed in the Province of Quebec. On the south shore of the St. Lawrence River the geology is dominated by limestones. Ion rosettes for the Nicolet basin and the area around Rimouski, Quebec clearly show calcium bicarbonate systems which easily override the presence of the other major ions despite the level of sulphate deposition which is comparable to that deposited on the more sensitive north shore of the St. Lawrence River (Thompson, 1983).

To further classify the 57 regions studied frequency distributions of alkalinity were prepared. Presented here are the results for five of the watershed areas showing again the diversity of the region (Figure 4). Alkalinity reported as less than zero represents an acid system and is resultant from the Gran analysis technique for alkalinity or is an estimate computed from pH and ion balance procedures discussed previously. The diverse geology of the Mt. Tremblant watershed, which is made up primarily of pre-Cambrian shield in the north and glacial till with some limestone in the south, contributes to the diversity of the distribution, whereas regions such as the Natachquan and Nicolet are distinctly univariate. These data can be reassessed in terms of the cumulative frequency distribution. Such a plot indicates the percentage of data gathered within each watershed as a function of the basin susceptibility (Figure 5). Regions located on the north shore of the St. Lawrence River within the region of high sulphate deposition display 30-50% alkalinity below zero and 80 to 100% below 100 μeq/L.

CONCLUSIONS

Diversity of the geologic factors, particularly between the north and south shores of the St. Lawrence River, is the paramount element controlling the system response to acidic loadings from the atmosphere. A common history of sulphate deposition diminishing from west to east links the two shores to the long range transport issue. There is now sufficient quantitative information available on the 57 watersheds to identify key regions as sites for model formulation and development bringing together components of the aquatic and geological chemistry. Investigations to bring this next phase of study to completion are currently underway.

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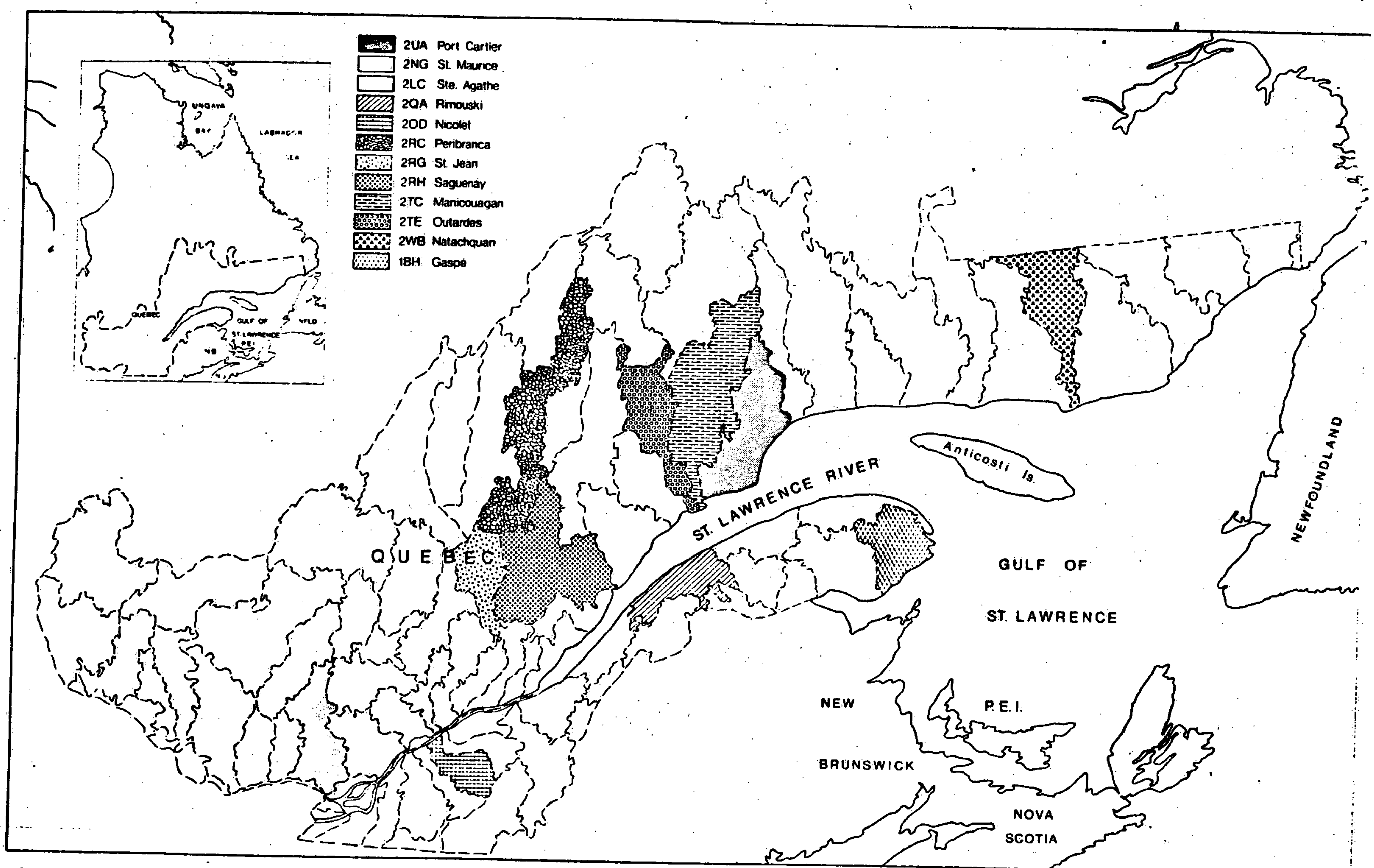


WATERSHED AREAS OF SOUTHERN QUEBEC

FIGURE 1:

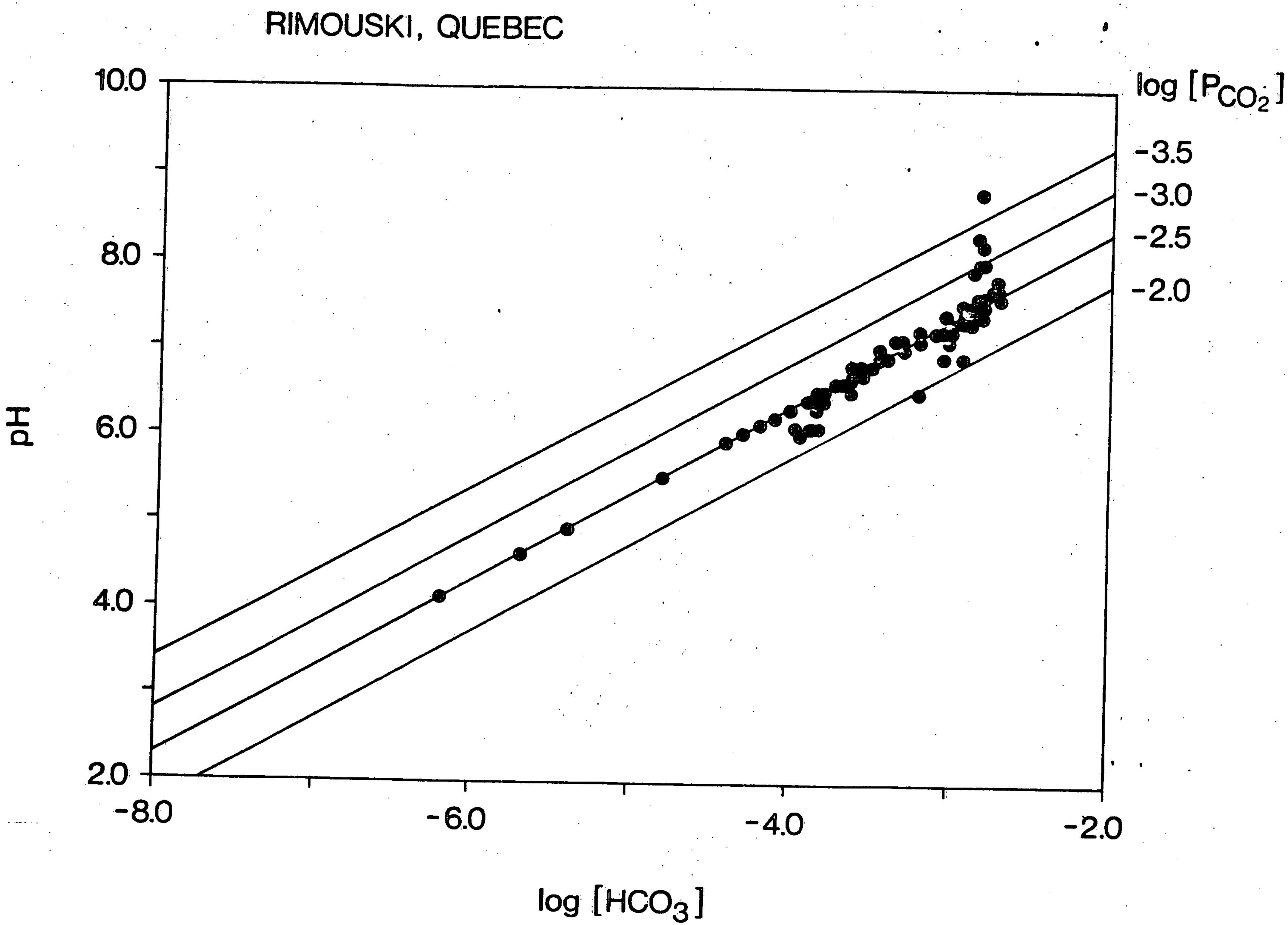

RIMOUSKI, QUEBEC
10.0
8.0
6.0
4.0
2.0
pH
-8.0
-6.0
-4.0
-2.0
log [HCO3]
log [PCO2]
-3.5
-3.0
-2.5
-2.0

FIGURE 2:

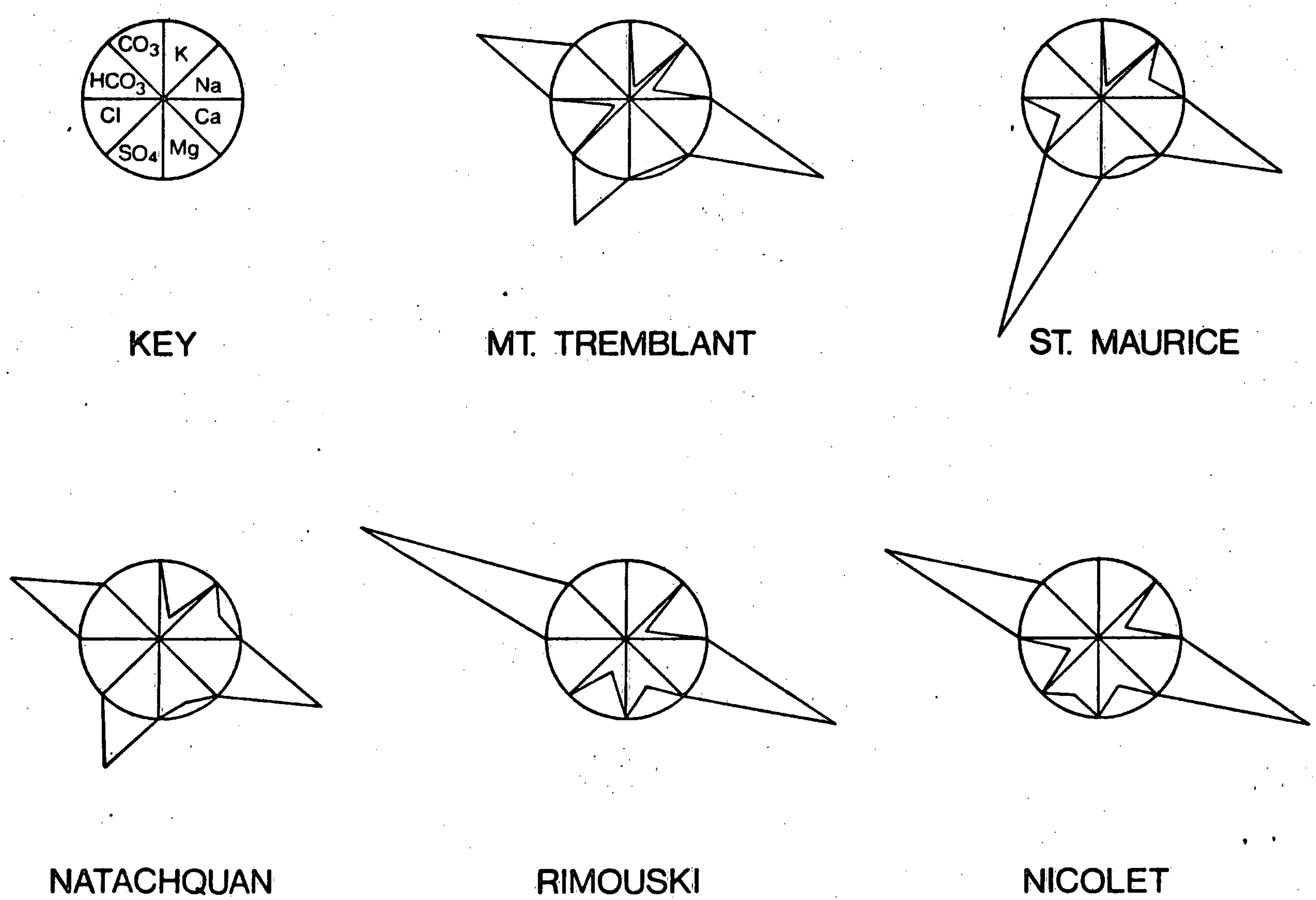

CO3
K
HCO3
Na
Cl
Ca
SO4
Mg
KEY
MT. TREMBLANT
ST. MAURICE
NATACHQUAN
RIMOUSKI
NICOLET

FIGURE 3:

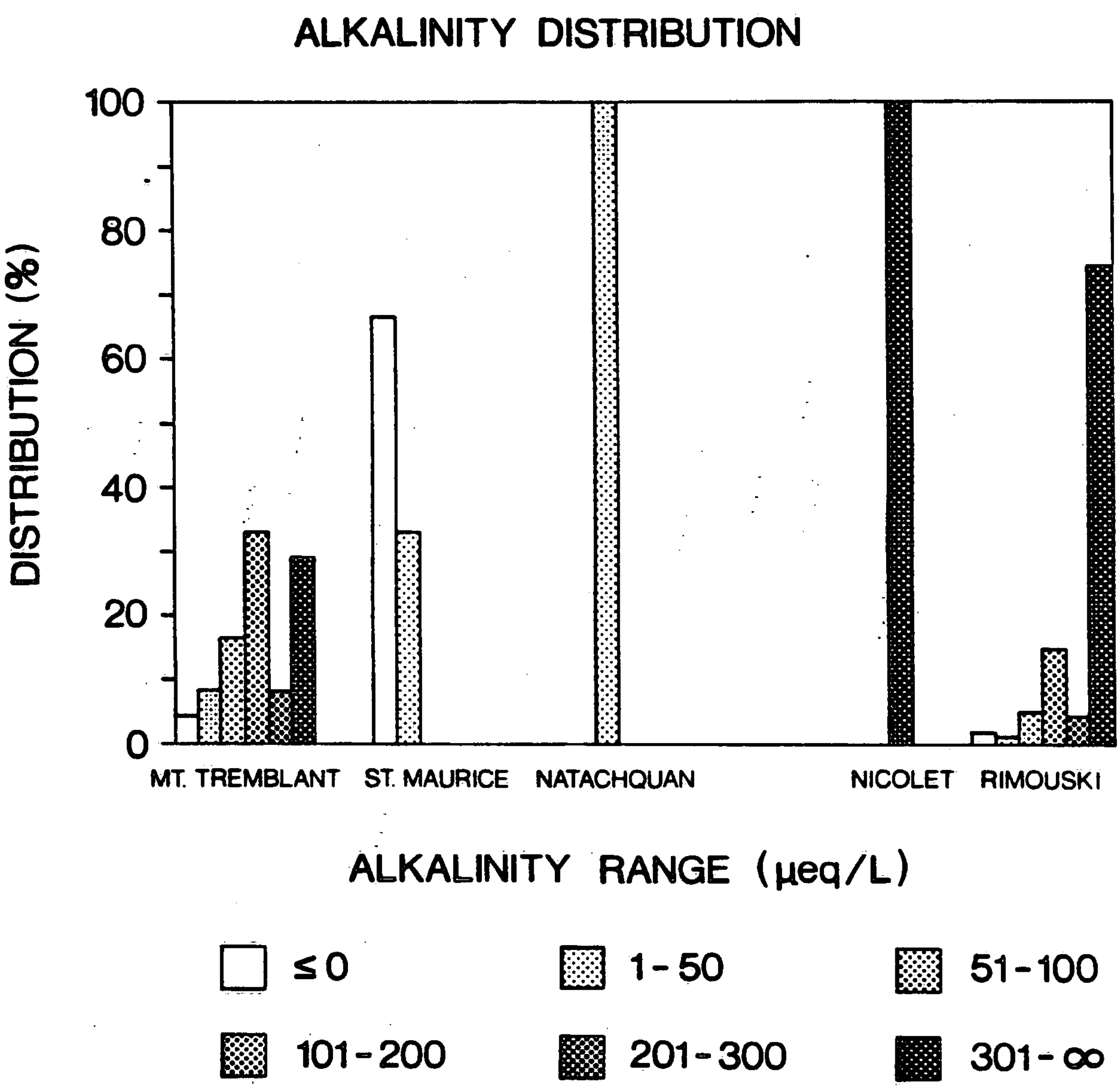
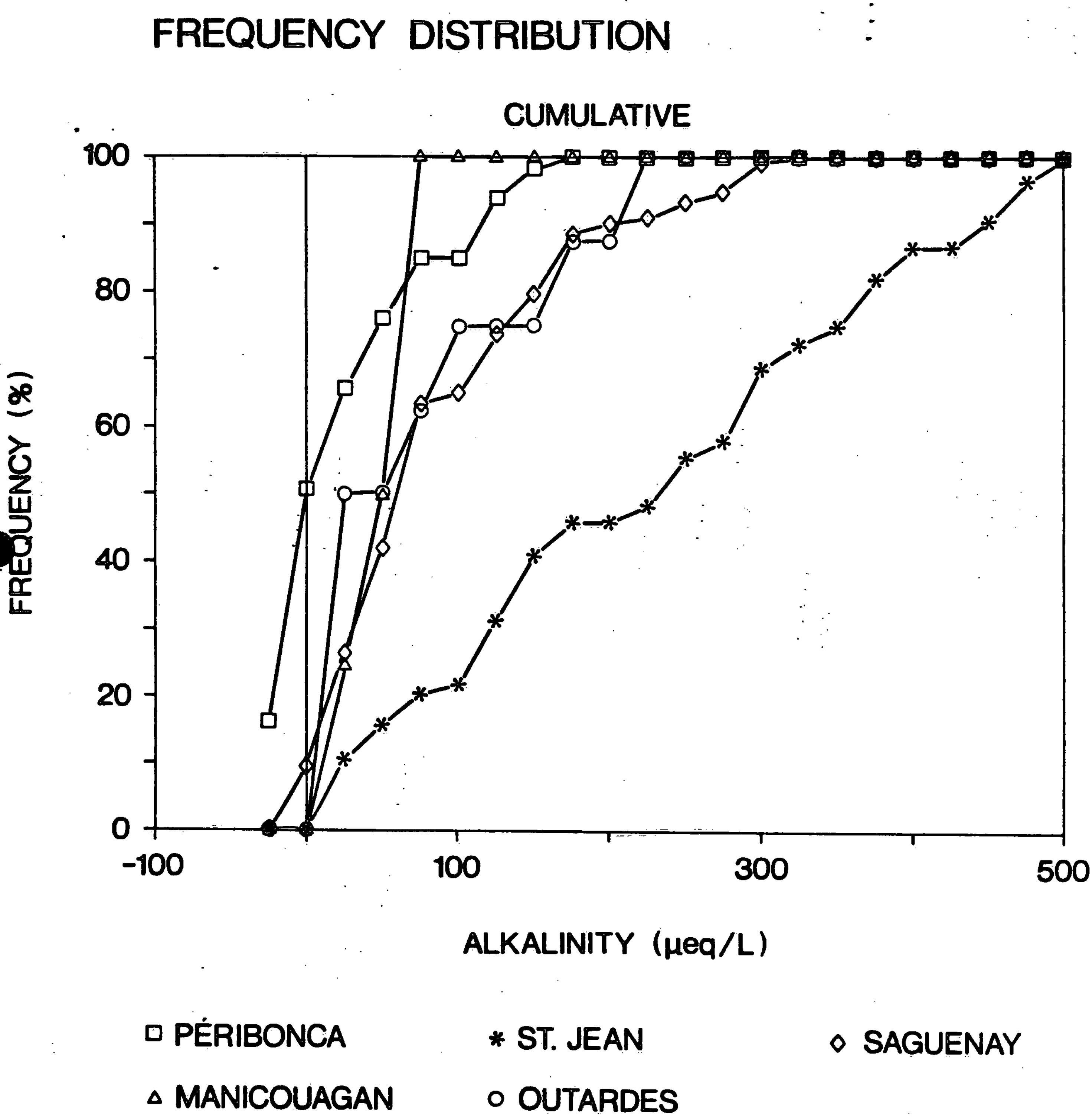

ALKALINITY DISTRIBUTION
DISTRIBUTION (%)
100
80
60
40
20
0
MT. TREMBLANT
ST. MAURICE
NATACHQUAN
NICOLET
RIMOUSKI
ALKALINITY RANGE (µeq/L)
≤0
1-50
51-100
101-200
201-300
301-∞

FIGURE 4:



FREQUENCY DISTRIBUTION
CUMULATIVE
FREQUENCY (%)
100
80
60
40
20
0
-100
100
300
500
ALKALINITY (μeq/L)
PÉRIBONCA
ST. JEAN
SAGUENAY
MANICOUAGAN
OUTARDES

FIGURE 5: