GOLD PLACER POTENTIAL OF THE NORTHERN NEWFOUNDLAND SHELF

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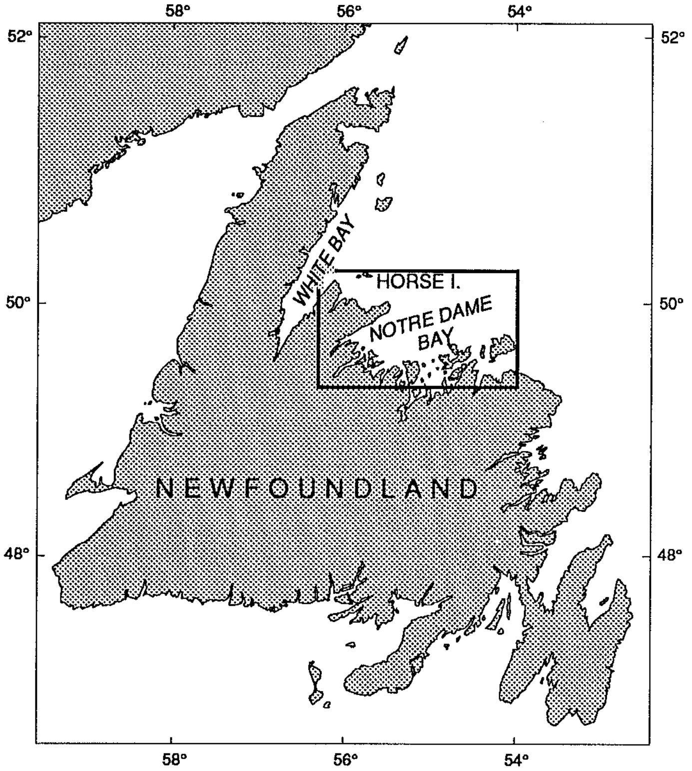

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Gold Placer Potential of the Northern Newfoundland Shelf

Centre for Cold Ocean Resources Engineering, 1991

This Open File contains a report which assesses the gold placer potential of selected inner shelf sites along the northeast coast of Newfoundland. The placer gold potential of four sites is examined to determine those areas with increased potential for secondary autochthonous placer deposits.

The research was sponsored and funded by the Canada-Newfoundland Cooperation Agreement on Mineral Development 1990-1994. This study was carried out by the Centre for Cold Ocean Resources Engineering under contract to the Geological Survey of Canada. The report has not been edited by the Geological Survey of Canada and statements contained herein do not necessarily reflect the views or policies of the Government of Canada.

John Shaw,
Scientific Authority

TABLE OF CONTENTS

Page

LIST OF FIGURES:

LIST OF TABLES:

LIST OF APPENDICES:

LIST OF PLATES:

SUMMARY

The Geological Survey of Canada recently conducted a reconnaissance nearshore survey of the northern Newfoundland shelf. Sediment data collected during the survey are used here to assess the regional gold placer potential of Baie Verte, the La Scie area, the Halls Bay area and Hamilton Sound.

A van Veen grab sampler was used to collect approximately .02 m^3 of surficial sediment at each sample station. Radar and LORAN C were used for navigation and positioning and an echosounder used to record water depth at each sample station.

The texture of each sample was analysed using a combination and wet and dry sieving techniques. A split of the >.063 mm to <2 mm size fraction of each sample was panned to a concentrate of 50-150 grains. Gold grains were then picked and mounted for examination under the scanning electron microscope.

A 30 gram unsieved sub-sample of each sample was analyzed for major and trace elements using lithium borohydrate fusion followed by ICP-MS. In addition, the mud fraction (<0.063 mm) of each sample was analyzed for gold and trace elements using Neutron Activation Analysis.

Seabed sediments in Hamilton Sound, in small coastal embayments in Baie Verte (e.g. Deer Cove) and between Sunday Cove Island and Long Island in the Halls Bay area form tightly-packed pebble pavements and are texturally suitable sites for secondary autochthonous placer gold development. Extensive exposures of bedrock in Baie Verte and offshore from La Scie may be favorable sites for primary autochthonous gold development, particularly where located offshore from zones of known mineralization.

The regional geochemical patterns observed in the offshore muds reflect local bedrock source terrains and the distribution of elements within regional lake sediments of the coastal hinterland.

Fourteen samples from the present study contain anomalous concentrations of gold (i.e. >50 ppb). Gold grades range from 50 ppb to 1180 ppb and are highest in the mud fraction. Gold grains within the sands range in grain size from 0.08-0.27 mm, contain from 0 to 17 wt% silver and exhibit distinct abrasional features. The makeup of the gold in the mud fraction is unknown.

The most significant concentrations of gold are found in northern Baie Verte. Deer Cove contains the highest overall grade with gold occurring within the sand and mud fraction of all 5 samples collected. Elevated concentrations of gold were also found in Green Cove, Marble Cove, offshore from La Scie, east of Long Island near the head of Halls Bay and southeast of East Indian Island in Hamilton Sound.

Particulate gold within secondary autochthonous placer deposits preferentially concentrates at the base of a reworked gravel lag, generally within 30-60 cm below the seabed. The grades of the surficial samples collected in the present investigation thus do not necessarily reflect the true grade of a deposit but rather the presence (or absence) of gold. Nonetheless some samples

contained greater than 900 ppb gold which is over half the mining grade of similar deposits elsewhere.

Several areas are worthy of follow-up work. A discussion of the recommended field procedures and key target areas is provided.

GOLD PLACER POTENTIAL OF THE NORTHERN NEWFOUNDLAND SHELF

1.0 INTRODUCTION

The possibility of placer gold occurring on the northern Newfoundland shelf was first suggested by Emory-Moore and Solomon (1989), who compiled and integrated regional geological evidence in a desk study of the placer potential of the insular Newfoundland shelf. A geophysical survey was subsequently carried out on the northern shelf in June, 1990 by the Geological Survey of Canada (GSC) using the research vessel CSS Hudson (Shaw and Wile, 1990). A large area was surveyed and sediment sampling was necessarily sparse. Nevertheless, gold anomalies were found in some of the shelf sediments (Shaw et al., 1990a).

On a subsequent GSC cruise, a vessel of shallower draft, the MV Navicula, was used to survey in greater detail the nearshore areas around Baie Verte, La Scie, Halls Bay and Hamilton Sound (Shaw et al., 1990b; Figure 1). This report presents a regional assessment of the gold placer potential of the northern Newfoundland shelf using sediment data collected during the Navicula cruise.

Genetic models of autochthonous marine placer gold formation are discussed in Section 2. Sections 3 to 7 review the present state of knowledge of the local geology as it pertains to marine placer potential. Section 8 details the methods of data collection and analysis. Data results and interpretations are presented in Sections 9 to 12. Finally, a brief discussion and recommendations for further work are provided in Section 13 and 14.

2.0 MARINE AUTOCHTHONOUS GOLD PLACER FORMATION

Marine placer gold deposits can be divided into allochthonous and autochthonous types, depending on the mode of mineral concentration (Emory-Moore and Solomon, 1989). Allochthonous placer deposits contain fine-grained platy gold. These deposits are commonly found in association with 'black sands' and can occur up to hundreds of miles from their source. Allochthonous gold deposits are generally found in high-energy beach zones and rarely form on the continental shelf.

Autochthonous gold deposits form close to source through entrapment of particulate gold within lag gravel sequences or, less commonly, within bedrock crevices. Autochthonous deposits derived from marine reworking of bedrock are referred to as 'primary' autochthonous deposits, and those formed through marine reworking of auriferous gravels (e.g. glacigenic sediments) are described as 'secondary' autochthonous deposits; these deposits may form on the beach or the continental shelf. Autochthonous placer deposits are the principal focus of the present investigation and are discussed in some detail below.

2.1 Primary Autochthonous Deposits

Primary autochthonous shelf placers form through post-glacial erosion of mineralized bedrock. The gold remains very close to the bedrock source and is often entrapped within associated gravels or natural bedrock riffles (e.g. bedding planes and vertical joints). The occurrence of these deposits is clearly dependent on the extent and grade of mineralized bedrock outcropping on the seabed. Where mineralized bedrock is present, high erosive energies must be available to effect the mechanical erosion of the rock, a factor which will decrease in likelihood with increasing water depth.

While several small primary autochthonous beach deposits have been mined (e.g. the Ovens district of Nova Scotia; Samson, 1984) there are no well documented examples of primary autochthonous deposits in the offshore.

2.2 Secondary Autochthonous Deposits

On high-latitude shelves one of the most common secondary sources of particulate gold is glacigenic sediment, including tills and glaciofluvial sand and gravel. Hence it is important to understand the factors which control the concentration and distribution of gold in glacigenic sediments and to assess the implications of post-glacial reworking of these sediments.

Gold in Tills

Tills are produced by the glacial erosion, transport and deposition of unconsolidated sediment and bedrock. Where bedrock is mineralized, debris eroded from an orebody is generally deposited within a few kilometres of the source, often forming an elongated lens of mineralized till, known as a dispersal train (DiLabio, 1990). Dispersal trains have an areal extent several orders of magnitude greater than their bedrock sources, are oriented parallel to the direction of ice flow and are generally 500-10,000 m long, 100-1000 m wide and

1-5 m thick (DiLabio, 1990). Some dispersal trains are considerably larger, ranging up to 30 km long and 1-2 km wide. Generally the concentrations of mineralized detritus within a dispersal train decrease rapidly in a down-ice direction (Shilts, 1976).

In areas which have experienced several episodes of glacial inundation, the till stratigraphy is complex and a till unit may be the composite of many overlapping dispersal trains (DiLabio, 1990). Where multiple tills are present, it is often very difficult to trace the source of mineralization.

While glacial erosion generally leads to dispersion of gold within tills, some tills contain economic concentrations of gold. For example, in Peru, gold is mined from tills in areas where ice has eroded a rich primary zone of gold mineralization (Herail et al., 1989). Glacial erosion of disseminated mineralization does not however yield productive placers within the associated tills (Herail et al., 1989). In the Cariboo district of British Columbia, basal lodgement tills and associated intraformational gravel bodies are mined (Eyles and Kocsis, 1989). Gold within the Cariboo till is fairly uniformly distributed and is spatially associated with underlying interglacial auriferous gravels. In addition, several important paleoplacers are mined from tillites. For example, gold is produced from Permian basal tillites in the Clermont goldfield of central Queensland, Australia (I'Ons, 1983). In South Africa, diamond placers also occur in Permian tillites, these having developed through the glacial erosion of kimberlite pipes and subglacial reworking of rich preglacial deposits (Eyles and Kocsis, 1989).

Gold in Glaciofluvial Sediments

Glaciofluvial gravels and sands are the first derivatives of till and have been subjected to transport by water in what may have been a different transport path from that of the till. Hence it is very difficult, particularly in thick sediment sequences, to determine the provenance of glaciofluvial sediment. The transport distances of gravel clasts within eskers have been examined by several workers (e.g., Lillieskold, 1990). Perhaps the most relevant study was an investigation by Lee (1965) who examined the relationship between different size classes of gravel clasts within an esker that crossed two gold veins. He found the transport distances ranged from 5 km for the coarse clasts (8-16 mm) to 13 km for the finer clasts. As particulate gold often moves with the gravels, these transport distances may be a reasonable approximation of the extent of movement of gold within glaciofluvial sediments. Fine colloidal gold can however occur several tens of kilometres from source.

In the Westland and Nelson provinces of New Zealand, glaciofluvial sediments have yielded rich gold placers (Boyle, 1979; Williams, 1974). The most productive placers occur in outwash deposits that were derived from the reworking of large end moraines. In general the grade of the placers decreases with increasing distance from the morainal complex. The richness of these deposits is attributed to the relatively large area of auriferous bedrock within the glacial drainage basin and the extended period of time in which the ancient ice terminus was stationary, thereby allowing meltwater streams to maintain a constant course (Kline, 1981). The gold in most of the glaciofluvial sediment is flaky and fine grained.

Glaciofluvial sediments are also mined in Peru, where gold concentrations within proximal glaciofluvial sediments increase by approximately 20% over the adjacent till (Herail et al., 1989). The grain size of the gold decreases downstream.

Gold in Reworked Glacigenic Sediment

Postglacial fluvial and marine reworking of auriferous drift, either economic drift or sub-economic drift, has in many areas led to the formation of productive secondary autochthonous placer deposits (e.g. the North Saskatchewan River; Boyle, 1979). Of particular interest to the present study is sediment reworking within the beach and nearshore zone.

Placer deposits formed though the marine reworking of glacigenic sediment occur in the USSR, Canada, New Zealand, Alaska and Chile (Elsieev, 1980). One of the most productive offshore autochthonous deposits, and perhaps the best analogue for the northern Newfoundland shelf, occurs offshore Nome Alaska. In the Nome area alone, approximately 5 million ounces of gold have been produced from fluvial, beach and glaciomarine deposits. All deposits are genetically related to glaciation in the area.

The highest gold content within the shelf sediments off Nome occur in a thin (30 - 60 cm) layer of relict lag gravels that overlie glacial drift (Nelson and Hopkins, 1972). The amount of gold within the gravels is spatially quite variable but over 30% of samples were found to contain greater than 600 ppb gold and some as much as 2,500 ppb (Nelson and Hopkins, 1972). The site has been recently mined and the reported ore grade is 1813 ppb (Bosse, 1990). The underlying, non-reworked glacigenic sediment is characterized by an average gold content of 70 ppb, this being typically one tenth that of the overlying lag gravels. Sediment deflation on the order of 1.5 to 2.5 m can account for the increase in grade within the lag gravels (Kaufman and Hopkins, 1989).

3.0 PHYSIOGRAPHY OF THE STUDY AREA

The present investigation focusses on four areas on the northern Newfoundland shelf: Baie Verte, the area offshore from La Scie Harbour, the Halls Bay area and Hamilton Sound (Figure 1).

The Baie Verte Peninsula and the Halls Bay area are characterized by highland plateaus separated by structurally controlled linear lowlands. The coastal zones generally consist of steep bedrock cliffs rising from 50-100 m above sea level. In many areas talus slopes are present and pocket beaches developed between rocky headlands. Baie Verte and Halls Bay are glacially overdeepened with water depths of greater than 300 m. Narrow shelves border the coast in both areas.

The coastal zone around Hamilton Sound is characterized by rocky, high relief, low elevation (<100 m) landforms. The inland areas exhibit a more uniform relief and are characterized by a discontinuous sediment cover with numerous exposure of bedrock. The Gander valley, with a relief of 100-200 m above sea level, dissects the interior uplands and forms a prominent bay along the southern perimeter of Hamilton Sound. The seabed in Hamilton Sound is fairly subdued with water depths rarely exceeding 40 m.

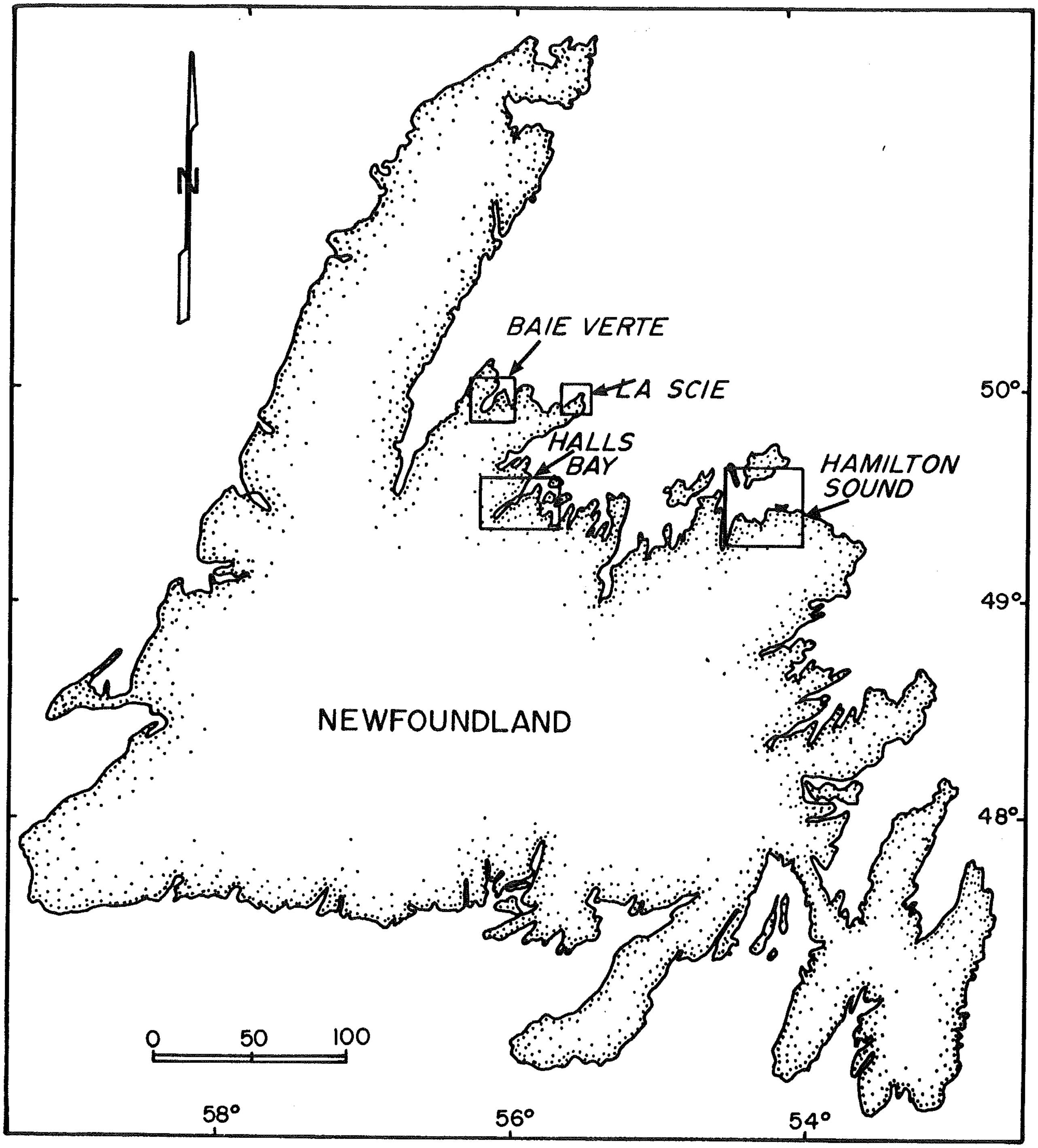


Figure 1. Location of the study area.

4.0 BEDROCK GEOLOGY AND GOLD MINERALIZATION

4.1 Bedrock Geology

Newfoundland has been divided into three major tectonic-stratigraphic subdivisions which collectively record a complex sequence of geologic events related to the evolution and destruction of the Lower Palaeozoic Iapetus Ocean (Williams, 1979; Williams and Hatcher, 1982). From west to east these zones are known as the Humber Zone, the Central Mobile Belt (which is composed of the Dunnage and Gander Zones) and the Avalon Zone. The study area falls primarily within the Central Mobile Belt and is characterized by lower Palaeozoic ophiolite sequences, island arc/back-arc basin volcanics and sediments and wedges of clastic marine sediments (Williams, 1978). Clastic and volcanic rock sequences which formed after accretion of the Lower Palaeozoic oceanic sequences onto the North American craton are also present.

Very limited information is available on the bedrock geology of the northern Newfoundland shelf. Regionally, the eastern Canadian shelf has been divided into an inner shelf zone, comprised of Precambrian and Palaeozoic crystalline basement rocks and a outer shelf zone, characterized by flat top banks underlain by a seaward thickening prism of Jurassic-Holocene sediments known as the Coastal Plain sediments (Slatt et al., 1972). Within the outer shelf zone of northern Newfoundland three northeast-trending banks, with bank tops at water depths of 150-250m, are underlain, at least in part, by Coastal Plain subarkosic rocks (Slatt et al., 1972).

4.2 Gold Mineralization

Gold has been recovered from several onshore deposits within the present study area and is the target of continued exploration activities. Tuach et al. (1988) provide a review of the distribution and genesis of known gold occurrences in Newfoundland. They identify two primary styles of gold mineralization within the study area: volcanogenic massive sulphide mineralization with which gold is often associated, and epigenetic vein and epithermal deposits in which gold is the primary target (Figure 2).

Epigenetic Mineralization

Epigenetic gold deposits occur within single and multiple veins and stockworks and are commonly associated with major N-NE and NE faults and lineaments (Tuach et al., 1988). Epigenetic deposits exhibit low to minor sulphide content and are commonly associated with silicified alteration zones.

There are numerous occurrences of epigenetic gold within the present study area. On the Baie Verte Peninsula significant deposits occur at Nugget Pond, Goldenville, Pine Cove, Stog'er Tight and Deer Cove (Figure 2). Gold within the epigenetic deposits commonly occurs as free fine-grained (<.05 mm) particles in narrow silicate veinlets and dissmeniated blebs within pyrite (Hibbard, 1983; Baie Verte '89'). Within the Nugget Pond deposit gold grains range in size from .01 to .1 mm, contain significant silver and are commonly associated with subhedral to euhedral pyrite (Swinden et al., 1990).

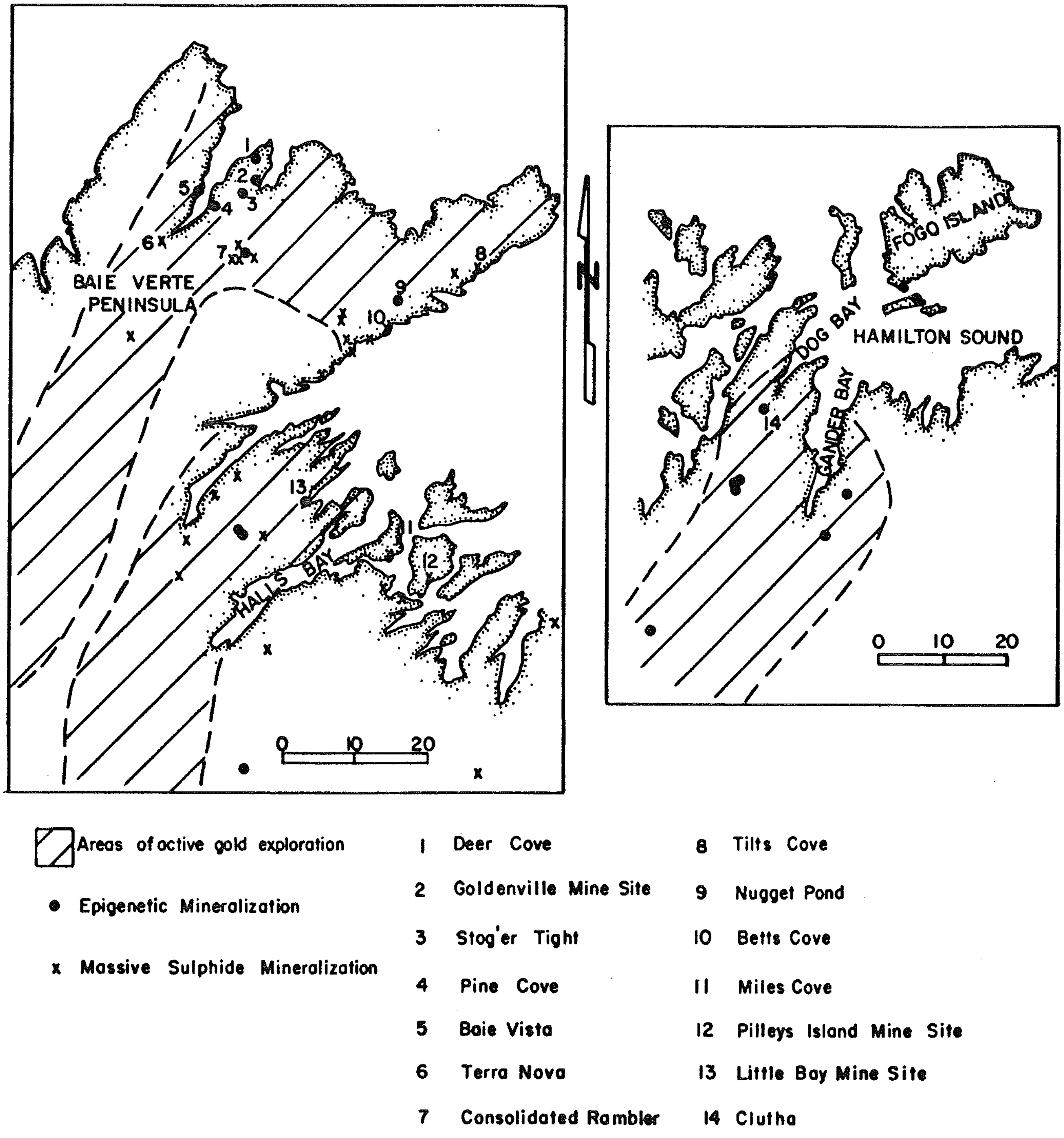


Figure 2. Gold Occurrences and Deposits.

Several occurrences of epigenetic gold are found within the northeastern Dunnage Zone, around Gander Bay and Dog Bay (Figure 2). The mineralization is localized along NE, NNE and NW structural lineaments and occurs in a variety of rock suites (Evans, 1991). The gold occurs both as coarse free gold and as discrete veinlets in pyrite and arsenopyrite (Evans, 1991; Simpson, A., pers. comm., 1991).

Massive Sulphide Deposits

Most of the massive volcanogenic sulphide deposits on the Baie Verte Peninsula are found within ophiolitic sequences; these include the Tilts Cove, Betts Cove, Consolidated Rambler and Terra Nova deposits (Figure 2). Minor amounts of electrum are present in the Betts Cove mine (Saunders, 1984) and the Tilt Cove mine (Donaghue et al., 1959). The Terra Nova mine, located within the Baie Verte river valley, contains minor amounts of gold; however the gold is not discernable in thin section (Hibbard, 1983). The Consolidated Rambler Mine contains significant gold which has been produced as a by-product during smelting (Hibbard, 1983).

In the Halls Bay area volcanogenic massive sulphide deposits occur within the Lushs Bight Group ophiolite. The sulphide occurrences contain variable amounts of pyrite, chalcopyrite, pyrrhotite, magnetite and sphalerite with local minor concentrations of gold and silver (Swinden and Baxter, 1984; Figure 2). Gold has been recovered from the Little Bay and Miles Cove deposits (Swinden and Baxter, 1984).

On Pilleys Island, basaltic and felsic volcanic rocks of the Roberts Arm Group host a significant volcanogenic sulphide deposit (Tuach, 1984). Mineralization is dominantly pyrite with some chalcopyrite. No gold was recovered from this deposit.

In general it is difficult to find information regarding the character of gold within the massive sulphide deposits of the study area. The Au content of these deposits appears to be quite low and the gold very fine grained.

5.0 QUATERNARY GEOLOGY

As discussed in section 2, the distribution of auriferous glacigenic sediment exerts a strong control on the formation of secondary autochthonous placers. Factors which regulate the distribution of auriferous drift include: the extent of ice cover; the ice flow patterns; the distribution of glacigenic sediment; and glacial dispersal patterns. A brief review of these factors is provided within the context of the present study area.

5.1 Ice Extent

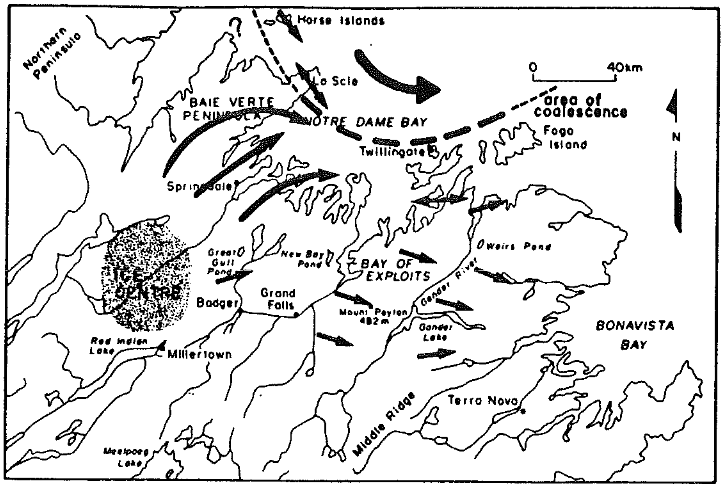
The island of Newfoundland was extensively glaciated during the Quaternary period. During the most recent Late Wisconsinan glacial period it is generally believed that the Island was not overridden by the Laurentide ice sheet but rather maintained an independent ice cap or ice caps (Tucker, 1976; Grant, 1989). The Late Wisconsinan stadial maximum in Newfoundland occurred between 14,000 and 13,000 years B.P. (Grant, 1989). Macpherson and Anderson (1985) provide palynological evidence from a peat bog core near Notre Dame Bay, which indicates that initial Late Wisconsinan warming began about 13.5 ka B.P. A cooler period occurred at about 11.3 ka B.P., and final warming ensued at about 10.5 ka B.P.

Two schools of thought exist on the extent of Late Wisconsinan ice in northern Newfoundland (Grant, 1989). The minimist model depicts a restricted ice cover over the Island with the northern Baie Verte Peninsula and the Horse Islands ice free. The maximal model, largely based on offshore stratigraphy and theoretical considerations, projects ice cover extending well into the offshore region in all areas of Newfoundland.

5.2 Ice Flow Patterns

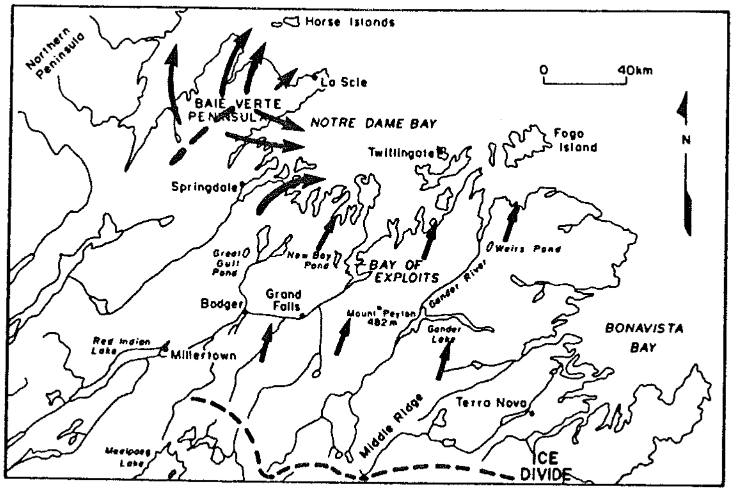
Grant (1974; 1989) and Rogerson (1982) mapped the regional ice flow of the study area and suggested that during the Late Wisconsinan, ice radiated from a centre located in central Newfoundland, within the region of the Topsail Hills. Grant (1974; 1989) suggests that a number of remnant ice caps formed during the final stages of deglaciation, these being largely controlled by local topography and each having its own flow record.

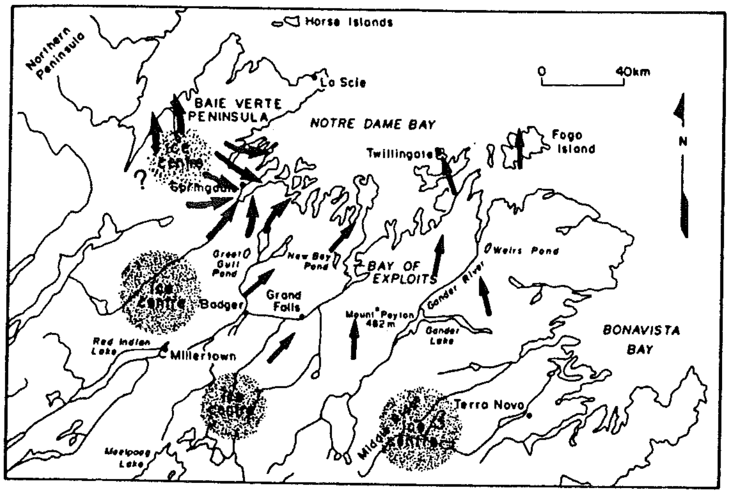
St. Croix and Taylor (1991) and Liverman (1991) discuss a four phase model for Late Wisconsinan deglaciation (Figure 3). St. Croix and Taylor (1991) propose that during the late Wisconsin maximum, ice caps centred on the Long Range Mountains and in central Newfoundland merged in Notre Dame Bay. The Long Range ice mass deflected ice radiating from central Newfoundland to the east, towards Bonavista Bay. As the Long Range ice began to retreat during the early



First ice-flow event

Second ice-flow event





Third ice-flow event

Figure 3. Ice Flow Events (from St. Croix & Taylor (1991) & Liverman (1991)).

stages of deglaciation, ice from central Newfoundland began to flow to the north. At this time an ice divide developed on the Baie Verte Peninsula with flow towards the coast (Liverman, 1991). As deglaciation continued, the central Newfoundland ice cap began to split and several independent ice caps were formed, each with its own localized flow. Finally, during the latter stages of deglaciation, an ice centre located in the Twin Lake area resulted in east/southeast-oriented ice flow in areas south and west of the Bay of Exploits. Liverman's (1991) work on the Baie Verte Peninsula and Horse Islands provides support for this model of deglaciation, particularly in the provision of striation and erratic evidence for a recent southeastward ice-flow event, presumably originating from an ice centre on the Long Range Mountains.

5.3 Distribution of Glacigenic Sediment

The coastal region of the Baie Verte Peninsula, Halls Bay and Hamilton Sound are characterized by a sparse, thin, discontinuous till cover with extensive areas of exposed bedrock (Liverman and Taylor, 1990). Thick surficial sediment cover is restricted to the central and southern lowlands of Baie Verte, the southern end of Halls Bay and the area south of Gander Lake. The stratigraphy in most areas is simple with a single diamicton overlying bedrock (Liverman, 1991; Batterson and Vatcher, 1991). Glaciofluvial sediment sequences occur along the Indian Brook Valley on the Baie Verte Peninsula, at Springdale, South Brook and West Bottom Brook in Halls Bay and south of Hamilton Sound within major river valleys such as the Gander and Southwest Gander valleys. Raised marine sediments occur within coastal sediment suites at the head of Hall's Bay, Baie Verte and Southwest Arm, at the head and along the eastern side of Gander

Bay, and along the coastal zone between Musgrave Harbour and Cape Freels, south of Hamilton Sound (Liverman and Taylor, 1990)

5.4 Glacial Dispersal Patterns

Within the Gander Lake area the dominant pattern of sediment dispersal appears to be associated with the most recent northerly flow event (Batterson and Vatcher, 1991). Although glacial transport distances are unknown, Batterson and Vatcher (1990) suggest that the sediments within the glacial diamictons are likely to have moved small distances (i.e. less than 1 km) and that within the glaciofluvial sediments, transport distances may exceed 5 km. Sediment dispersal patterns on the northern Baie Verte Peninsula are probably dominated by the effects of radial flow from an ice divide centered on the Peninsula, with ice flow towards the coast. Hence in the Baie Verte area, sediment dispersal was probably to the north, with some local topographic variation. In the Kings Point area, on the southeast Baie Verte Peninsula, the dominant direction of sediment dispersal is to the east with clast transport distances of 1-2 km (Liverman and Scott, 1990).

6.0 POST GLACIAL SEA LEVEL HISTORY

In the area between Bonavista Bay and Hamilton Sound, marine limit is estimated at 43 m above present (Grant, 1980). Shaw and Forbes (1990) suggest that between 12,000 and 10,000 years B.P., sea level fell below present levels to an undetermined depth and that sea level has remained stable for at least 2,000 years.

In the Springdale area, raised marine terraces indicate a post-glacial marine limit of up to 75 m above present. Mollusc shells collected from marine clays were dated at 12,000 ± 200 BP (Tucker, 1974). Other dates on shells from raised marine sediments in the Halls Bay and Green Bay area range from 11,000 - 12,000 BP (Liverman, 1991).

Shells from a silty clay unit within a bank of the Baie Verte River are radiocarbon dated at 11,520 ± 180 years (GSC-55; Dyck and Fyles, 1963). The dated unit is at an approximate elevation of 54 m with the limit of marine submergence in the area around 66 m above present.

Grant (1989) used shoreline displacement curves to predict a continuous drop in post-glacial sea levels from 80 m to present sea level. The sea level curve has a strong inflection point at approximately 8,000 years BP where the rate of sea level regression slowed considerably; this change corresponds to an elevation of approximately 25 m above present sea level.

In summary, it is apparent that the western part of the study area (Baie Verte and the Halls Bay area) has experienced a relatively rapid drop in post-glacial sea level while the Hamilton Sound area has experienced less overall sea level movement with a possible regressive and transgressive phase.

7.0 MARINE CLIMATE

The tides within the study area are mainly semi-diurnal with a mean tidal range of 0.9 - 1.0 m in Hamilton Sound and around the Baie Verte Peninsula (Canada, Fisheries and Oceans, 1991). The open sea coast is affected by intense wave activity during the ice-free season with an annual significant wave height of approximately 9 m; fifty percent of the time wave heights exceed 1.9 m (Walker, 1984). Although there are no coastal wave data for the study area, a coastal wind station at Comfort Cove, in Notre Dame Bay, reports the strongest winds out of the north/northwest, with the most frequent winds out of the east/southeast (Environment Canada, 1982). Mean annual wind velocities range from 17 - 21 km/hr.

Wave energy is significantly less in sheltered areas such as Halls Bay. However, tidal and ocean currents may play a significant role in sediment dispersal.

8.0 SAMPLE COLLECTION AND ANALYTICAL METHODS

A van Veen grab sampler was used to collect approximately .02 m^3 of sediment at each site. The samples are representative of the upper 5-10 cm of seabed sediment. Where coarse sediment (pebbles and cobbles) was encountered, sample recovery was poor.

Radar and LORAN C were used for navigation and positioning and an echosounder used to record water depth at each sample station (Shaw et al., 1990b). Positional accuracy ranges from 1-140 m.

Sub-samples of each sample were wet sieved through a .063 mm mesh size. The >0.063 mm fractions were then dry sieved through a bank of sieves with mesh sizes of 0.105 mm, 0.250 mm, 0.500 mm, 1.00 mm, 2.00 mm, 4.00 mm, 9.53 mm, 12.7 mm, 19.05 mm, 25.4 mm, 38.10 mm, 44.45 mm, 50.8 mm, 63.5 mm and 76.2 mm.

The >0.063 mm to <2 mm size fraction of each sample was weighed and panned to a concentrate of 23-25 grams. The concentrate was further panned to a final concentrate of 50-150 grains. Gold grains were then picked and mounted for examination of grain morphology under the scanning electron microscope and an evaluation of grain chemistry using energy dispersive x-ray analysis.

A 30 gram unsieved sub-sample of each sample was analyzed for major and trace elements using lithium borohydrate fusion followed by ICP-MS. In addition, the mud fraction of each sample and five blind duplicate samples were analyzed for gold and trace elements using Neutron Activation Analysis.

In selected samples an attempt was made to identify the lithologies of up to 100 gravel clasts.

Analytical data are provided in Appendices A - C.

9.0 CLAST LITHOLOGY

Mapping of gravel clast lithologies within overburden sediments is commonly used to assess glacial dispersal patterns. An attempt was made in the present study to identify clast lithologies of selected sediment samples. Unfortunately, several problems were encountered and the results are of limited value.

The absence of distinctive rock units for use as a direct 'tag' of bedrock provenance make an evaluation of ice flow patterns within the present study area very difficult. For example, several gabbro clasts were identified in samples from northern Baie Verte. Gabbroic rocks occur on both sides of the Bay and at varying inland distances, so little information on glacial dispersal patterns can be gleaned. In order to assign a clast to a particular rock unit it is often necessary to undertake a detailed petrologic study, which is beyond the scope of the present study.

In the marine environment there is the additional factor of ice-rafted pebbles. As will be discussed later there are several sites within the present study area where ice rafting of clasts is considerable. Clearly the presence of ice-rafted clasts would not reflect glacial dispersal patterns.

10.0 SEDIMENT TEXTURE

As discussed in Section 2.0 primary autochthonous gold deposits are most likely to form in high-energy areas where bedrock is exposed at the seabed. Preferred sites for secondary autochthonous placer formation are those characterized by a high gravel content where gold, if present, remains in situ, trapped within the interstices of the gravel framework. Hence it is useful to classify the surficial sediment into discrete textural classes (Figure 4) and to identify areas where bedrock is exposed and crevices or depressions are visible. A ternary plot, modified from Folk (1954), is used to classify sediment texture. Class divisions were chosen to reflect the degree of gravel armouring. Where sediments are characterized by a high mud, low gravel content the sediment isassumed to be poorly armoured (if at all) and hence the suitability of the sediments to host autochthonous placer deposits is considered low. Conversely, where the percentage of gravel is high and that of fine sediment is low, the sediment is assumed to be well armoured and the placer potential comparably higher. Using the textural data reported here, seabed photos (Shaw et al., 1990b) and sidescan data (Shaw, 1991; Shaw, in prep), a brief description of the textural character of the seabed within the study area is provided; emphasis is placed on the textural suitability of the seabed sediments to host autochthonous gold placers.

Hamilton Sound

Hamilton Sound exhibits a general trend of decreasing grain size with increasing water depth, particularly with respect to the gravel and mud fractions; sand occurs at all water depths (Figure 5). Gravel facies are abundant in Hamilton Sound and generally form tightly-packed pavements composed of subangular to subrounded clasts ranging up to 0.9 m in diameter (Shaw, et al., 1990b). The gravel clasts are often heavily encrusted with Lithothamnion and support extensive growth of seaweed, suggesting a fairly long period of

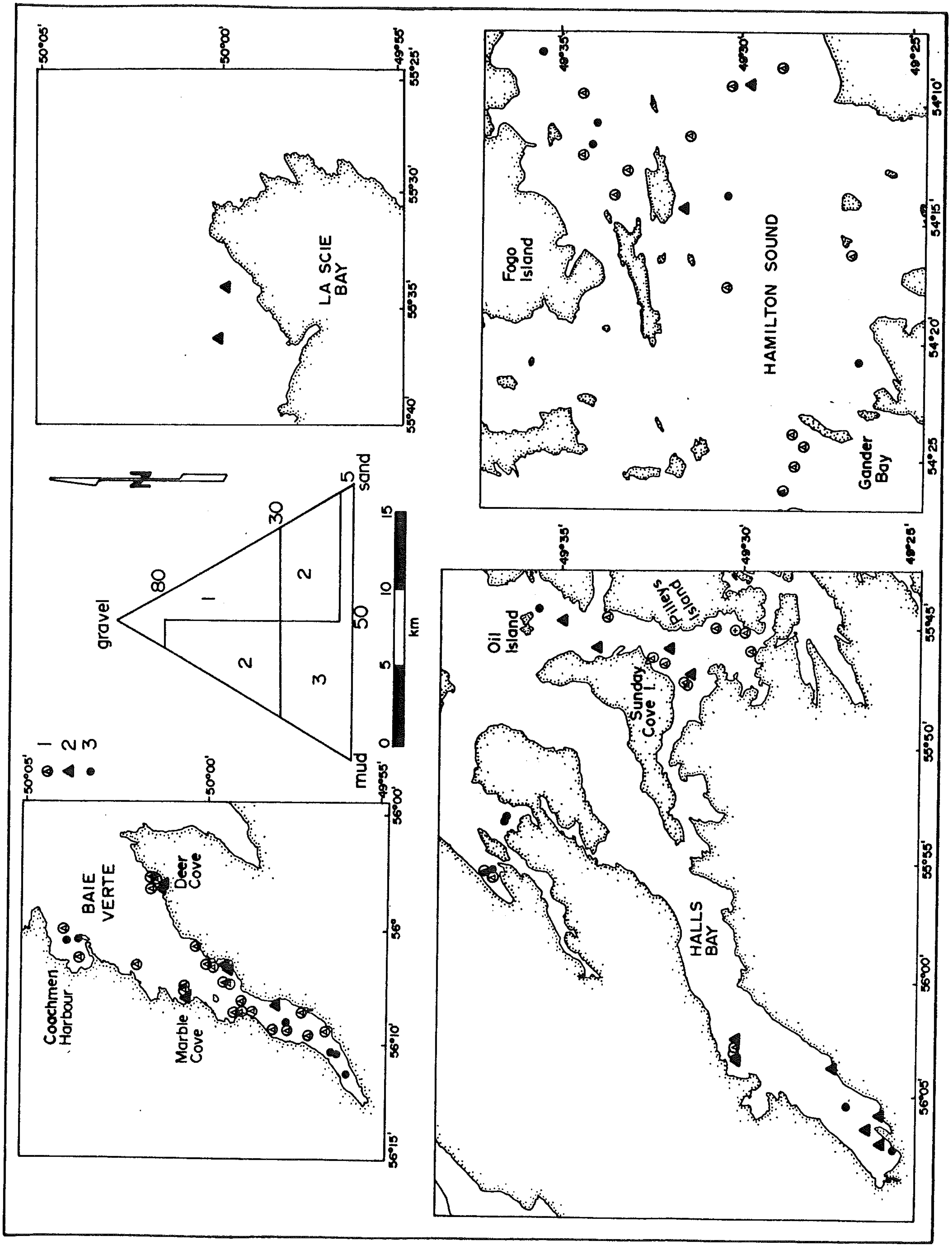


Figure 4. Distribution of Textural Classes.

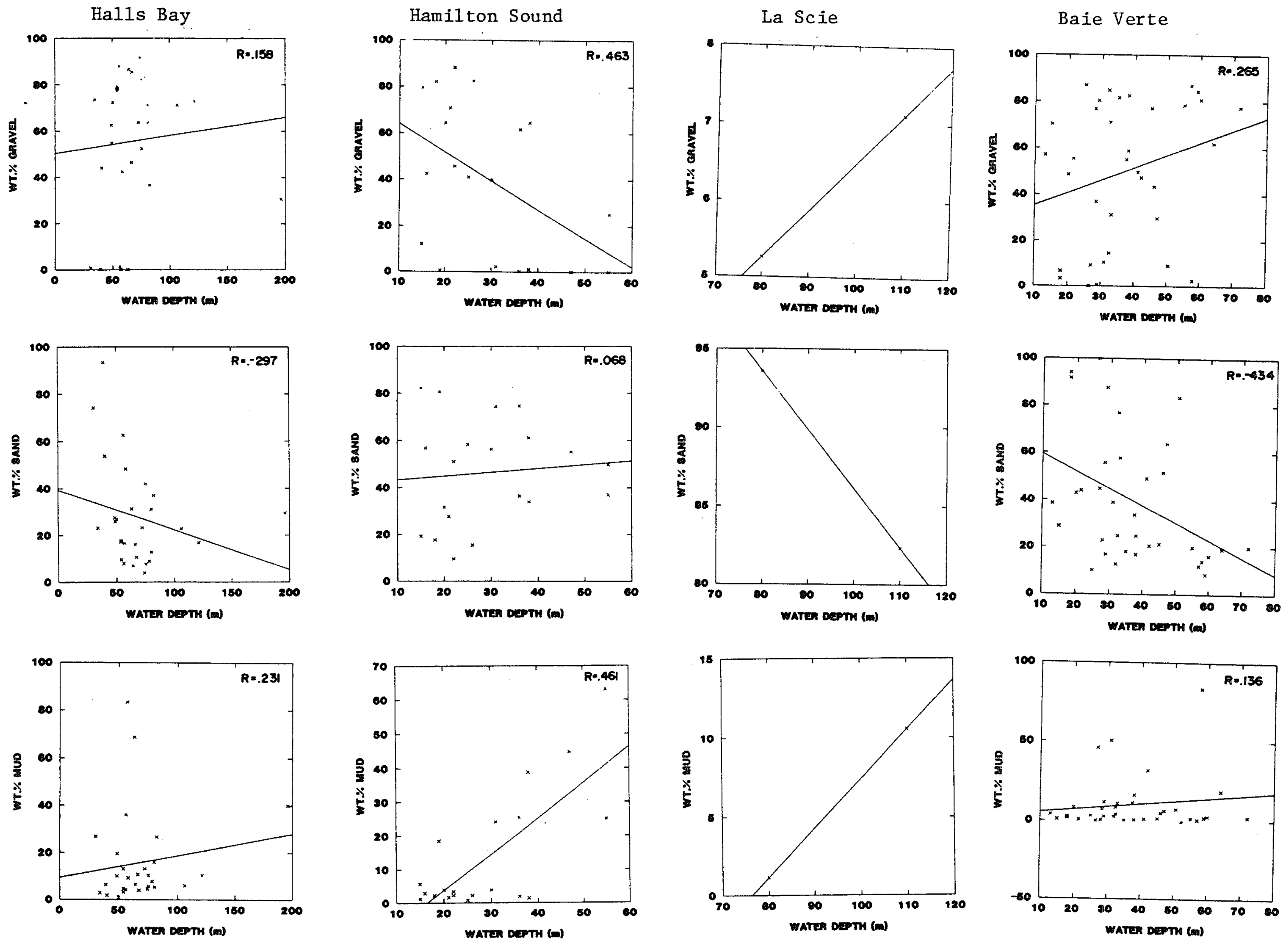


Figure 5. Scatter Plots of Sediment Texture Versus Water Depth.

immobility. These gravels probably represent the coarse end-member of reworked glacigenic material and are texturally ideal sites for secondary autochthonous placer gold development.

In some areas of Hamilton Sound bimodal gravel populations occur (class 2; Figure 4). It is apparent from seabed photos that the gravel clasts are resting on a fine sand substrate and therefore are most likely ice rafted.

Baie Verte

Gravel abundances exhibit no correlation with water depth in Baie Verte (Figure 5). Strongly bimodal gravel facies are found within deep basinal areas and near the head of the bay. These gravels are generally ice-rafted clasts resting on the surface of muddy sediments.

Gravel pavements with minor mud and variable sand content occur in shallow coastal areas where they form discrete pockets of sediment within small coastal embayments (e.g. Deer Cove, Marble Cove and Coachmen Harbour). Many of the gravel clasts are encrusted with Lithothamnion, suggesting limited mobility. These gravels, like those in Hamilton Sound, are the product of marine reworking of glacigenic material and are texturally attractive sites for placer development but appear to be fairly localized.

Extensive exposures of bedrock occur on the seabed in Baie Verte (Shaw, in prep) and may provide suitable sites for primary autochthonous gold development, particularly where located offshore from zones of known mineralization (e.g. Deer Cove and Devils Cove).

La Scie

Two samples were analyzed offshore from the La Scie area, one at 80 m water depth and the other at 110 m water depth. A marked decrease in sand content is associated with an increase in mud content between the 80 m and 110 m sample (Figure 5). Gravels, where present, appear to be fairly mobile as indicated by gravel bedforms identified on sidescan records (Shaw, 1991). Gold, if present, might occur at the interface of the mobile gravels and the underlying non-reworked material.

There is an extensive area of bedrock exposure trending northeast offshore from La Scie (Shaw, 1991). The bedrock has an irregular bathymetric expression with 12-15 m escarpments and surface depressions. If the bedrock is mineralized, then it may host primary autochthonous deposits, particularly in areas close to the shore where wave energy is greatest.

Halls Bay Area

Sediment texture exhibits no correlation with water depth in Halls Bay (Figure 5). Gravels are found in water depths of up to 110 m. All of the gravel facies within Halls Bay and Little Bay are bimodal, composed of subrounded to subangular clasts resting on fine muddy sediments. The clasts are often encrusted, range in size up to 1.1 m and can form up to 80 percent by weight of the sample. These gravels are interpreted to be rafted by sea ice, and their abundance is attributed to colluvial sedimentation along the steep rocky shorelines.

The nearshore sediments east of Sunday Island are generally gravel-rich (Figure 4) and between Sunday Cove Island and Long Island form a closely packed pebble pavement. The latter area is relatively more exposed to the open ocean and is quite shallow, hence the absence of fine sediments. The seabed between Sunday Cove and Long Island appears to be the only site in the Halls Bay area that is texturally suitable for placer development.

11.0 SEDIMENT GEOCHEMISTRY

Although post-depositional diagenetic processes may alter the chemistry of offshore sediments, most of the trace and major elements concentrations in detrital sediments occur in mineral structural sites rather than adsorbed onto minerals, organic matter and oxide coatings (Hirst, 1962a and b). Hence the type and quantity of elements present within offshore sediments is a direct function of sediment source and sediment texture, the latter being governed by the depositional environment.

Within the present study, a split of the whole sample and the mud fraction of each sample were analyzed. There is significant variation, on a per sample basis, in sediment geochemistry between the two data sets (Appendix E), inferring a strong textural control on sediment geochemistry. The geochemistry of the muds is used for provenance evaluations as it is least likely to be affected by physical sorting processes and elements are expected to be homogeneously dispersed throughout the sample medium.

The sample data were divided into four regions (delimited principally on the basis of sample distribution): Baie Verte, La Scie, Halls Bay and Hamilton Sound. Where concentrations of an element were below detection limit, a value of 1/2 the detection limit was assigned. Descriptive statistics for all elements are provided in Appendix E. Hg, Ir, Se, Sr and Ta content were found to be at or below the detection limits and so were eliminated from further analysis.

A Kruskal-Wallis one-way analysis of variance was used to determine the variation in element concentration between each region. The variance test determines whether differences among the various samples are actually population differences (between regions) or whether the differences are chance variations which might be expected among random samples from the same population (Hammond and McCullagh, 1978). Au, As, Ba, Ca, Co, Cr, Fe, Hf, Na, Ni, Rb, Sb, Sc, Th, V, La, Ce, Nd, Sm, Ev and Lv were found to exhibit significant regional variation (population differences) and are considered useful indicators of regional provenance. All other elements do not exhibit significant (>95% confidence level) variation.

Cumulative frequency curves were used to determine natural breakpoints or sub-populations in the element data which did show significant regional variation. These breakpoints were then used to classify the data for use in discrete-symbol maps of element distribution (Appendix F).

Not surprisingly, the regional geochemical patterns observed in the offshore muds reflect local bedrock source terrains. For example, the high Ca content of sediments within northwestern Baie Verte is closely associated with a localized exposure of carbonate rocks immediately to the west of the area. High Co and Fe concentrations within Baie Verte, La Scie and the Little Bay area appear to reflect local sulphide mineralization within the coastal ophiolitic and gabbroic terrains. The high Cr values in all areas except Halls Bay reflect ophiolitic source terrains. Finally, the high Ba content of sediments in western Hamilton Sound is associated with a large granitic massif exposed along the coast; the Ba is probably bound in the alkali feldspars.

The regional geochemical patterns also reflect the distribution of elements within regional lake sediments of the coastal hinterland (Davenport, 1990); this suggests that regional dispersal of muds within the offshore is minimal. Interestingly the range in concentration of most elements is similar in both the offshore muds and the regional lake sediments. Br, Au, Hf and Cr concentrations are however markedly higher in the offshore sediments and As concentrations are slightly lower.

Some marked geochemical anomalies occur within the shelf sediments in the area between Sunday Cove Island and Pilleys Island that are not detected on the lake sediment maps. Na, Th, Rb, Ni and Ba exhibit distinct highs in the offshore muds but are near background in the lake sediment maps. The reason for this variation may be the lack of suitable lake sediment in the area and hence the inability to detect local anomalies.

Hamilton Sound exhibits what appears to be a mixing of source terrains. The coastal rock suite south of Hamilton Sound differs geochemically from the islands to the north of Hamilton Sound (e.g. Fogo Island). These differences are reflected in the lake sediment geochemistry and provide a useful means of assessing the relative contributions of each region to the Hamilton Sound sediments. For example, high concentrations of Na, Sb, Rb, Ni and Ba within the offshore muds correlate with high values in the coastal rock suite; the islands exhibit low concentrations of these elements. High concentrations of La, Th, Tb, Br, Sc, Ni and Sm within the offshore muds correlate with high values on the islands and do not reflect the lower values to the south.

12.0 GOLD WITHIN THE SHELF SEDIMENTS

12.1 Distribution of Gold

Fourteen samples from the present study were found to contain anomalous concentrations of gold (i.e. >50 ppb) in the mud fraction (Table 1). The makeup of the gold is unknown. Gold within the muds may take one of several forms: free particulate gold; a lattice constituent; a sub-microscopic component of pyrite or various sulphosalts; complexed with organics; or a thin coating on secondary minerals. Clearly the form of the gold is critical in any appraisal of the placer potential and will require further evaluation.

The gold content of the mud fraction was found to be highly correlated with Cr, Sb and W in Baie Verte (Table 2). There were no correlations between gold and other elements within the Halls Bay area. Gold content is negatively correlated with Co and Cr and positively correlated with Rb within the Hamilton Sound sediments.

TABLE 1: Concentration of Gold Within the Northern Newfoundland Shelf Sediments

Sample #	ppb Au in mud (NAA)	ppb Au in sand (panning)
33	52	3.4
69	60	-
79	58	-
103	347 (946)*	-
105	859 (1180)*	7.6
107	250 (289)*	1.6
109	224	1.9
111	226 (380)*	1.6
121	81	0.5
125	86	-
129	56	-
131	127	1.2
136	684 (1050)*	3.5
178	64	-

* duplicate

TABLE 2: Spearman Correlation Matrix for Au Within the Mud Fraction

	Co	Cr	Cs	Rb	Sb	W
Hamilton SD (n=20)	-0.49	-0.44	0.44	0.48	0.17	*
Halls Bay (n=29)	*	*	*	*	*	0.39
Baie Verte (n=35)	*	0.67	*	-0.33	0.52	0.54

* variables are not significantly correlated at the 95% confidence level

Eight of the samples were found to contain particulate gold grains within the sand fraction (Table 1). The grades of the sand fraction are markedly lower than the muds. The gold grains within the sands range in grain size from 0.08-0.27 mm and contain from 0 to 17 wt% silver. In come instances, gold grains are coated with a Zn compound.

The distribution of gold within the surficial shelf samples is illustrated in Figure 6. The most significant concentrations of gold are found in northern Baie Verte. Deer Cove contains the highest overall grade with gold occurring within the sand and mud fraction of all 5 samples collected in the area. Elevated concentrations of gold were also found in Green Cove and Marble Cove.

Anomalous gold concentrations were identified in single samples off La Scie, east of Long Island near the head of Halls Bay and southeast of East Indian Iswland in Hamilton Sound.

It is important to stress that particulate gold within secondary authochthonous placer deposits will preferentially concentrate at the base of a reworked gravel lag, generally within 30-60 cm below the seabed. The gold grades of the surficial samples collected in the present therefore not necessarily reflect the true grade of a deposit but rather provide indications of the presence of placer gold.

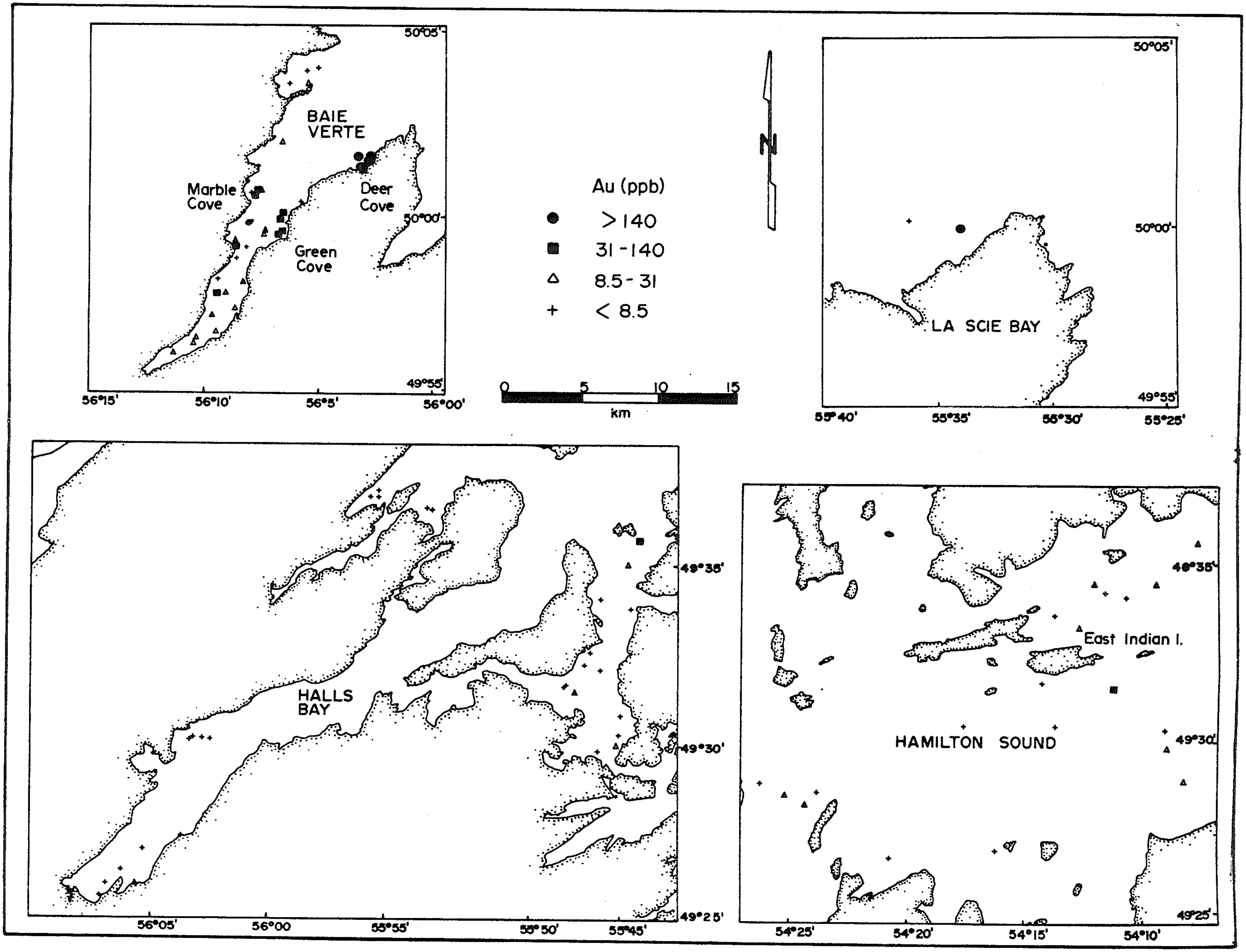


Figure 6. Distribution of Au within the offshore muds.

12.2 Gold Grain Morphology and Chemistry

Regardless of their primary origin, particulate gold grains are physically and chemically altered within glacial, fluvial and marine environments. Physical changes are primarily changes in grain shape, not grain weight. For example, during glacial transport gold particles become slightly rounded and exhibit rolled edges, crush marks, striations and matted surfaces (Herail et al., 1989; Simpson, A., pers. comm., 1991). Glaciofluvial transport produces a grain morphology very similar to that of fluvial transport, namely well rounded, highly flattened and striated (Herail et al., 1989). Mechanical abrasion of gold in the marine environment is substantial, with rounding of grains occurring over very short transport distances (i.e. 30 m; Gorshkov et al., 1972). Most authors ascribe changes in the shape of gold grains to the distance of transport from the point of grain liberation. Yeend (1975) found that mechanical abrasion of gold is also related to the velocity of sediment movement and the textural character of the host sediment.

Chemical alteration of gold, which is a time-dependent versus distance-dependent factor, includes both internal and external corrosion. The gold/silver alloy on the surface of the gold grain is attacked by chemically active water, leaving an outer rim of high-purity gold known as the patina. The effects of this alteration can be seen in the development of numerous etch marks on the grain surface. In one investigation, the purity of the patina was found to change on average 0.4 units per 100 m of fluvial transport and 2.2 units per 100 m of transport in the sea (Gorshkov et al., 1972). The increase in electrochemical corrosion in the marine environment is a result of its electrolytic content.

Internal corrosion of gold grains results from the weathering out of primary minerals such as sulphides. The primary mineral phases may weather out at the site of primary bedrock mineralization or at some intermediate site along the transport path. The cast of the weathered grains forms a protected cleft where secondary clay minerals form.

Unfortunately, there has been little detailed work done on the chemical and mechanical alteration of gold in the marine environment. The relatively high energy and unique chemical environment of the oceans will undoubtedly imprint a distinctive signature on gold particles. Gold grains within marine placer deposits are polycyclic, representing a complex history of mechanical and chemical alteration. The evaluation of grain textures and chemistry is thus very qualitative but nonetheless a valuable tool in estimating relative transport distances and possible sub-populations.

The gold grain classification used in the present investigation was developed by Simpson et al.(1989). The extent of mechanical and chemical abrasion of each gold grain is determined using the visual and chemical criteria discussed above, and these indices are used to rank the interpreted distance of transport from the point of grain liberation. It is important to appreciate that grain liberation does not necessarily occur at the site of bedrock mineralization but may occur at any point along a transport path through release from, for example, a large gravel clast. In practice this scheme has been found to be very useful in tracing primary bedrock sources although it must be stressed that it does not always work as the alteration processes are very complex.

A brief discussion of gold grain morphology and chemical composition for each region is provided below.

Baie Verte

There appears to be two distinct populations of gold grains within the samples from Deer Cove. The first population is represented by grains with fresh irregular features, minor folding of exposed wire knobs, minimal corrosive etching, and in general, little or no Ag content (Plate 1). Some of these grains have an almost crystalline appearance, possible originating as a polygranular gold grain (Plate 2). These grains are interpreted to have travelled less than 500 m from their site of liberation.

The second population of grains exhibit more regular grain morphologies (rounded, equi-dimensional or spherical), micro and macro folding, extensive surface matting and striations, some percussion marks and extensive chemical etching (Plates 3-6). Well preserved casts of primary host minerals are apparent in some grains, with the recessed areas exhibiting less evidence of mechanical and chemical alteration. The Ag contents of these grains range from 0 to 10 wt%. In the recessed casts, the Ag signature is stronger relative to the more exposed corroded portions of the grain, suggesting a primary source rich in Ag. These grains are interpreted to have travelled greater than 500 m. The distinction between these populations is most evident within samples 105 and 109, where

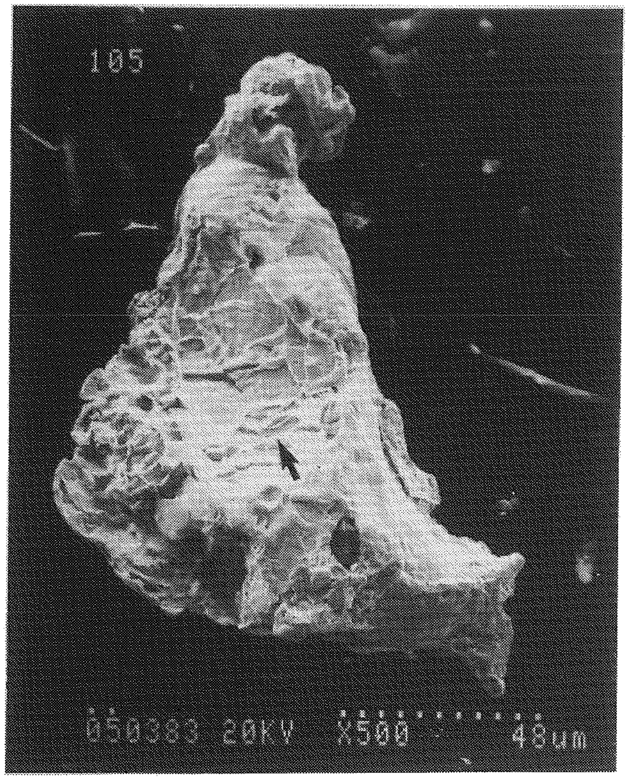


Plate 1.

Fresh gold grain with very little evidence of chemical etching and only minor rounding of grain edges. Note the fresh grain cast where primary crystal faces are preserved (see arrow).

Plate 2

Gold grain with no evidence of chemical or physical abrasion. Primary crystal faces apparent. Characterized by high Si and As content. Somewhat of an enigma. May be secondary gold?

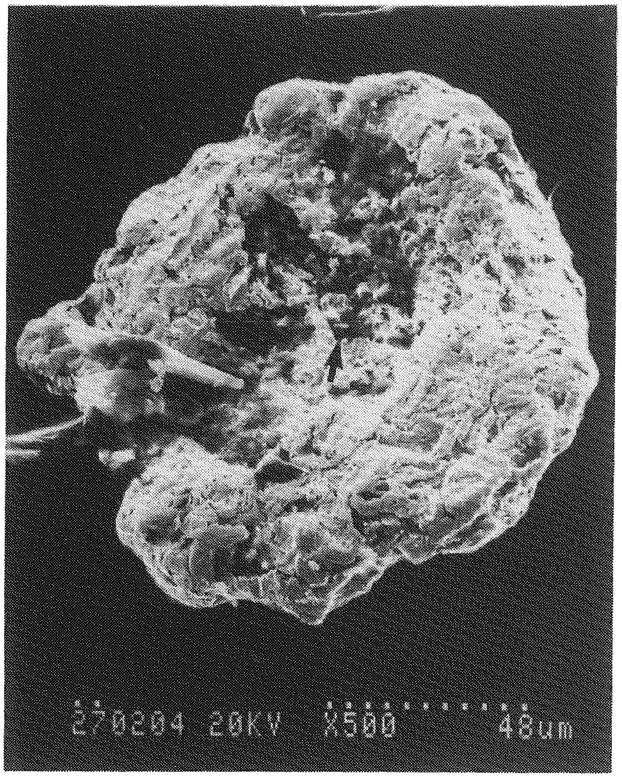


Plate 3

Well travelled gold grain with evident pitting, chemical etching and rounding of grain edges. Note the growth of secondary clay minerals within recessed areas (see arrow).

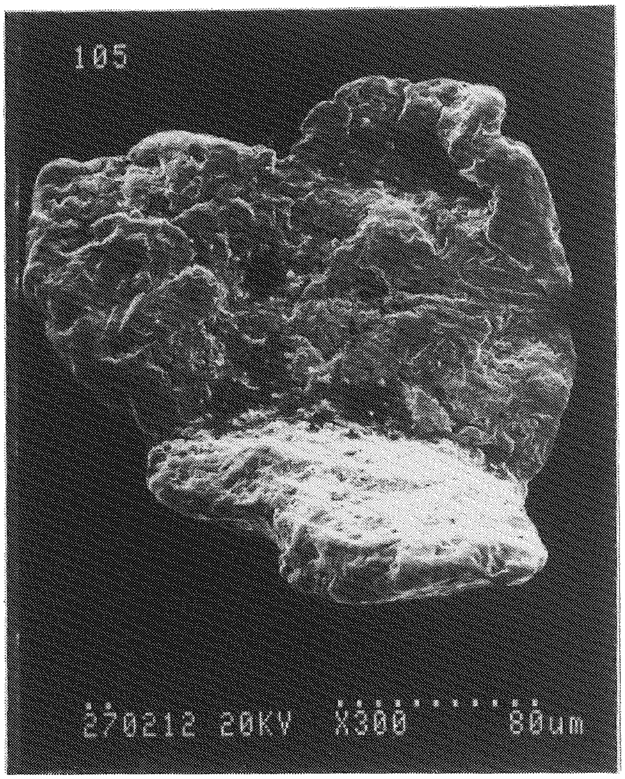


Plate 4

Well travelled gold grain with evident pitting, chemical etching and rounding of grain edges.

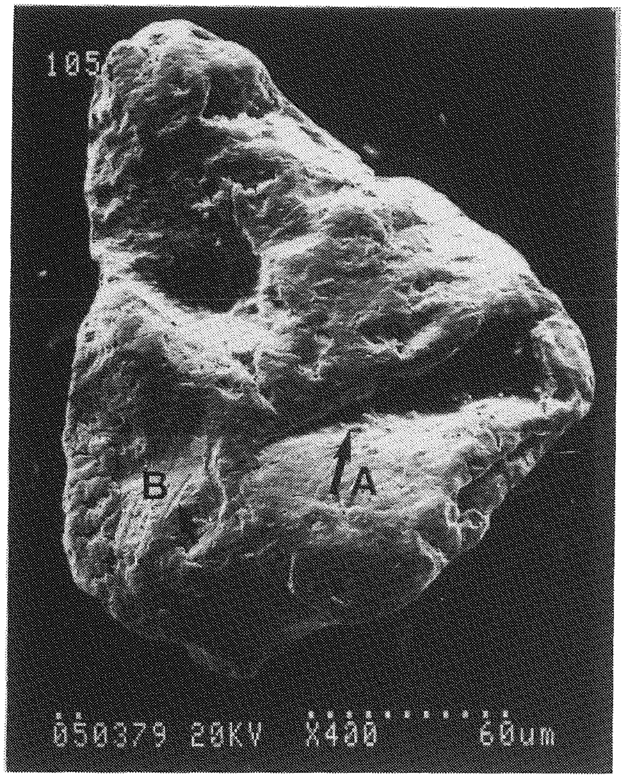


Plate 5

Highly abraded grain exhibiting very regular edges, large scale folding (A) and numerous striations (B).

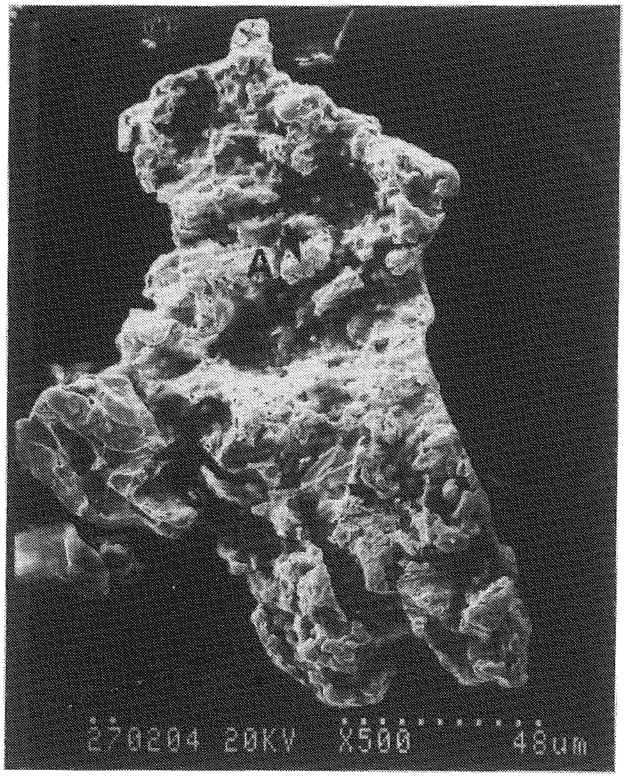


Plate 6

Gold grain that has undergone extensive chemical and physical alteration. A good example of a pitted grain surface. Surface matting of what were probably fine wires of gold is also evident (A). Folded grain edges.

several grains were available for examination and both populations were well represented. In sample 105, seven grains fell within population one and six within population two. Sample 109 had three grains in population one and six in population two. Samples 107 and 111, with only 5 and 4 grains respectively, contained grains representative of the second population only.

The two populations of grains within the Deer Cove area may suggest the mixing of two primary sources, one Ag-poor site located close to the site of deposition and a more distal Ag-rich source. The Deer Cove gold deposit, located approximately 1 km inland from the coast is known to contain low Ag (Wilton,D. pers. comm., 1991) and hence may be the source of population one. Alternatively these grains may have been liberated from a submarine bedrock source in the immediate Deer Cove vicinity. The source of grains from population two is unknown.

Unfortunately, the sample from Green Cove contained only two gold grains and the two samples from Marble Cove contained only one gold grain each, making interpretation difficult. The grains from both sites exhibited moderate levels of mechanical and chemical alteration, suggesting transport distances greater than 500 m. Striations, matting, folding of grain edges, and regular outlines attest to mechanical abrasion; extensive etching and pitting to chemical abrasion. One grain from each site contained some silver, the others were pure gold.

La Scie

A bimodal distribution of gold grains is apparent from the six grains within sample 136. Two of the grains are very fresh, probably having travelled less than 200 m from their site of liberation. One of the fresh grains contains 20 wt% silica and appears to have a crystalline form indicative of a single grain from a polygranular chain of gold grains (Plate 7). The other fresh grain exhibits a very wiry morphology that probably resulted from growth within microfractures of the host mineral (Plate 8). It contains 11 % silver and has undergone very little transport, if any.

The remaining four grains are more intensely abraded and corroded, with evidence of etching, folding and numerous striations. One of these grains contains minor silver. In general these gold grains have probably travelled greater than 500 m.

The source of the fresh grains appears to be proximal and Ag-rich. The sample is located approximately 2 km from the coast, in 80 m of water, suggesting an extension of the onland mineralization into the offshore. The more distal grains, while apparently low in Ag, may have been derived a source rich in Ag and have undergone corrosive leaching of the silver, resulting in a gold-rich rim.

Hamilton Sound

Five gold grains were found in sample 33, located southeast of East Indian Island. All the grains exhibit evidence of mechanical and chemical alteration

Plate 7

Crystalline gold with high Si and As content (similar to grain in Plate 2). Secondary?

Plate 8

Extremely fresh gold grain that maintains a wiry shape and that probably formed within micro-fractures of sulphide minerals. There is no evidence of chemical etching or pitting.

and are interpreted to have travelled in excess of 500 m. The grains are characterized by regular outlines, folding of grain edges, extensive matting and corrosive etching and pitting (Plates 9 and 10). Only one of the grains contains silver.

13.0 DISCUSSION

The small sample size and sample density, and the large areal extent of the present study make it difficult to make any unequivocal statements about autochthonous placer formation on the northern Newfoundland shelf. It is apparent however that several areas are well suited for autochthonous gold placer formation, both with respect to geological and environmental considerations, and in that detrital gold is present in some locations. As the highest concentrations of secondary autochthonous gold would be expected to occur at 30-60 cm below the seabed, and sampling within the current investigation was limited to the upper 10 cm, the gold grades observed reflect the presence (or absence) of gold, not necessarily the grade of a potential deposit. Although the highest concentration of gold occurs within the < 0.063 mm size fraction, some samples contain > 900 ppb gold which is over half of the mining grade offshore Alaska.

Interestingly, anomalous concentrations of gold observed within the offshore sediment are commonly associated with terrestrial zones of epigenetic mineralization and are conspicuously absent in areas of massive sulphide mineralization. This is particularly evident in the Halls Bay area where gold onshore is frequently found in association with massive sulphide deposits, but these sediments may be a function of the depositional environment or low sample

Plate 9

Well travelled gold grain exhibiting folded, rounded edges, extensive surface matting and some pitting.

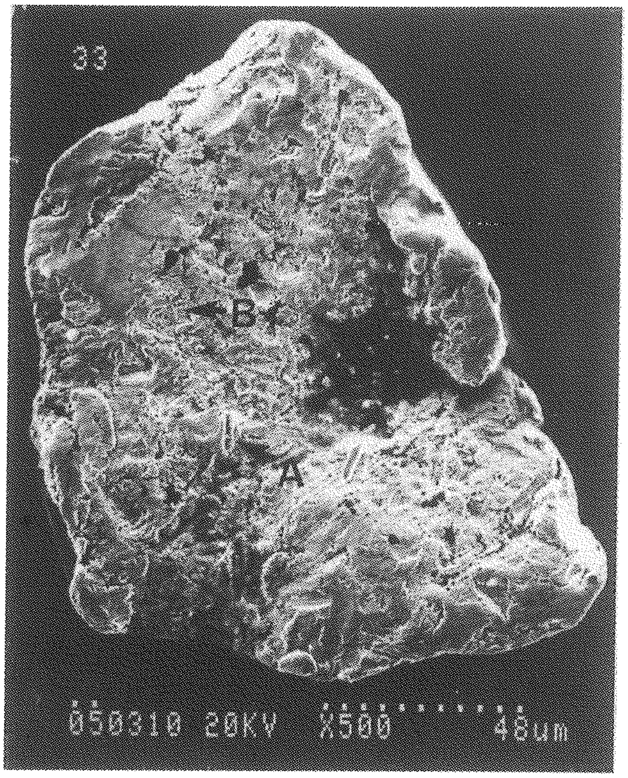


Plate 10

Grain that has undergone extensive chemical and physical abrasion. Rounded edges, percussion marks (A), extensive matting, pitting and chemical etching (B) apparent.

very little gold is seen in the offshore sediment. While the absence of gold in density, it may also be a function of the style of primary mineralization.

Gold within the massive sulphide deposits of Newfoundland is generally very fine-grained (not visible) and may be in some instances intergrown with the sulphide minerals. Any gold weathered from these deposits or associated tills would be equally fine grained and may ultimately be widely dispersed as colloidal gold or be adsorbed on secondary clay minerals. If indeed massive sulphide deposits are not good sources of placer gold, then considerable source terrain can be eliminated from further investigation.

14.0 RECOMMENDATIONS FOR FURTHER WORK

Several factors suggest that the Halls Bay area is not a favorable site for autochthonous placer development: the dominantly massive sulphide source terrain with only minor occurrences of Au ore; the protected, low energy environment of the bay with little evidence of gravel lag development except around Long Island; and the absence of particulate gold within all but one sample. Selected areas around the Baie Verte Peninsula and in Hamilton Sound are however considered worthy of further work. A brief description of recommended survey methods and key target areas is provided.

14.1 Survey Methods

Follow-up surveys should include the following:

1. A series of side scan lines should be run to try and isolate lag gravel facies and bedrock exposures.
2. A more detailed side scan mosaic of target areas could then be used to identify appropriate sampling sites.
3. At each sample station a bottom photograph should be taken, preferably with some sort of scale bar attached to the trigger line.
4. Large volume surficial samples should be collected at each sample station. The IKU grab could be used or, for shallow water surveys, perhaps the hydraulically-actuated bucket sampler developed by Scott et al. (1991) would be appropriate. At the very least, multiple samples should be collected using the van Veen grab sampler.
5. At selected stations multiple large volume samples should be collected in order to assess the natural compositional variability.
6. Where possible vibrocoring of the sediment should be undertaken in order to evaluate vertical variability in sediment texture, geochemistry and where possible, gold grades.

7. Regional sub-bottom profiling is also useful in establishing the Quaternary history of the area and how it might impact on the distribution of auriferous glacigenic sediment.

In addition, all sediment finer than 1 mm should be panned for gold rather than using a grain-size cut-off of 0.063 mm. It is apparent that a high percentage of the gold found within the northern shelf sediments is less than 0.063 mm (Table 2). Gold finer than 0.020 mm cannot be recovered by standard mechanical techniques.

14.2 Target Areas

Coastal Embayments, Eastern Baie Verte

Devils Cove, Deer Cove, and Pine Cove are worthy of follow-up work. The proximity of these sites to known epigenetic gold mineralization and the presence of particulate gold within the coastal tills in the area (Milner, 1987) suggest a high availability of gold to the offshore region. At the Deer Cove site, coarse sediment lags provide a good 'trap' for gold as is apparent in the relatively high grade of all samples. Similar sediment facies may occur within Pine Cove and Devils Cove.

While the spatial extent of lag gravel formation in these coves is probably quite limited (e.g., in Deer Cove lag gravels extend, at surface, over an area of 1.0 X 0.75 km; Shaw, in prep) the possible tonnages are well in keeping with the concept of a cottage mining operation.

Mings Bight

Due to uncharted waters in Mings Bight, no samples were collected there during the Navicula cruise. Mings Bight is however a promising site for autochthonous gold placer formation, for many of the same reasons as Baie Verte. Mings Bight occurs along a prominent mineralized lineament and physiographically is the likely repository of till and glaciofluvial sediments derived from it. Free gold is known to occur within the epigenetic deposits of the area. The Bight is fairly well exposed to the open ocean and should provide the high energies needed for placer formation.

La Scie

The area offshore from La Scie provides a very unique setting in which primary autochthonous gold deposits may be present. The large bedrock exposure found offshore exhibits a distinctive northeast linear trend and appears to host some primary gold mineralization (as determined by the extremely fresh character of gold grains). Furthermore, the mobility of gravels at depths of up to 80 m attests to the very high energy of the area; this being favourable for the mechanical attrition of bedrock.

The samples analyzed in the present study were collected at water depths in excess of 80 m; this is well beyond the practical limit of dredging. Areas in which bedrock is exposed in shallower water (e.g. immediately off La Scie Harbour) provide a more promising site for primary autochthonous placer formation and should be examined more fully.

Eastern Coast of Baie Verte Peninsula

Gold is found principally in association with massive sulphide occurrences along the eastern margin of the Baie Verte Peninsula (e.g., the Tilts Cove and Betts Cove deposit; Figure 2). The presence of a source of gold, the open coastal exposure, and the thin discontinuous sediment cover over much of the shelf area (Shaw, 1990) suggests that the coastal region may be a favourable site for autochthonous placer formation. Within the nearshore zone, the thin drift cover may contain mineralized detritus derived from either the mineralized bedrock onshore or, as in the La Scie area, zones of offshore mineralization. Some samples were collected in the area during the Hudson cruise, (Shaw et al., 1990a) one of which contained > 500 ppb gold, but all were in deep water and beyond the practical limit of dredging.

Sampling of this area may help to establish whether massive sulphide occurrences are suitable sources of particulate free gold.

Gander Bay and Dog Bay

Only one sample collected in Hamilton Sound contained anomalous gold. The absence of gold may be attributable in part to the sampling technique insofar as gold, if present, will probably be richest at 30-60 cm below the surface of the seabed. Another important consideration is the location of sample sites relative to sites of primary gold mineralization. The richest source terrain in the area occurs along a 35 km wide band extending south from Gander Bay and Dog Bay (see Figure 2). If we assume the maximum distance of gold transport within tills to be 1 km and within glaciofluvial sediments to be 10 km (see section 2), the most likely site for auriferous drift to occur is within Gander Bay and possibly Dog Bay. Samples have not been collected in these areas, but perhaps should be in any follow-up survey.

15.0 ACKNOWLEDGEMENTS

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Appendix A. Textural Data

sample #	76.2 (mm)	63.5 (mm)	50.8 (mm)	44.45 (mm)	38.1 (mm)	25.4 (mm)	19.05 (mm)	12.7 (mm)	9.53 (mm)	4 (mm)	2 (mm)	1 (mm)	0.5 (mm)	0.25 (mm)	0.105 (mm)	0.063 (mm)	<.063 (mm)
7	15.82	0	0	2.86	4.23	2.47	1.18	0.24	0.39	7.78	7.51	7.68	10.78	15.1	16.88	6.29	2.9
9	0	6.48	17.85	7.54	1.5	19.31	16.58	12.01	0.89	0.25	0.05	0.13	0.95	2.66	6.59	5.06	2.14
11	13.43	12.01	11.39	7.02	9.23	13.08	8.48	8.71	2.12	2.57	0.25	0.23	0.92	1.92	3.88	2.55	2.21
13	0	0	0	0	0	1.81	0	0.69	0.59	13.24	23.7	12.18	13.9	12.64	13.01	4.43	3.79
15	0	0	0	0	0	0	0	0.26	0.09	0.1	0.09	0.11	0.74	2.28	27.26	50.27	18.49
17	0	0	4.89	0	7.88	15.11	12.9	9.59	4.43	12.92	3.18	2.75	3.45	6.06	7.23	8.07	1.57
21	0	0	7.33	2.88	6.52	10.77	16.1	17.86	8.51	10.73	1.44	0.65	1.4	2.5	8.64	4.44	2.21
23	0	10.59	49.07	7.21	18.79	2.7	0.8	4.73	4.5	1.09	0.1	0.03	0.03	0.05	0.2	0.1	0.01
25	0	0	0	0	0	4.46	1.15	0.75	1.05	3.06	1.65	4.84	16.36	14.31	28.67	18.05	5.64
27	0	0	0	0	0	0	0	0	0	0.1	0.08	0.11	0.44	1.99	13.1	45.4	38.77
33	0	5.92	0	0	4.77	1.1	1.03	2.73	3.88	14.89	6.62	8.47	10.27	8.85	27.61	3.1	0.73
37	0	0	0	0	0	0	0	0	0	0	0.03	0.02	0.22	0.68	6.5	29.51	63.04
41	0	0	0	0	0	0	0	0	0	0	0.05	0.01	0.03	0.38	7.7	47.02	44.72
43	0	0	0	0	0	0	0	0	0	74.67	4.85	4.21	3.61	4.01	5.65	1.78	1.2
45	0	0	0	0	1.23	2.51	9.42	25.11	6.47	16.63	3.09	1.45	1.68	2.57	18.94	6.98	3.86
47	0	0	0	0	1.47	2.17	3.49	4.75	3.68	16.62	13.45	15.03	15.08	7.68	5.37	7.84	3.35
51	0	0	0	0	0	0	0	0	0	2.15	0.08	0.05	0.08	0.43	11.39	61.73	24.07
53	0	0	0	0	0	0	0	0	0	0.07	0.08	0.38	0.91	2.22	42.4	28.53	25.41
55	0	0	0	0	0	5.01	9.65	11.33	2.17	20.28	13.32	10.09	8.96	9.79	6.03	1.54	1.83
57	0	0	18.22	0	0	3.62	0.97	0.31	0.39	0.84	0.87	0.89	1.27	2.5	11.31	33.77	25.01
59	0	0	0	2.46	2.1	10.78	12.9	15.78	9.86	8.57	2.19	2.35	2.57	3.61	23.28	2.17	1.36
61	5.75	7.12	5.86	5.16	6.17	11.22	10.25	8.16	4.26	10.26	4.34	3.39	4.48	3.84	5.66	2.45	1.6
63	0	0	6.5	2.33	5.94	11.19	8.78	15.14	10.79	13.92	5.8	3.38	3.31	3.62	4.6	2	2.7
65	0	12.07	6.88	0	2.97	5.66	4.82	7.42	4.51	12.96	4.69	2.57	2.26	2.89	5.33	6.06	18.87
67	0	0	0	0	1.89	0.59	1.62	3.4	6.31	36.96	4.2	2.26	4.86	9.83	12.09	4.57	11.38
69	0	31.35	0	0	0	7.06	1.97	3.37	5.19	13.37	8.04	7.47	9.19	6.04	4.71	1.31	0.91
71	0	0	5.69	0	1.8	15.7	12.77	30.24	13.76	3.26	1.23	1.16	1.04	1.41	3.57	1.23	7.14
73	0	0	0	0	10.67	9.52	9.13	4.95	5.16	15.49	3.87	2.54	2.7	3.49	7.87	8.12	16.47
75	0	0	15.36	5.03	0	4.3	7.63	3.14	2.63	5.06	4.12	2.97	2.89	3.05	6.38	5.21	31.83
77	0	0	0	0	0	0	1.3	0.25	0.54	0.23	0.16	0.13	0.8	1.66	4.17	7.26	83.45
79	0	0	14.29	0	0	2.71	0.55	0.71	2.12	7.98	8.6	10.26	12.95	13.88	14.08	4.57	7.23
81	0	0	0	0	11.89	22.39	24.88	14.27	5.64	6.08	1.75	1.83	2.57	1.63	2.32	1.75	2.98
83	0	0	30.13	0	12.03	22.52	8.22	8.38	1.59	1.34	0.57	0.97	1.76	1.99	5.87	2.18	2.45
85	0	0	10.68	3.43	10.5	4.49	0.76	2.51	1.91	5.73	8.69	7.72	9.86	10.9	10.96	3.43	8.4
87	0	0	0	0	0	4.03	2.35	1.03	0.23	0.94	0.56	1.86	5.85	8.96	15.42	12.73	46.02
89	0	0	0	0	0	1.38	4.38	0.74	1.09	2.09	0.72	1.08	1.32	2.3	18.38	15.97	50.51
91	0	0	0	2.03	0.92	6.99	7.49	10.22	5.6	15.2	8.49	12.2	19.11	5.28	1.86	0.03	3.94
93	0	0	0	0	0	0.35	0	0.05	0.02	0.11	0.11	0.04	0.1	0.73	63.92	22.69	11.81
95	0	0	0	0	0	1.01	0	0.42	0.18	0.42	1.29	0.55	0.94	5.37	73.09	13.97	2.66
97	0	0	0	0	0	0	0	0	0	0	0.04	0.03	0.22	2.33	52.05	24.22	21.11
99	42.37	0	25.05	3.59	5.2	7.04	0.58	0.71	0.4	0.84	1.05	1.1	1.78	2.64	4.68	1.84	0.74
103	24.45	11.75	4.36	9.34	12.22	8.81	3.48	2.13	0.93	1.9	2.29	1.64	1.75	3.02	9.8	1.81	0.31
105	0	0	5.94	6.61	2.57	17.05	6.56	3.76	1.84	4.33	1.02	1.03	2.49	11.23	30.34	4.07	1.1
107	10.4	0	13.25	3.99	0	6.34	3.21	0.7	0.65	2.92	1.98	1.87	2.92	8.38	32.27	6.13	4.95
109	0	0	0	3.12	0	2.74	1.04	0.95	0.48	0.55	0.22	0.19	0.89	6.44	58.83	17.12	7.37
111	0	0	5.58	2.81	4.27	6.4	3.72	3.04	1.45	1.97	0.53	0.43	1.42	8.09	43.96	9.85	6.4
113	52.28	8.62	6.31	3.13	0	3.72	2.61	1.08	0.69	1.97	2.06	2.27	2.8	3.01	7.09	1.7	0.67
115	0	0	12.17	3.93	2.62	14.26	11.93	12.23	8.32	10.05	2.14	1.19	1.22	2.42	11.02	4.1	2.37
117	5.31	5.79	13.02	6.44	7.79	16.21	5.68	6.63	4.16	7.36	2.42	2.81	2.91	2.16	6.66	1.75	2.88
119	0	0	17.21	17.71	16.69	16.41	1.04	0.74	0.54	0.68	0.1	0.12	0.37	1.85	12.71	9.73	4.09
121	0	2.63	30.65	9.02	6.49	14.91	2.78	3.48	3.26	3.02	0.63	0.61	1.29	3.01	14.55	3.33	0.34
123	0	0	0	0	0	0.69	1.58	1.17	0.42	1.42	1.34	2.29	5.4	17.12	47.15	19.63	1.74
125	0	0	0	0	3.05	4.4	12.45	7.67	4.73	15.95	7.11	4.83	9.61	16.66	8.55	4.39	0.57

The grain size data are recorded in percentage by weight retained on the various mesh sizes.

sample #	76.2 (mm)	63.5 (mm)	50.8 (mm)	44.45 (mm)	38.1 (mm)	25.4 (mm)	19.05 (mm)	12.7 (mm)	9.53 (mm)	4 (mm)	2 (mm)	1 (mm)	0.5 (mm)	0.25 (mm)	0.105 (mm)	0.063 (mm)	<.063 (mm)
127	9.16	5.64	12.32	0	2.28	10.13	8.66	8.13	4.83	10.12	5.97	4.71	4.57	3.43	5.39	3.03	1.62
129	0	0	0	0	0	12.48	7	6.07	1.48	3.49	0.83	0.46	1.08	4.67	33.53	18.01	10.89
131	0	0	0	0	0	3.33	4.68	4.76	0.94	0.54	0.26	0.25	0.97	4.7	40.65	30.33	8.55
136	0	0	0	0	0	0.68	2.38	0.73	0.29	0.72	0.46	0.4	1.87	7.25	70.83	13.22	1.14
138	0	0	0	0	0	0	2.75	3.08	0.46	0.43	0.39	3.41	12.21	13.75	28.49	24.46	10.54
140	0	0	16.15	8.38	17.37	26.47	8.85	5.01	2.33	4.06	1.43	1.32	6.74	1.48	0.35	0.01	0.01
142	0	0	0	0	0	0	0	0	0	0.08	0.06	0.07	0.27	1.12	4.59	10.43	83.35
144	0	0	0	0	0	0	1.05	0.17	0	0.05	0.09	0.12	0.47	2.33	21.77	37.85	36.09
146	0	0	0	0	2.02	6.62	9.59	14.85	12.67	27.88	4.62	2.11	1.85	2.72	6.15	4.24	4.67
148	0	0	0	0	0	0	0	0	0	0.08	0.03	0.06	0.14	0.63	9.82	20.57	68.67
150	0	18.48	16.01	0	0	3.48	8.32	3.87	1.69	2.22	0.62	0.37	0.63	1.13	5.48	18.12	19.59
152	61.07	0	0	0	0	5.32	0.68	1.75	0.31	1.94	3.03	4.98	6.15	5.55	4.48	1.84	2.91
154	0	15.31	0	0	0	5.35	5.16	4.98	4.14	19.77	7.81	5.92	6.39	5.81	5.6	3.7	10.02
156	21.14	0	15.7	6.12	2.7	4.53	6.05	5.67	3.42	9.59	4.13	3.31	3.86	3.82	3.88	2.69	3.15
158	0	11.32	9.6	5.89	3.13	10.67	8.7	9.64	7.14	15.44	4.02	2.64	2.33	2.19	2.27	1.08	3.96
160	22.04	8.94	7.31	4.46	6.8	14.84	10.36	8.53	4.18	3.27	0.94	0.47	0.43	0.67	1.09	1.12	4.57
162	30.32	17.97	0	0	4.6	9.91	7.67	6.61	2.67	2.1	0.62	0.46	0.63	1.01	2.02	3.38	10.27
164	0	0	5.72	2.47	7.66	2.95	2.83	3.27	1.83	12.9	12.74	9.71	9.58	9	9.49	4.2	5.64
166	0	0	0	0	6.39	15.2	10.51	18.59	19.05	17.56	0.66	0.85	0.93	1.64	2.61	1.77	4.25
168	26.63	10.19	0	3.79	9.86	13.04	11.09	5.72	1.85	2.48	0.69	0.33	0.75	2.24	3.96	0.99	6.4
170	0	18.5	16.67	2.3	0	1.18	1.37	1.04	3.02	19.03	9.28	5.48	5.08	5.64	7.54	2.95	0.92
172	0	0	4.84	3.43	1.49	8.16	3.88	3.59	1.65	6.85	10.09	10.04	11.9	14.54	13.33	3.99	1.86
174	20.21	0	11.93	5.52	1.67	5.13	2.48	4.04	3.14	13.08	4.14	2.66	2.7	3.12	7.34	6.92	5.94
176	0	0	0	0	4.73	8.9	7	6.42	5.02	21.76	9.74	3.63	3.92	4.69	10.18	8.66	5.32
178	0	0	0	0	0	0	0	0	0	0.04	0.02	0.07	2.1	13.83	60.53	16.77	6.38
186	0	0	0	0	0	0	0	0	0	0.39	0.3	1.63	4.3	4.92	20.68	42.61	26.9
188	0	12.09	25.03	2.36	7.12	8.16	6.14	6.73	3.61	4.56	1.63	1.18	1.07	0.91	1.87	4.46	13.08
190	27.55	11.58	5.89	0	2.37	0.58	2.57	1.45	1.83	6.3	3.58	2.63	3.44	3.46	6.38	7.23	13.12
192	34.63	0	4.13	4.64	6.55	5.41	2.07	2.31	1.83	5.26	4.5	2.42	2.18	2.23	2.68	3.21	15.94
194	28.43	0	0	0	0	1.12	0	0.5	0.18	0.25	0.11	0.11	0.27	0.47	7.96	20.53	40.07
196	0	0	0	0	3.95	7.45	10.86	5.47	2.91	8.87	2.92	4.48	6.51	6.58	13.06	17.67	9.25
198	26.59	6.98	6.62	2.15	13.34	5.95	3.01	2.67	1.26	2.7	1.64	1.71	2.19	2.94	3.57	6.3	10.36
200	47.43	9.2	0	0	6.63	4.8	5.63	4.09	1.48	2.99	1.14	0.69	0.84	0.82	1.16	5.31	7.77
202	0	12.58	12.4	4.66	6.19	10.15	15.78	11.1	6.25	6.36	1.15	0.81	0.82	0.82	1.38	3.06	6.5
204	26.98	0	12.57	0	2.78	1.57	2.3	4.9	4.15	12.61	5.48	2.83	2.84	2.69	2.67	4.93	10.7

Appendix B. Geochemical Data from the Mud Fraction

sample number	Au ppb	Ag ppm	As ppm	Ba ppm	Br ppm	Ca %	Co ppm	Cr ppm	Cs ppm	Fe %	Hf ppm	Hg ppm	Ir ppb	Mo ppm	Na ppm	Ni ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sr %	Ta ppm	Th ppm	V ppm	W ppm	Zn ppm
7	0	0	10	240	360	4	9	240	0	2.62	18	0	0	0	18700	0	55	1	11	0	0	0	7.9	4.5	0	124
9	10	0	9	410	380	3	9	170	2	2.38	14	0	0	0	17300	0	46	0.9	10	0	0	0	7.1	2.8	0	98
11	11	0	13	260	510	6	9	140	2	2.37	10	0	0	0	14800	0	45	2	9.5	0	0	0	7	4.8	0	139
13	0	0	12	310	530	6	9	140	0	2.27	9	0	0	0	15700	0	36	1.2	9.5	0	0	0	6.4	4	0	90
15	0	0	5	400	88	4	10	590	0	2.77	29	0	0	0	21000	0	32	0.7	14	0	0	2	9.4	4.7	0	0
17	5	0	6	380	78	3	8	330	0	2.47	25	0	0	5	22400	0	48	1	12	0	0	0	8.8	3.5	0	0
21	0	0	11	210	500	4	10	340	0	2.66	14	0	0	5	16400	0	32	1.3	11	0	0	0	7.7	5.8	0	66
25	0	0	7	270	65	2	9	420	0	2.58	30	0	0	0	22700	0	43	0.8	13	0	0	1	10	4.5	0	92
27	0	0	4	370	70	3	8	280	0	2.48	21	0	0	0	24400	0	43	0.9	12	0	0	0	8.1	2.8	0	56
33	52	0	10	380	32	4	8	510	0	2.8	45	0	0	0	22700	0	50	1.9	14	0	0	0	13	5.1	0	133
37	6	0	6	380	150	4	8	200	0	2.36	16	0	0	0	23000	0	44	1.2	11	0	0	0	9.1	3.2	0	56
41	12	0	4	330	41	3	6	160	0	2.32	18	0	0	0	22900	0	48	0.6	12	0	0.0	0	8.8	3.6	0	81
43	10	0	5	250	120	4	7	190	0	1.84	17	0	0	0	20200	0	47	2.4	9.2	0	0	0	6.5	2.5	0	74
45	6	0	7	290	180	2	7	240	0	2.01	25	0	0	0	19200	0	50	0.8	9.7	0	0	0	8.6	4.4	0	66
47	10	0	8	350	130	3	6	160	0	1.94	15	0	0	0	20400	0	46	0.7	9.3	0	0	0	6.5	2.9	0	57
51	0	0	3	300	29	3	7	420	0	2.59	49	0	0	0	18600	0	37	0.7	13	0	0	2	12	4.5	4	93
53	0	0	3	370	59	2	7	270	0	2.3	22	0	0	0	21500	0	38	0.7	11	0	0	0	8.8	3.3	0	0
55	16	0	5	380	66	4	7	180	2	2.26	17	0	0	0	23200	0	47	1.8	11	0	0	0	7.7	3	0	163
57	12	0	5	310	110	3	6	220	0	2.07	19	0	0	0	18700	70	34	0.7	10	0	0	0	8.3	3.6	0	78
59	9	0	7	350	98	8	7	270	0	2.05	19	0	0	0	18600	0	44	0.6	9.6	0	0.1	1	7.4	2.3	0	61
61	27	0	5	190	140	6	16	450	0	4.06	10	0	0	0	17200	0	30	0.5	26	0	0	0	4.9	2.6	0	141
63	15	0	5	290	220	8	17	400	0	3.96	8	0	0	0	16400	0	0	0.6	24	0	0	0	4.7	2.7	0	126
65	10	0	9	260	200	3	19	490	0	4.05	6	0	0	0	15500	110	0	0.7	24	0	0	0	5.3	2	0	77
67	0	0	15	310	340	8	17	290	0	3.61	4	0	0	0	13900	0	30	0.6	16	0	0	1	4.6	3.7	0	0
69	60	0	15	110	170	2	44	1300	0	5.3	8	0	0	0	10600	500	68	2.4	16	0	0	0	2.7	4.3	0	165
71	0	0	24	260	390	2	19	290	0	3.92	4	0	0	0	15800	0	0	0.6	17	0	0	0	6.6	6.4	0	112
73	0	0	11	260	250	4	18	450	0	4.04	6	0	0	0	18000	92	41	0.6	23	0	0	0	5.4	1.5	0	108
75	24	0	12	270	290	3	18	310	3	4.11	5	0	0	0	18500	95	32	0.4	21	0	0	0	5.6	2.8	0	111
77	11	0	12	330	260	3	17	290	0	3.74	4	0	0	0	17600	0	43	0.6	20	0	0	0	5.6	2.7	0	102
79	58	0	11	390	260	5	16	470	0	3.81	7	0	0	0	16900	90	0	0.5	21	0	0	0	4.4	3.6	0	146
81	15	0	10	210	180	4	19	340	0	4.18	7	0	0	0	21400	0	0	0.6	25	0	0	0	5.1	2.5	0	82
83	9	0	8	190	200	4	17	440	0	3.9	8	0	0	0	18900	0	0	0.5	23	0	0	0	5.9	2	0	70
85	20	0	15	420	290	3	18	320	2	4.01	6	0	0	0	19200	130	32	0.7	21	0	0	0	5.5	4	0	84
87	20	0	8	230	210	3	16	360	2	4.1	6	0	0	0	21000	0	0	0.6	24	0	0	0	5.1	3	0	0
89	11	0	9	440	200	3	17	360	0	3.98	7	0	0	0	21400	0	0	0.5	24	0	0.0	0	5.6	3.8	0	109
91	13	0	13	300	150	3	26	250	0	4.03	5	0	0	16	15200	0	37	0.6	18	0	0.0	1	4.7	6.5	0	147
93	9	0	3	100	11	9	8	250	2	6.14	74	0	0	0	13600	0	0	0.4	63	0	0	3	10	5.5	0	0
95	7	0	4	260	25	9	9	220	0	5.59	49	0	0	0	16200	70	41	0.4	55	0	0	3	9.9	2.6	0	0
97	6	0	3	140	16	6	7	140	0	3.43	23	0	0	0	17900	0	31	0.3	41	0	0	2	6	2.5	0	0
99	7	0	0	170	42	7	10	240	2	4.1	30	0	0	0	16000	0	0	0	35	0	0	2	7.4	2.1	0	131
103	347	0	6	190	39	13	18	1100	0	4.65	29	0	0	0	13900	80	0	1.9	34	0	0	1	12	2.5	27	75
105	859	0	4	210	36	12	16	830	0	4.01	17	0	0	0	16400	0	0	1	37	0	0	0	9	2.4	22	0
107	250	0	7	190	210	10	17	580	0	3.66	7	0	0	0	15300	0	0	0.7	27	0	0	0	5	1.6	0	99
109	224	0	3	210	58	10	21	1300	0	4.19	13	0	0	0	15100	0	0	1	36	0	0	0	6.6	2.2	8	0
111	226	0	5	240	120	10	22	1300	0	4.1	7	0	0	0	14100	120	0	0.9	31	0	0	0	4.1	1.6	7	69
113	9	0	8	300	230	9	13	330	0	4.33	13	0	0	0	14600	0	37	0.6	25	0	0	2	6.1	2.7	0	162
115	8	0	6	270	120	6	17	360	0	4.28	8	0	0	0	19000	150	0	0.5	28	0	0	0	5	2.1	0	115
117	43	0	5	270	110	7	17	540	0	4.61	13	0	0	0	18800	0	0	0.5	32	0	0	0	6.3	2.6	0	98
119	21	0	4	130	58	7	17	600	0	5.37	17	0	0	0	17300	120	0	0.3	39	0	0	2	5.9	2.5	0	101
121	81	0	5	120	100	9	19	1000	0	6.59	58	0	0	0	15700	130	0	0.8	44	0	0	2	11	3.7	0	114
123	0	0	4	170	80	9	19	1700	0	6.66	52	0	0	0	13400	130	36	0.7	46	0	0	2	8.7	3.5	0	118
125	86	0	7	160	170	10	16	770	0	4.47	19	0	0	0	12900	100	0	1.1	30	0	0.0	0	4.6	2.1	0	102

sample number	Au ppb	Ag ppm	As ppm	Ba ppm	Br ppm	Ca %	Co ppm	Cr ppm	Cs ppm	Fe %	Hf ppm	Hg ppm	Ir ppb	Mo ppm	Na ppm	Ni ppm	Rb ppm	Sb ppm	Sc ppm	Se ppm	Sr %	Ta ppm	Th ppm	V ppm	W ppm	Zn ppm
127	36	0	5	250	140	7	18	470	0	4.57	11	0	0	0	19200	99	0	0.5	30	0	0	0	5.5	2.1	0	93
129	56	0	5	310	120	6	18	510	0	5.09	15	0	0	0	20500	91	0	0.7	35	0	0	0	6.2	3.4	0	108
131	127	0	5	260	180	5	19	480	0	5.17	15	0	0	0	19000	0	31	0.6	33	0	0	1	6.4	3.2	0	63
136	684	0	4	150	6	5	20	660	0	29.5	78	0	0	0	5990	0	0	0.9	31	0	0	4	12	4.9	0	115
138	0	0	3	390	34	5	13	550	0	5.19	24	0	0	9	19000	0	0	0.5	19	0	0	0	8.3	2.7	0	75
142	7	0	7	490	220	4	17	150	0	4.6	3	0	0	0	18700	0	0	0.5	36	0	0	0	1.5	2.3	0	151
144	0	0	2	160	98	6	18	160	0	4.5	3	0	0	0	18500	0	0	0.3	39	0	0	0	2.1	2	0	123
146	0	0	6	100	130	6	21	120	0	5.46	3	0	0	0	21700	0	0	0.6	38	0	0	0	1.5	0.7	0	0
148	0	0	5	310	180	6	18	120	0	5.33	3	0	0	10	21700	0	0	0.8	36	0	0	0	1.7	2.4	0	0
150	7	0	7	110	130	5	16	110	0	5.27	3	0	0	0	20600	0	0	0.6	36	0	0	0	2	1.5	0	117
152	0	0	17	780	270	4	14	160	0	3.26	8	0	0	0	17000	0	0	1.4	18	0	0	0	5.5	4.3	0	101
154	17	0	13	580	230	4	12	130	0	3.15	7	0	0	0	21200	0	37	1.2	17	0	0	0	4.4	2.7	0	80
156	0	0	14	450	230	3	12	120	0	3.29	7	0	0	0	22000	0	40	1	18	0	0	0	5.9	2.5	0	0
158	0	0	16	400	360	3	12	97	0	3.06	6	0	0	0	18400	0	42	0.9	15	0	0	0	5.5	3.3	0	120
160	0	0	10	380	180	4	11	110	0	2.87	7	0	0	0	22400	0	0	0.6	18	0	0	0	5.5	3.9	0	0
162	0	7	10	470	210	4	12	120	0	3.05	8	0	0	0	22300	0	0	1.3	19	0	0.1	0	5.1	3.2	0	0
164	11	0	13	310	260	3	11	150	0	3.14	8	0	0	0	20600	0	50	0.8	18	0	0	0	5.5	3.8	0	104
166	0	0	14	380	280	2	11	95	0	3.22	7	0	0	0	18900	0	63	0.7	18	0	0	0	5.7	2.8	0	134
168	0	0	20	340	400	2	11	99	0	3.24	5	0	0	0	17700	0	0	0.9	14	0	0	1	5.5	2.8	0	113
170	0	0	8	340	130	4	11	120	0	3.5	12	0	0	0	21700	120	0	1.5	24	0	0	0	6.1	2.1	0	126
172	0	0	9	440	170	7	12	83	0	3.16	8	0	0	0	18300	0	30	0.6	19	0	0	0	5.7	1.2	0	103
174	0	0	13	380	270	3	12	84	0	3.34	6	0	0	0	18000	0	39	0.6	17	0	0	0	6.3	2.7	0	0
176	18	0	5	630	31	4	10	84	0	3.09	11	0	0	0	24900	99	42	0.6	19	0	0	0	6.5	1.8	0	0
178	64	0	4	2000	83	4	9	95	0	3.09	23	0	0	0	24600	0	0	0.6	20	0	0	0	9.7	3.2	4	85
186	0	0	8	370	68	3	8	76	0	3.01	20	0	0	0	24500	0	43	0.4	15	0	0	0	6.2	4.1	0	78
188	0	0	11	300	120	2	10	70	0	2.94	11	0	0	0	23900	0	0	0.6	14	0	0	2	5.5	3.3	0	0
190	0	0	14	300	96	3	9	83	0	3.21	12	0	0	0	24500	0	31	0.5	15	0	0	0	5.3	3.5	0	0
192	9	0	17	350	160	2	10	70	0	2.96	8	0	0	0	22100	0	0	0.6	13	0	0	0	5	3.3	0	0
194	5	0	10	370	67	2	9	73	0	2.78	10	0	0	0	23100	0	30	0.5	13	0	0	0	4.7	3	0	83
196	5	0	17	340	130	3	12	89	2	3.53	15	0	0	0	23300	80	50	0.8	16	0	0	0	5.9	4.8	0	63
198	0	0	7	270	71	3	9	76	0	3.04	11	0	0	0	24700	0	34	0.5	14	0	0	0	5	2.6	0	72
200	0	0	6	320	55	2	9	73	0	2.76	11	0	0	0	24600	0	38	0.5	13	0	0	0	4.5	3	0	0
202	0	0	6	340	56	1	8	69	0	2.62	10	0	0	0	25300	0	37	0.6	13	0	0	0	4.1	2.7	0	0
204	0	0	9	300	70	2	8	69	0	2.65	11	0	0	0	24000	0	0	0.4	13	0	0	0	4.6	3.2	0	67

sample number	La ppm	Ce ppm	Nd ppm	Sm ppm	Ev ppm	Tb ppm	Yb ppm	Lv ppm
7	36	74	28	5.4	1.5	1.1	3.84	0.65
9	32	62	25	5	1.4	0.8	2.9	0.39
11	31	57	31	4.7	1.4	0.7	2.69	0.32
13	31	59	31	4.7	1.4	1.2	2.77	0.5
15	45	92	36	7.1	1.9	1.2	4.9	0.75
17	36	73	25	5.7	1.6	1.3	4.46	0.64
21	34	66	28	5.3	1.5	1.2	3.42	0.48
25	44	91	31	6.8	1.8	1.3	4.77	0.69
27	38	82	29	6.4	1.7	1.2	4.42	0.54
33	52	110	42	8	2.1	1.3	5.93	0.64
37	36	74	27	6.1	1.7	1.1	3.8	0.48
41	37	77	30	6.3	1.6	1.2	4.77	0.68
43	30	64	20	4.9	1.4	0.9	3.49	0.56
45	35	71	24	5.4	1.5	0.9	4.18	0.62
47	30	62	20	4.9	1.4	0.7	3.42	0.45
51	53	110	39	8.2	1.9	1.5	6.55	0.87
53	39	80	33	6.4	1.7	1.1	4.72	0.72
55	32	79	25	5.6	1.5	1.4	4.12	0.62
57	33	69	29	5.3	1.4	1.1	3.8	0.52
59	30	63	20	4.8	1.4	0.9	3.32	0.38
61	22	47	16	4.3	1.6	1.1	3.67	0.47
63	23	49	21	4.1	1.4	0.8	3.3	0.51
65	24	47	16	4.2	1.1	0	3.05	0.52
67	25	50	17	3.6	1.1	0.9	2.25	0.28
69	12	25	10	2.2	0.7	0	1.75	0.22
71	27	49	19	4	1.2	0	2.44	0.36
73	23	47	15	4.3	1.3	0.7	3.11	0.47
75	25	46	19	4.1	1.3	0	2.7	0.5
77	24	48	19	4.1	1.4	0	2.76	0.27
79	22	44	18	3.8	1.3	0.9	2.69	0.39
81	22	45	20	4.1	1.5	0	3.29	0.35
83	24	51	14	4.3	1.5	0.9	3.22	0.39
85	26	50	28	4.4	1.4	0.9	3.1	0.44
87	25	55	29	4.6	1.7	0	3.16	0.57
89	26	60	15	4.7	1.7	0	3.09	0.51
91	22	46	16	3.7	1.3	0.7	2.28	0.3
93	52	110	48	12	4.7	2.6	12.7	1.66
95	45	110	41	11	4	2.3	10.3	1.5
97	31	68	33	7.5	2.8	1.9	7.36	1.09
99	35	75	27	7.6	2.8	2	6.6	0.7
103	35	69	22	5	1.5	1	3.71	0.37
105	28	58	24	4.5	1.4	1.7	3.41	0.47
107	19	39	12	3.1	1	0.9	2.42	0.32
109	22	50	20	3.9	1.4	1	3.37	0.23
111	16	34	13	2.7	0.8	0.9	2.3	0.3
113	29	63	23	5.4	1.9	1.3	4.21	0.5
115	22	48	19	4.3	1.5	0.9	3.32	0.5
117	26	53	25	5.4	1.8	1.2	4.69	0.68
119	28	66	25	6.6	2.3	1.3	5.85	0.71
121	42	96	35	8.6	2.9	2.3	8.88	1.1
123	33	71	31	6.9	2.4	1.7	7.93	1.15
125	22	45	13	4.4	1.5	1	4.62	0.61

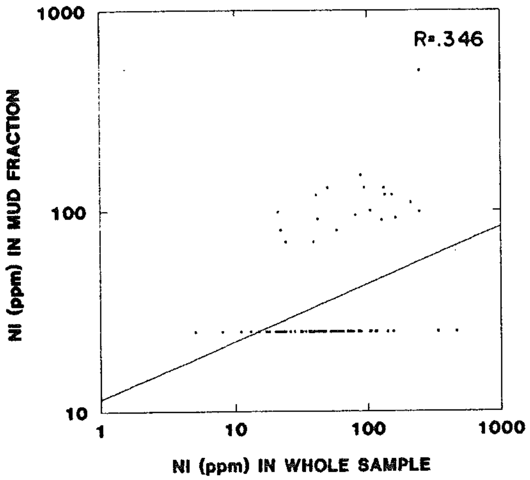
sample number	La ppm	Ce ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Yb ppm	Lu ppm
127	25	52	17	5	1.7	0.7	4.06	0.57
129	26	59	20	5.4	1.9	1	4.81	0.74
131	26	57	20	5.1	1.7	1.3	4.68	0.69
136	42	83	32	7.7	2.2	1.4	8.02	0.97
138	40	82	36	7.6	2.4	1.3	5.2	0.61
142	12	27	14	2.8	0.9	0.7	2.35	0.28
144	10	18	7	2.7	1	1	3.18	0.46
146	8	18	9	2.5	1	0	3	0.17
148	10	23	10	2.8	1.1	0	3.05	0.27
150	8	22	0	2.7	1.2	0	2.93	0.5
152	22	40	16	3.9	1.3	0	3.09	0.65
154	23	48	19	4	1.3	0.7	2.92	0.4
156	24	49	0	4.3	1.4	0	3.28	0.53
158	24	47	21	4.1	1.3	0	2.82	0.4
160	21	46	8	3.9	1.2	0	3.25	0.41
162	23	47	14	4.3	1.2	0	3.72	0.62
164	24	50	21	4.1	1.5	0.8	3.13	0.51
166	23	44	18	3.9	1.2	0	2.95	0.5
168	24	50	18	4	1.2	0	2.7	0.48
170	24	53	17	4.1	1.4	0.6	3.77	0.71
172	23	45	23	4	1.2	0.8	2.83	0.4
174	25	49	21	4.1	1.1	0.7	2.55	0.34
176	25	50	19	4.1	1.2	0.8	3.11	0.44
178	35	69	25	5.3	1.4	0.9	4.61	0.7
186	27	61	20	5.4	1.5	1.6	6.53	0.97
188	25	51	21	5.1	1.4	1.3	4.57	0.59
190	25	54	21	5	1.5	1.1	4.95	0.73
192	23	52	16	4.7	1.3	1	3.89	0.53
194	22	49	16	4.3	1.3	1.1	3.82	0.43
196	25	55	21	5	1.6	1.5	4.98	0.62
198	23	45	20	4.4	1.3	0.7	4.11	0.62
200	21	46	17	4.2	1.2	0.7	4.05	0.56
202	21	44	16	4.1	1.2	0	4.06	0.55
204	21	45	18	4.1	1.3	1	3.64	0.52

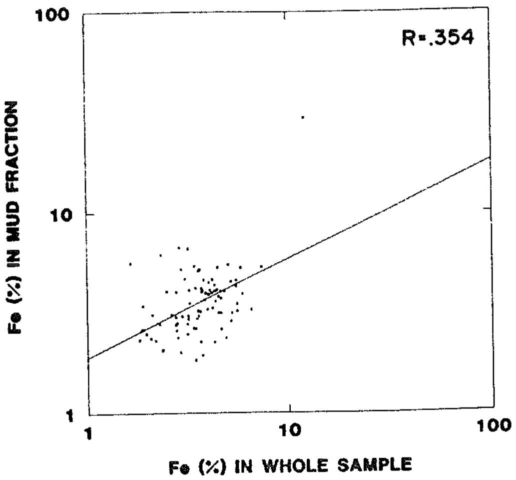
Appendix C. Geochemical Data from a Split of the Whole Sample

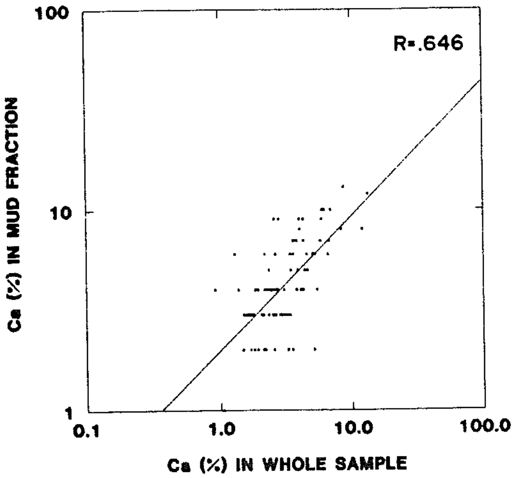
SAMPLE #	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	Cr_2O %	Ba ppm	Cu ppm	Zn ppm	Ni ppm	Co ppm	Sr ppm	La ppm	Zr ppm	Ce ppm	Y ppm	Nb ppm	Ta ppm
90-035-007	66.83	13.00	5.74	2.29	1.29	2.00	2.15	0.65	0.17	0.36	.023	676	29	117	40	15	158	2	67	70	23	20	20
90-035-009	69.34	11.20	3.48	1.65	2.35	2.29	1.49	0.54	0.15	0.15	.021	280	41	45	54	19	205	56	89	20	21	20	20
90-035-011	64.98	14.07	6.06	2.29	1.81	1.93	2.41	0.77	0.13	0.19	.024	335	19	90	58	39	209	32	71	20	24	20	20
90-035-013	64.71	13.46	4.54	2.14	3.03	2.58	1.81	0.62	0.19	0.17	.021	354	19	66	57	16	233	27	65	53	19	20	20
90-035-015	74.14	11.64	2.83	1.63	1.92	2.78	1.38	0.71	0.15	0.15	.033	269	5	48	44	5	196	2	123	170	19	54	20
90-035-017	65.50	14.89	3.88	1.96	4.05	2.35	1.29	0.56	0.18	0.16	.024	303	26	39	76	63	288	35	96	85	17	20	20
90-035-021	66.18	12.41	4.18	2.58	2.70	2.84	1.40	0.70	0.16	0.13	.034	293	21	60	75	44	196	45	70	309	18	61	20
90-035-025	71.52	12.91	3.43	1.76	2.36	2.67	1.22	0.57	0.13	0.17	.021	283	26	33	42	70	224	2	67	107	14	20	20
90-035-027	72.52	11.09	2.42	1.33	2.29	2.79	1.69	0.54	0.17	0.11	.019	262	7	49	22	61	221	30	121	86	19	20	20
90-035-031	70.61	10.84	2.58	1.40	2.83	2.81	1.30	0.55	0.19	0.13	.018	298	20	70	32	51	244	49	154	50	16	20	20
90-035-033	63.66	11.61	3.46	1.74	7.56	2.28	1.40	0.51	0.12	0.19	.018	240	24	37	62	93	494	24	65	93	13	20	20
90-035-037	67.12	9.66	2.55	1.46	3.80	3.34	1.44	0.55	0.18	0.11	.021	291	17	47	20	72	264	68	137	150	18	20	20
90-035-041	71.90	11.07	2.25	1.26	2.88	2.97	1.71	0.54	0.16	0.11	.011	318	5	32	18	40	258	8	174	37	19	20	20
90-035-043	64.42	11.18	4.28	1.93	5.71	2.39	1.48	0.67	0.18	0.30	.020	265	5	46	28	56	372	2	76	91	18	57	20
90-035-045	70.38	11.29	3.59	1.83	3.00	2.45	1.41	0.60	0.14	0.11	.020	302	24	42	40	72	282	2	124	141	18	53	20
90-035-047	65.19	13.10	4.63	2.37	4.53	2.17	1.34	0.66	0.14	0.17	.017	296	21	50	57	5	331	22	73	107	17	20	20
90-035-051	76.59	10.42	2.30	1.14	2.24	2.75	0.78	0.57	0.12	0.12	.019	263	22	36	34	41	226	13	176	125	15	20	20
90-035-053	73.38	11.09	2.69	1.39	2.36	2.51	1.20	0.56	0.13	0.15	.014	288	10	26	23	23	232	2	115	73	21	20	20
90-035-055	65.36	12.76	5.31	2.30	3.72	2.65	1.79	0.77	0.18	0.27	.016	313	30	95	26	23	254	54	120	165	21	51	20
90-035-057	68.17	10.84	2.92	1.60	3.68	2.75	1.14	0.58	0.17	0.14	.019	284	19	32	24	50	274	74	168	75	20	84	20
90-035-059	56.45	10.98	2.92	1.38	11.68	2.07	1.49	0.45	0.08	0.10	.014	393	5	28	21	71	754	2	32	20	8	20	20
90-035-061	60.35	11.78	5.95	4.77	5.00	3.53	0.90	0.76	0.11	0.10	.033	167	37	59	77	36	246	2	55	78	15	48	20
90-035-063	61.31	12.28	4.81	3.79	5.62	3.35	1.14	0.71	0.13	0.08	.037	218	11	44	70	64	279	2	44	176	12	80	20
90-035-065	56.19	11.28	5.34	8.43	4.44	2.88	0.89	0.75	0.16	0.09	.091	196	67	65	212	43	182	2	60	87	18	20	20
90-035-067	39.94	9.05	5.39	4.39	16.83	3.00	0.50	0.62	0.15	0.08	.045	161	37	73	103	16	660	17	38	33	14	45	20
90-035-069	55.52	8.56	5.52	11.85	4.54	3.05	0.75	0.69	0.16	0.09	.128	121	22	85	249	69	191	33	58	34	14	53	20
90-035-071	49.76	9.88	7.31	13.05	4.92	2.47	0.95	0.62	0.15	0.11	.096	99	24	94	467	63	224	2	25	60	14	41	20
90-035-073	53.77	10.62	5.69	7.15	4.28	3.31	1.02	0.80	0.23	0.08	.070	213	20	79	163	90	229	2	49	198	16	20	20
90-035-075	53.57	12.13	5.46	4.68	4.11	3.79	1.12	0.69	0.17	0.09	.038	252	36	80	81	69	236	2	47	57	10	41	20
90-035-077	50.74	11.14	5.74	5.14	4.23	3.87	1.16	0.81	0.27	0.08	.041	275	45	58	114	74	261	62	72	30	19	84	20
90-035-079	58.53	13.27	5.56	6.39	5.42	3.08	0.60	0.65	0.12	0.09	.067	249	14	58	127	5	265	2	19	20	8	20	20
90-035-081	57.53	12.92	4.56	3.36	3.72	4.64	1.38	0.72	0.18	0.07	.030	358	47	98	44	96	306	13	81	218	13	38	20
90-035-083	55.91	10.68	4.97	5.22	3.57	3.60	1.25	0.74	0.25	0.07	.052	301	44	107	106	67	243	2	67	34	15	39	20
90-035-085	64.48	12.41	4.58	3.18	3.50	3.99	1.28	0.87	0.17	0.07	.040	229	13	56	50	86	297	2	79	59	16	20	20
90-035-087	57.02	11.76	5.04	4.68	3.97	4.19	0.78	0.86	0.26	0.12	.087	253	28	74	105	77	261	31	75	81	30	20	20
90-035-089	57.44	10.58	5.15	4.45	3.58	4.20	1.14	0.86	0.20	0.08	.050	269	42	81	117	62	268	19	77	86	20	20	22
90-035-091	26.82	5.59	3.06	2.67	2.10	4.45	1.02	0.40	0.20	0.05	.034	176	63	40	141	44	177	2	5	155	12	20	20
90-035-093	71.31	11.57	2.88	0.97	3.87	4.10	0.91	1.33	0.44	0.08	.014	183	5	18	15	22	221	11	166	97	28	20	20
90-035-095	71.70	10.86	2.04	0.88	3.57	5.27	0.95	0.88	0.29	0.06	.012	166	5	10	39	16	200	13	58	130	15	20	20
90-035-097	73.67	10.36	2.33	0.97	3.64	3.88	0.72	0.95	0.32	0.06	.011	156	8	10	26	32	207	41	122	31	22	20	20
90-035-099	52.31	7.35	3.97	8.72	9.39	2.84	0.15	0.67	0.24	0.08	.090	202	16	133	338	44	395	31	44	107	12	20	20
90-035-103	54.59	11.12	3.79	4.01	12.19	3.06	0.38	0.42	0.13	0.07	.039	201	7	32	58	16	426	15	5	20	10	20	20
90-035-105	42.72	10.50	3.42	3.75	18.66	2.88	0.71	0.33	0.11	0.06	.038	126	5	33	60	5	686	2	7	20	7	20	20
90-035-107	56.48	12.20	4.75	5.80	8.28	3.50	0.84	0.49	0.16	0.09	.054	204	19	55	105	31	300	53	38	132	13	50	20
90-035-109	55.24	10.79	4.29	10.04	8.63	2.63	0.76	0.37	0.09	0.09	.145	188	16	53	156	5	216	24	65	84	10	20	20
90-035-111	50.95	10.37	4.64	11.00	9.65	2.42	0.51	0.32	0.11	0.09	.149	139	13	47	153	5	224	2	5	44	6	21	20
90-035-113	61.91	12.41	5.33	2.28	5.97	2.74	1.66	1.77	0.25	0.09	.023	437	5	53	48	59	263	69	99	134	21	20	20
90-035-115	50.48	14.57	6.83	7.92	9.19	3.00	0.88	0.49	0.15	0.12	.063	113	11	40	89	48	181	4	5	88	10	20	20
90-035-117	59.71	13.18	5.19	3.89	5.33	3.52	0.96	0.80	0.18	0.09	.031	252	5	35	39	31	252	12	39	87	14	20	25
90-035-119	66.19	10.44	4.22	4.81	5.03	2.83	0.91	0.90	0.21	0.08	.066	239	5	43	135	37	208	2	36	41	28	20	25
90-035-121	67.22	11.42	3.92	4.23	5.55	2.83	0.74	0.69	0.16	0.08	.070	210	5	42	94	5	192	9	49	20	17	20	20
90-035-123	59.54	14.88	3.55	6.15	8.19	2.73	0.33	0.56	0.12	0.07	.077	75	5	24	133	73	139	2	9	27	9	20	20

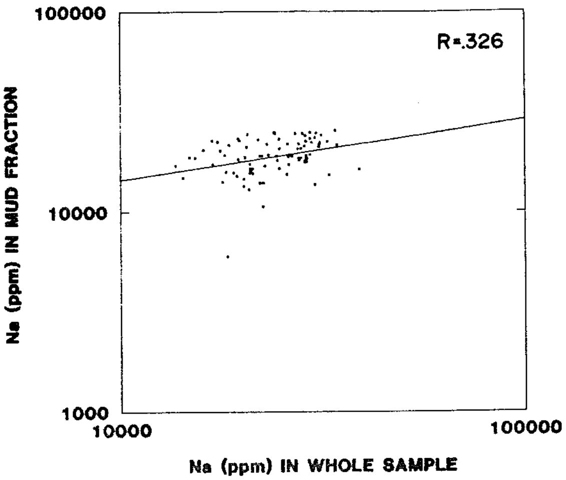
SAMPLE #	Si02 %	Al203 %	Fe203 %	Mg0 %	Ca0 %	Na20 %	K20 %	Ti02 %	P205 %	Mn0 %	Cr20 %	Ba ppm	Cu ppm	Zn ppm	Ni ppm	Co ppm	Sr ppm	La ppm	Zr ppm	Ce ppm	Y ppm	Nb ppm	Ta ppm
90-035-125	57.76	12.49	4.98	6.36	8.35	2.81	0.43	0.50	0.15	0.09	.053	137	13	62	105	62	268	33	34	76	14	20	20
90-035-127	55.75	10.95	6.82	8.04	5.98	3.15	0.79	0.63	0.17	0.09	.764	160	5	82	247	36	249	2	39	137	11	20	20
90-035-129	66.46	12.76	4.41	2.77	4.72	3.71	0.84	0.79	0.19	0.07	.022	236	5	32	42	5	284	65	77	39	15	20	20
90-035-131	64.08	13.30	4.49	3.05	4.79	3.90	1.07	0.86	0.15	0.07	.024	222	5	56	53	17	276	2	71	105	140	20	20
90-035-136	51.85	10.53	14.98	2.86	6.41	2.49	1.13	7.03	0.90	0.31	.051	206	5	71	52	87	410	2	177	138	25	83	28
90-035-138	68.15	11.48	3.63	3.22	3.26	3.04	2.12	0.93	0.26	0.07	.052	487	15	57	78	5	275	38	176	121	17	20	21
90-035-140	66.92	12.28	4.69	1.21	3.43	3.90	2.67	0.98	0.33	0.09	.002	463	9	59	5	41	242	65	212	131	42	22	20
90-035-142	50.48	13.51	6.40	3.99	6.34	3.73	0.96	0.68	0.15	0.10	.019	157	40	72	46	5	195	45	56	25	18	32	20
90-035-144	55.53	13.78	6.22	3.89	7.07	3.73	0.39	0.68	0.14	0.10	.020	166	50	75	47	34	207	35	55	69	16	20	26
90-035-146	54.68	14.36	9.11	4.69	7.30	3.51	0.50	0.92	0.16	0.15	.012	1179	39	69	35	28	154	28	22	20	18	20	20
90-035-148	53.40	12.27	7.04	3.82	5.51	3.96	0.62	0.83	0.18	0.10	.016	134	95	76	37	19	185	66	52	76	220	20	27
90-035-150	55.39	15.13	7.18	3.65	6.11	3.79	0.90	0.93	0.14	0.11	.010	121	10	69	13	102	171	27	57	141	17	52	20
90-035-152	53.63	14.93	8.09	4.14	3.81	1.85	3.21	0.78	0.27	0.17	.049	862	20	201	89	52	144	2	5	129	16	20	30
90-035-154	57.13	13.33	5.75	3.25	3.05	3.86	2.33	0.70	0.26	0.09	.013	545	14	77	32	17	227	11	80	209	15	31	20
90-035-156	58.83	13.66	4.92	2.75	2.98	4.22	2.19	0.67	0.28	0.08	.007	571	12	65	37	57	211	71	60	77	17	20	20
90-035-158	61.16	13.72	4.44	2.49	2.44	3.92	1.75	0.57	0.23	0.08	.008	553	15	82	54	19	218	40	129	33	21	20	22
90-035-160	56.13	12.68	6.42	3.83	5.33	3.89	1.43	0.80	0.25	0.11	.009	409	39	78	65	44	291	46	96	58	18	20	20
90-035-162	58.39	11.72	3.94	2.50	3.29	4.39	1.57	0.65	0.26	0.07	.013	428	24	67	31	20	271	41	113	228	20	21	20
90-035-164	59.61	13.25	6.49	4.05	4.45	3.35	1.28	0.87	0.17	0.10	.028	342	19	83	73	58	257	62	93	255	16	20	20
90-035-166	55.29	15.82	6.88	5.34	3.57	3.29	0.85	0.61	0.19	0.09	.029	313	20	96	85	14	157	34	59	20	14	20	20
90-035-168	54.02	8.50	4.41	2.74	7.13	3.91	1.35	0.56	0.32	0.07	.015	377	59	93	34	23	292	2	108	88	24	34	20
90-035-170	59.85	13.05	6.89	4.12	5.99	3.12	1.08	0.68	0.19	0.11	.018	271	37	319	41	37	211	48	111	37	26	23	20
90-035-172	59.88	12.00	5.56	3.39	8.02	2.65	1.03	0.51	0.11	0.10	.008	270	37	66	38	16	252	31	101	20	21	30	20
90-035-174	61.63	13.32	5.21	3.39	4.74	3.74	1.24	0.48	0.15	0.10	.012	289	42	113	8	72	205	8	88	76	24	35	20
90-035-176	68.04	12.90	3.24	1.99	3.11	3.25	2.06	0.49	0.18	0.06	.006	475	18	56	21	30	327	23	123	20	15	20	20
90-035-178	71.92	12.32	2.61	1.45	2.55	3.26	2.35	0.51	0.14	0.06	.005	861	14	47	15	39	275	30	154	20	20	53	20
90-035-186	70.01	11.19	3.40	1.30	2.49	3.66	2.09	0.78	0.17	0.06	.007	328	20	58	23	20	216	25	317	20	40	25	20
90-035-188	65.73	11.38	3.93	1.75	2.95	3.88	1.66	0.78	0.21	0.07	.006	314	16	81	18	5	271	6	260	52	32	20	20
90-035-190	66.54	11.85	4.52	1.92	2.86	3.81	1.64	0.80	0.21	0.07	.006	347	34	71	17	5	255	51	225	145	44	32	20
90-035-192	61.97	12.13	4.34	2.08	3.06	4.02	1.66	0.67	0.23	0.07	.005	310	29	34	37	5	236	42	208	146	32	42	20
90-035-194	66.08	11.71	3.88	1.84	2.68	3.98	1.59	0.79	0.21	0.06	.010	344	19	63	24	5	244	26	195	280	30	63	20
90-035-196	66.22	12.15	4.00	1.91	3.24	4.10	1.45	0.73	0.16	0.07	.006	373	37	66	22	22	261	69	192	62	28	66	20
90-035-198	68.10	11.77	3.66	1.67	2.21	3.98	1.42	0.70	0.18	0.06	.007	328	23	76	11	17	238	27	212	20	29	26	20
90-035-200	68.98	10.96	3.40	1.52	2.07	4.13	1.79	0.65	0.19	0.06	.006	318	22	42	36	5	227	19	177	65	24	39	20
90-035-202	72.91	11.15	2.35	0.98	1.48	4.60	1.87	0.36	0.13	0.04	.002	234	15	33	17	18	188	22	176	112	26	31	23
90-035-204	67.05	12.04	4.31	2.05	2.50	4.25	1.40	0.69	0.18	0.07	.007	291	10	61	36	24	263	25	147	87	24	50	20

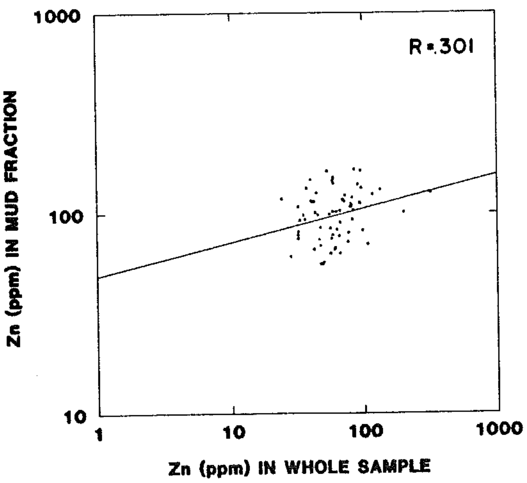
Appendix D. Scatter Plots of Element Concentrations Within the Whole Rock Data Versus Element Concentrations Within the Mud Data

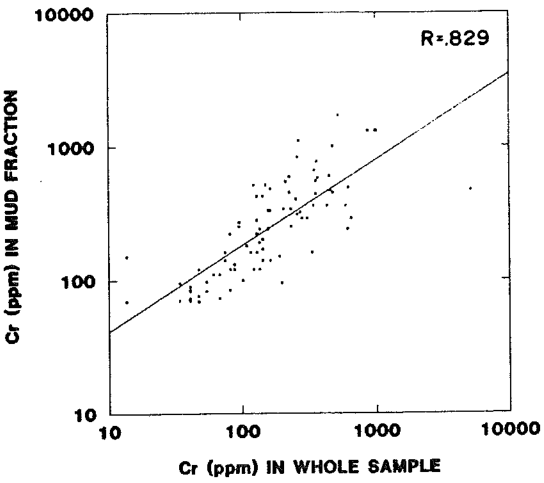

R=.346
1000
100
10
1
10
100
1000
Ni (ppm) IN MUD FRACTION
Ni (ppm) IN WHOLE SAMPLE

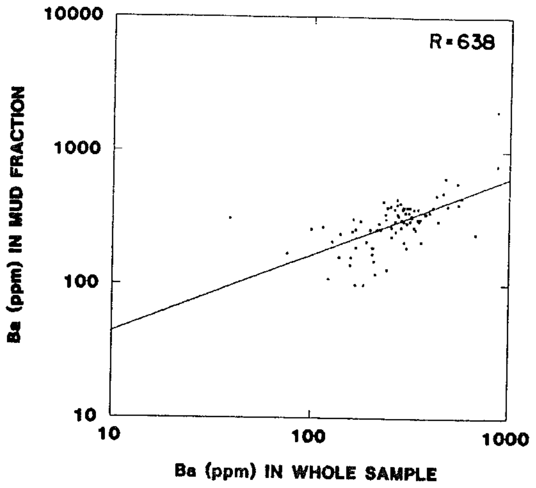

R=.354
100
10
1
1
10
100
Fe (%) IN MUD FRACTION
Fe (%) IN WHOLE SAMPLE

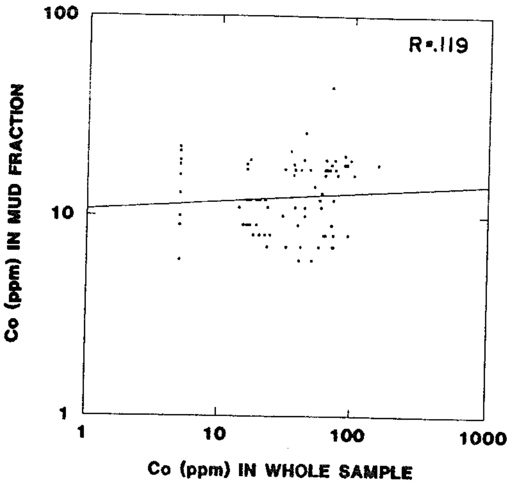

R=.646
100
10
1
0.1
1.0
10.0
100.0
Ca (%) IN MUD FRACTION
Ca (%) IN WHOLE SAMPLE

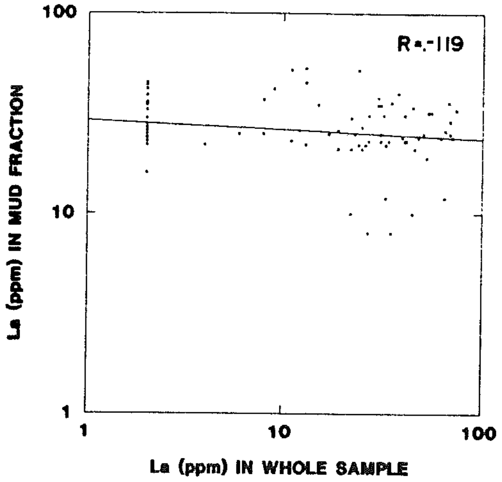

R=.326
100000
10000
1000
10000
100000
Na (ppm) IN MUD FRACTION
Na (ppm) IN WHOLE SAMPLE

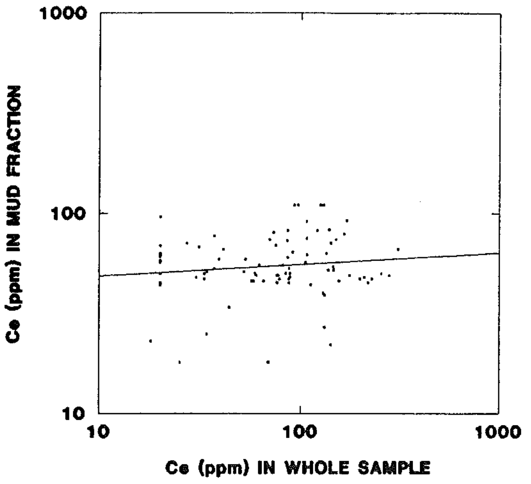

R=.301
1000
100
10
1
10
100
1000
Zn (ppm) IN MUD FRACTION
Zn (ppm) IN WHOLE SAMPLE


R=.829
10000
1000
100
10
10
100
1000
10000
Cr (ppm) IN MUD FRACTION
Cr (ppm) IN WHOLE SAMPLE

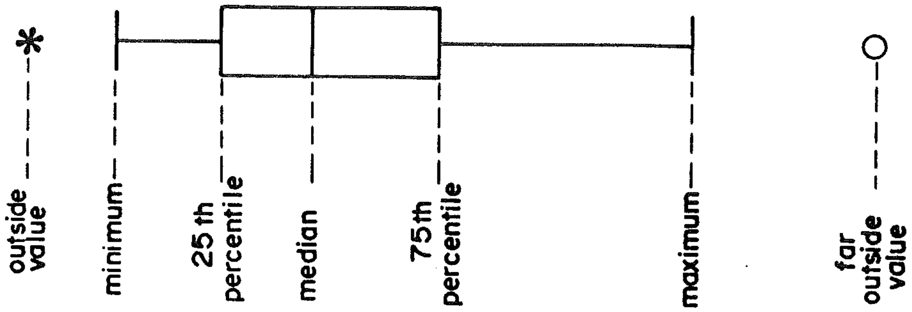

R=.638
10000
1000
100
10
10
100
1000
Ba (ppm) IN MUD FRACTION
Ba (ppm) IN WHOLE SAMPLE

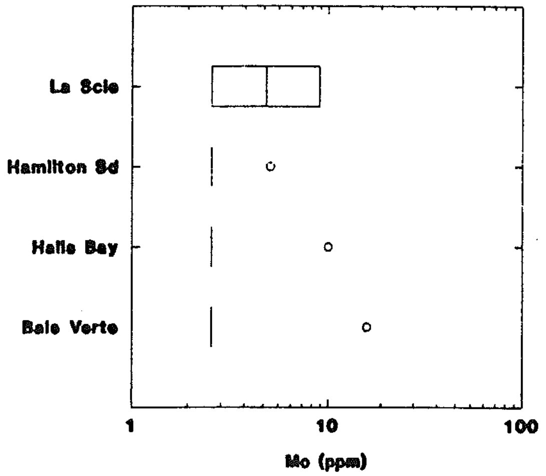

R=.119
100
10
1
1
10
100
1000
Co (ppm) IN MUD FRACTION
Co (ppm) IN WHOLE SAMPLE

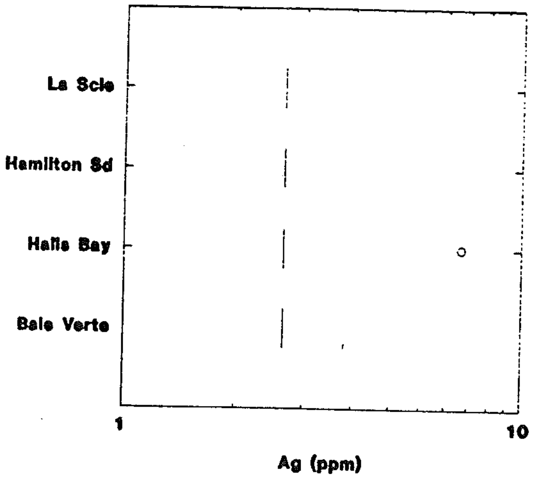

R=-.119
100
10
1
1
10
100
La (ppm) IN MUD FRACTION
La (ppm) IN WHOLE SAMPLE

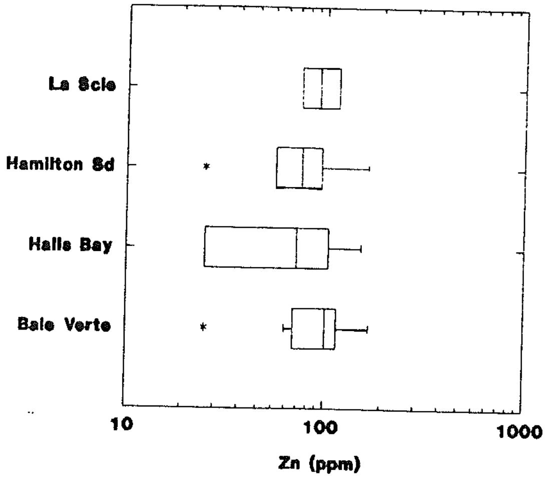

1000
100
10
10
100
1000
Ce (ppm) IN MUD FRACTION
Ce (ppm) IN WHOLE SAMPLE

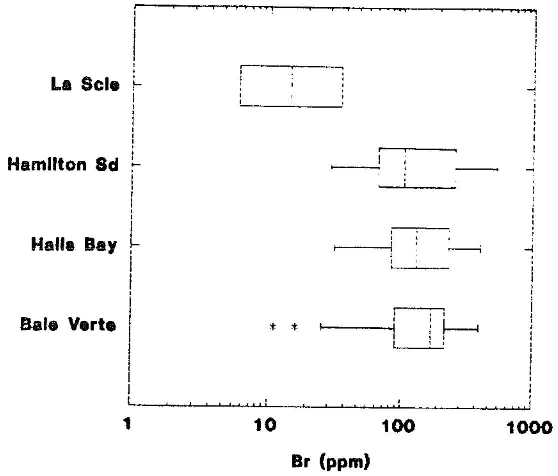
Appendix E. Box and Whisker Plots of Elements Within the Mud Fraction

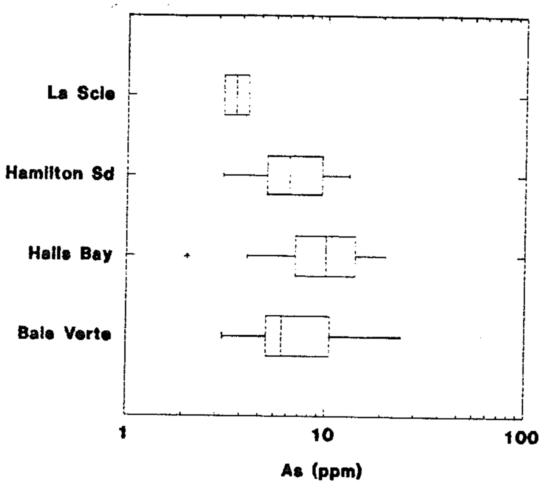

outside value
minimum
25 th percentile
median
75 th percentile
maximum
far outside value

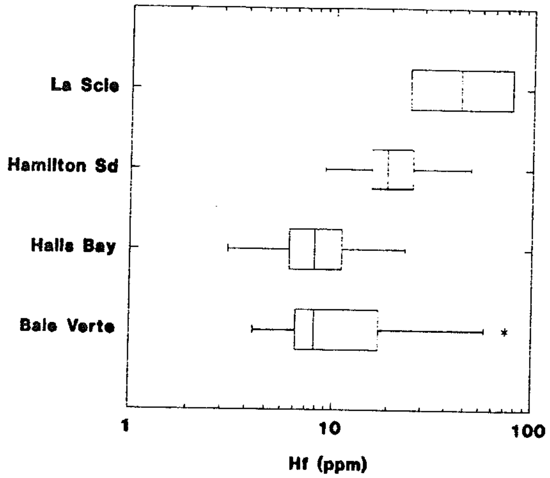

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Mo (ppm)

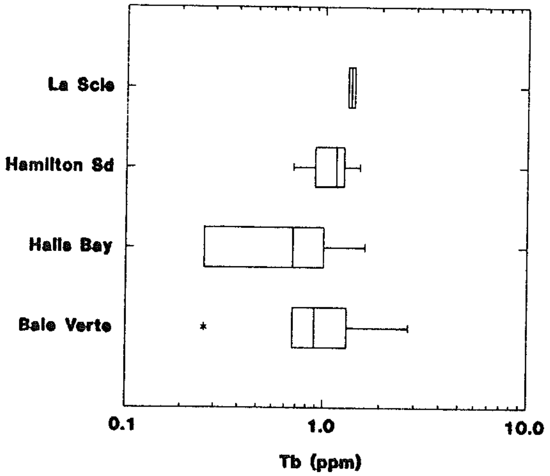

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
Ag (ppm)

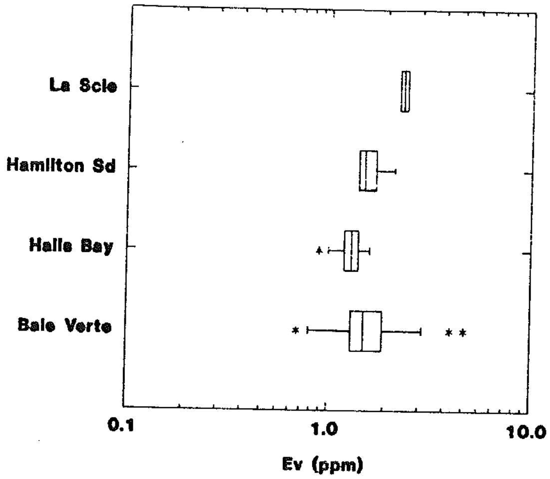

La Scie
Hamilton Sd
Halls Bay
Baie Verte
10
100
1000
Zn (ppm)

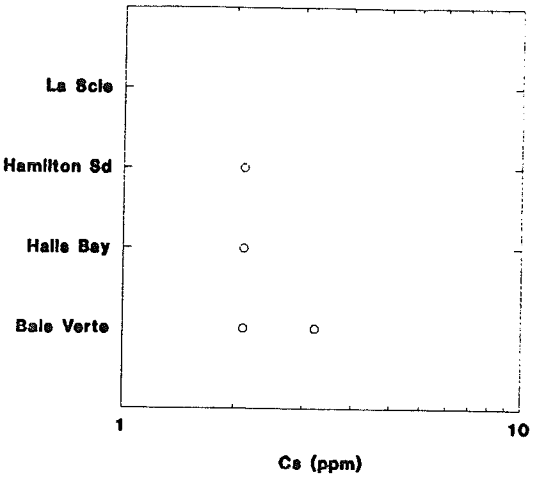

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
1000
Br (ppm)

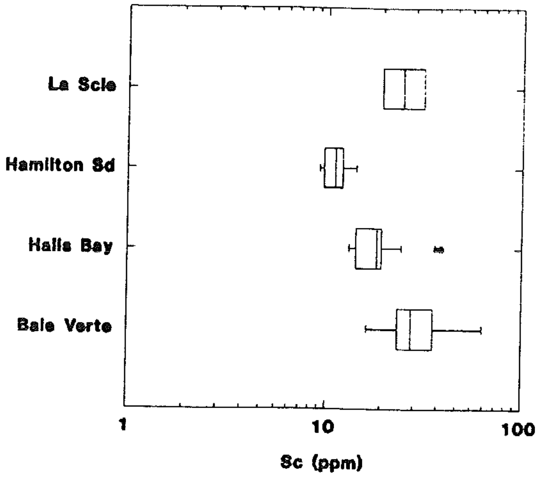

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
As (ppm)

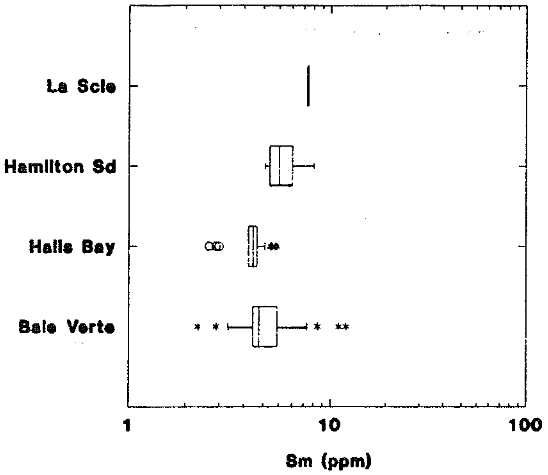

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Hf (ppm)

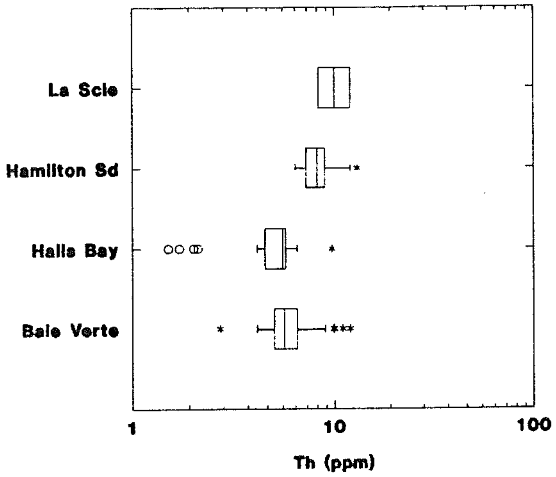

La Scie
Hamilton Sd
Halls Bay
Baie Verte
0.1
1.0
10.0
Tb (ppm)

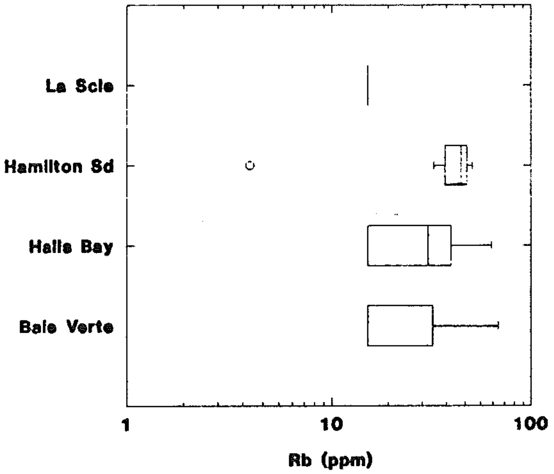

La Scie
Hamilton Sd
Halls Bay
Baie Verte
0.1
1.0
10.0
Eu (ppm)

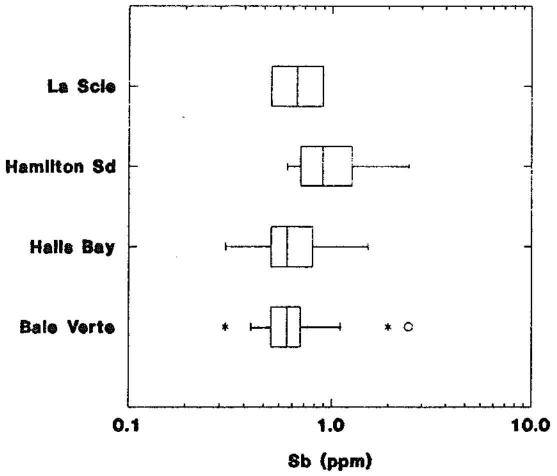

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
Cs (ppm)

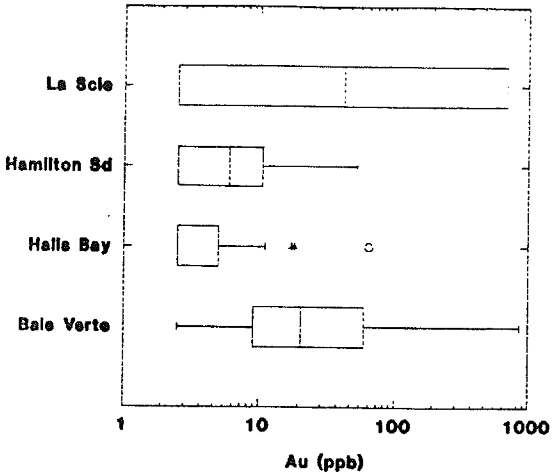

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Sc (ppm)

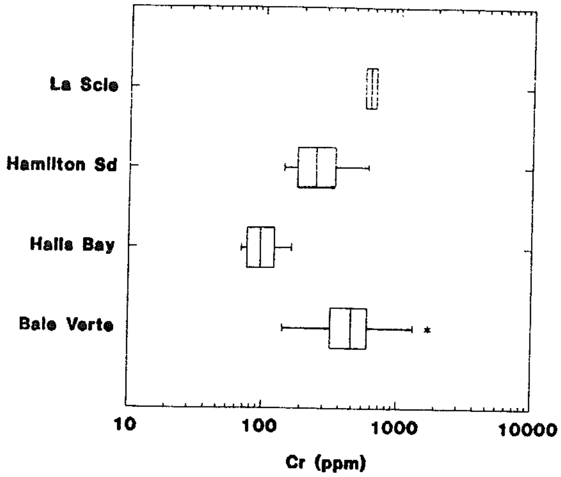

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Sm (ppm)

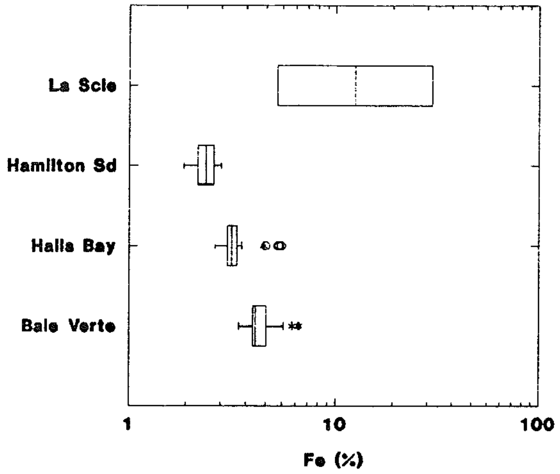

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Th (ppm)

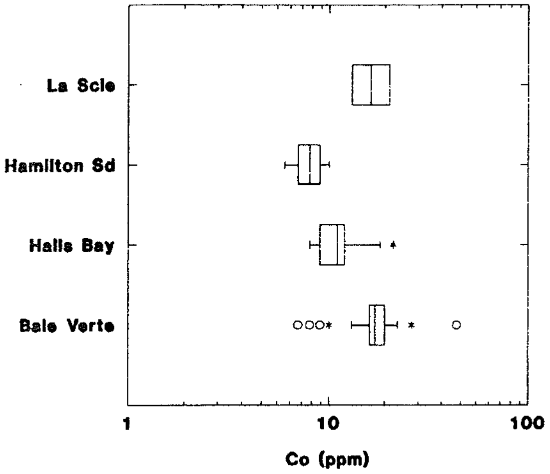

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Rb (ppm)

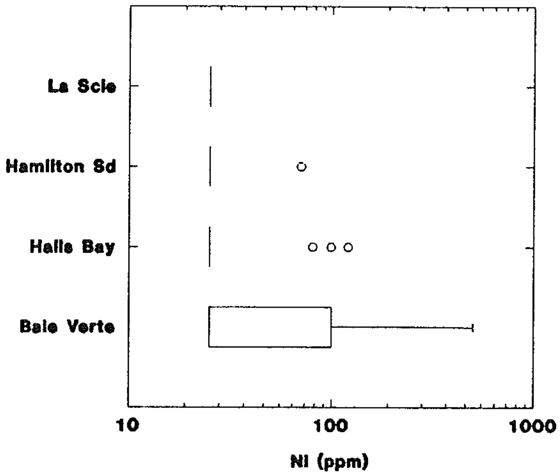

La Scie
Hamilton Sd
Halls Bay
Baie Verte
0.1
1.0
10.0
Sb (ppm)

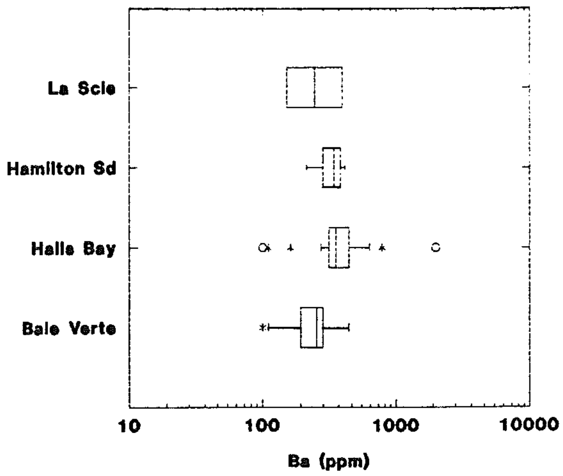

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
1000
Au (ppb)

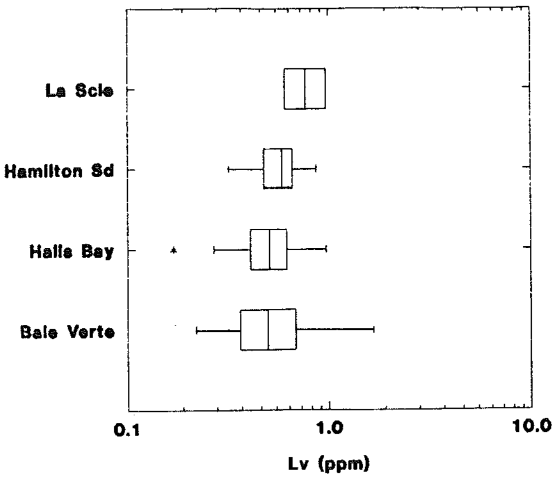

La Scie
Hamilton Sd
Halls Bay
Baie Verte
10
100
1000
10000
Cr (ppm)

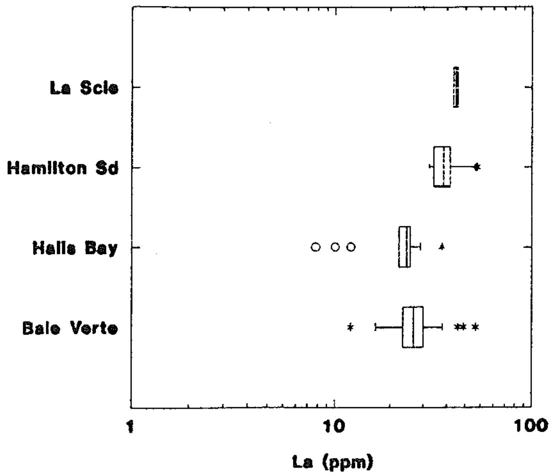

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Fe (%)

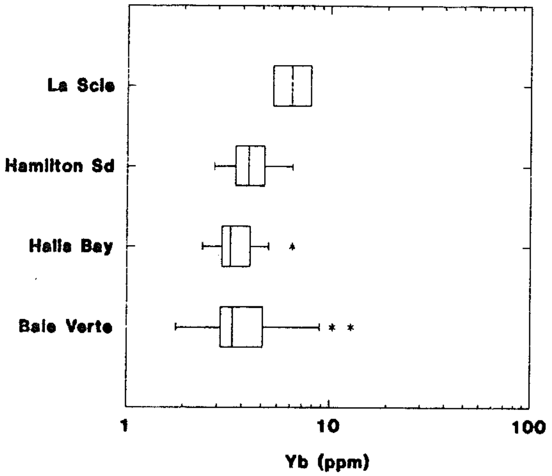

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Co (ppm)

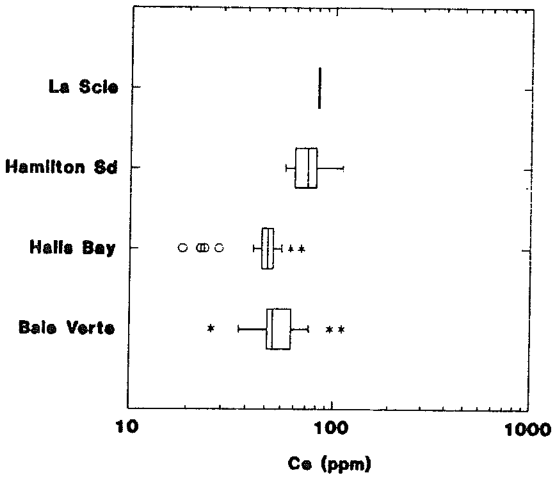

La Scie
Hamilton Sd
Halls Bay
Baie Verte
10
100
1000
Ni (ppm)

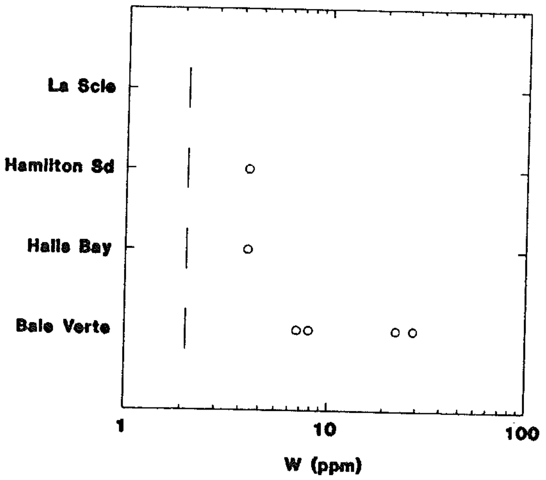

La Scie
Hamilton Sd
Halls Bay
Baie Verte
10
100
1000
10000
Ba (ppm)

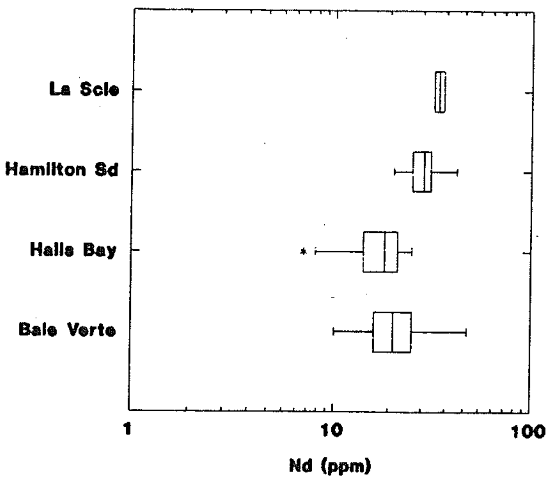

La Scie
Hamilton Sd
Halls Bay
Baie Verte
0.1
1.0
10.0
Lu (ppm)


La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
La (ppm)

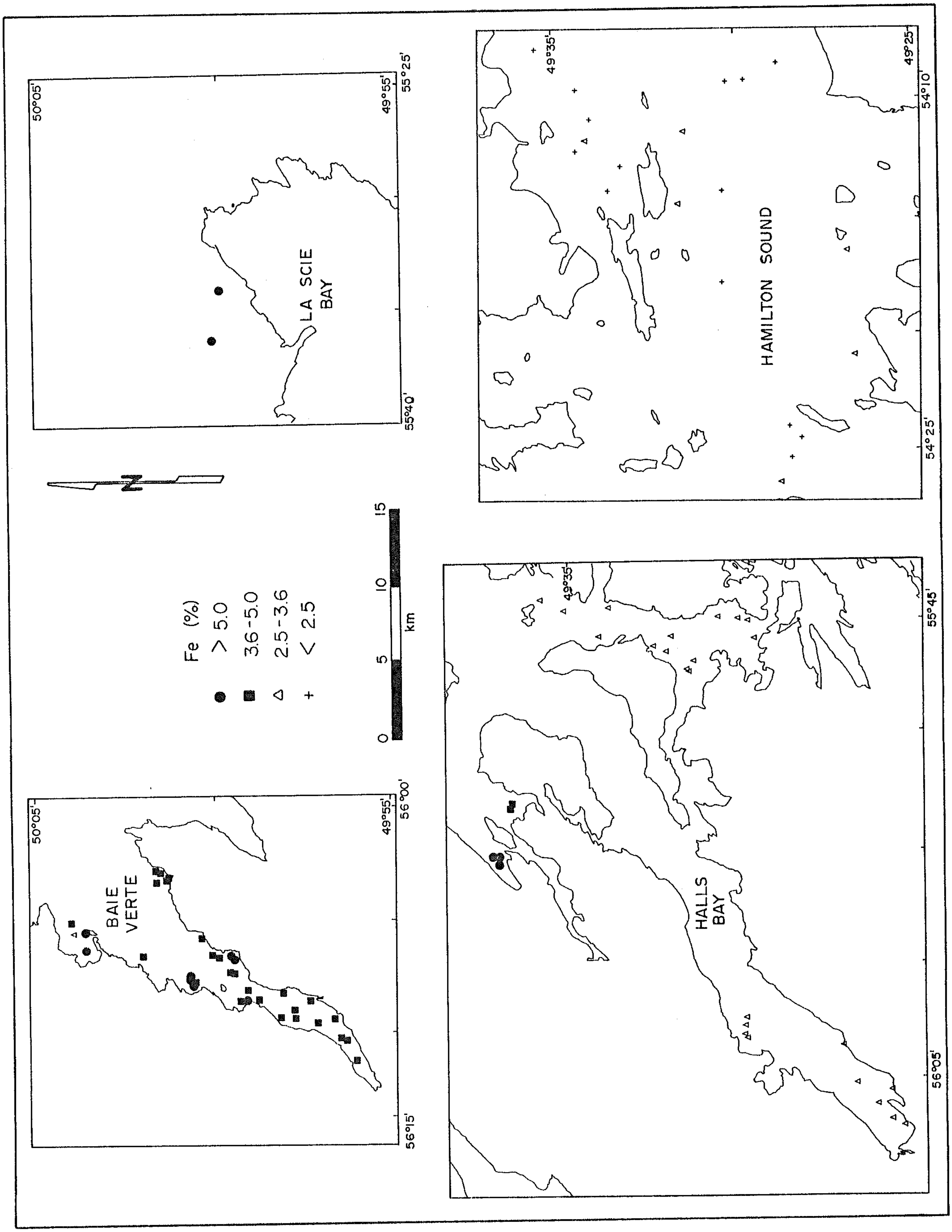

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Yb (ppm)

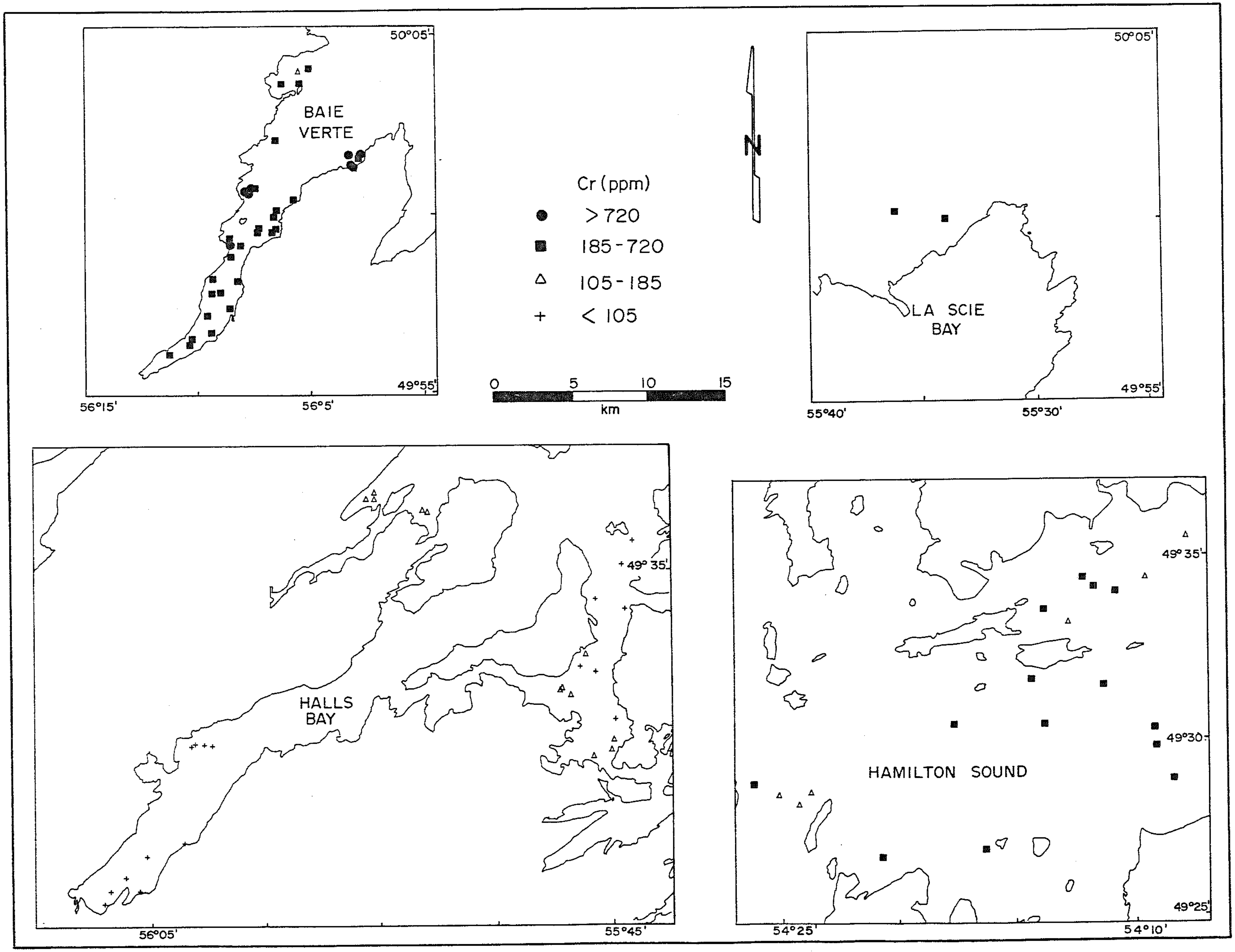

La Scie
Hamilton Sd
Halls Bay
Baie Verte
10
100
1000
Ce (ppm)

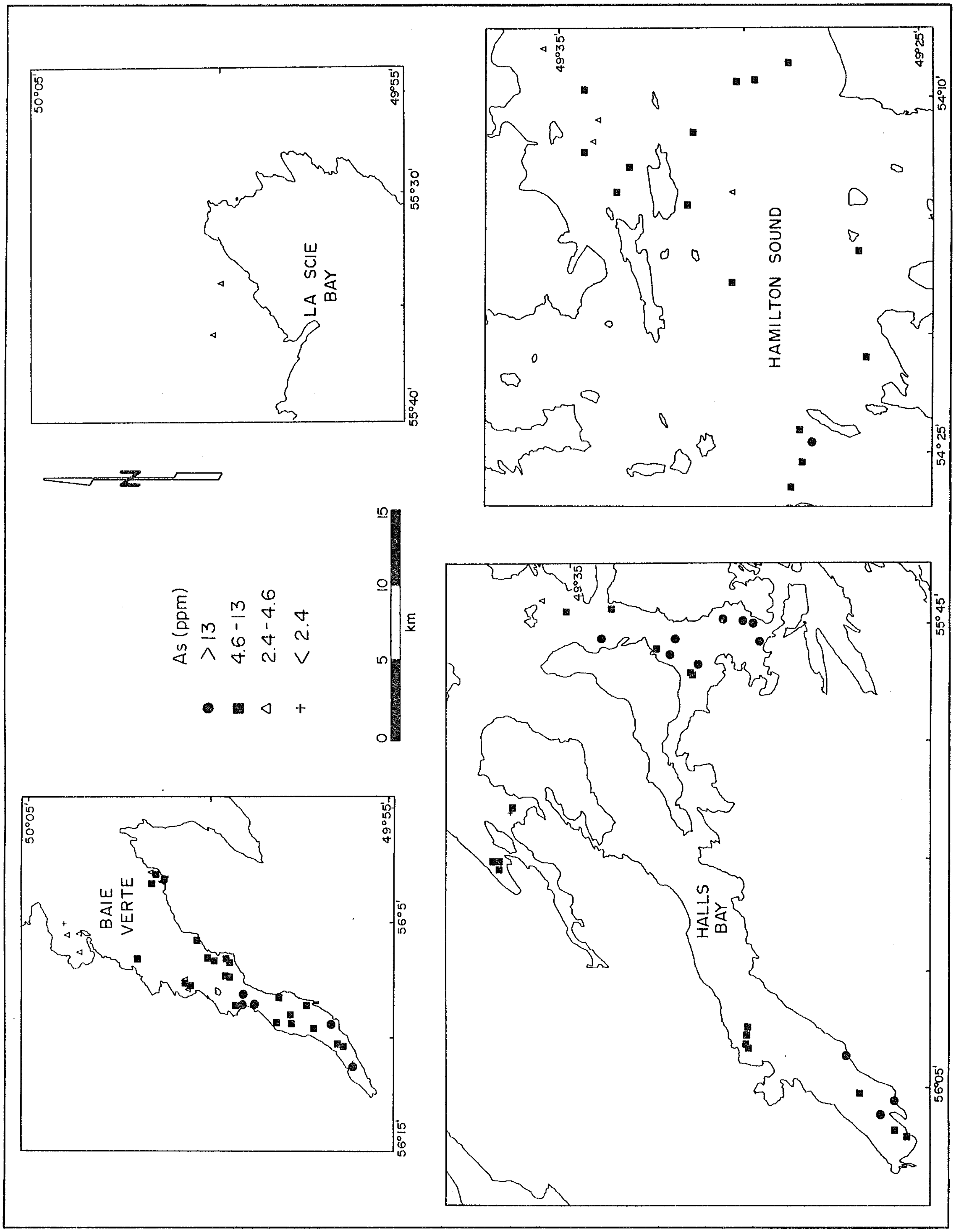

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
W (ppm)

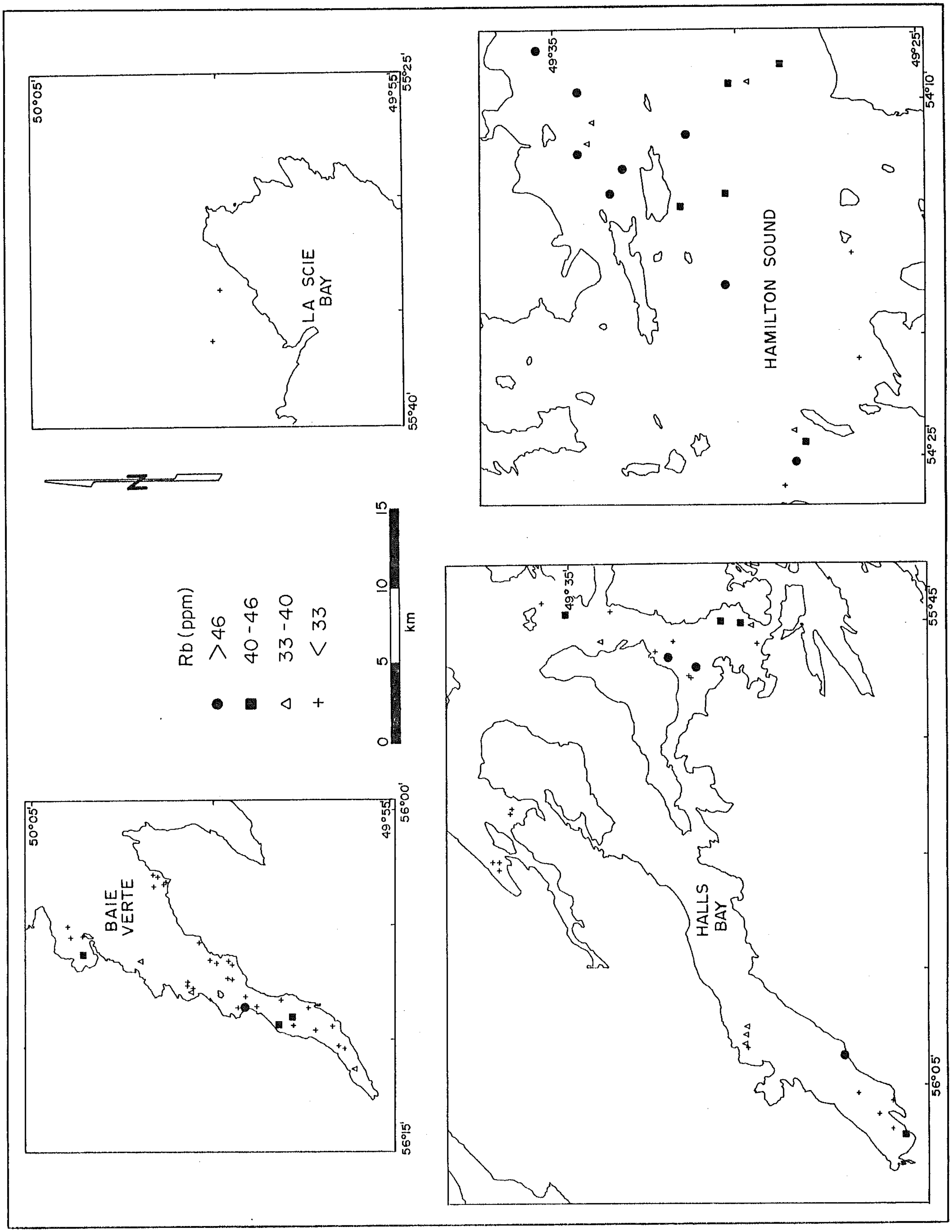

La Scie
Hamilton Sd
Halls Bay
Baie Verte
1
10
100
Nd (ppm)

Appendix F. Element Distribution Maps

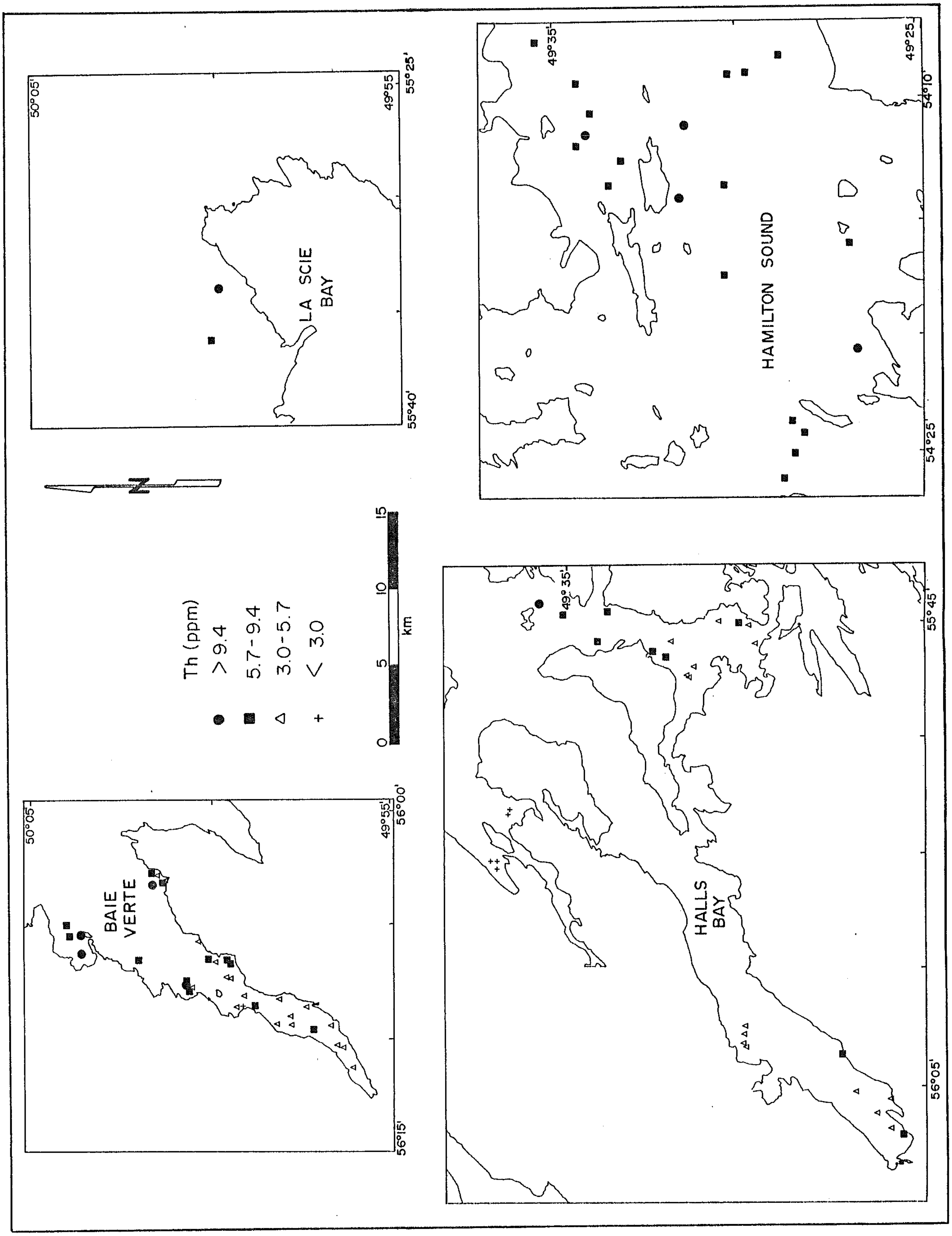

Fe (%)
● > 5.0
■ 3.6-5.0
△ 2.5-3.6
+ < 2.5
0 5 10 15
km
N
BAIE VERTE
50°05'
49°55'
56°00'
56°15'
LA SCIE BAY
50°05'
49°55'
55°25'
55°40'
HALLS BAY
49°35'
55°45'
56°05'
HAMILTON SOUND
49°35'
49°25'
54°10'
54°25'

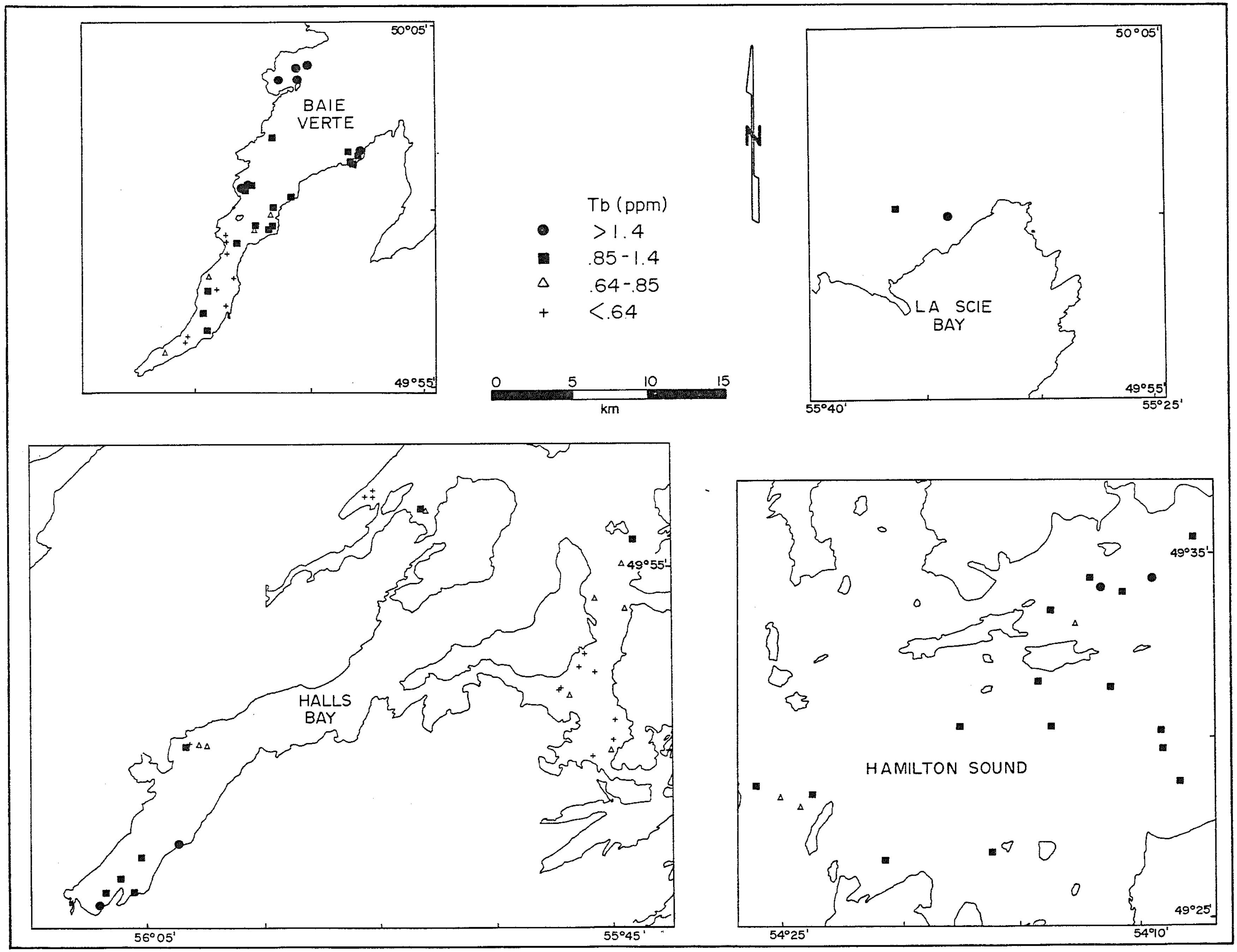

BAIE VERTE
50°05'
49°55'
56°15'
56°5'
Cr (ppm)
● >720
■ 185-720
△ 105-185
+ < 105
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°30'
HALLS BAY
49° 35'
56°05'
55°45'
HAMILTON SOUND
49° 35'
49°30'
49°25'
54°25'
54°10'

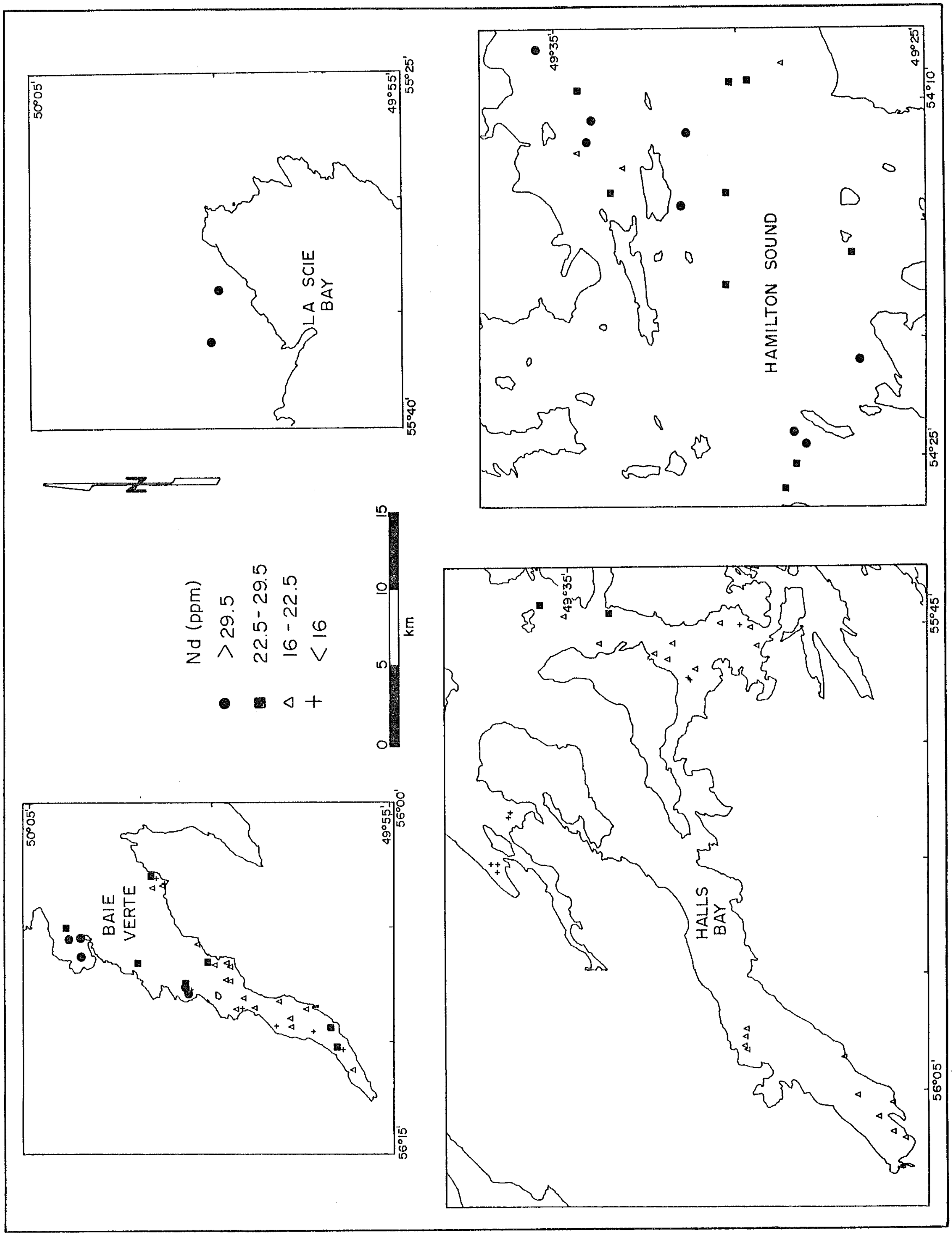

As (ppm)
● >13
■ 4.6-13
△ 2.4-4.6
+ < 2.4
0
5
10
15
km
N
BAIE VERTE
50°05'
49°55'
56°5'
56°15'
LA SCIE BAY
50°05'
49°55'
55°30'
55°40'
HALLS BAY
49°35'
55°45'
56°05'
HAMILTON SOUND
49°35'
49°25'
54°10'
54°25'

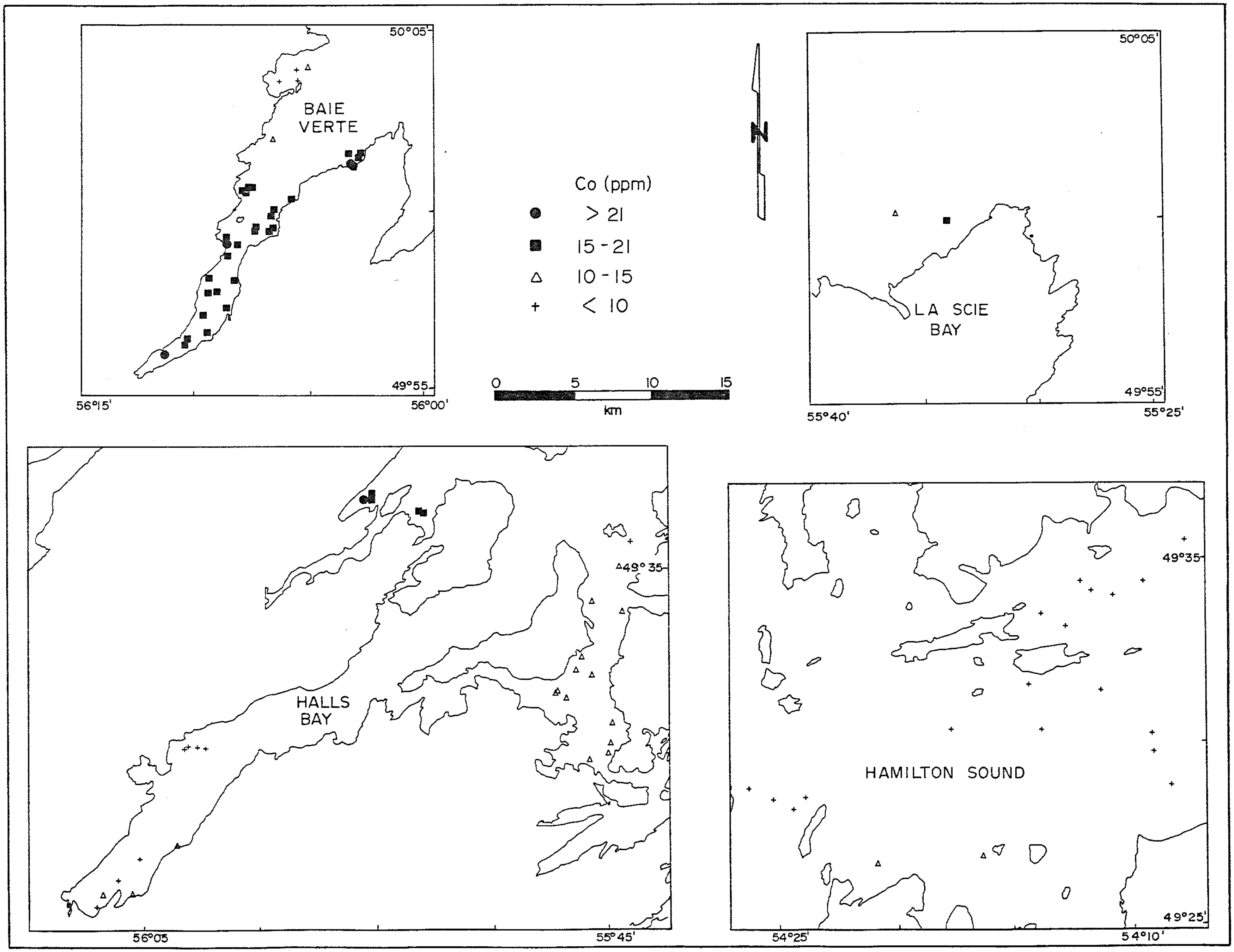


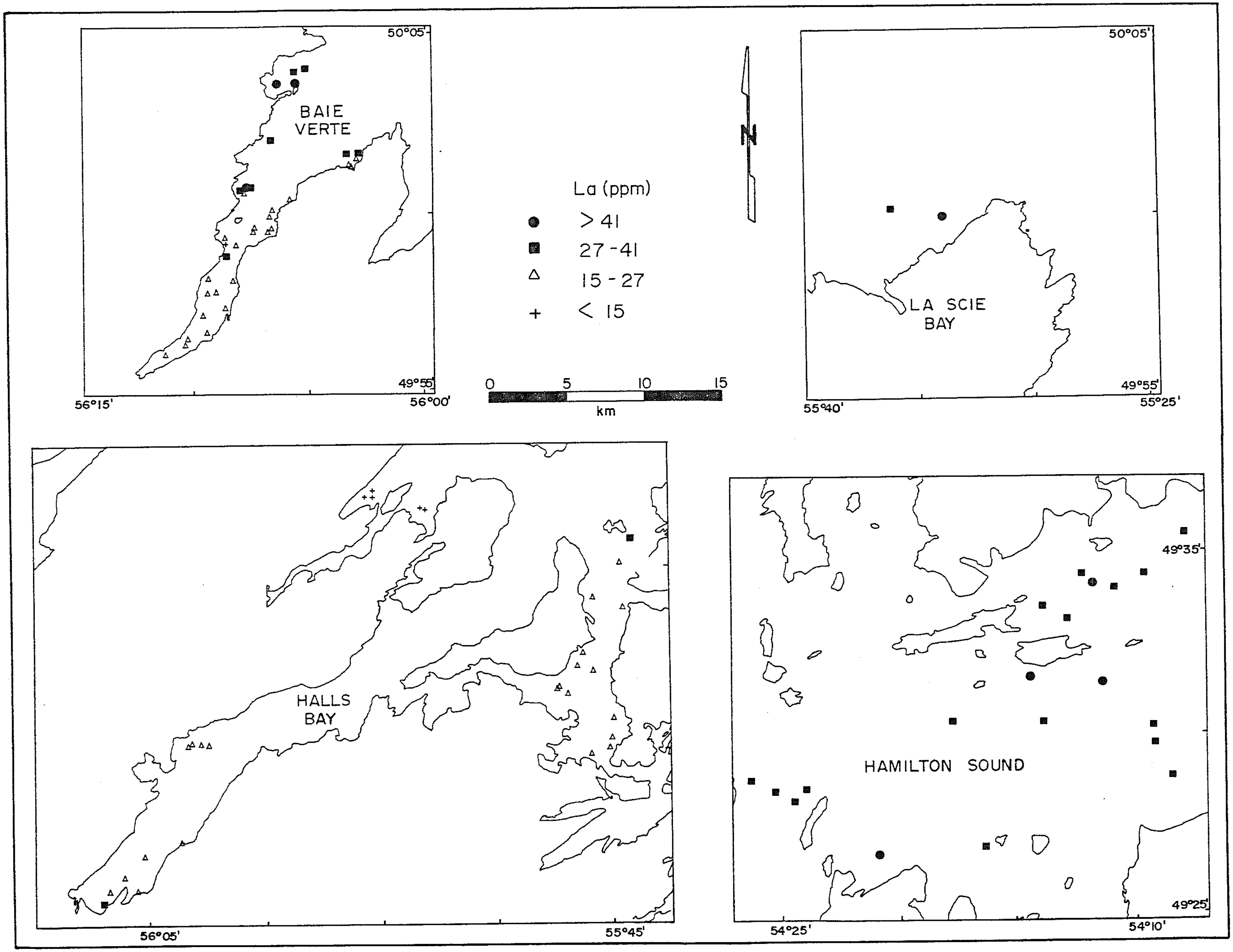
Rb (ppm)
● >46
■ 40-46
△ 33-40
+ <33
0
5
10
15
km
N
BAIE VERTE
50°05'
49°55'
56°15'
56°00'
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49° 35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

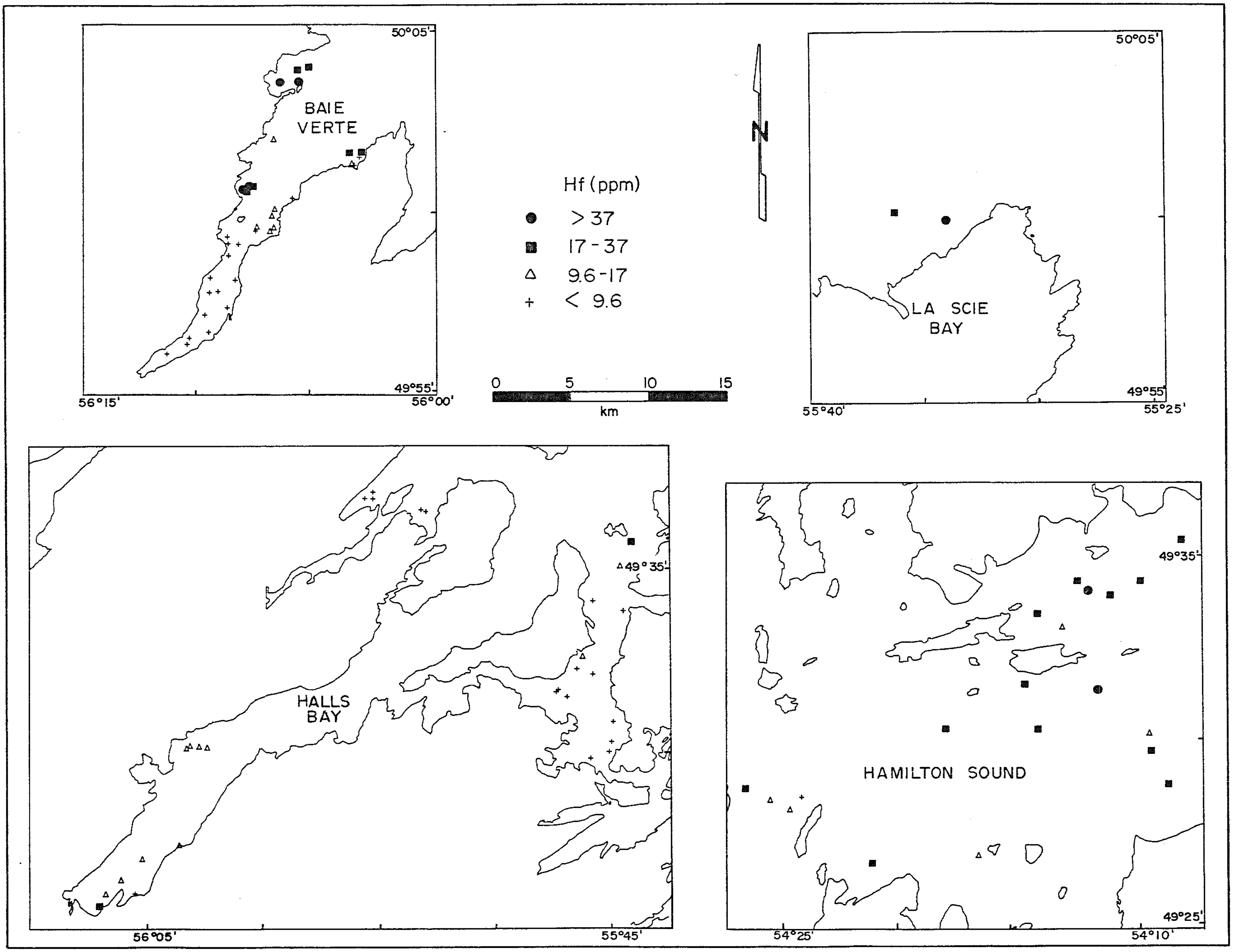

Th (ppm)
● >9.4
■ 5.7-9.4
△ 3.0-5.7
+ < 3.0
0
5
10
15
km
N
BAIE VERTE
50°05'
49°55'
56°15'
56°00'
LA SCIE BAY
50°05'
49°55
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45
HAMILTON SOUND
49°35'
49°25
54°25
54°10'

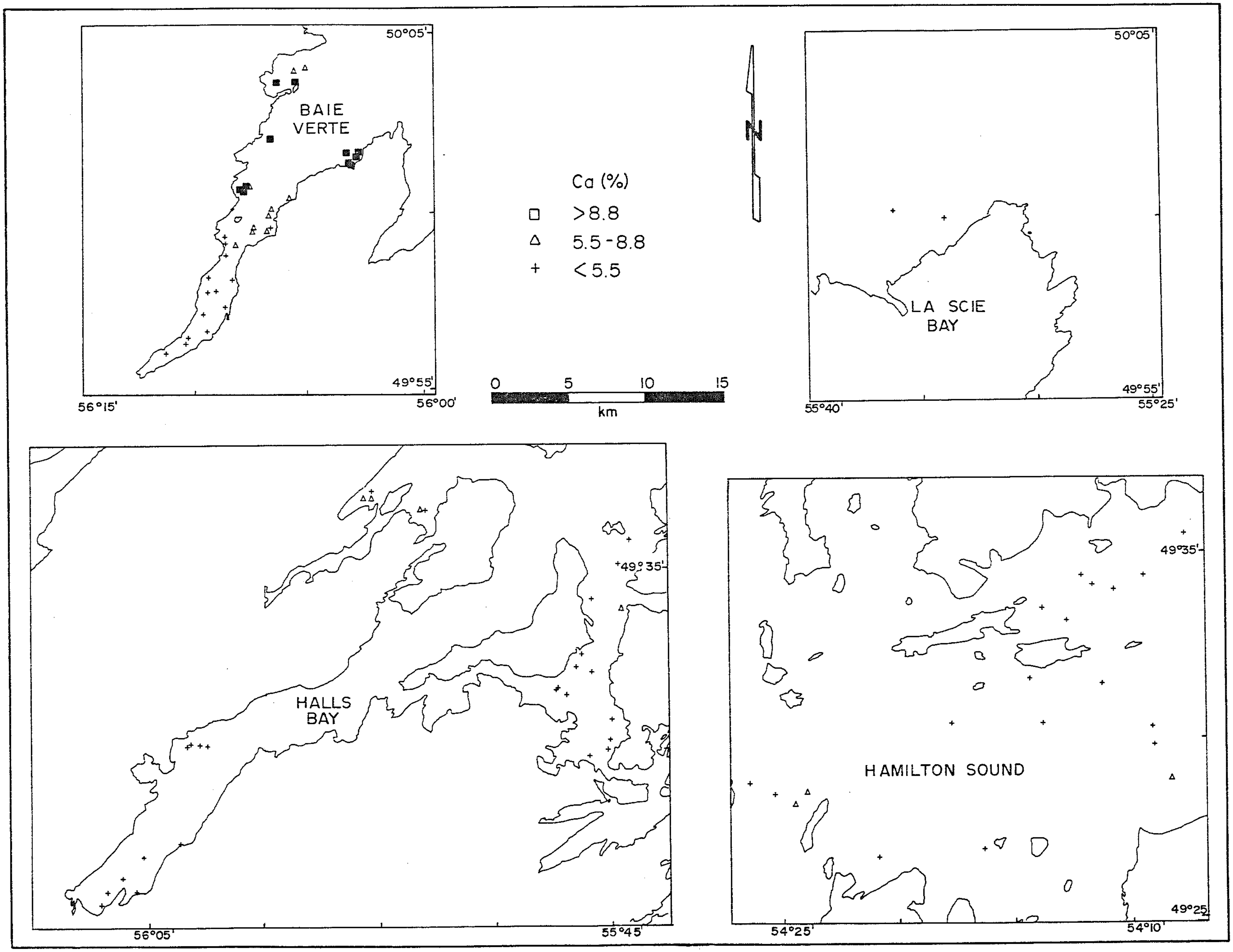

BAIE VERTE
50°05'
49°55'
Tb (ppm)
● >1.4
■ .85-1.4
△ .64-.85
+ <.64
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°55'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

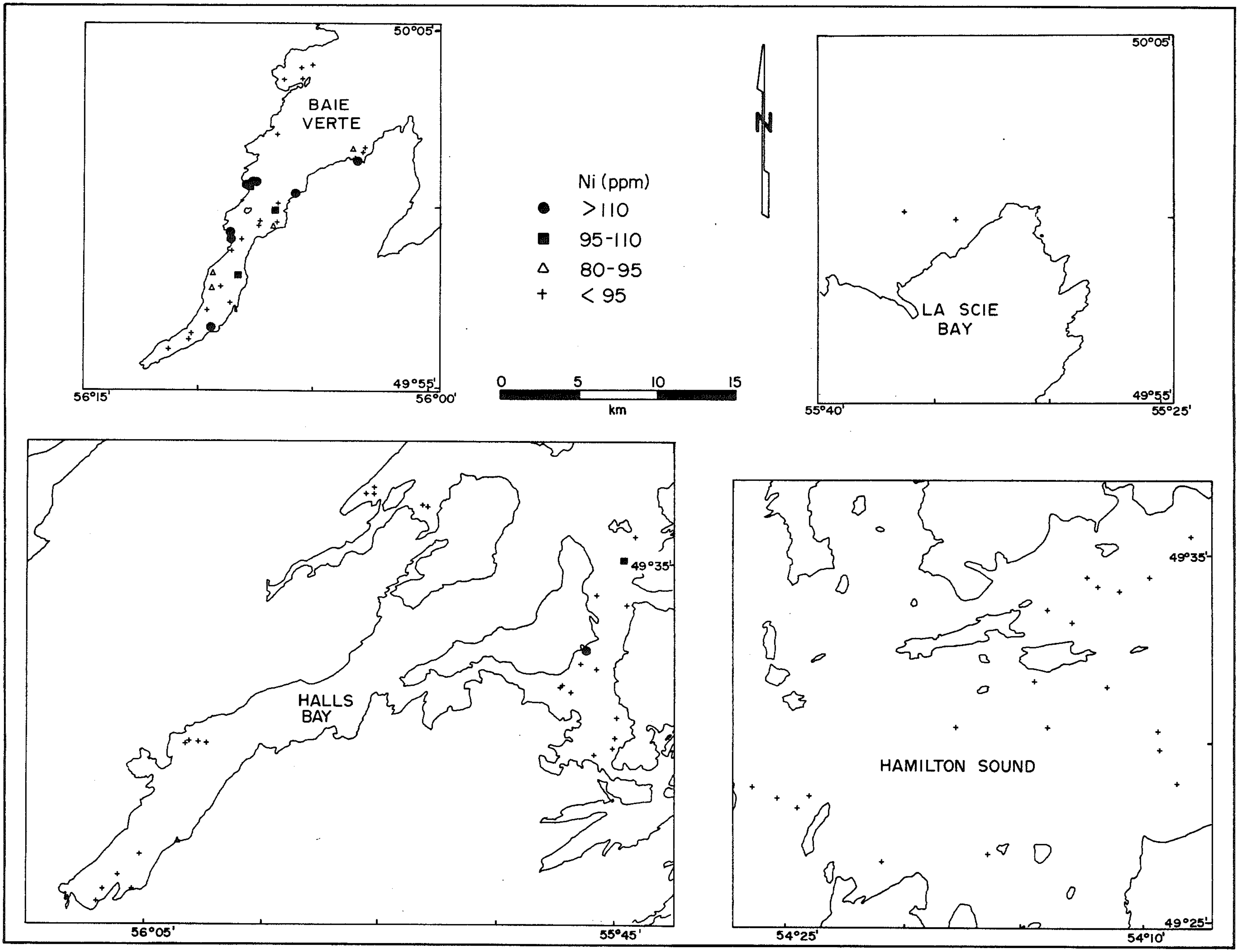

Nd (ppm)
● > 29.5
■ 22.5 - 29.5
△ 16 - 22.5
+ < 16
0
5
10
15
km
N
BAIE VERTE
50°05'
49°55'
56°15'
56°00'
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

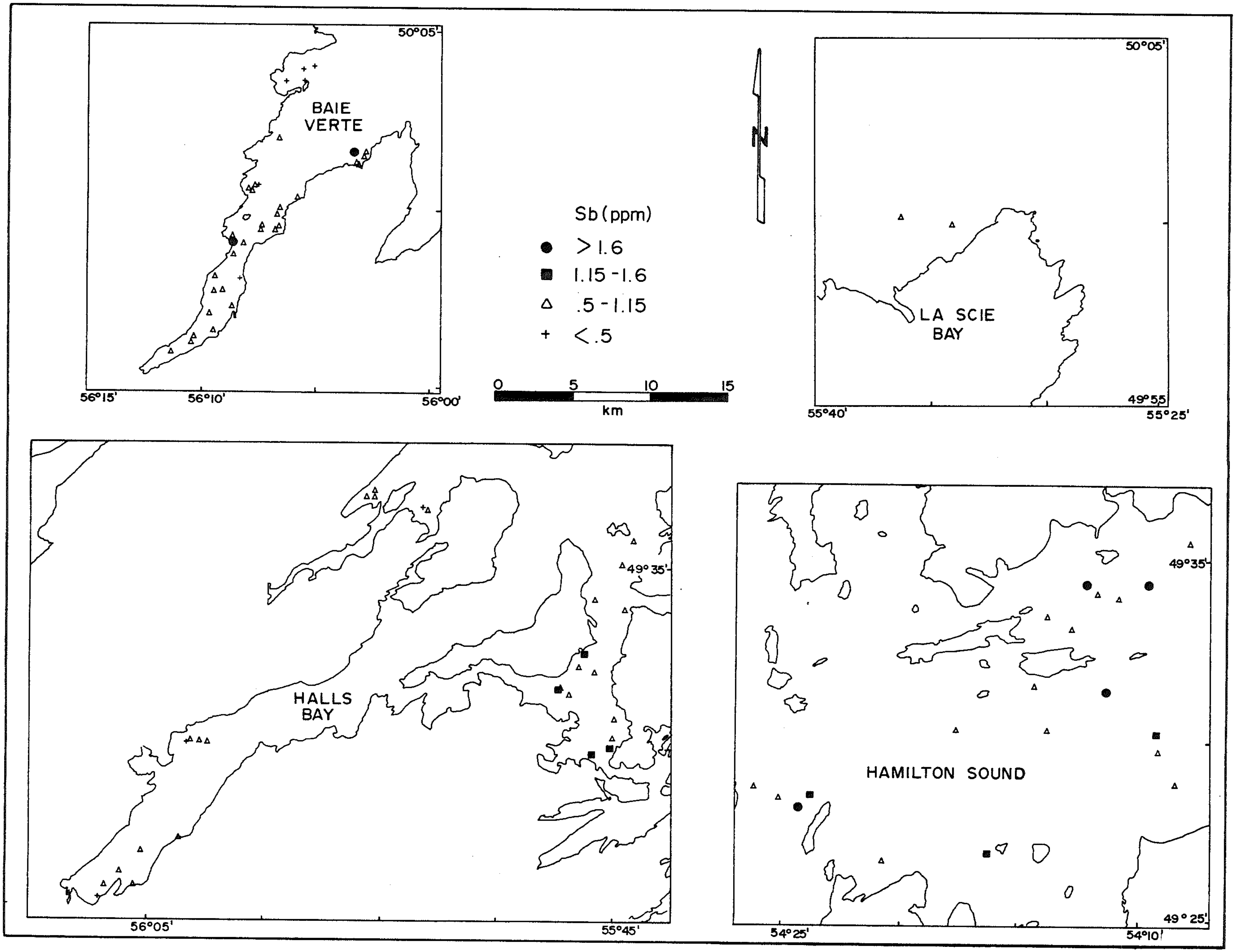

BAIE VERTE
50°05'
49°55
56°15'
56°00'
Co (ppm)
● > 21
■ 15 - 21
△ 10 - 15
+ < 10
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49° 35
56°05
55°45'
HAMILTON SOUND
49°35
49°25'
54°25'
54°10'

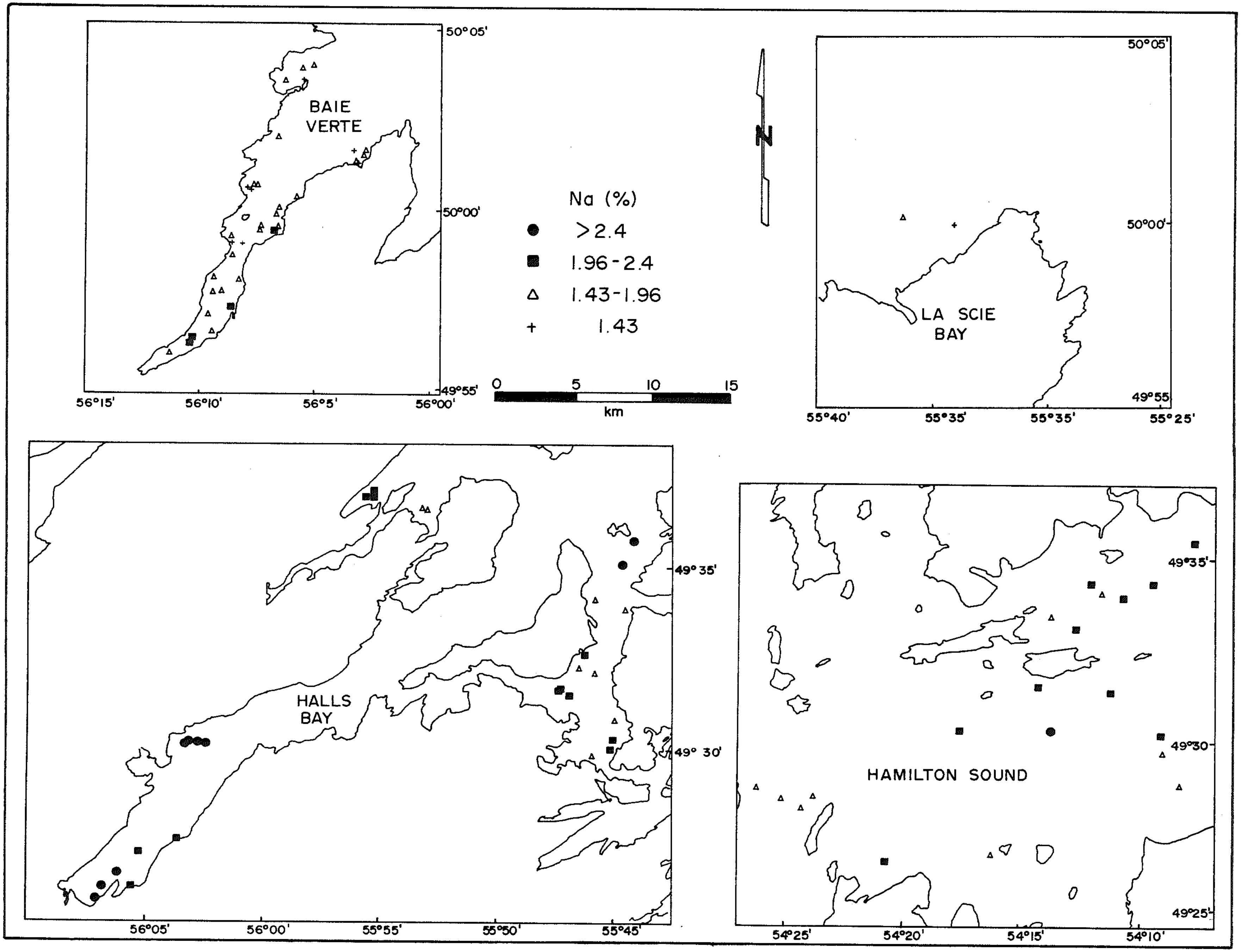

BAIE VERTE
50°05'
49°55'
56°15'
56°00'
La (ppm)
● > 41
■ 27 - 41
△ 15 - 27
+ < 15
0 5 10 15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

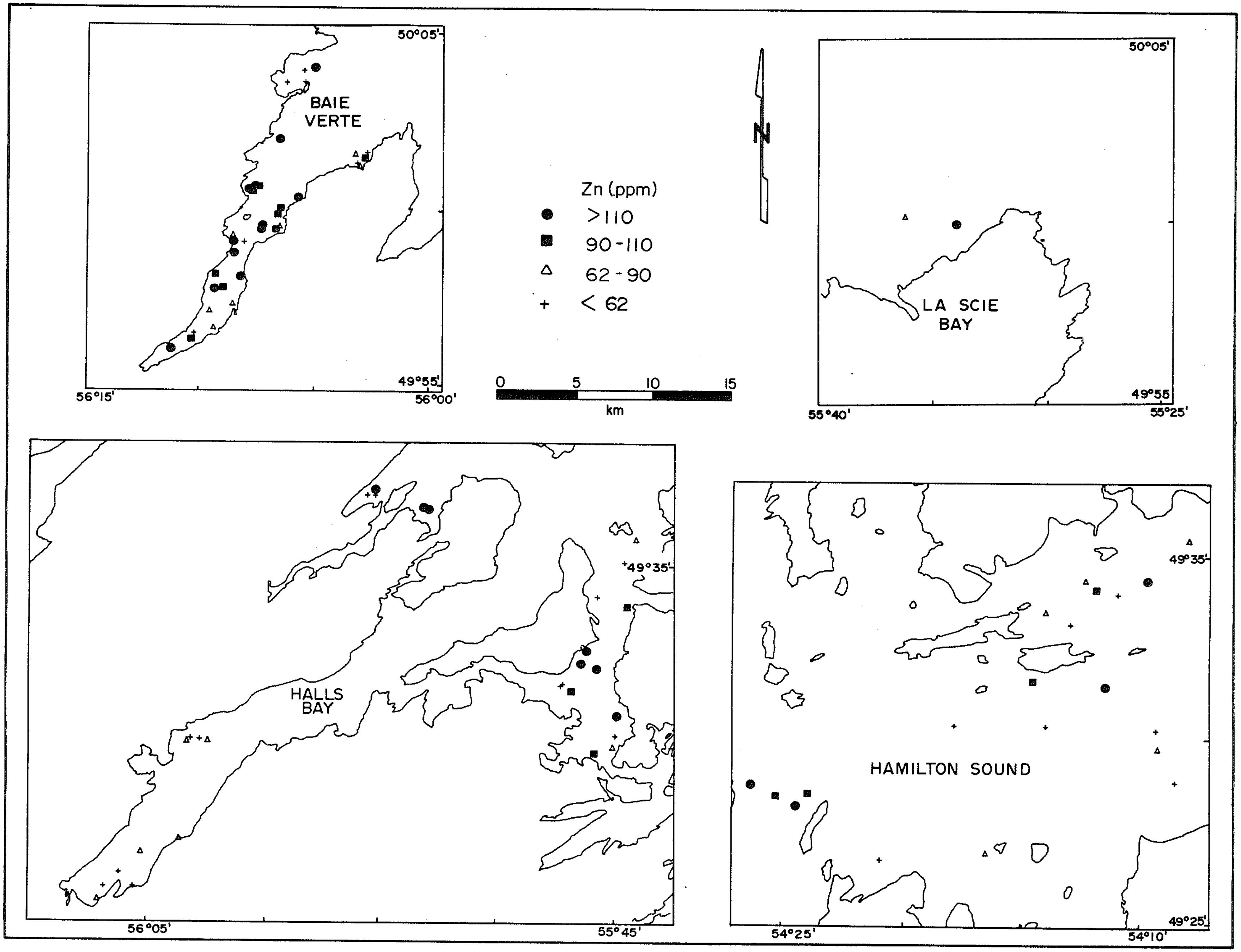

BAIE
VERTE
50°05'
49°55'
56°15'
56°00'
Hf (ppm)
● >37
■ 17-37
△ 9.6-17
+ < 9.6
0
5
10
15
km
N
LA SCIE
BAY
50°05'
49°55'
55°40'
55°25'
HALLS
BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

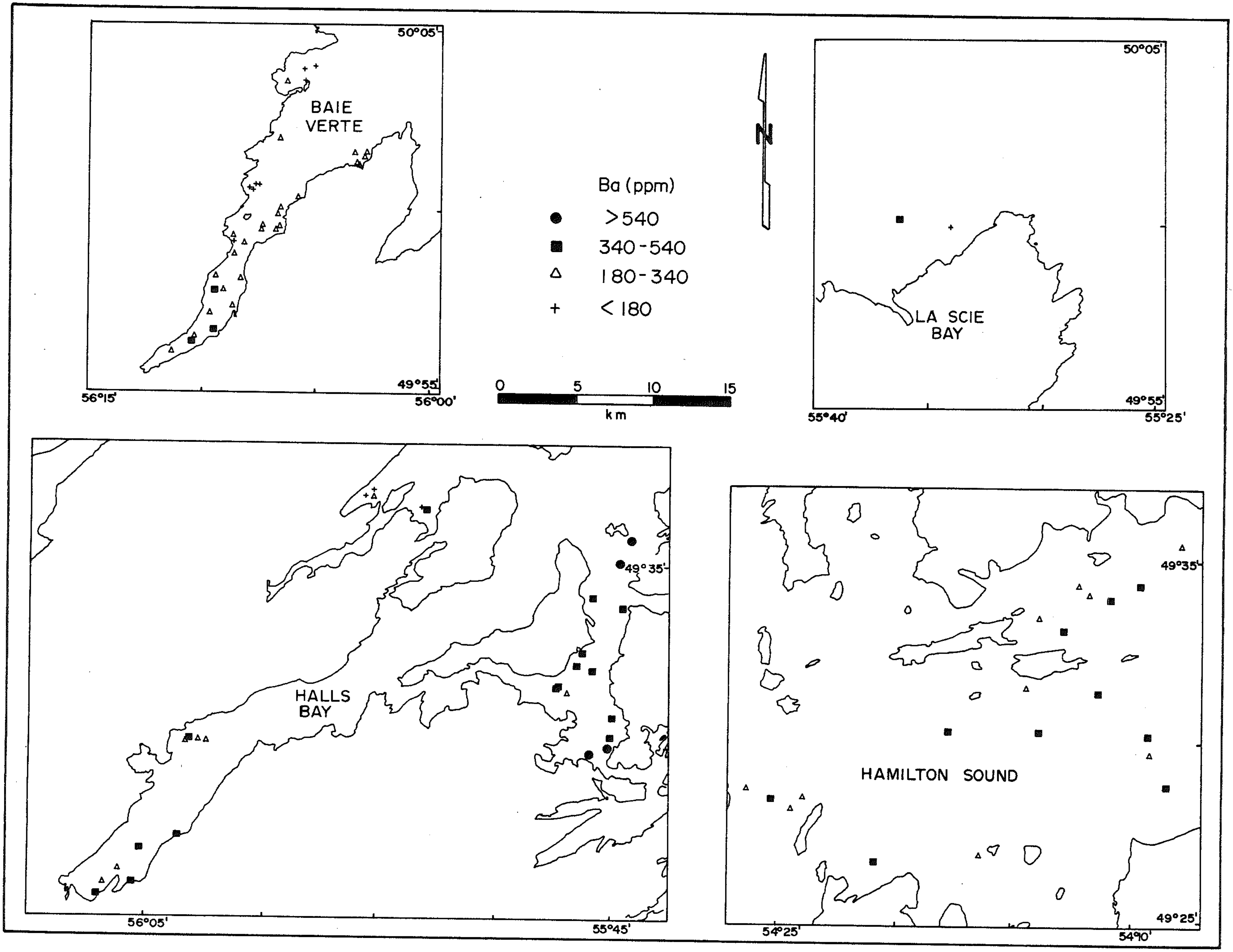

BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Ca (%)
☐ >8.8
△ 5.5-8.8
+ <5.5
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25
54°25'
54°10'

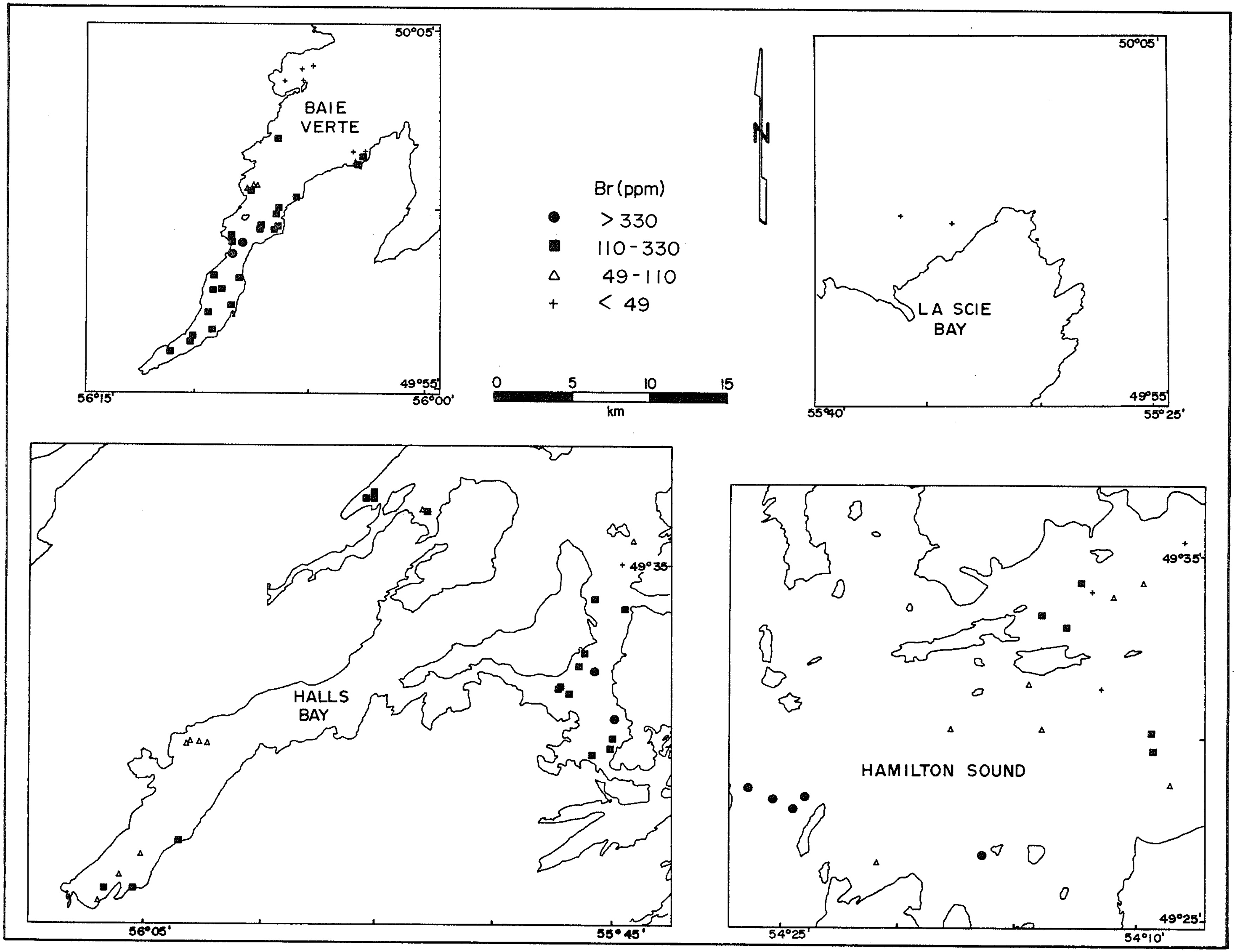

BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Ni (ppm)
● >110
■ 95-110
△ 80-95
+ < 95
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

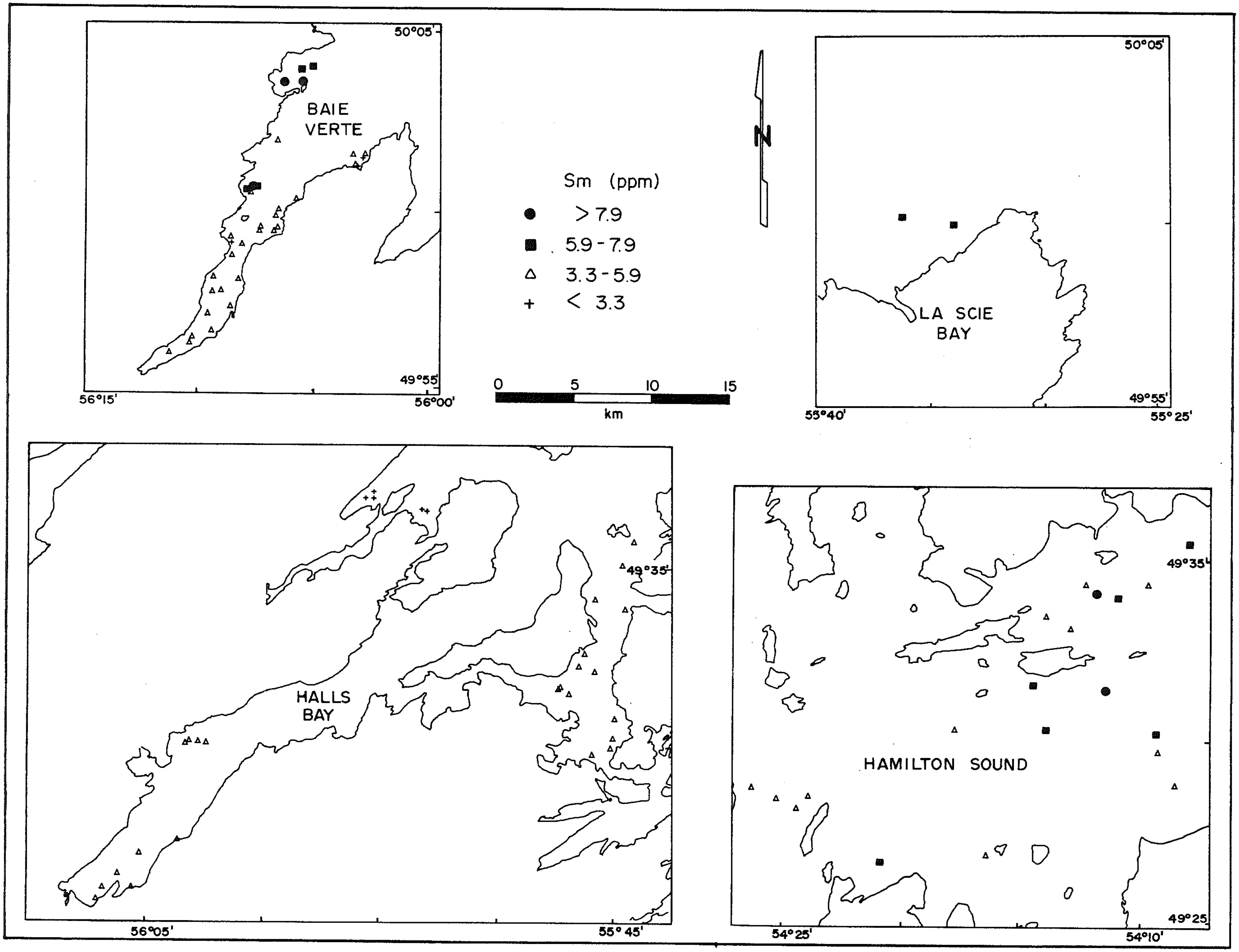

BAIE VERTE
50°05'
56°15'
56°10'
56°00'
Sb (ppm)
● >1.6
■ 1.15 - 1.6
△ .5 - 1.15
+ <.5
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

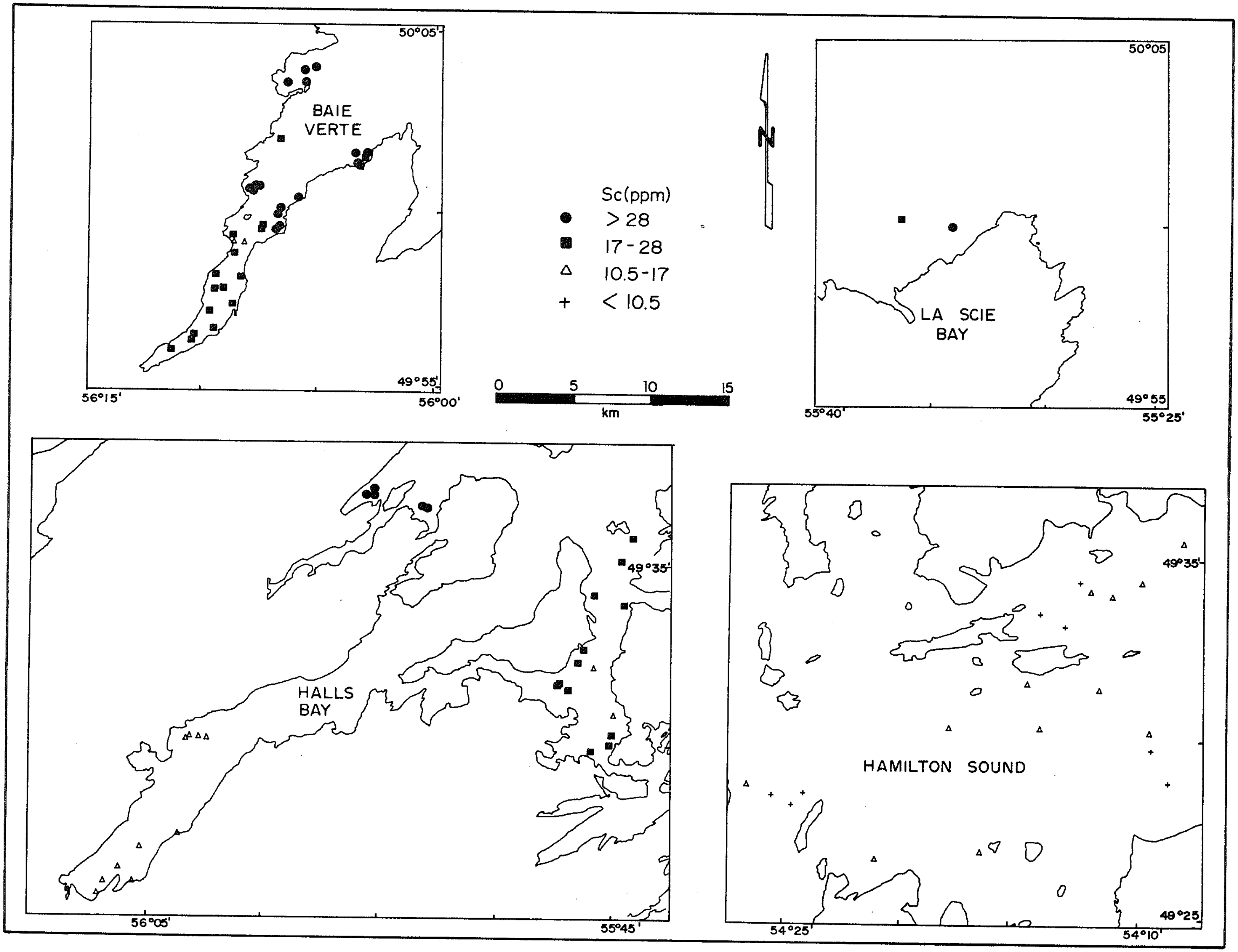

BAIE VERTE
50°05'
50°00'
49°55'
56°15'
56°10'
56°5'
56°00'
Na (%)
● >2.4
■ 1.96-2.4
△ 1.43-1.96
+ 1.43
0
5
10
15
km
N
LA SCIE BAY
50°05'
50°00'
49°55
55°40'
55°35'
55°35'
55°25'
HALLS BAY
49° 35'
49° 30'
56°05'
56°00'
55°55'
55°50'
55°45'
HAMILTON SOUND
49°35'
49°30'
49°25'
54°25'
54°20'
54°15'
54°10'


BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Zn (ppm)
● >110
■ 90-110
△ 62-90
+ < 62
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'

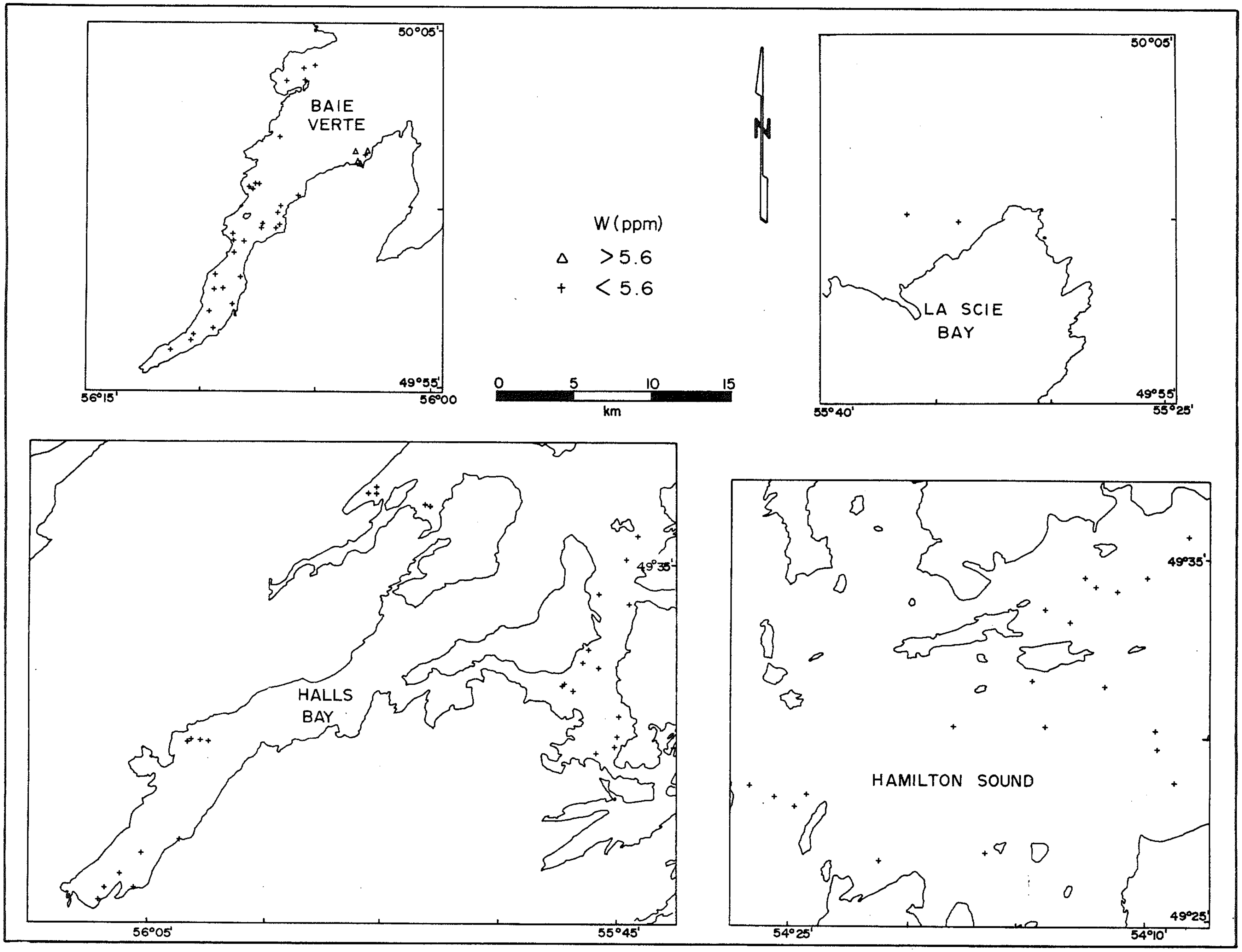

BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Ba (ppm)
● >540
■ 340-540
△ 180-340
+ <180
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'


BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Br (ppm)
● > 330
■ 110-330
△ 49-110
+ < 49
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'


BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Sm (ppm)
● >7.9
■ 5.9-7.9
△ 3.3-5.9
+ < 3.3
0
5
10
15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'



BAIE VERTE
50°05'
49°55'
56°15'
56°00'
Sc(ppm)
● > 28
■ 17 - 28
△ 10.5-17
+ < 10.5
0
5
10
15
km
N
LA SCIE BAY
50°05
49°55
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25
54°25'
54°10'


BAIE VERTE
50°05'
49°55'
56°15'
56°00
W (ppm)
△ >5.6
+ <5.6
0 5 10 15
km
N
LA SCIE BAY
50°05'
49°55'
55°40'
55°25'
HALLS BAY
49°35'
56°05'
55°45'
HAMILTON SOUND
49°35'
49°25'
54°25'
54°10'