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REGIONAL AND DETAILED GEOCHEMICAL EXPLORATION STUDIES IN GLACIATED TERRAIN IN NEWFOUNDLAND

E.H.W. HORNBROOK P.H. DAVENPORT AND D.R. GRANT

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FOREWORD

The principal objective of the pilot studies described in this report was the identification of techniques that could be applied on a regional scale. That was accomplished and the results of some of the subsequent regional surveys have already been released. However, of equal benefit to the exploration fraternity, this report provides a well documented account of intensive geochemical evaluations of two areas, each representative of major metallogenic belt. Also, the geochemical interpretations presented have had the benefit of Pleistocene geological studies, an aspect too often neglected.

This work marked the Mineral Development Division's initiation into large scale geochemical and geological operations, activities for which the Division was ill-prepared at the time. In this respect, we wish to acknowledge the invaluable assistance of the Geological Survey of Canada in providing expertise and equipment to implement the pilot studies, and the continuing interest and commitment of the Survey personnel involved, especially W. H. Poole, E. H. Hornbrook and D. R. Grant.

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J. M. Fleming,
Director,
Mineral Development Division.

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ABSTRACT

Pilot geochemical exploration studies, with surficial geological support, were carried out to test and evaluate the effectiveness of various regional and detailed techniques for base-metal exploration within two distinct geological terrains in Newfoundland. Studies were carried out near a massive sulphide base-metal deposit in Ordovician Wild Bight Group volcanic rocks in the Notre Dame Bay area, and near zinc sulphide deposits in Cambro-Ordovician carbonate rocks on the Great Northern Peninsula at Daniel's Harbour.

Steam and lake sediments, lake waters, B and C horizon soils, and till were sampled. Basal till samples were collected by a percussion drilling technique. Water samples were analyzed for Cu, Zn, Ni and Hg, and sediment, soil and till samples for Cu, Zn, Ni, Co, Pb, Ag and Mn. Certain of the latter samples were analyzed also for As, Fe and Hg.

Regional lake and steam sediment surveys have delineated target areas for follow-up studies characterized by relatively high element values: As, Zn and Cu in the Notre Dame Bay area, and Zn in the Daniel's Harbour area. Fe, Mn and organic content acting singly or in combination were found to have a significant effect on the distribution of certain elements in lake and stream sediments. Thus, in future surveys, their scavenging influence should be removed, as required, by data processing prior to interpretation. Stream sediment surveys were applicable at regional or follow-up study levels. Lake waters are not as effective as lake and stream sediments but they appear to have potential for regional exploration.

Detailed follow-up soil and upper till studies in the New Bay Pond area near the massive sulphide deposit did not effectively detect dispersion haloes. Soil sampling was effective in the Daniel's Harbour area where element dispersion haloes in both B and C horizon soils defined areas of suboutcropping mineralization.

In the Notre Dame Bay area, the basal till sampling technique was particularly effective in the plateau peat bog terrain overlying the massive sulphide deposit. It provided information on anomalous Zn, Cu and As geochemical and glacial dispersion patterns that reflected the presence of the known sulphide body. The technique also provided a means of discriminating between those geophysical anomalies caused by a suboutcropping sulphide source from those that were not. In the Daniel's Harbour area, where the till thickness exceeded 6 feet, basal till sampling effectively provided a definition of zinc dispersion patterns in the till indicating the source of soil anomalies. At till depths less than 6 feet, B and C horizon soils were found to be adequate and as effective as basal till sampling.

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The cooperation and reliable support provided by Universal Helicopters of Gander, Newfoundland is appreciated. The experience and ability of the pilot, Mr. Garth Gordon, was a welcome asset. Mr. J.J. Lynch of the Geological Survey deserves credit, who with the help of Mr. L.J. Trip, now with the Department of Environment, set up the analytical procedures and trained the analytical staff as required. Analytical work has been carried out under the daily supervision of Mr. F. Goudie and Mr. B. Pynn.

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INTRODUCTION

Pilot geochemical exploration studies have been carried out to assess the applicability of various techniques to base-metal exploration within two distinct geological terrains in Newfoundland. The location of the two study areas is shown in Figure 1. The first area, referred to here as the New Bay Pond area, is on the south side of Notre Dame Bay, and contains a diamond-drilled, but otherwise undisturbed, pyritic, massive-sulphide, base-metal deposit. This deposit was discovered by Noranda Exploration Company Limited in 1971, and occurs within the Wild Bight Group volcanic rocks of Ordovician age (Williams 1967, Noranda 1972). The second area, the Daniel's Harbour area, on the west side of the Great Northern Peninsula, contains a number of zinc sulphide deposits, which occur within Lower Ordovician carbonate rocks. The first of these deposits, which are owned by Newfoundland Zinc Mines Limited, was discovered in 1963. Some of the smaller deposits have been trenched, but the majority are undisturbed.

In each area, both reconnaissance and detailed geochemical studies were carried out. The reconnaissance studies comprised both lake water and sediment sampling, together with stream sediment sampling. The more detailed studies involved the sampling of soil, upper till and basal till in the immediate vicinity of the known deposits in each area, in order to detect and delineate the base-metal dispersion patterns from the patterns in each of these media.

In conjunction with the geochemical studies carried out by Hornbrook and Davenport, reconnaissance studies to determine the nature and provenance

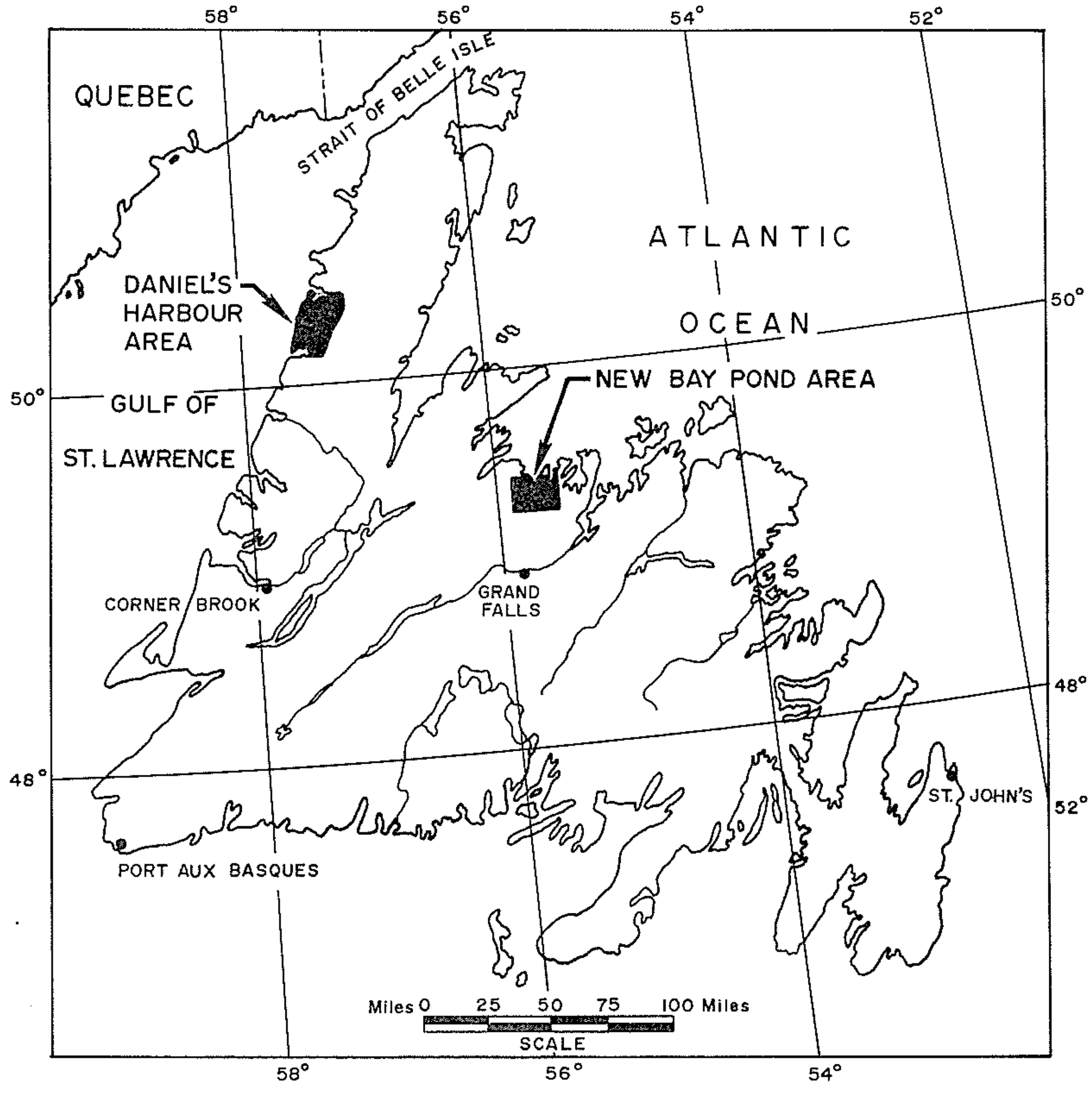

Figure 1 Location of New Bay Pond and Daniel's Harbour Areas, Newfoundland.

of the Pleistocene drift were carried out by Grant. The purpose of these Pleistocene studies was to augment the available scanty data on the Quaternary geology of the two study areas, and to facilitate the interpretation of the geochemical data.

These pilot studies are a part of a continuing three-year geochemical exploration program, and form the basis for the development of the optimum techniques for geochemical exploration in these two types of terrain. Although the studies were intended primarily to guide the development of this program, the results of these studies may be of interest to companies planning to carry out base-metal exploration in similar terrains in Newfoundland.

SAMPLING METHODS

Lake Sediments - The effectiveness of regional geochemical lake sediment surveys in Canada has been, and is, a subject of some controversy. In certain areas, success or qualified failures have been the result, but, in far too many cases, such surveys result in uninterpretable data. According to Timperley *et al.* (1973), the predominant reason for some drainage system (lake sediment) surveys producing confusing results in the Canadian Shield has been the unqualified grouping together of unlike sample media and attempting to interpret subsequent analytical data as though all sample media collected were the same.

Parameters relevant to lake sediment sampling conditions in Newfoundland are basically similar to those of the Canadian Shield because the two areas have many common environmental features including Boreal forest cover, climate, topography and the presence of till. Study areas were located in forested areas of Newfoundland that are comparable to the Canadian Shield excluding the barren regions. Thus, a discussion of lake sediment sampling problems in the Canadian Shield is applicable to the study areas in Newfoundland.

In regional programs more attention should be given to the type of lake sediment sample collected and the location of the sample site in the lake. Ideally, what is required of a sample and/or site is: the sample is dominantly composed of fine material, less than 230 mesh ($<63\mu$) which may or may not include an organic fraction; the sample has homogeneity of composition from lake to lake and finally, the site and sample composition provide an element content that is representative of the total lake basin drainage system. Thus, factors controlling these requirements should be considered when determining sample type and site location in lake sediment surveys. Factors would include the origin or source of the sample material, and processes active in the chemical, physical and biological conditions that influence the composition, mode of transport and sedimentation of lake sediments. Original sources of lake sediment sample material are related to the surrounding bedrock, till, vegetation and adjacent stream and lake sediments. Sedimentation and transport are controlled by the chemical, physical and biological environmental processes in the lake, in its inflow and outflow drainage and in surrounding rock, till and vegetation. Composition of the sediment sample at the sample site can be very much changed from its original composition at its source. Changes in composition of the sediment occur because of the influence of the above processes acting individually or combined to different degrees during transport, sedimentation and after deposition depending upon the ultimate location of the sediment in the lake. For example, shore or near-shore lake sediments derive much of their material from adjacent higher ground by erosion and solifluction, and wave and shore current activity whereas centre lake bottom sediments derive most of their material from sedimentation of suspended matter, (Thomas et al. 1972). Obviously then, centre lake bottom sediments contain material that is more representative of the total drainage system than a near-shore sediment, a major requirement for regional surveys. Assuming that the bedrock, till and vegetation throughout the total drainage system of a lake are similar, then it would appear that near-shore and centre lake bottom sediments would be similar in composition and element assemblage. This is usually not the case. Many processes influence the sediment material, both during transport from its source to place of deposition and after deposition, frequently radically changing its composition and trace element content. Different processes act on the material in different ways depending on whether the material is deposited in the centre lake basins or near the shore in shallow water.

Briefly, the following are among other processes or factors probably more critical in their relationship to shore sediments than to centre lake sediments: lake level fluctuations; seasonal or cyclic variations in pH, Eh, temperature and dissolved gases; sedimentation of a wide size range of particulate material; spring run-off; fall accumulation of organic debris near the shore facing prevailing winds; biological activity; compositional and particle size variations in inlet and outlet bays; variations in organic content (localized peat bog drainage into bays); local influence by contamination or ground water input. Some factors such as spring and fall turnover do effect both centre and near-shore lake environments. Centre lake bottom sediments however should provide the best opportunity to obtain a homogeneous lake sediment sample within a lake and among different lakes as well as being the most representative material of the drainage system as a whole relative to shore sediments.

In the New Bay Pond and Daniel's Harbour areas organic sediments were collected at or near the bottom in the approximate centre of the sample lake or from deeper basins in large lake bays. Shore or nearshore sediments were not collected. Lake sediment samples from the New Bay Pond area were generally more homogeneous than those from the Daniel's Harbour area. Total organic matter content estimated from weight loss on ignition of the New Bay Pond area samples ranged from about 5 to 55 per cent with a mean of 26 per cent, while those from Daniel's Harbour ranged from 5 to 65 per cent with a mean of 15 per cent.

Lake sediment samples were collected by means of a weighted, hollow, pipe-like sampler having a one-way valve in its lower section (see Fig. 2). The valve prevented loss of the sample during retrieval of the loaded sampler from the lake bottom. Sampling was carried out from the pontoon of a helicopter by lowering down, or allowing the sampler to free-fall through the water to penetrate the organic-mineral soil accumulation at the lake bottom. After the sampler was retieved, the sample was shaken out of the lower section, examined, and transferred to paper sample bags. Features of the sample and sample site such as water depth, colour and pH, composition of the sample and nature of the surrounding terrain were recorded.

Lake Waters - Two lake water samples were required for analysis: one for Hg and the other for Cu, Zn, and Ni determinations at each lake sediment site. Samples 500 ml. in volume were collected by hand approximately 8 inches below the surface of the water in polyethylene bottles. Bottles were rinsed at least twice at the sample site with lake water prior to collection. Features recorded at the site for lake sediment samples were applicable to water samples.

Stream Sediments - Streams in the New Bay Pond area were suitable for sampling except in certain parts of the southern and western portions, where drainage is poorly developed and intermittent in large upland plateau peat bogs. At Daniel's Harbour drainage is irregular with springs, sink holes and intermittent drainage associated with the karst terrain. Uniform sample site distribution at the desired sample density was not possible in either of the study areas. During sampling an attempt was made to avoid organic material and collect only the finer silt- and clay-rich sediment. At Daniel's Harbour

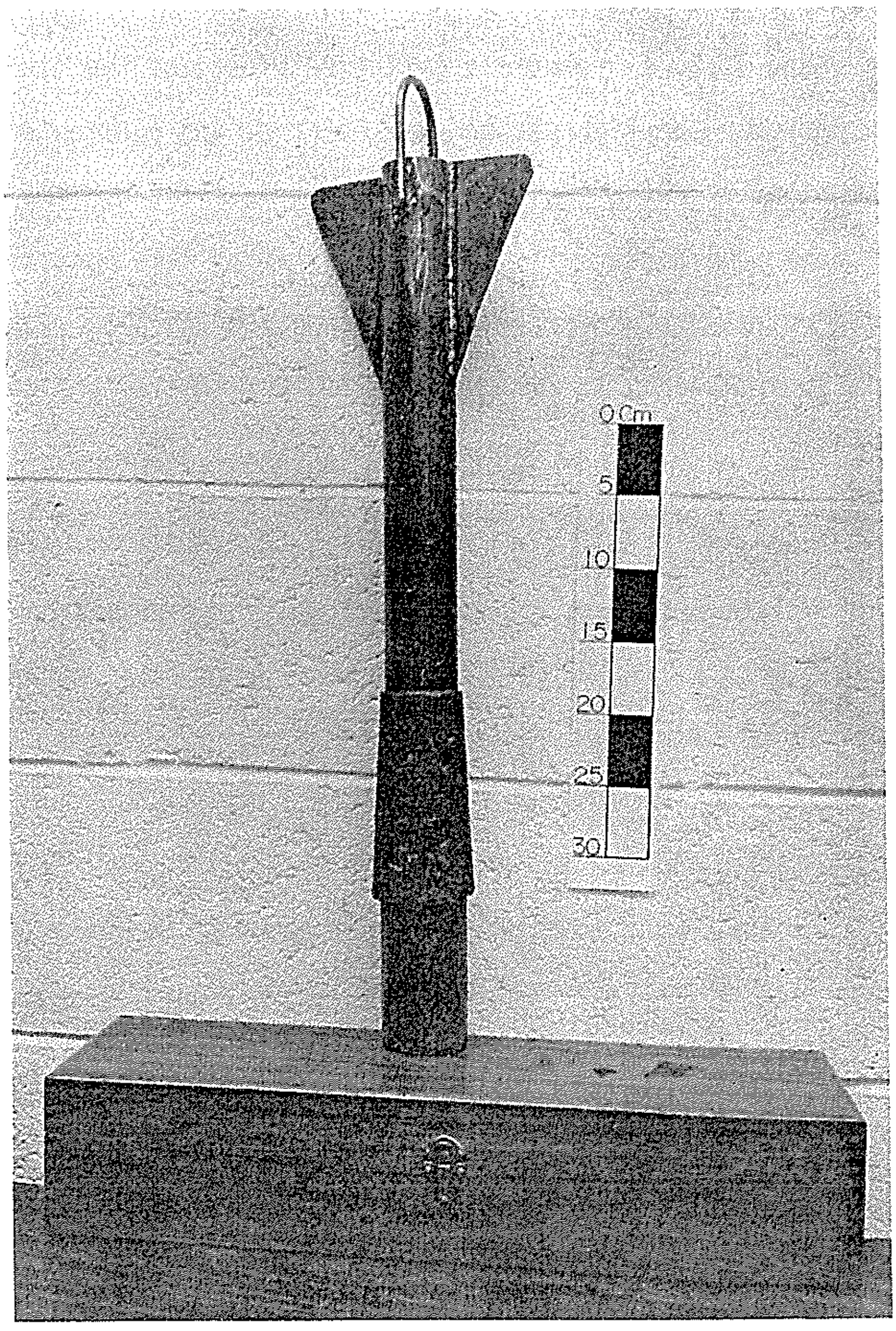

Figure 2   Lake sediment sampler .

the problem was primarily to avoid organic material and at New Bay Pond to collect sufficient fine material to constitute a sample. Sediment samples were routinely collected at least every 1,000 feet along stream beds. They were also collected at stream junctions, at short streams between closely spaced lakes and where possible on intermittent streams. In the figures of this report intermittent streams in drainage systems are depicted as solid lines rather than the more conventional dotted lines for visual clarification. Samples were collected by hand from two or more places at each site and placed in paper sample bags.

Coded field cards similar to that shown on page 23 in Allan et al. (1973) were used for notes and the card descriptions included such aspects as landscape features, presence of Mn stain, Fe stain or both, and the sample composition.

B and C Horizon Soils - Soil horizons at New Bay Pond are not only poorly developed but erratic in occurrence. The lack of soil horizon development and uniform distribution prevented realistic use of soils as a geochemical sample medium. Soil development, when present, was usually related to stands of deciduous forest growing in the large upland bog plateaus. Soil samples were collected, where possible, in the vicinity of the base metal deposit.

At Daniel's Harbour, in the areas sampled, soil horizons were better developed and more uniformly distributed, allowing effective and realistic use of soils as a geochemical sampling medium. Soils were collected over and adjacent to known Zn mineralization. The B and C horizon soils were collected by hand from a pit previously dug with a spade and placed in paper sample bags for transport.

Upper till - Upper till samples, comprised of till material at the peat-till interface, were routinely collected only in the New Bay Pond area. Here, the juxtaposition of swamp and well drained areas with consequent soil development precluded the attainment of a uniform sampling coverage of upper till samples, hampering the comparison of metal distributions between this medium and the basal till. At Daniel's Harbour, bog coverage in the area of basal till sampling was minor, and therefore upper till material was not sampled. New Bay Pond upper till samples were collected at an average depth of 6 feet using a standard soil auger or a Hiller peat sampler. Frequently, water saturation of material at the interface prevented sample recovery. Samples were stored in paper sample bags.

Basal till - Till sampling has been carried out by different techniques for many years primarily for the detection and definition of element dispersion haloes or down-ice dispersion fans in the till generated from a bedrock source. Descriptions of some of the techniques available would include the following: basal till sampling by a truck-mounted Failing rotary drill (Fortescue and Hornbrook, 1969); till sampling by a Nodwell mounted dual tube rotary drill (Skinner, 1973); lodgement till sampling from fresh exposures on watercourses and ditches (Shilts, 1973); basal till sampling by a portable Pionjar machine (Hornbrook and Gleeson, 1972).

In recent years, interest in, and use of, the Pionjar technique is increasing because of certain advantages it has relative to other techniques, including low capital and operational costs.

For this program, basal till samples were collected by means of a Pionjar BR-52 machine, XRT drill rod and a custom built point and sampler. The technique and equipment have been developed and described by Gleeson and Cormier (1971). The sampler and point are shown in (Fig. 3).

Generally the technique used was as follows. Firstly, the drill rod and point were driven down to bedrock to obtain the thickness of till. Secondly, the sampler was exchanged for the point after pulling the rod. Thirdly, at a new hole, about a foot from the first hole, the sampler was driven down to within one foot of bedrock. By rotating the rod at surface, the central part of the sampler core tube was withdrawn leaving a hollow core tube approximately 6 inches long. Fourthly, the sampler was driven the remaining distance to bedrock achieving approximately 100 per cent over-drive to pack the hollow sampler core tube with till material. Fifthly, the rods and sampler were withdrawn using a jack and the sample was recovered from the core tube by extruding it with wooden dowelling into a paper sample bag.

Assuming suitable equipment is available the rate of collection by this technique varies considerably depending almost entirely on the nature and thickness of the till. For example, in the New Bay Pond area a two-man team generally achieved 4 holes sampled per 8 hours on site where equipment

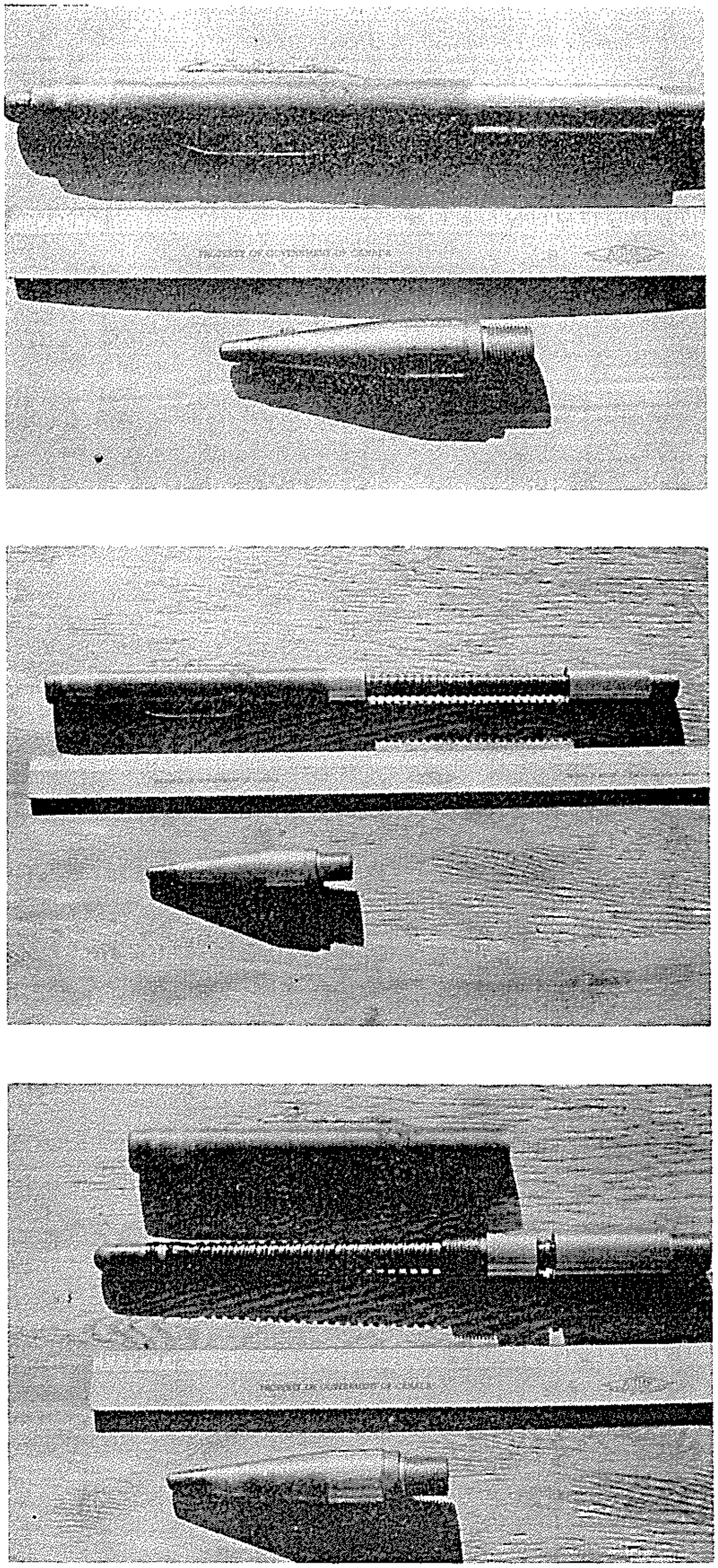

Figure 3 Till sampling drill point and sampler: above — sampler with sample chamber closed; centre — sampler with sample chamber open; below — sampler dismantled.

was packed 400 feet between sites and the 10 to 15 feet of till present was difficult to penetrate. It was not unusual to have difficulty in retrieving the full sampler in this till because of the boulders and cobbles present. Under optimum till conditions the above rate can be easily exceeded and samplers of larger capacity can be used. Till conditions at Daniel's Harbour were more amenable to this technique than at New Bay Pond. In both areas basal till samples were collected over and adjacent to known sources of mineralization in bedrock and, in places, profile sampling was carried out.

SAMPLE PREPARATION

Sediment sample drying and water stabilization procedures were done in the field base camp while the remaining sample preparation was done at the Mineral Development Division Base Camp laboratories at Springdale, Newfoundland.

Lake and stream sediments, B and C Horizon soils and till samples were collected in paper sample bags to facilitate air drying carried out at ambient temperatures.

Prior to stabilization, pH measurements were completed on water samples in the field base camp using a portable pH meter. Lake and stream waters were rendered stable in the field no later than the evening of the day they were collected. Water samples for Hg determination were stabilized by the addition of 5 ml. of 5% w/v $KMnO_4$ and 25 ml. of concentrated H_2SO_4 and those for Cu, Ni and Zn determinations by the addition of 5 ml. of concentrated HNO_3.

Dried sediment and till samples and stabilized water samples were periodically transported to the laboratories at Springdale.

At Springdale, all sieving was carried out with stainless steel sieves having the screen fixed to rim with epoxy resin and all sieve cleaning was carried out with compressed air and clean paint brushes. Lake and stream sediments, B and C horizon soils and upper till material were dry sieved to obtain the minus 80 mesh ($<170\mu$) portion for analysis. Basal till samples were dry sieved to obtain three fractions: coarse fraction, plus 50 mesh, ($>297\mu$); intermediate fraction, minus 50 ($<297\mu$) plus 230 mesh ($>63\mu$) for heavy mineral separation; and the fine fraction, minus 230 ($<63\mu$). The coarse fraction was retained for future mineralogical examination, primarily for presence of sulphides and rock composition. The fine fraction was ready for digestion without further preparation. Heavy liquid separation using tetrabromomethane, specific gravity 2.96, was carried out on the minus 50 ($<297\mu$) plus 230 mesh ($>63\mu$) fraction to obtain a heavy mineral fraction (HMF). The heavy mineral fraction obtained was analyzed, and the light mineral separates retained. Water samples required no further preparation prior to analysis.

Percentage weight loss on ignition was determined for most lake and stream sediments. Unfortunately, some samples did not have sufficient material for this determination. Briefly, a sample was heated in an oven overnight at 110°C to drive off excess moisture and weighed. The sample was ignited in a muffle furnace on a 3-hour-long, time-temperature controlled rise to 500°C where it remained for an hour. The weight before and after ignition was used to calculate percentage weight loss of combustibles and volatiles providing a measure of each sample's total organic matter content.

ANALYTICAL METHODS

Lake and stream sediments were analyzed for Fe and also together with B and C horizon soils and till samples for Cu, Zn, Pb, Co, Ni, Ag and Mn. New Bay Pond stream sediments and minus 230 mesh (<63μ) till samples were analyzed for As. In addition, the above sample types from the New Bay Pond area were analyzed for Hg. Lake waters were analyzed on one sample for Cu, Zn and Ni with a separate sample for Hg.

The Cu, Zn, Pb, Ni, Co, Ag, Mn and Fe contents of the particulate samples were determined by atomic absorption spectrophotometry. A 200 mg aliquot of sample was digested in 3 ml of a 4M HNO_3 - 0.1M HCl mixture at 100°C for 90 minutes. Arsenic was determined colorimetrically after a hot concentrated HNO_3 - $HClO_4$ digestion.

Mercury in both particulate and water samples was determined by a cold vapour atomic absorption technique, which is described for particulate samples by Hornbrook and Jonasson (1971), and for both waters and particulate samples by Jonasson _et al_. (1973). Essentially, mercurous and mercuric ions are reduced by stannous ions in acid solution to elemental mercury, which is flushed from the system by a stream of air, and introduced into the light path of an atomic absorption spectrophotometer.

Water samples were analyzed for Cu, Zn and Ni by atomic absorption spectrophotometry after buffering with a sodium acetate-acetic acid solution and addition of ammonium pyrrolidine dithiocarbamate and solvent extraction into methyl isobutyl ketone. The fuel mixture was adjusted because the solvent is combustible.

DATA PROCESSING

Fluctuation of element content in sediments unrelated to mineralization presents problems in the interpretation of analytical data. Frequently, a significant amount of fluctuation may be caused by the scavenging of elements from water by Fe, Mn and organic material in combination or separately. The scavenging, by precipitation and/or adsorption, causes an element enrichment in lake or stream sediments producing an apparent high concentration of elements.

Rose and Suhr (1971), for example, have used regression analysis to investigate relationships between elements and measured variables such as, in this program Fe, Mn and organic content of sediments.

If the portion of the variability in the element content of stream or lake sediments due to the co-precipitation of Zn and/or Cu etc. with manganese, iron and organic content can be removed, the resultant element distribution will more closely reflect the element distribution in bedrock, and hence the confidence with which high element values may be related to mineralization is increased.

The degree of correlation of elements with either Mn or Fe or organic content is determined by calculating the correlation coefficient between each element and each of these three variables in each data set. If a certain element, for example zinc, is strongly correlated with manganese, the greater part of this correlation may be attributed to co-precipitation of zinc manganese oxides and hydroxides in the stream or lake environment (Horsnail, Nichol and Webb, 1969). The effect of manganese co-precipitation on the zinc distribution may be largely removed mathematically by a procedure known as linear regression. In other cases, zinc may be significantly correlated with both Mn and Fe, and possibly organic content in addition. It may then be necessary to carry out sequential linear regression analysis of Zn against each of the variables Mn, Fe and organic content in turn, thus removing most of the effects of these processes of co-precipitation and adsorption on the zinc distribution. Commonly, however, Mn and Fe are themselves strongly correlated, and thus simple linear regression of Zn (and other elements which are strongly correlated with Fe and Mn) with either Mn or Fe will suffice to eliminate most of the co-precipitation effects with both Mn and Fe. This simplifies the mathematical treatment of the data.

The Fe and organic content of all samples was not determined because of lack of material in certain cases, thus only simple linear regression of elements against manganese is considered in this report, in cases where elements showed a significant degree of correlation with manganese.

Simply stated, the element content of each sample is plotted against the manganese content for all the samples of a particular data set. In the present study, because the element frequency distributions are more nearly log-normal the logarithms of the elements and manganese values are plotted. A straight line is fitted to the data by the least squares method, and the equation of the line is computed, with manganese as the independent variable. The significance of the regression is tested statistically using Fisher's F test to determine whether the regression has led to a significant reduction of variability. A measure of this reduction in variability may be determined by calculating the degree of fit of the line. In, for example, Daniel's Harbour stream sediments, the reduction in variability of Zn on regression with manganese in significant at the 95% confidence level and the degree of fit is 34.4% which is reasonably high. In some cases, when large numbers of samples are involved the regression may be statistically significant, but the degree of fit low. Often in these cases the geochemical significance of the regression is questionable.

Using the computed regression equation and the measured manganese content of each sample, a predicted element value is calculated. Since log transformed data were used in this case, the ratio of the actual element content to the predicted content is calculated for each sample. The logarithms of these ratios are the residual scores. If a residual score is positive, (that is the ratio of the actual element content to the predicted element content is greater than unity), then there is an "excess" of the element in the sample above that which is expected on the basis of its manganese content. For convenience the residual scores are normalized into standard deviation (Std. Dev.) units. This facilitates comparison of the residual element scores with the actual element values of the samples when the latter are also expressed in standard deviation units.

TECHNIQUES EMPLOYED IN PLEISTOCENE STUDIES

The surficial geology of the New Bay Pond and Daniel's Harbour map-areas, as shown on the accompanying maps, (Figs. 4 and 5) respectively and previously summarized (Grant, 1973a,c), is a statement of the configuration of exposed and submask bedrock, and of the origin and composition of the overburden that covers most of these areas. This information is derived largely from airphotos, supplemented by road and aerial reconnaissance, and by observation and sampling of most natural and artificial exposures. The basic premise of airphoto interpretation of the physical environment is that geomorphic patterns are a combination of erosional and depositional features produced by various processes acting on bedrock for varying periods and to differing degrees depending on its structure and lithology. Thus relief patterns are a direct expression of both the structure of exposed and submask bedrock, as well as of the origin and probable composition of the unconsolidated covering materials. In short, relief reveals origin and that in turn implies distinctive composition.

NEW BAY POND AREA

The work in this area, located about 25 miles north of Grand Falls, was carried out between the 24th. of June and the 21st. of July. A base camp was established on the west shore of New Bay Pond, which was connected by a private road to the Trans-Canada Highway. Although a number of logging roads exist in the area, most of these had been trenched and were impassable to four-wheel drive vehicles. Most of the work was carried out to the north of the base camp, within the Robert's Arm 1:50,000 topographic map sheet 2E/5, and the field parties were flown to and from base camp to their sampling areas each day by a Bell 47G-2 float-equipped helicopter.

The topography of the area is fairly rugged, particularly near the coast. The highest point in the area is 1177 feet above sea level, and most of the area lies below 1,000 feet in elevation. Many of the hills are small, steep-sided features. Bogs are widespread throughout the area, and large expanses of bogland are developed on upland plateaus in the southern part of the area. Drainage consists of a system of streams and lakes whose general trend reflects the northeasterly and northerly structural trends of the underlying bedrock. The area is densely forested, with the exception of the boglands, with a mixed boreal forest type of flora. White and black spruce, white pine, balsam fir and white birch are the most abundant species.

GEOLOGY OF THE AREA

Briefly stated the study area is underlain by a succession of mafic to felsic volcanic rocks of Ordovician age (Fig. 6). These rocks belong to the Wild Bight Group (Williams, 1967 and Noranda Exploration Company Limited, 1972), and are comprised of mafic pillow lavas, and coarse agglomerates and lapilli tuffs of intermediate composition, together with locally developed rhyolite and porphyritic rhyolite or rhyolitic quartz porphyry. Carbonaceous shale, cherts and fine-grained tuffs are intercalated with mafic and intermediate volcanic rocks in places. In the southwest part of the area lies a portion of a composite gabbroic-dioritic-granodioritic intrusive body, and a similar, though smaller body is exposed on the eastern margin of the area. Small diorite intrusive bodies are scattered throughout the area, and basic to ultrabasic dykes and sills have been recorded from the vicinity of the sulphide deposit discovered by Noranda Exploration Company Limited (R. Hawkes, pers. comm. 1972). The study area occupies the centre of a regional anticlinorium (Williams, 1962), and the dominant trend of the folds in the area is northerly to northeasterly. Faulting in the area is widespread, the major faults striking northeast, together with a second, less well-developed, northerly-trending set.

MINERALIZATION

Within the study area, three distinct types of base-metal mineralization are known. The most promising type from an economic viewpoint is the pyritic polymetallic massive sulphide deposit discovered by Noranda Exploration Company Limited. The following brief description of the deposit is based on data provided by Noranda Exploration Company Limited. This deposit, which has a strike length of about 1,700 feet and a maximum width of about 200 feet at suboutcrop, occurs in felsic volcanic rocks - rhyolitic agglomerate, porphyritic rhyolite, and rhyolitic quartz porphyry. Pyrite is the dominant sulphide, together with fine-grained sphalerite and chalcopyrite. The sulphides occur as a matrix to the agglomerate and as a massive sulphide body in which quartz is the principal gangue mineral. A bulk sample assayed by Noranda Exploration Company Limited indicated a grade of 0.79% Cu, 0.58% Zn, 0.38% As, together with lesser concentrations of Co, Sb, Pb, Bi, Ni, Ag and Au. The Hg content of the sulphides is substantial. Values of the order of 12 ppm Hg were found in the present study in random sulphide samples indicating that in sphalerite, where Hg is preferentially found, the Hg content would be about 200 ppm. Distinct zinc-rich and copper-rich zones are apparent in the deposit. A number of electromagnetic anomalies are present in the vicinity of the deposit, having essentially similar strike directions to the deposit. The stronger of these are due to graphitic horizons, and most of the remainder are very weak anomalies. The deposit of Noranda Exploration Company Limited appears to be very similar to the Lockport and Indian Cove sulphide deposits, which lie just outside the area to the north, on the east and west sides of Seal Bay, respectively. The Noranda deposit is the largest of these three, and is undisturbed except for diamond-drilling, and was therefore chosen for the orientation study.

Two other types of mineralization have been reported in the area by Potter (1956). Pyrite with or without chalcopyrite has been found as stringers in basalts and sheared basalts. In addition, pyrite-chalcopyrite-sphalerite stringers have been found in some sheared or altered dioritic intrusive bodies. Both these types of mineralization occur on the east side of the area, and have not been found to be of economic significance.

SURFICIAL GEOLOGY

The northern third of the area near the coast is characterized by large tracts of exposed or sparsely tree covered bedrock (R;Rc) that is heavily ice-scoured and shaped into large rôches moutonnées aligned north-northeast (020^{0}) parallel to the presumed maximum or predominant ice-flow direction (Fig. 4). In coastal re-entrants small areas of marine sediment (M,Mv, Md) cling to rock slopes, and in the lower reaches of coastal valleys are tongues of emerged estuarine and marine sediment composed of sandy gravel overlying dense stony pelite that was deposited up to elevations of 200-250 feet during the postglacial submergence that encroached up the bays as the glaciers retreated about 12,000 years ago. The marine facies grades inland and intertongues with overlapping small glacial fans (GFf) and post-glacial alluvium (Fp); all have been deeply dissected by stream erosion during the subsequent fall of sea level, although a renewed submergence is again drowning the estuaries and their contained sediment.

The rocky coastal zone is succeeded farther inland by a transitional zone of rock knobs, crag-and-tail hills and patches of thin till (Mv/Rc/R). The south half of the map-area is mainly extensive areas of thick streamlined till (Md), plastered on both up- and down-ice flanks of bedrock prominences. On valley sides the till and interspersed bedrock knolls are locally deeply dissected and channelled by former streams of glacial meltwater (Mc; Re) that reveal the pattern of deglacial downwasting and up-valley recession of ice tongues. Larger, broader valleys are occupied by fields of hummocky and/or ridged disintegration moraine marking areas of final ice dissipation. Paradoxically, the valleys exhibit more exposed bedrock or thinner till cover, whereas the rock prominences are flanked by deep till cover and were apparently the loci of subglacial accretion. In detail, each hill is surmounted by a scoured crag anchoring a ramp and tail of till, as if there were a later degradation of the till surface by a change in ice-flow regime.

The evidence of direction and sequence of ice-flow supports this. The gross parallelism of bedforms (drumlinoids, crag-and-tail, rôches moutonnées) corroborated by more than fifty striation measurements show that the main ice-flow was to the north-northeast ($025^{\circ} \pm 10^{\circ}$). However, more than half the striation occurrences showed one, and sometimes two, later sets trending easterly ($080^{\circ} \pm 30^{\circ}$), that were often found on secondary bevelled facets truncating the primary stoss-and-lee forms. An outcrop showing all three phases of ice movement may be, seen on an island in New Bay Pond. There is little evidence of associated drift transport except for a slight deflection of till tails evident northeast of New Bay Pond. Moreover, most of the multiple striated outcrops were covered, not by basal till, but by loose, rubbly ablation till, signifying that the later movement had only a superficial influence. The reason for this later divergent flow is inferred from the fanlike pattern that becomes more easterly to the south and converges on an area of disintegration moraine south of Frozen Ocean Lake, interpreted as the site of a recessional remnant. The westward rather than southward retreat in the New Bay Pond sector, shown also by the orientation of side-hill meltwater channels, is believed related to the proximity of a major calving bay (Bay of Exploits) to the east, that imparted a westerly component of retreat relative to the southerly influence of marine incursion proceeding inland from Seal and Badger Bays on the north.

Some aspects of the surficial geology are relevent to geochemical exploration. The following terrain conditions may be cited: 1) extensive organic cover saturated by high water tables, often perched on hard pan horizons; 2) the focus of metal dispersion lies in an area of relatively thin till reworked by meltwater, that produced abrupt changes in stoniness, relief, introduction of fluvially transported material from outside the area, and a reduced proportion of fines in surface horizons; 3) the juxtaposition of contrasting terrains, such as drumlinoid till areas signifying active basal shear and scouring, and ribbed hummocky moraine associated with impeded flow and basal detachment; 4) the unusual combination of thick till around rock hills with exposed bedrock in valleys, possibly related to the transition from the outer 'driftless' zone to the inner 'morainal' zone (Jenness, 1960); 5) a two- or threefold sequence of glacial flow directions, with the later movements of lesser, but still largely unknown importance.

To complement the geochemical analysis of 'micro-detritus', glacial dispersion of rock fragments was studied by measuring the content of various lithologic species in the tills. The amount of transported granite was chosen as typical, to depict the influx of foreign materials from source terrains beyond the target geochemical area. Granite material transport amounts to 40 per cent in the tills on, and near, the base-metal prospect, which is three to four miles down-drift from the granite terrain. Hence, without scaling down to allow for the relatively small mineralized subcrop area, theoretically a similarly extensive metallized dispersion fan could be expected down-ice from the orebody.

SOIL DEVELOPMENT

During the past 11,000 - 12,000 years since deglaciation, soil profiles have developed in the till. The nature of the soil profiles formed is related to the drainage regime of the tills. In freely drained areas podzols are well developed, whereas gleyed podzols, gleysols and organic soils are developed in areas of impeded drainage.

Peat bog development has occurred in two main ways. Small bogs occupy local depressions in areas of moderate topographic relief. Extensive, open bogs, typically domed, occupy flatter upland areas. Within these bogs, small areas of bedrock or moraine crop out, and podzolic soils may be developed in the higher, freely drained areas of these morainal deposits. Thus in many places a variety of soil types are present within a small area, making it impossible to sample any particular soil type consistently.

GEOCHEMISTRY OF LAKE SEDIMENTS AND WATERS

Sediment and water samples were collected from 100 lakes in 90 square miles achieving a sample density of slightly over one sample per square mile. Sample site locations on Figure 7 show however, that a uniform sample density throughout the sampled area was not possible because of the uneven distribution of lakes. Further, the west and northwest boundaries of the lake study area do not extend as far west as the margin of the stream study area.

Lake water samples were essentially clear and devoid of suspended matter and generally had a pH very close to 7.0. Lake waters were analyzed for Zn, Cu, Ni and Hg but only the Zn data has useful potential. Most of the Zn determinations (Fig. 8) were below the detection limit of the analytical method (1 ppm), and insufficient determinations were obtained for statistical treatment. All Ni and almost all Cu determinations were below the analytical detection limit. The Hg data are described below.

These analytical limitations, which can be overcome, severely limit the usefulness of the present data. The zinc data are plotted (Fig. 8) and high zinc trends comprised of many stations are apparent, which correspond well with areas of high zinc values in lake sediments, which are discussed below. Thus, lake waters may be as effective as lake sediments as a sampling medium for regional geochemical exploration, provided adequately sensitive analytical methods are employed.

Colours and textures of the organic lake sediment sample material observed and recorded in the field were classified. The reliability of such a classification of data is open to question because of the subjective human influences operative when describing parameters like colours, etc. When the classified parameters were compared to analytical data no obvious relationship could be found. This is a desirable result and not unexpected because every attempt was made to achieve homogeneity of sample characteristics when sample sites were selected. In a few samples, the elements values were low as expected because they were deliberately collected from a small pond in a plateau peat bog and a sandy gravel bar in an otherwise suitable lake. Centre lake bottom organic sediments appear to provide a suitable medium for regional geochemical surveys when aforementioned appropriate considerations are exercised in the selection of sample sites.

The distribution of Mn in the lake sediment sample area is shown in Figure 9. Strong, widespread areas of high Mn values occur in the eastern portion of the area while lower Mn values occur adjacent to the South Twin Lake granodiorite. The distribution of Mn in the east shows no obvious relationship to the bedrock geology and only a vague relationship to the terrain type that is dominantly rock or rock covered with a thin veneer of till. Mn values are log-normally distributed and range from less than 50 ppm to 26,000 ppm with a log mean of 333 ppm. Variations of this order will influence element values in view of the well know scavenging action of Mn.

Regression against Mn was carried out for Cu, Zn, Pb, Ni, Co, Hg and Ag. Hg was also regressed against the organic content. The patterns of distribution for all residual element data were essentially similar, because they all had the same general trend with minor variations in the location of the strongest anomalous zone in the trend. Therefore only Zn and Cu as the significant metals of economic interest will be discussed in detail and where appropriate other element data will be mentioned. The effect of regression can be assessed using Figures 10 and 11. Here, respectively, actual Zn and residual Zn distributions are plotted in the form of anomaly maps. In both cases standard deviation units are used for contouring the data. It is immediately evident that the major eastern trend of high Zn persists after regression in the residual Zn plot. There have been important changes in the size, location and strength of anomalous zones within the trend however. Further, similar significant changes have occurred in the central and western portion of the study area. Thus, residual Zn plots provide a superior definition and a more meaningful relationship to the element distribution in bedrock when the influence of Mn is removed. Similar useful changes were produced through regression of other element data. Therefore, regression analysis facilitates the interpretation of the relationship between element anomalies and their source.

The eastern half of the study area has a large horseshoe-shaped residual Cu and Zn anomaly (Figs. 11 and 12 respectively), containing a few multi-station strongly anomalous zones. The western half has only a few separate small anomalies, some of which are supported by high Cu or Zn values at adjacent stations.

Regional lake sediment surveys are not designed for, nor are they necessarily capable of, detecting individual mineral deposits. The base-metal prospect was not detected by an anomalous element expression in lakes adjacent to the prospect. It is, however, located within a geological area that has been geochemically defined as a favourable area for further study.

Regional lake sediment surveys are designed to delineate trends in element distribution where abnormally high element concentrations exists. Trends can be locally modified by geochemical haloes about individual mineral occurrences. For example, the copper-rich sulphide occurrence at the north end of Long Pond and Trout Lake generate an adjacent strongly anomalous Cu zone in the horseshoe-shaped Cu trend (Fig. 12) but not a strongly anomalous Zn zone in the Zn trend (Fig. 11) because Zn mineralization is weak or absent. Other strong zones within the "horseshoe" anomaly may be generated by similar sulphide occurrences or by mineralized till which has been transported from a source in an up-ice southwest direction.

Generally, the size and strength of geochemical anomalies are directly related, not to the tonnage of a sulphide body at depth, but to the amount of mineralized material exposed at the suboutcrop surface and/or the amount of mineralized material removed by glaciation and presently distributed in a down-ice direction in the till. Another major factor is the intensity of weathering and leaching processes, which lead to solution or particulate transport of metals and eventually their chemical or physical incorporation into a sediment. Generally where weathering processes are inhibited by features of the environment such as the huge plateau peat bog over the base metal prospect, it is unlikely that leaching and solution transport over any great distance will take place. The geochemical halo related to the prospect, with respect to lake sediment surveys, is undetectable, or in fact does not exist in this case. Weathering processes are generally active in areas of high local relief, outcrop, thin veneer of till, or where the till is porous and permeable to groundwater.

The felsic volcanic host rock for the prospect is shown in only a few locations in the geology map (Fig. 6) but in fact may also be present elsewhere within the predominantly intermediate volcanic, unit 2. The large anomalous Cu-Zn zone in the southeastern part of the horseshoe anomaly may be caused by mineral occurrences in the felsic volcanic rocks north of Lewis Lake, or in unknown felsic rocks north and west of the lake. Pb, Ni and Ag anomalies are also found north of Lewis Lake. The main element anomalies here could also be generated from sulphides in rocks originally located north of Great Lewis Lake and glacially transported northeastward. Till cover is thin or absent here suggesting a relatively local source for the lake anomalies rather than a remote source and long distance transport of till. The other larger and stronger Cu anomaly associated with a weaker Zn anomaly occurs 2.5 miles southwest of Seal Bay in a terrain that is dominantly exposed bedrock. Ag, Pb, Ni and very strong Co anomalies are also present here. Again, the anomalies could be locally derived but they could also be generated from mineralized felsic volcanic rock glacially transported northeastward from near the felsic rocks containing the base metal prospect. Till cover north of the prospect is abundant and may conceal unmapped felsic rocks on the margin of the mafic volcanic belt (Fig. 6). Both the Noranda base metal prospect and the Indian Cove sulphide deposit occur in felsic volcanic rocks found on the margin of the mafic volcanic belt (Fig. 6) that is delineated by the strong aeromagnetic anomaly shown in Map 4460G,(Geological Survey of Canada, 1969). Thus all the marginal areas of the mafic volcanic belt should be examined by follow-up work in addition to those marginal portions having related lake sediment anomalies.

Obviously, regional lake sediment surveys of this type do develop strong, persistent, multi-station anomalies permitting concentrated follow-up studies in appropriate areas. Areas for follow-up work may be chosen because they contain anomalies, or through interpretation, they can be shown to contain the possible source generating the anomaly. Therefore, almost all of the eastern half, including the mafic volcanic belt, and only certain locations in the western half of the area warrant further study. In a similar manner several hundred square miles of the Notre Dame Bay region could be examined to provide an initial screening process to delineate favourable and reduced areas for further study.

Thus the regional lake sediment survey has defined trends with significant Cu, Zn, etc. values for follow-up work and indicated anomalous areas for intensive study.

The most direct method to follow up the lake sediment survey results was to carry out stream sediment surveys of the drainage systems contributing to anomalous lakes and their adjacent terrain.

GEOCHEMISTRY OF STREAM SEDIMENTS

Six hundred and seventy-six stream sediment samples were collected over 150 square miles achieving a sample density of between 4 and 5 samples per square mile (Fig. 7). The area of stream sediment sampling included that of the lake sediment survey. This permits an assessment of stream sediment data for regional surveys, and of the reliability of lake sediment survey data to discriminate between favourable areas and those areas designated for no further study. Sample site locations in Figure 7 show that there are several portions of the study area particularly near the east and west margins that are lacking adequate sample coverage. The Mn and residual Zn and Cu data reported here, Figures 13, 14 and 15 respectively, were for all sample stations,but the As data (Fig. 16) were not, because samples from certain station samples lacked sufficient material for analysis. Among the 45 sample stations without As data are a few that have anomalous Cu and/or Zn contents. Figure 7 shows sample stations where As data is absent and they are also identified in Figure 16.

Log normal Mn values range from less than 50 ppm to over 50,000 ppm with a log mean of 1400 ppm. Some sample stations had Mn values in excess of 10%. Mn distribution in Figure 13 shows that Mn is generally highest in the south central and eastern portions of the area. The high Mn values in the peaty terrain of the south central portion were not revealed in lake sediment data (Fig. 9). Low Mn values occur amongst the higher ones reflecting variable environmental conditions. Stream sediments have a tremendous variation in Mn content which will influence, through the scavenging action of Mn in the sediments, their Cu, Zn and As, etc. content. To nullify this influence, regression of Zn, Cu, As, etc. against Mn was carried out.

To demonstrate the effectiveness of the regression, actual and residual As are plotted for the southeastern portion of the study area between Lewis and Great Lewis Lakes in Figure 17, and for reference the Mn values may be noted for appropriate sample stations (Fig. 13). A comparison of As values (Fig. 17) reveals the following. Certain As values, location "A", are emphasized as more anomalous in the residual As plot while other As values, location "B", are suppressed. Thus regression analysis serves to modify the element content at each sample station to produce a more realistic representation of element distribution by the removal of the Mn influence.

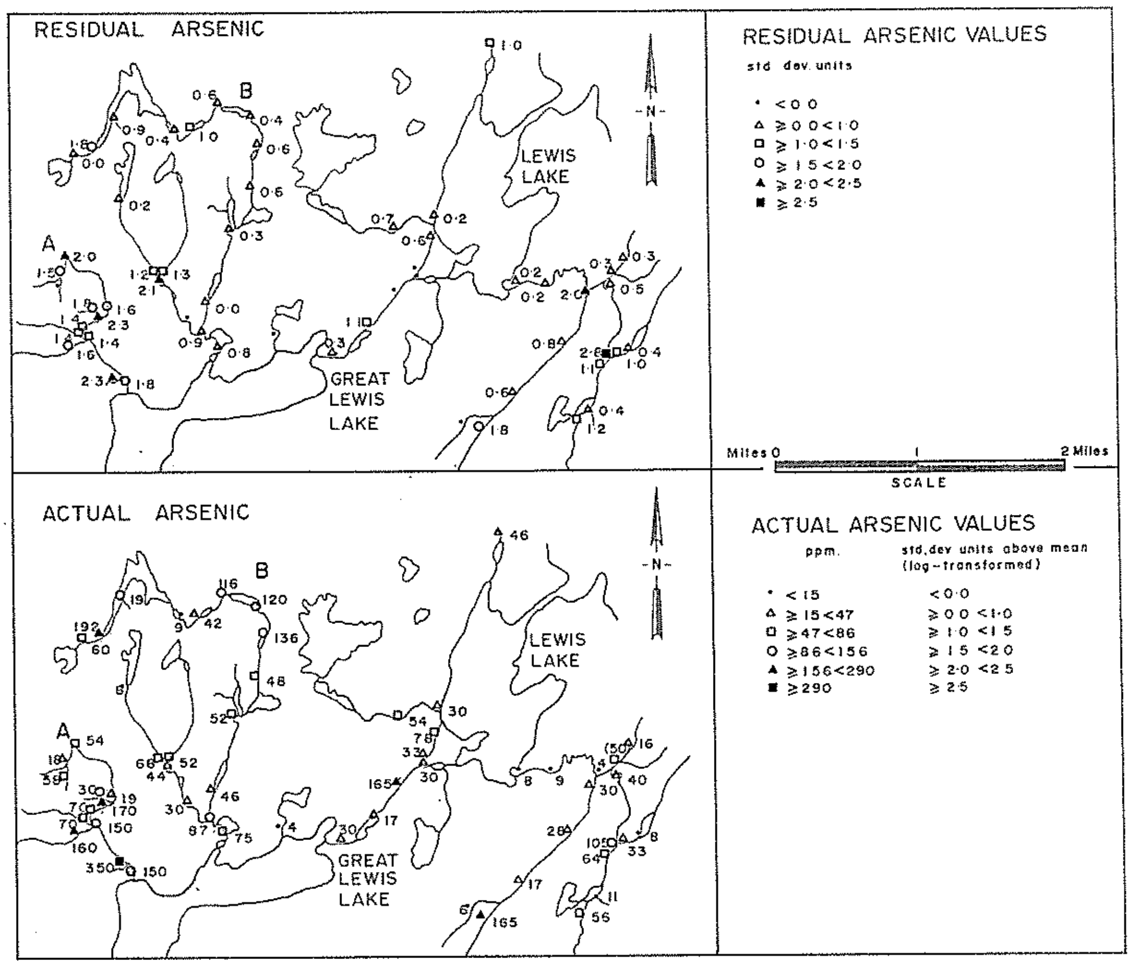

Figure 17 Residual and actual arsenic distribution in stream sediments, New Bay Pond Area.

Only positive residual scores are plotted for the Zn, Cu and As stream sediment maps, in Figures 14, 15 and 16 respectively. Sample stations with negative scores are shown as a location dot. Single station Cu, Zn or As anomalies are too numerous to describe individually and it is more realistic to describe clusters of anomalous stations. Many anomalous clusters do include stations where values are not anomalous. Most anomalous clusters are composed of several stations, some of which occupy a terrain or a unique chemical and/or physical environment different from the majority. Hg will be discussed below. Co, Ni, Pb and Ag were not as effective as Cu, Zn and As although their distribution is similar.

An examination of the Cu, Zn and As maps reveals the following. The most impressive anomalous cluster is located 3 miles southwest of Seal Bay on mafic volcanic rocks. It commences with abruptly anomalous Zn and Cu values on the west side of the cluster, at the margin of a peat bog, and decreases in value in the down-ice-direction eastward where streams flow over intermediate volcanic rocks. Cu and Zn values one mile west of the cluster, on a creek flowing north draining the peat bog, are background and quite low respectively except for one remote Zn value of 1.6 Std. Dev. The terrain overlying the western contact of the mafic and intermediate volcanic rocks, between the anomalous cluster and the stream, is a plateau type peat bog with no surface streams. The Cu and Zn anomalous cluster indicate that the source may be under the peat bog and not west of it. Arsenic values, unlike Cu and Zn, are quite high in the stream down drainage west of the peat bog and decrease farther west but they are scarce at the Zn-Cu anomalous cluster. Zn and particularly Cu are not significantly mobile in the reducing conditions of the peat bog while As may be (Boyle and Jonasson, 1973). It is suggested, therefore, that the spatial distributions of As, Zn and Cu reflect the different weathering processes operating within and away from the bog environment. It is postulated that the source of the As anomaly is within the area of the bog itself where As is mobile but Zn and Cu are not, and that the Cu-Zn anomaly is generated by the weathering of subjacent mineralized material in the tills, this material having been moved northeastwards from the western margin of the mafic volcanic belt. Precipitation of As in the streams takes place because it moves in solution in groundwater out of the reducing bog environment into an oxidizing stream environment, where it precipitates in the presence of iron probably as iron arsenate. In the iron-rich environment of a leached till which underlies the Cu-Zn anomaly, arsenic passing into solution in the zone of leaching is readily precipitated with iron before reaching the stream sediment environment, and hence is not mobile (I.R. Jonasson, pers. comm., 1973). It is further suggested that the bedrock source of both the As and Cu-Zn anomalous clusters is sulphide mineralization under the peat bog which lies over the western margin of the mafic volcanic rocks. It is possible that unmapped felsic volcanic rocks, similar to the host rocks of the known base-metal prospect to the south, are present here. Such a source would also account for the lake sediment anomalies southwest of Seal Bay mentioned above.

Several square miles of terrain in the vicinity of the felsic volcanic host rock of the base-metal prospect are deeply covered by hummocky organic material in the form of large open peat bogs which in places are spruce covered. This organic terrain has inhibited the weathering, solution and transport of Cu and hence the development of Cu stream sediment anomalies. The 2.0 Std. Dev. Cu value northeast of Gull Pond is west of the peaty terrain. Zn is relatively more mobile than Cu under these conditions (reducing bog environment) and shows possible evidence of the prospect in downstream stream sediments where values of 1.5, 2.0 and 2.1 Std. Dev. are found (Fig. 14). Other Zn values northeast of Gull Pond, close to, and upstream from, the Cu values mentioned above are as high as 2.7 Std. Dev. The very high Zn value, 4.7 Std. Dev., south of the prospect warrants further study if resampling confirms the value because the lake sediment sample there also has a positive residual Std. Dev. Significant As values of 4.5 and 1.8 Std. Dev. occur downstream from the prospect where high Zn values over 2.0 Std. Dev. were found. There is no As data for the sample station with 1.5 Std. Dev. Zn content. A grab sample from angular sulphide float found in a stream bed approximately 1,500 feet northeast in a down-ice direction from the prospect (Fig. 18) contained 432 ppm As. A 4.5 Std. Dev. As value found in the stream sediments routinely collected only a few hundred feet downstream from the float. The basal till, only 1,000 feet away in an up-ice-direction from the float, has anomalous As content, which persists farther up-ice from and over the margin of the suboutcrop mineralization of the prospect as will be described below. Other As and Zn values of 1.2 and 1.8 Std. Dev. respectively on the next stream north reinforce the interest in this particular area. In fact

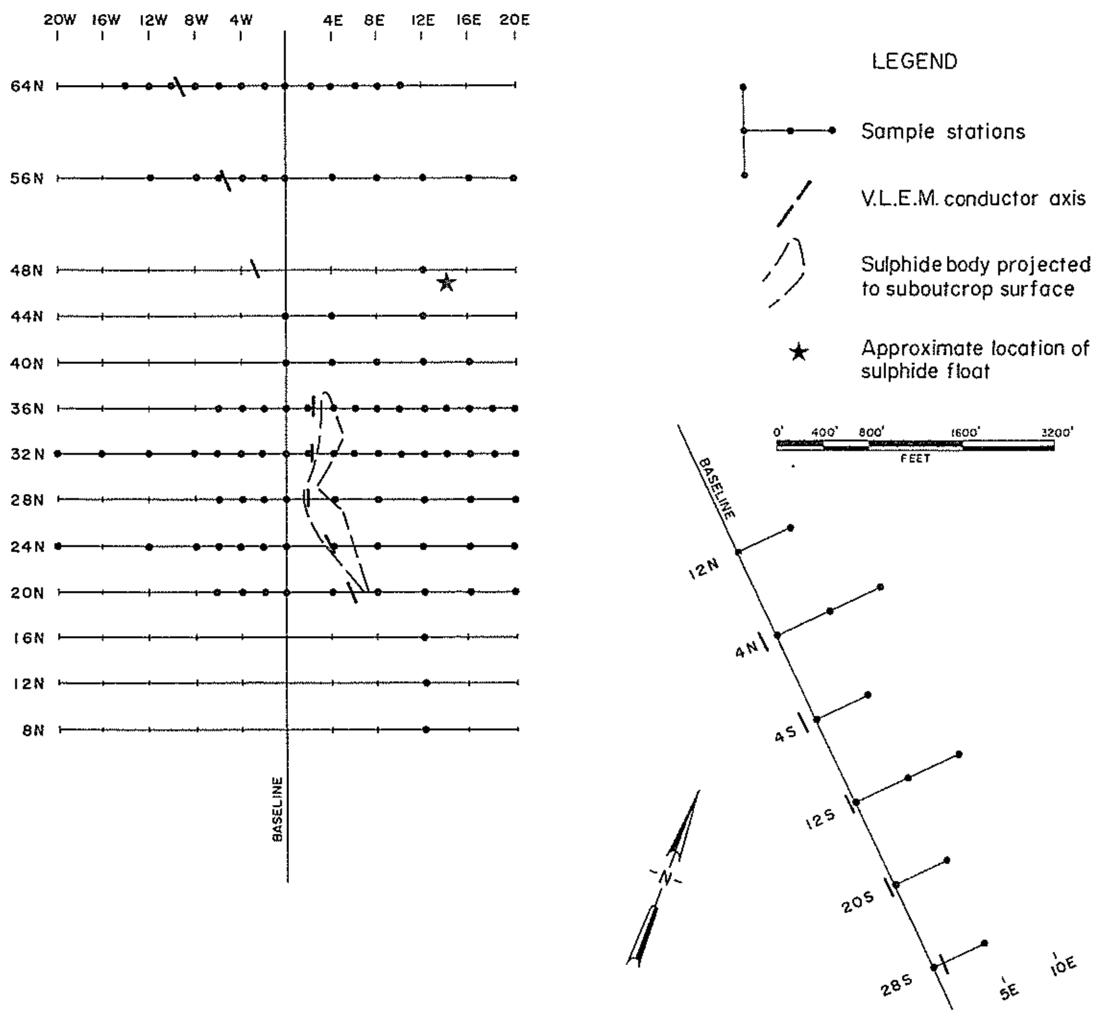

Figure 18   Main sampling grids, New Bay Pond Area.

the Zn- and As-rich stream sediments downstream from the prospect are very close to anomalous till found north of the prospect. As a conjecture, follow-up detailed studies on this particular stream could have led to the discovery of the sulphide float, and eventually to the prospect through basal till sampling techniques discussed later.

Anomalous Cu, Zn and As stations northeast of Gull Pond are generated by a mineralized source that is not likely to be in the granodiorite located less than one mile southwest in an up-ice-direction. Thus, the bedrock source is probably very close and the till movement local, since anomalous stations are unlikely to be derived from a source several miles away in an up-ice-direction. These anomalies may be developed directly from weathering of bedrock or on mineralized till locally derived.

The highly anomalous As site (4.3 Std. Dev.) and associated threshold level As values, approximately 2 miles north-northwest of the prospect are probably again very close to a mineralized source. The source is probably located southwest to west-southwest in an up-ice direction. The lake farther upstream from the anomalous As site is not anomalous, but streams flowing into it from the south and northwest have anomalous As content. The location of the anomalous stations suggests that the area immediately north of of northwest part of the lake is favourable. The area is situated on the western margin of the mafic volcanic rocks where, by a short northward projection, felsic volcanic rocks, which only 2 miles south contain the prospect, may occur.

Thus, through an interpretation of data and with geophysical control the prospect could have been discovered, and a picture develops where the western margin of the mafic volcanic rocks is a source of geochemical anomalies under suitable conditions. It is suggested that along the western margin of the mafic volcanic rocks, felsic volcanic rocks similar to those which contain the known base metal prospect may be present in places.

The whole of the area from Lewis Lake to the north end of Long Pond has only three stream sediment samples. Their Zn, Cu and As contents are sufficient to confirm the Cu and Zn sediment anomalies, but do not support detailed interpretation. This area should be resampled to include the sampling of seepages, springs and short, intermittent streams to obtain more information. This area should not be neglected because of the lake sediment anomalies, supporting stream sediment anomalies and the nearby exposure of felsic volcanic rocks north of Lewis Lake. Cu values in stream sediments north of Long Pond are probably related, through glacial movement and down-stream drainage, to the known copper occurrence at the end of Long Pond.

A significant cluster of anomalous Cu, Zn,and to a lesser degree As, values occur in a few square miles of small lakes and bedrock terrain approximately 2 miles northwest of the north end of Lewis Lake. There is little till present and active weathering of bedrock has probably produced the anomalies. Thus the source is likely local because values decrease southwesterly in an up-ice direction, suggesting the movement of mineralized till into this small area from the southwest did not occur. Thorough field studies may reveal gossans that are generating the anomalies.

There is a good cluster of anomalous As values in peaty terrain north of the northwest bay of Great Lewis Lake. Associated Zn and certainly the Cu values are not impressive, but this is not unusual in peaty terrain where relatively, only As is mobile. The anomalies in streams draining the peat bog may be located on mineralized till that has been derived from the west where the felsic volcanic rocks containing the prospect occur. If sulphide mineralization is present in the felsic volcanic rocks under plateau peat bogs south of the prospect, then a possible source may be present less than one mile in the up-ice direction from the As anomalies. Alternately, meltwater streams (Fig. 4) may have carried elements eastward into the area where eventually the Cu and Zn became immobile and As mobile in the present bog-stream system. This interpretation again supports the western mafic volcanic margin as a target area. Till sampling provides a method of evaluating the till element content under the peat bog adjacent to anomalous As stations.

There are substantial As and Cu values southeast of Lewis Lake but the Zn values are not impressive. The unusual relationship of As, Zn and Cu may be a reflection of the relative amounts in the source rather than the results of the influence of the surface environment. Certainly the area warrants further study.

The sites containing high As values in the southwest portion of the study area, some of which are on the granodiorite, should be resampled for verification. There are two anomalous Cu values (both 2.0 Std. Dev.) and one highly anomalous

Zn value (3.4 Std. Dev.) a few miles west of the south end of Badger Bay. The values, including As, are probably derived from a local source in the bedrock terrain, but because of the very high Zn content the area should be resampled. At present there are only two anomalous stations, and unless a larger area can be developed, they do not comprise an interesting target for prolonged study.

B AND C HORIZON SOILS AND UPPER TILL

The following numbers of samples were collected on the main grid in the vicinity of the prospect (Fig. 18): twenty-six B horizon, twenty-nine C horizon and forty-one upper till samples. Generally, both B and C horizon samples were collected at each sample station where podzolic soil profiles were developed. Upper till samples were collected at stations where peat bog was present such that a combination of the two provided reasonable coverage of portions of the main grid on a 400 foot by 200 foot basis. Characteristically B and C horizon samples were composed of a sandy till material often containing pebbles. Soil horizons were differentiated by the more intense colour of the B horizon, usually brown, relative to the C horizon. Poor soil horizon development made differentiation difficult and on occasion, impossible. Upper till samples were collected at the peat-till interface under the treeless portions of the plateau peat bog. Samples were usually water saturated and composed of grey to brown sandy till. Occasionally a grey blue clay material was sampled.

Detailed follow-up geochemical studies in a pleateau peat bog terrain cannot be effectively carried out using soil B and C horizon materials because of the erratic and generally poor development of soil profiles. There were not sufficient data for statistical treatment, but the higher Zn and Cu content of the C relative to the B horizon was observed. Soil data and sample locations were not included in this report because, relative to other sample media data, they do not support reliable interpretations or conclusions. Anomalous Zn, Cu, Co, Ni, Ag and Pb plotted values showed only a tentative relationship to the location of the prospect and/or related sulphide-rich till. Hg is described later.

A potentially more effective technique for follow-up surveys was the sampling of the upper till. The element content of upper till samples was greater than soils and they were available wherever there was till. Anomalous Zn and Cu values suggested the location of the prospect and related sulphide-rich till but were too few in number and too widely spread in this case to be conclusive. Thus, the data and sample locations were not included in the report. Further study of the upper till sampling technique in this and similar terrains may however provide a useful alternative to basal till sampling in plateau bogs.

BASAL TILL SAMPLING

The purpose of the overburden-drill program was to determine the presence, nature and configuration of the down-ice element dispersion halo from a drilled but otherwise undisturbed sulphide body. The program also investigated adjacent vertical loop electromagnetic (V.L.E.M.) anomalies to determine whether or not chalcophile elements were present in sufficient quantities in the underlying till to suggest a sulphide source for the conductors. The main overburden drill target was the sulphide body, which constituted the base-metal prospect, and the secondary targets were the axes of two V.L.E.M. conductors located southeast and north of the sulphide body. The targets are shown in Figure 18.

The sulphide body, in a felsic volcanic host rock is probably exposed for most of its strike length at the suboutcrop level (R.J. Hawkes, pers. comm. 1973). It is located in a large poorly drained plateau type peat bog terrain. Here, the till thickness is variable but seldom more than 10 feet. It is overlain by accumulations of peaty material from 2 to 7 feet thick. On the grid, outcrop is scarce reflecting the subdued ridges and shallow valleys of the suboutcrop topography. Both the peat bog and suboutcrop surface are essentially flat-lying to the south of the prospect, slope gently away to the northeast and have a steeper slope to the west, northwest and north. Winnowing action of former glacial meltwater streams, once actively flowing northwest in the area, Figure 4, has created a cobble-boulder mantle capping much of the till. The boulder mantle inhibited penetration through the till to bedrock during drilling operations. The basal till lying directly on bedrock is probably a lodgement till laid down during the strong initial northeasterly movement of ice. It probably was not disturbed by weaker subsequent ice movements or by later meltwater action because surface features developed during the first movement have not been extensively modified. Basal till samples usually had a greyish colour and only occasionally was any excess water found with the sample. Samples were composed of course sandy particles with some angular pebbles and fine rock flour material. Some fresh unweathered sulphide minerals were found in basal till samples immediately east of the sulphide body. There is little evidence to suggest extensive groundwater movement in the till but the till-peat interface was frequently water saturated. Thus, extensive leaching and migration of elements in solutions is unlikely in the till. Characteristics of the basal till do not negate the possibility of only a short transport distance from a bedrock source to deposition.

One hundred and twenty-five basal till samples were collected at the one hundred and thirteen sample stations shown in Figure 18. Some profile sampling was carried out on line 28N, east of the baseline. Till studies by Garrett (1971) and C.F. Gleeson (pers. comm. 1973) have shown that greater contrasts between anomalous and background metal element content can be obtained in the heavy mineral fraction relative to either respectively the minus 80 mesh (<177μ) or the minus 230 mesh (<63μ) fraction in an unweathered till. Both heavy metal and minus 230 mesh (<63μ) fractions were prepared and analyzed in this study to ensure that satisfactory contrasts would be obtained for interpretation. While the initial and generally dominant mode of element dispersion in till from a bedrock sulphide source is by particulate transport during ice movement, further element dispersion may occur by solution of both the sulphides in bedrock and in the till and subsequent lateral migration in groundwater solution. The element dispersion patterns revealed by analysis of the heavy mineral fraction are related to the initial particulate dispersion only, whereas the patterns in the minus 230 mesh (<63μ) fraction reflect both particulate dispersion and any later hydromorphic dispersion.

Anomaly maps of Co, Ni, Ag and Pb distribution were essentially similar to those of Cu, Zn and As that are shown respectively in Figures 19a, b, 20a, b and 21. Sufficient heavy mineral separates were not available for As or Hg determinations. Contour intervals were arbitrarily chosen to clarify anomalous patterns and to facilitate or emphasize points of comparison among Cu, Zn and As distributions in heavy mineral separates and minus 230 mesh (<63μ) till. All element data have a log normal distribution about the geometric mean. The geometric means of Zn and Cu, first in minus 230 mesh (<63μ) till and then in heavy mineral separates, and of As in minus 230 mesh (<63μ) till are respectively: Zn - 45 ppm, 66 ppm, Cu - 16 ppm, 26 ppm; As - 7 ppm. The heavy mineral separates have a higher content of Zn and Cu than minus 230 mesh (<63μ) till. On the anomaly maps, Figures 19a, b, 20a, b and 21, certain highly anomalous Cu, Zn and As values much above the highest contour values are shown for certain stations to effectively demonstrate the immense contrasts possible. Contrasts of this order normally indicate the presense of sulphide minerals in the till, but such large contrasts are not required in order to permit construction of meaningful element dispersion patterns. Hg is described later.

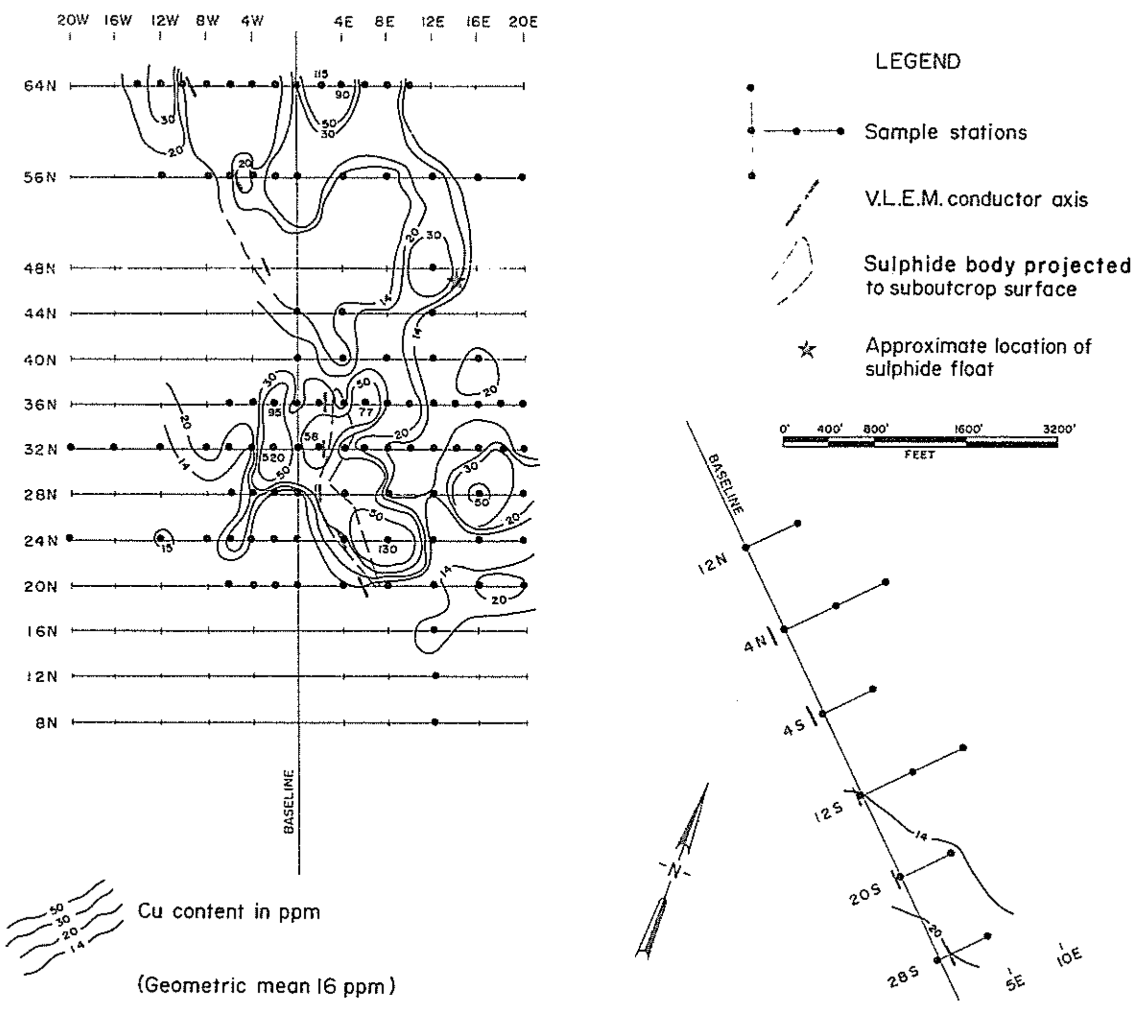

Figure 19a Basal till copper anomaly map, minus 230 mesh (<63μ) fraction, New Bay Pond Area.

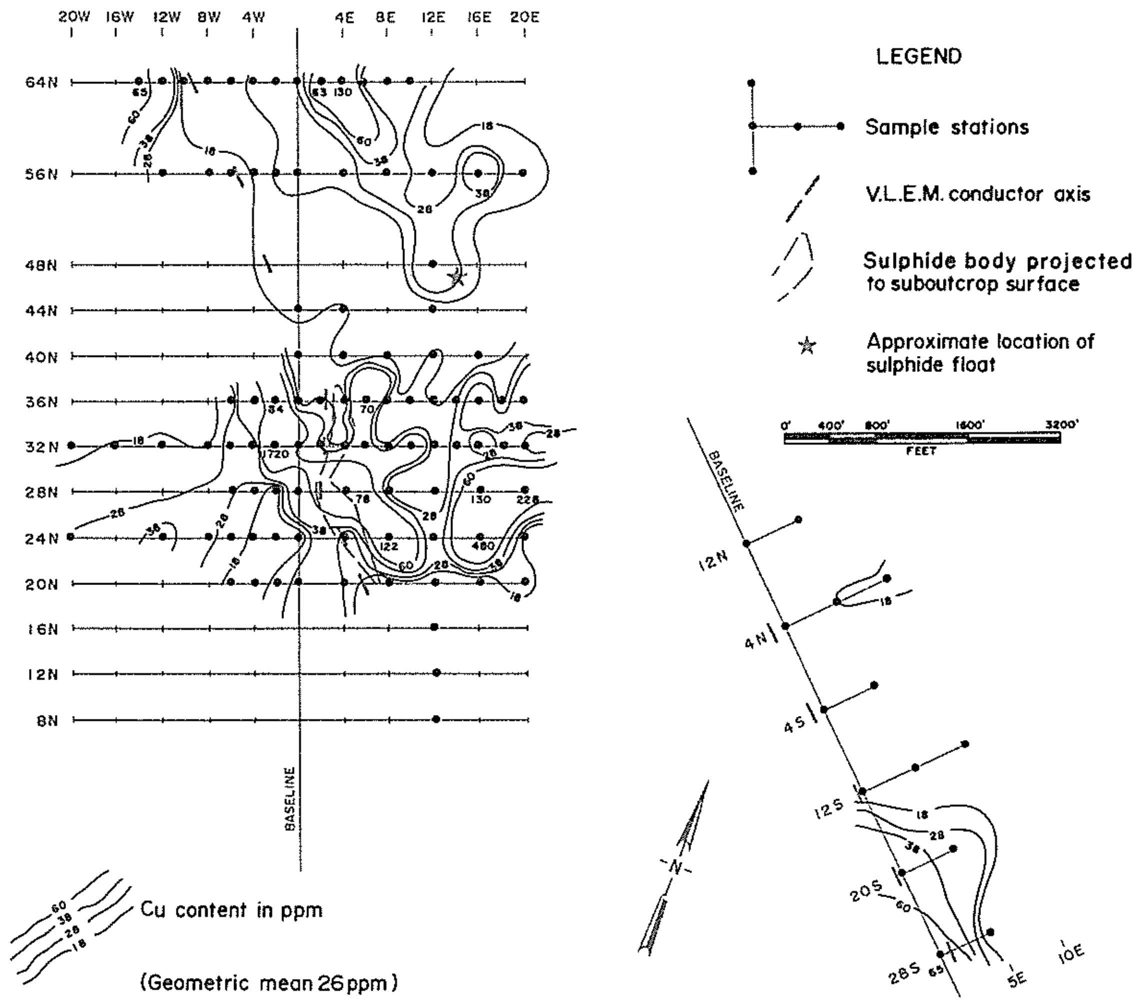

Figure 19b Basal till copper anomaly map, heavy mineral fraction, New Bay Pond Area.

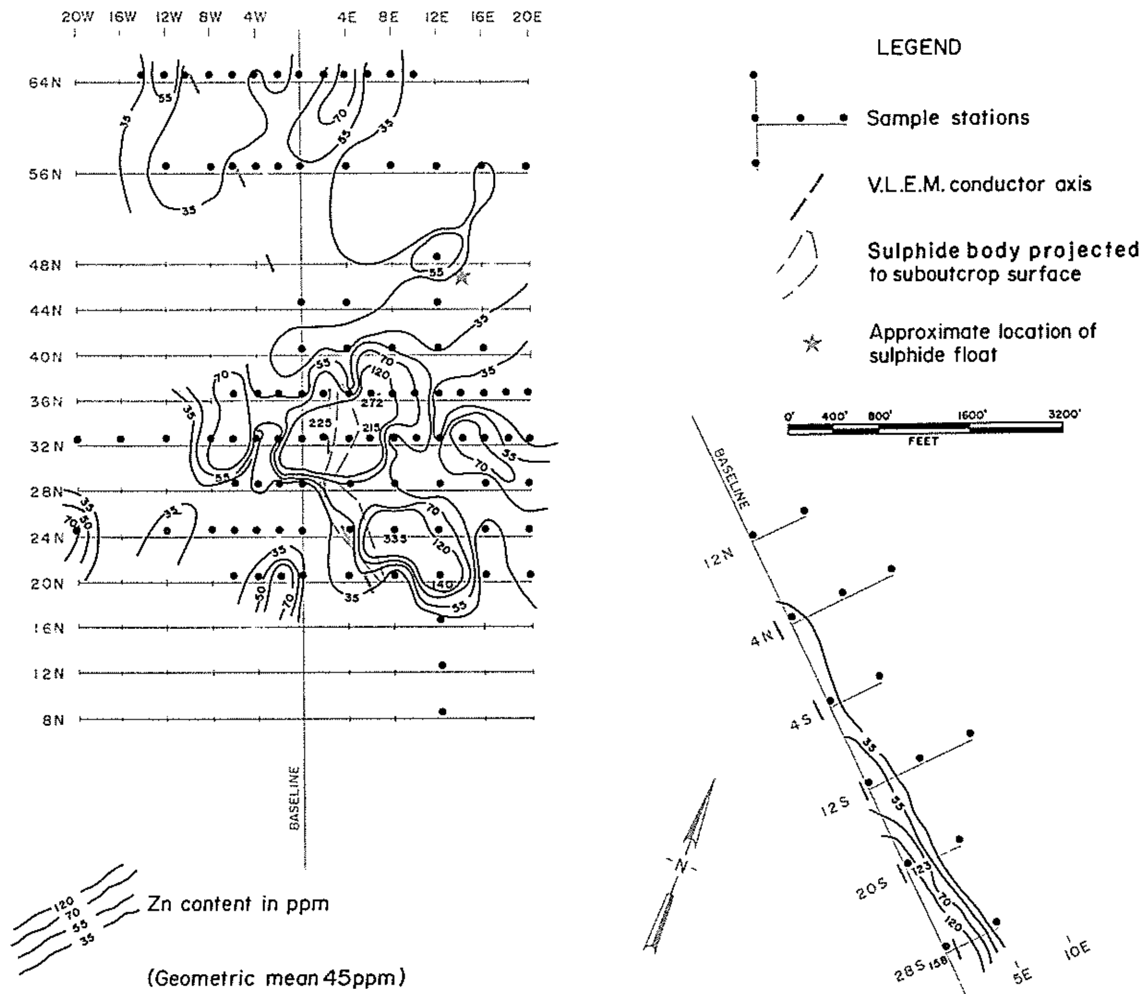

Figure 20a Basal till zinc anomaly map, minus 230 mesh (<63μ) fraction, New Bay Pond Area.

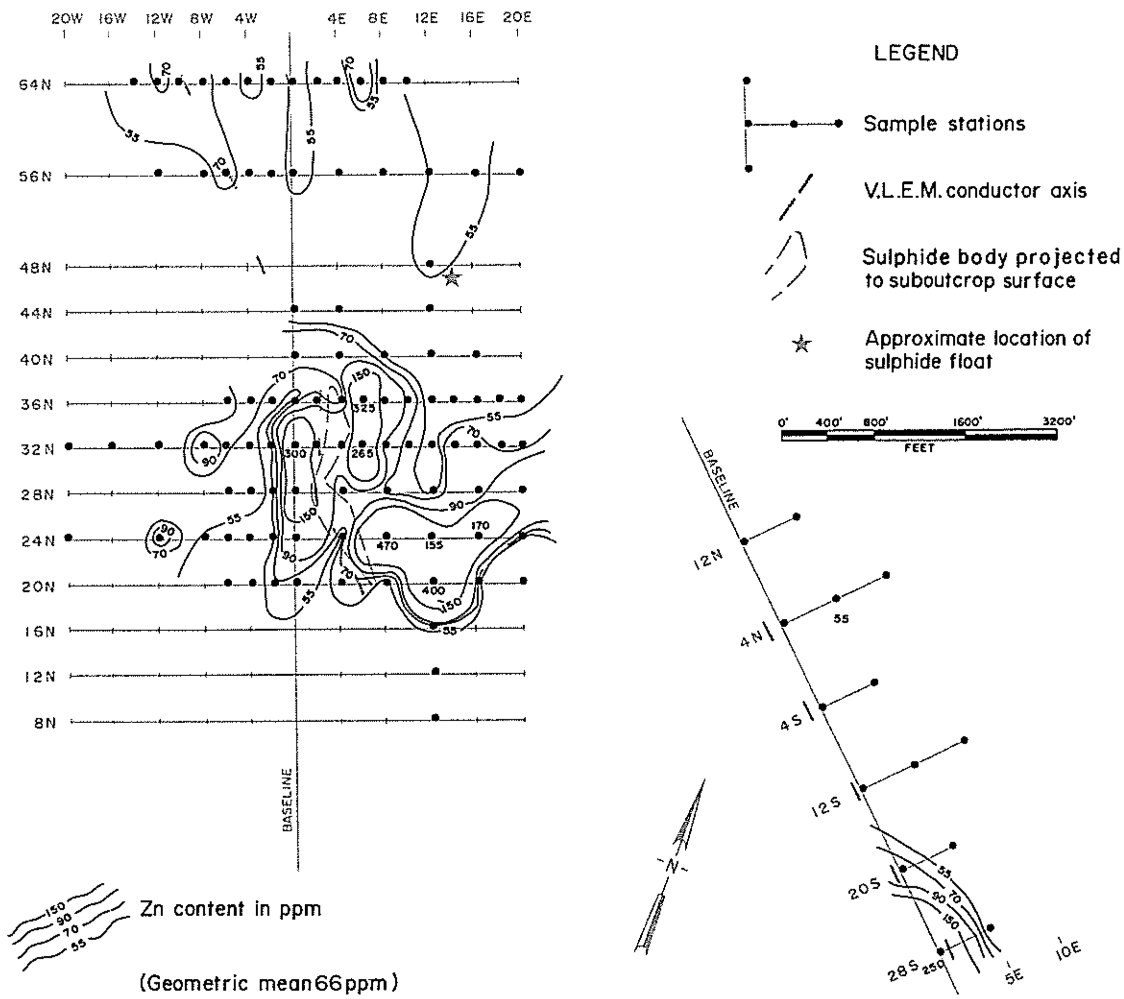

Figure 20b Basal till zinc anomaly map, heavy mineral fraction, New Bay Pond Area.

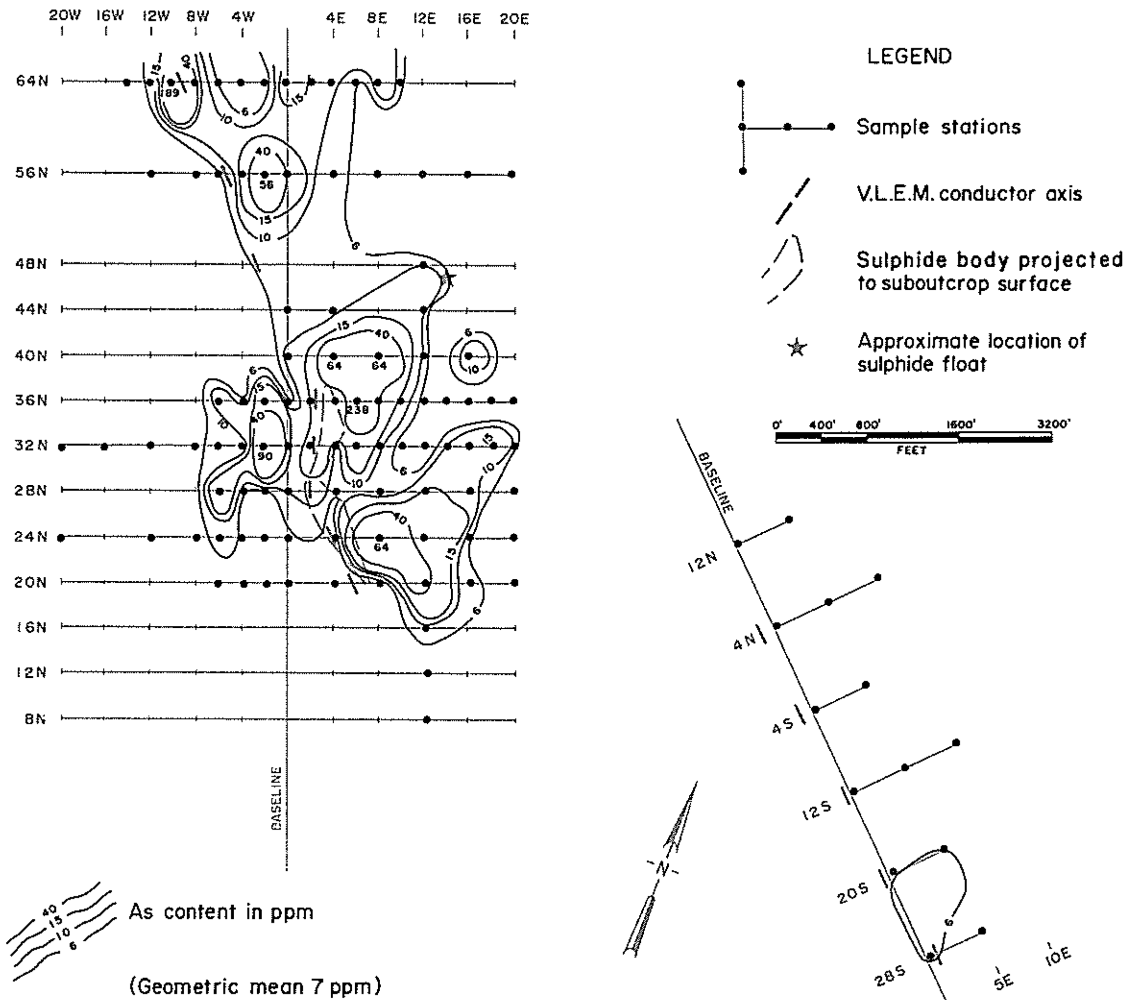

Figure 21 Basic till arsenic anomaly map, minus 230 mesh (<63μ) fraction New Bay Pond Area.

Base Metal Prospect - The following observations are warranted after a comparison among the Cu, Zn and As anomaly maps. Essentially their element dispersion haloes are similar: strong anomalies are present on, and in a down-ice direction from the sulphide body and its V.L.E.M. conductor axis; erratic, and at some stations reasonably high, anomalies are associated with the northern V.L.E.M. conductor axis; but only a very weak As anomaly is associated with the south end of the southeastern V.L.E.M. conductor axis. There are however subtle but significant differences. Anomalous Cu and Zn contours in heavy mineral separates are open to the east of the grid whereas they are closed or significantly decreased in value in the minus 230 mesh (<63μ) fraction. This difference, plus the enriched metal content mentioned earlier, indicated that element anomalies in heavy mineral separates have a greater contrast, and will persist much farther in a down-ice direction than in minus 230 mesh (<63μ) fraction. Thus, heavy mineral separates provide a superior sample medium. In this case though, element anomalies in both sample media satisfactorily detect the sulphide body on any of the basal till sample lines from 20N to 36N.

The strongest Zn and Cu anomalies are related to the southern half of the sulphide body where R.J. Hawkes (pers. comm. 1972), has noted that higher grade mineralization occurs. Such a relationship cannot here be construed for general application as an indication of grade or tonnage because of the many variables involved.

Generally west of, and in an up-ice direction of movement from the northern half of the body, there are Zn, Cu and As anomalies in both sample media. The anomalies in the minus 230 mesh (<63μ) fraction might have been interpreted as being entirely due to a westward lateral hydromorphic dispersion downslope away from the sulphide body without HMF data. The presence of corresponding anomalies in the heavy mineral fraction indicates that these anomalies are due to particulate dispersion from a source farther southwest in an up-ice direction. But, west of these anomalies, the sample density may not be sufficient to detect undiscovered Cu-Zn-As-rich till. Further sampling is required to confirm the presence of metal-rich till west-southwest of these anomalies.

Data from the profile sampling is shown in Table 1 and it confirms the Cu-Zn enrichment in the heavy mineral fraction. The highest value in a given profile is not necessarily found in the till sample collected on bedrock. Obviously, at these stations arbitrary judgement had to be made when constructing the Cu, Zn and As contours on the anomaly maps. Based on the limited available data in Table 1, till samples collected at the bedrock surface will suffice for initial detection of element-rich till associated with a target. During initial sampling of a target it is not logistically feasible to carry out complete profile sampling on each hole although this would constitute the ideal approach. Follow-up sampling, when element-rich till is found should include some profile sampling as well as increased sample density. Profile sampling data will permit a vertical as well as lateral evaluation of element distribution, which is important, particularly

TABLE 1 Profile Basal Till Data from Line 28N

Element	Copper (ppm)		Zinc (ppm)		Arsenic (ppm)	Sample Height (feet)[3]	Hole Depth (feet)
Material	<63μ[1]	HMF[2]	<63μ[1]	HMF[2]	<63μ[1]		
Station							
(Baseline)	8	52	37	170	4	2	
0+00	12	42	37	63	10	0	9
	18	20	70	58	4	7	
4+00E	62	66	88	105	6	5	
	14	38	39	60	5	3	
	35	78	54	75	6	0	19
	12	18	18	58	4	6	
8+00E	14	18	35	60	5	4	
	12	18	26	70	8	2	
	6	14	18	45	7	0	13
12+00E	14	15	46	52	20	2	
	14	15	37	63	8	0	7
16+00E	18	65	30	98	5	2	
	50	130	40	68	13	0	9
	30	20	107	80	8	6	
20+00E	20	20	52	45	4	4	
	22	228	54	150	4	2	
	24	96	58	110	4	0	17

1. <63μ - minus 230 mesh basal till

2. HMF - Heavy mineral fraction, plus 230 mesh (>63μ) minus 50 mesh (<297μ) basal till

3. Height of lowest part of sample above bedrock.

where the suboutcrop relief is rugged. Configuration of the suboutcrop surface has a significant effect upon the down-ice direction distribution of till from a given bedrock source. For example, transported element-rich till may be deflected from the down-ice direction of movement by prominent ridges or it may be sheared and possibly thrust over older barren till in valleys or it may become interbedded with a different barren till.

Dispersion patterns of Cu, Zn and As in a down-ice direction from the sulphide body support the suggestion that large and small volumes or segments of sulphide-rich till are transported from the sulphide body and distributed amongst other till having near-background element content. Larger segments are closer to the sulphide body and smaller segments are more distant. Essentially, the dispersion halo from such a sulphide body becomes undetectable when, sampling at a given density in a down-ice direction away from the body, the possibility of finding decreasingly smaller segments of sulphide-rich till becomes remote. Sulphide-rich basal till would have been found with increasing frequency and in larger segments if, for example, exploration basal till sampling on 400-foot centres had been carried out at several stations on a line proceeding southwest in an up-ice direction from the sulphide mineral float located, as mentioned earlier, in the stream (Fig. 18).

Although it is possible, it is assumed unlikely to have a major sulphide body that produces a good V.L.E.M. conductor without having related sulphide minerals in the adjacent till unless the body is completely buried below the bedrock surface. Where sulphides are present in suboutcrop, basal till sampling over the V.L.E.M. conductor axis will indicate and confirm the above relationship. Where no sulphide minerals are found in the till, it is assumed that the conductor is not a sulphide body. The element dispersion pattern from the sulphide body was detected by basal till sampling on 400-foot centres. A complete picture of the dispersion halo would be obtained by increased till sampling density and some profile sampling in each hole.

Southeastern V.L.E.M. Conductor - The nature of the southeastern V.L.E.M. conductor has not been investigated by diamond drilling (R.J. Hawkes, pers. comm. 1972). Significant Cu and Zn values were found in the till only at the extreme south end of 0+00 (baseline) and 28S (Figs. 19 and 20). Certainly the northern part of the conductor probably is not composed of sulphide minerals and it is probably graphitic argillites. Graphitic argillites with some carbonates are found on strike farther south near Great Lewis Lake. The Cu-Zn rich till at the south end may have been derived from a sulphide mineral source farther southwest, in an up-ice direction of movement remote from the V.L.E.M. conductor and glacially transported to its present location over graphitic argillites. If the V.L.E.M. conductor near 28S on the baseline is due to sulphide minerals, Cu-Zn rich till would be expected to occur in the till sample at 5W on line 28S, but only background Zn and Cu values below the Zn and Cu geometric means are found. In fact, the Cu-Zn rich till is found west of the conductor axis and only fill-in basal till sampling would determine how far east or west it extends. The present level of data now available suggests that this V.L.E.M. conductor axis is not related to a local sulphide source but it may be located in a down-ice direction from an unknown sulphide source.

Northern V.L.E.M. Conductor - Graphitic argillites have been found in one diamond drill hole on the northern V.L.E.M. conductor axis, and significant Cu, Zn and As values are found in the till on lines 56N and 64N. The As values are found directly on or near the conductor axis while the major Cu and Zn values are found and begin at least 1,000 feet in a down-ice direction from the northern end of the axis. Strong anomalies open to the north on line 64N indicate potential drill targets farther north. It is unlikely that segments of mineralized till identified here by Cu, Zn and As values have been glacially transported from the sulphide body farther south. The existence of sulphide minerals in the till adjacent to the northern V.L.E.M. conductor has been determined by basal till sampling on two lines across the strike of the conductor. The data, particularly the As data which have high values on and immediately adjacent to the conductor axis suggest the conductor contains sulphide minerals. Initial basal till sampling has detected the sulphide minerals, but to confidently continue exploration, further basal till sampling on 200-foot centres over and northwest of the conductor should be carried out.

Thus, initial basal till sampling data has discriminated between the northern and southeastern V.L.E.M. conductors and is the basis for recommending further work on the former and none on the latter.

GEOCHEMISTRY OF MERCURY

The very high Hg contents in the sulphide minerals, particularly sphalerite, suggest that Hg has good potential for use as a pathfinder element. The suspected poor quality of some Hg determinations in addition to other limitations discussed below, prevented definitive interpretations and conclusions concerning its distribution. Despite this, certain aspects of the Hg data warrant further comment.

Mercury distribution as might be anticipated from the above is similar to that of Zn in lake waters because it defines the eastern half and certain parts of the central-northern portions of the study area as follow-up areas.

Lake sediments have a relatively higher Hg content than overlying lake waters. The Hg content of lake sediments is strongly influenced by the sediments' organic content. Although Fe and Mn have a strong relationship to each other, they have little or no relationship to the organic content. The first Hg distribution map obtained by regression of Hg against Mn is therefore of little use. The second map produced through regression of Hg against organic content is valuable to determine Hg distribution except that it is not complete. The organic content was determined in 70 out of the 100 samples collected. Even this incomplete picture of Hg distribution, which is not included in this report, shows Hg distribution patterns similar in configuration to those obtained by Cu and Zn regression against Mn. Therefore, with further data and regression against sample organic content, Hg distribution patterns would certainly be useful for lake sediment geochemical exploration.

Hg distribution in stream sediments is influenced more by the organic content than by the amount of Fe or Mn present. The organic content for all stream sediment samples could not be determined because most samples did not have enough minus 80 mesh (<177μ) material. Hg was regressed against Mn for all stream sediment samples: Fe and Mn are closely correlated. The pattern of Hg distribution thus obtained is in fact less valid than could be obtained by regressing Hg against the organic content of the sediment samples. The partly valid picture of Hg distribution was similar in many respects to the distribution of Cu, Zn and As after they were regressed against Mn. Therefore, the use of Hg in stream sediment surveys is realistic and would be effective after regression against organic content for stream sediment geochemical exploration.

The attempt to determine the usefulness of Hg in B and C horizon soils and upper till for exploration purposes was inconclusive. The content of Hg in these material is significant and its distribution is similar to that of Cu, Zn, etc., but both the lack of satisfactory sample material and the poor distribution of sample sites discussed previously prevent adequate assessment of the effectiveness of Hg for soil geochemical exploration.

The pattern of Hg distribution in minus 230 mesh (<63μ) basal till is essentially similar to that of Cu, Zn or As. Values up to 320 ppb Hg were found. It is very probable that even higher values would be found in the HMF had there been sufficient material for Hg determinations. It is not yet apparent whether Hg will be more useful in basal till studies relative to the other elements.

SUMMARY AND RECOMMENDATIONS

Pilot geochemical studies in the New Bay Pond area have had both positive and negative results. Studies have been successful at the regional, follow-up and detailed follow-up levels of geochemical exploration. Summary, conclusions and recommendations will be discussed within each level.

REGIONAL SURVEYS

Centre lake bottom organic sediments have been shown to be an effective sample medium for regional geochemical surveys. The potential effectiveness of lake water surveys will become clearer with the use of more sensitive analytical techniques than those used in this study to determine element concentrations in water. The scavenging activity of the manganese, iron and organic matter in lake sediments influences, by enrichment, their element contents and produces false anomalies. Regression of the elements against manganese etc. removes these influences. Residual element scores after regression provide superior and more reliable forms of data for interpretive purposes than untreated actual analytical data.

Regional lake sediment survey data have delineated trends in the study area where abnormally high concentrations of elements exist. The trends enclose strong, persistent, multi-station anomalies that permit concentrated follow-up studies in appropriate areas. The survey is not designed to be capable of detecting individual deposits, particularly those situated in large inland plateau peat bogs, but it may indirectly delineate favourable host rocks in such a terrain. Thus, several hundred square miles of the Notre Dame Bay region could be evaluated by lake sediment surveys to provide an initial screening process to delineate favourable areas of reduced size for follow-up studies, especially when aeromagnetic and other regional geophysical data and bedrock geology are also considered.

FOLLOW-UP STUDIES

Stream sediments are an effective sample medium for follow-up geochemical surveys in the New Bay Pond area. Iron and manganese, and to a lesser degree, organic content, have a significant effect on stream sediment element content where they produce false anomalies through scavenging processes. It was necessary to regress stream sediment analytical data against manganese, but in fact regression against iron is preferable and ideally, if reliable Hg data is desired, it should be against all three, i.e., Mn, Fe and organic content. Stream sediment analytical data without regression should only be interpreted in a superficial manner because they are not necessarily valid or a reliable reflection of the distribution of the elements in bedrock.

Stream sediment surveys have successfully delineated targets for detailed follow-up studies that are within the favourable areas outlined by the lake sediment study. Stream sediment surveys could, in fact, be carried out for regional geochemical investigations replacing lake sediment surveys, but the sample density must be maintained regionally at the follow-up density level of 4 to 5 samples per square mile. The advantage of regional stream over lake sediment surveys is: weak dispersion haloes from a deposit may be present in adjacent streams, but in this scavenging environment, they may not persist and be found in down-drainage lakes remote from the source. Thus, stream sediment surveys have detected the halo about the base metal prospect while the lake sediment surveys failed to do so.

In the Notre Dame Bay region, regional stream sediment surveys at a sample density of 4 to 5 samples per square mile will provide realistic targets for detailed follow-up studies. Stream sediment surveys are effective in peat bog areas providing arsenic is present in the type of base-metal occurrence being sought, since it is more mobile than Zn and even more so than Cu in such a reducing environment. It is conceivable, that if arsenic had been determined in lake sediments, they would have been more effective for lake sediment geochemical exploration in the inland plateau bog areas. Effectiveness of follow-up level geochemical exploration is often improved when used in conjunction with geophysical exploration (electromagnetic surveys).

DETAILED FOLLOW-UP STUDIES

B and C horizon soils are not effective for detailed follow-up studies in areas of predominantly inland plateau peat bogs because of the erratic distribution and poor development of soils. The soil study has shown, however, that there is a higher base-metal content in the C horizon.

Upper till sampling constitutes an approach with more potential largely because of the assumed availability of the medium at all sample stations. The metal content of the samples collected has suggested the location of the sulphide body and/or its related sulphide-rich till. Further development of this approach could lead to a useful alternative to basal till sampling, or at least the initial application of it.

Basal till sampling successfully detected and delineated the Cu, Zn and As dispersion patterns from a known sulphide body source. It also provided a means of discriminating among those V.L.E.M. anomalies that are related to a sulphide conductor and those that are not. The heavy mineral fraction is a more effective sample medium than the minus 230 mesh (<63μ) till fraction, but both sample media effectively defined the location of the sulphide body. Initial basal till sampling at 400-foot centres over target areas, including V.L.E.M. conductor axes, will detect base-metal-rich till at the suboutcrop surface where base-metal glacial dispersion patterns are similar to that from the known sulphide body. Base-metal dispersion patterns that provide sufficient information for a diamond drilling program are obtained by an increase of the basal till sampling density to, at least, 200-foot centres and the collection of profile samples in each hole.

The sequence of either regional lake sediment surveys and subsequent follow-up stream sediment surveys, or regional stream sediment surveys alone, succeeded by exploration basal till sampling in an up-ice direction from the sulphide float in the arsenic-rich stream, could have led to the discovery of the base metal prospect.

Other base metal targets are probably present in the area and have been suggested by the pilot study data.

DANIEL'S HARBOUR AREA

Work in this area was carried out between the 24th. July and the 28th. August 1972. Access to the area is by means of route 430 from Deer Lake, a distance of about 110 miles. The all-weather gravel highway lies along the coast, and within the area a few logging roads provide some degree of access to four-wheel drive vehicles. A base-camp connected by private road to the main highway was established near the main deposit, about 5 miles northeast of the town of Daniel's Harbour. A Bell 47G-4A float-equipped helicopter was used for movement of personnel carrying out stream sediment and lake sediment and water sampling.

The area surveyed comprised the coastal plain between River of Ponds Lake on the north and Portland Creek Pond on the south, an area of about 350 square miles (Fig. 22). The undulating coastal plain is underlain by Ordovician carbonate rocks, which form low cliffs 20-60 feet high along the coast. The maximum elevation of the coastal plain is a little over 600 feet above sea level. The dissected escarpment of the Long Range Mountains, which stand 1500 to 2100 feet above sea level, forms the eastern boundary of the plain.

Lakes and streams are numerous in the area, although their areal distribution is uneven, there being few lakes or streams in the north-central part of the area. Some of the lakes are intermittent (periodically drying up) and many streams flow for some distance underground, particularly in the north-central part of the area. Sinkholes and springs are widespread. In general the drainage pattern seems poorly adjusted, although some systems trend north-south to northeast-southwest, paralleling a major trend of faulting in the area.

Treeless swamps occur as a discontinuous belt along the coast, and also in a north-south strip from Portland Creek Pond, through Brian's Pond to River of Ponds Lake. These large bogs are drained by networks of meandering streams. Small bogs are widespread throughout the area marginal to lakes and in local depressions. In the better drained areas mixed boreal forest is developed, with spruce, tamarack, balsam fir and white birch being the dominant tree types.

GEOLOGY OF THE AREA

The coastal plain is underlain by a succession of Cambro-Ordovician platform sediments, lying on a Precambrian basement (Fig. 22). The basement rocks are exposed on the eastern margin of the area in the up-lifted block of the Long Range Mountains, and consist of granites and gneisses having a Grenville radiometric age (Poole, Kelley and Neale, 1964).

Overlying the basement complex, and exposed as a northeast trending fault-bound wedge, is the Labrador Group of Lower Cambrian age. In the field area the Labrador Group has been subdivided by Nelson (1955) into the upper Hawke Bay Formation - quartzite, shale and dolomite - and a lower subgroup, comprising the Bradore and Forteau Formations of Schuchert and Dunbar (1934), which consists of arkose, conglomerate, shale and limestone. The Labrador Group is in fault contact with the Cambro-Ordovician St. George Group, a succession of limestone and dolomite 2,000-3,000 feet in thickness (Cumming, 1967). The upper 400-500 feet of this group consist of a more or less dolomitized algal limestone, overlain by about 280 feet of dolomites (Collins and Smith 1972a). The Table Head Group, comprised of grey limestone, dolomite and shale of Middle Ordovician age, overlies the St. George Group with disconformity (Cumming 1968). The thickness of the Table Head Group in the area is in excess of 1100 feet (Cumming 1967).

Towards their stratigraphic top, the Table Head limestones become progressively more shaley, and are overlain by sequence of calcareous green shales and sandstones, with occasional thin interbedded limestone beds. These comprise the "clastic unit" of Figure 22. A limestone breccia unit (Cow Head Breccia type using the nomenclature of Baird, 1960) is restricted to the south-western most part of the area around Daniel's Harbour. The relationship of this limestone breccia unit to the other units is not clear.

The sedimentary succession has been gently folded, with more intense folding occurring adjacent to major faults. These faults are normal, with upthrow on the southeast side (Cumming 1967), and trend northeast to north-northeast.

MINERALIZATION

Occurrences of zinc sulphide mineralization in the St. George's Group are known throughout its extent from the northern tip of the Great Northern Peninsula to the Port au Port Peninsula. The study area contains the largest zinc sulphide deposits found in the belt. Diamond drilling has proved 12 bodies of heavy sphalerite mineralization, the largest of which contains 4,400,000 tons of 8.8 percent Zn (Northern Miner, 1974). The deposits all occur within the upper 400-500 feet of the St. George's Group, below the disconformity with the overlying Table Head Group (Collins and Smith, 1972 a,b).

Their host rock is a diagenetic facies of the algal limestones which occurs between about 200 and 500 feet stratigraphically below the disconformity immediately beneath the dolomites which in this area represent the uppermost part of the St. George Group. This particular facies is completely dolomitized, consisting of coarsely crystalline white dolomite in a matrix of fine-grained brownish dolomite. This distinctive rock type has been termed "pseudobreccia".

Sphalerite is the only ore mineral, occurring in a white dolomite gangue, with quartz as a very minor gangue mineral. The sphalerite contains little iron, is moderately rich in cadmium (Sangster 1968), and has less than 0.2 ppm Hg. Thus, Hg has little potential as a pathfinder element. The grade of zinc in the deposits is variable, and the larger deposits exhibit a high grade core, surrounded by irregular, low grade, mineralized "haloes" (Wade 1967).

The "pseudobreccia" itself is sporadically mineralized in many places, and even where apparently unmineralized is somewhat enriched in zinc relative to the other carbonate units in the area (Sangster 1968). The genesis of these deposits has been discussed by Cumming (1968), Sangster (1968), Roedder (1971) and Collins and Smith (1972 a,b).

Galena is known only at three very small occurrences in the area one of which is shown in Figure 22, where galena and sphalerite occur together. Outside the surveyed area, small galena-sphalerite occurrences are known in the St. George Group. One sphalerite and one galena occurrence are known from carbonates of Lower Cambrian age in the Hawke Bay-St. John's Bay Area.

SURFICIAL GEOLOGY

This region features contrasting lithologic terrains of granite characterized by scoured outcrops and summit areas of deep colluvium, and a lowland carbonate terrain locally karstic with extensive bogs (Fig. 5). Surficial cover on the lowland varies from thin patchy tills, to thick stony pelite, to fields of bouldery moraines, all of which have been reworked during a former marine submergence. Earlier reports outlined the nature of glaciation (Grant, 1969a, b; 1972b), the surficial geological setting of mineralized boulder fans (Grant, 1972a), and the extent and age of marine reworking (Grant, 1972c; 1973b).

Rock relief and outcrop distribution generally correlates with elevation. The crystalline rocks of the Long Range Mountains are everywhere at or near the surface with rôches moutonnees and stoss-and-lee ledges studded with perched erratics. Interior plateau valleys are forested (Rc), and summits near the escarpment are mantled with felsenmeer (Cv; Rw) and colluvium with solifluction stripes, and peat polygons (C/O). The plateau escarpment slopes where steepest are underlain by colluvial debris aprons and talus cones (Ca; Cf) ascending to sheer gullied rock cliffs (Re); where gentler, the slopes are forested rock (Rc), mixed slope debris (Cv) and locally a thin till veneer (Mv). The glacial troughs cutting the escarpment are floored with fluvial and glaciofluvial veneers, and a few are separated from the lowland by an end moraine (Mr). Abutting the foot of the escarpment is a fault-slice of the Hawke Bay Formation comprising mainly quartzites presenting steeply dipping, strike-faulted beds that produce prominent rectilinear ridges, flat-iron hills, and hogbacks with little or no drift cover and thin forest (Rc). The remaining 10-15 miles of the lowlands proper are underlain by horizontal to slightly inclined strata with variable but generally north-northwestward strike. Less soluble strata in the carbonate sequence produce belts of curvilinear and cuesta-form ridges. Low, mesa-like hills appear to represent remnants of Table Head Group limestone. Clastic, mainly shale rocks of the Humber Arm Group underlie low areas with extensive bogs and deep tills. The more soluble members of the St. George Group produce extensive areas of solution-collapse terrain, marl-bottom ponds, springs, and disappearing and intermittent lakes and streams.

The composition and thickness of surface deposits is extremely variable and difficult to predict, except for the following generalizations. Thicknesses increase from zero to thin and patchy over the foothills to more than 100 feet at the coast. The till varies from a bouldery veneer on bedrock hills to 20-30 feet in depressions. The matrix is largely carbonate detritus rich in granite erratics from the Long Range. In shale areas the till is rubbly with little influx of foreign lithologies. Below 350-400 feet, the limit of former marine reworking, the till surface is winnowed, littered with ice-rafted blocks, and admixed with finer marine sediment, including shell fragments. In lake and river basins, the discontinuous till blanket is organized into multitudes of regularly spaced, sharp-crested narrow De Geer-type minor moraines (best seen as spits, islands and shoals, about 2,500 feet long, less than 150 feet wide and 25 feet high and about 500 feet apart). These represent ice-frontal annual recessional moraines or ice-marginal crevasse-fillings constructed as the glacier retreated in the high-standing marine water. The wave-washed boulders of these moraines are frequently riddled with the borings of bivalves. As the ice retreated, the sea encroached inland to the escarpment up to elevation 350-400 feet (Grant, 1972a, c). In addition to the submarine moraines and effects of the marine overlap are noted as winnowing of the till surface, degradation of the hummocky morainal relief (Mw), flights of raised beaches (Mr), trimlines on inter-lobate moraine (Mr), and scarps on marine deltas and terraces (Md; Mt). Over large areas the effects of wave-washing are obscured by soils, but in most depressional areas a thin blanket of shelly sand and gravel is preserved. Near the coast however, where water depth was greater and the overlap of longer duration (4000-5000 years) a deposit of stony fossiliferous clay over 100 feet thick was formed which is now well exposed by coastal cliffs. It accumulated beyond the ice margin by deposition of ice-rafted debris. Consequently, the material has till-like texture and wide provenance but lacks the consolidation of a subglacial material. The lithology is not of subjacent derivation but it is largely crystalline rocks from the Long Range, although the matrix is rich in detrital carbonate.

Evidence of glacier movement is abundant and consistent. There is no proof that Labradorean ice impinged on this part of Newfoundland, as is commonly assumed. Except for two dubious coastwise striations near Hawke's Bay and St. Paul's, all ice-flow indicators show westward flow from the Long Range to the coast (Grant, 1972a). The content of Long Range granite erratics in lowland till decreases regularly westwards. Mineralized boulder trains fan westwards. All striations point westwards, and tracts of De Geer moraines everywhere perpendicular to them, reveal a lobate pattern of retreat ascribed to piedmont lobes pouring down from between plateau nunataks, along escarpment troughs that lead to the basins of Portland Creek, Brian's, Eastern Blue and Western Blue Ponds (Grant, 1969a).

An end moraine, built about 13,000 years ago by the coalesced piedmont tongues, skirts bedrock prominences east of River of Ponds Lake, showing topographic channelling of the thin mobile ice. Kettled interlobate moraines showing circular dead-ice depressions, trail west from nunataks like Blue Mountain and Gros Paté. A series of recessional valley moraines record the final retreat toward the median line of the Long Range Plateau.

In summary, a number of surficial geological conditions are pertinent to geochemical drift prospecting. Certain favourable characteristics may be cited:

(1) The direction of glacial transport is fairly confidently established as westwards ($270^{o}\pm40$) with precise local trends given by striations and moraines;

(2) Tills, where correctly identified and thin, are of local derivation - for example, nearly pure shale debris occurs in areas mapped as shale;

(3) The surficial geological interpretation adds considerable information about the nature and structure of submask bedrock (e.g. stratification trend and fracture pattern) which it is hoped will be used in conjunction with existing outcrop-based geological maps. On existing geological maps, some inferred conformable contacts, for example, are at variance with geomorphic stratification trends, and some major faults seem over-generalized.

However, adverse aspects are in the majority:

(1) Till thickness, and hence lithology, varies considerably; thinner tills are of more local derivation; top of till sheet contains more transported material;

(2) Marine action has affected most of the lowlands, reworking, sorting,

or burying the till beneath submarine derivatives - more than half the materials collected on a random sampling system were of marine origin, and therefore of variable affinity to the parent till or bedrock;

(3) The onset of subaerial soil formation on the lowlands is significantly diachronous; since 4000 - 5000 years elapsed while marine waters withdrew from the initial 400-foot stand, soils at the coast on any material are only half as mature as those above marine limit;

(4) The widespread karst development and the unsystematically fluctuating water levels are regarded as an important complication;

(5) Much reliance is being placed on purportedly well-understood bedrock geology; large areas have few if any outcrops, and therefore interpretation should be qualified in terms of existing factual observations.

SOIL DEVELOPMENT

Residual soils are absent in the area, the soil profiles being developed in glacial drift. In the better drained areas podzols and brown forest podzols are developed within the area of soil sampling in the present study (Fig. 22). These podzols consist typically of a few inches of organic litter overlying a thin 3 to 6 inch-thick leached A horizon. The B horizon is well developed, varying in colour from ochreous red to chocolate brown, commonly 24-36 inches thick. In poorly drained areas gleysols are developed, and commonly peat accumulations are present in depressions.

GEOCHEMISTRY OF LAKE SEDIMENTS AND WATERS

Organic lake sediments and lake waters were sampled from 125 sites over a trapezoidal area of approximately 250 square miles (Fig. 23).

The various types of material sampled are outlined in Table 2. In places, two of these types were encountered in a single core. Although the number of samples of any particular type is too small for a rigourous comparison of the metal content and ignition loss between the groups, no group appears to be distinct from the others on the basis of these parameters. Therefore the samples have been treated as a homogeneous group.

Sphalerite is the only major sulphide mineral in the majority of the known sulphide occurrences in this area, and thus zinc is the most important base-metal although some contain in addition to Cd, very minor concentrations of Pb, Cu, Ag, and Hg. The distribution of zinc in the lake sediments should, therefore, best reflect the distribution of the known sulphide mineral occurrences. There is no apparent correlation between the zinc and manganese contents of the samples. There are fairly weak statistical correlations between the zinc and both the iron and to a lesser extent the organic content of the samples. Geochemically, however, these correlations were not considered to be significant. The frequency distribution of zinc in the lake sediments is strongly log-normal, with a positive skew. The contour levels, arbitrarily chosen, are as follows:

2700 ppm Zn	3.5 standard deviations above the mean
1000 ppm Zn	2.5 standard deviations above the mean
400 ppm Zn	1.5 standard deviations above the mean
150 ppm Zn	0.5 standard deviations above the mean

TABLE 2 Appearance of Organic Lake Sediment Samples Collected in the Daniel's Harbour Area

SAMPLE TYPE	DESCRIPTION
A	Tan yellow, creamy texture
B	As A, containing gastropod shells
C	Brown, greasy, clayey texture with gritty fragments
D	As C, containing gastropod shells
E	Black
F	As E, containing gastropod shells
G	Grey, sandy, often containing woody fragments
H	As G, containing gastropod shells
J	Green brown
K	Peaty
L	Brown, jelly-like
M	Chocolate-brown

The zinc distribution in the lake sediments is shown in Figure 23. The main zone of sphalerite mineralization six miles north-northeast of Daniel's Harbour is revealed as a highly anomalous area, with the zinc content of the lake sediments ranging from 6250 to 14,500 ppm Zn - by far the highest Zn values obtained. In addition, the lake sediments west of (i.e. down-ice from) this highly anomalous zone are also characterized by high background concentrations of zinc, and similar values are found to the east and north-east.

The sediments from lakes lying close to the contact of the St. George and Table Head Groups on the east side of the area from Brian's Pond to River of Ponds Lake contain anomalous or high background concentrations of zinc. The anomalous values here (up to 1800 ppm Zn) are lower than in the highly anomalous main zone to the north-northeast of Daniel's Harbour. Two zinc occurrences are known in the St. George Group in this eastern part of the area (Fig. 22) and it would seem likely that several more occurrences are present. A single lake sediment sample two miles northeast of Daniel's Harbour is highly anomalous in zinc (2000 ppm).

As a check on sampling reproducibility, the area of highly anomalous lake sediments associated with the main sphalerite occurrences was resampled. The original anomaly was defined by six samples, and was confirmed by all of the ten additional samples collected from the same lakes, at different sites. The zinc content of all these samples exceeded 1000 ppm and eight out of the ten contained in excess of 2700 ppm. In detail there were marked variations in the zinc content of sediment from different parts of the same lake, but since all the samples were highly anomalous in their zinc content, the variation in the zinc content of samples from the same lakes in this case is not critical.

A further confirmation of representativity of the zinc content of the lake sediment samples is afforded by comparing the results of the present study with those of a previous, unpublished survey (Cominco 1969). In this earlier study lake sediment samples, mainly of the uppermost organic-rich layer, were collected over a slightly larger area and at a density of about 2-3 samples per square mile. Whilst the absolute zinc concentrations reported by Cominco are significantly lower, in general, than those obtained in the present study, the patterns developed in both studies are very similar. In particular, the lake sediments in the area of the main sphalerite occurrence are clearly highly anomalous in zinc in both studies.

The lake water samples were analysed for Zn, Cu, Ni and Hg. Of these elements, only the zinc distribution proved useful in delineating areas of known mineralization. The zinc water analyses were, however, of poor precision as the analytical method was insufficiently sensitive. The zinc distribution in the lake sediments is more reliable and more clearly defines the locations of the mineralized zones.

GEOCHEMISTRY OF STREAM SEDIMENTS

Stream sediment samples were collected from 640 sites over an area of approximately 350 square miles (Figs. 24, 25 and 26). In addition to Fe and Mn, the samples were analysed for Cu, Zn, Pb, Co, Ni and Ag. The Cu, Pb, Co, Ni and Ag data are not particularly relevant to prospecting for this type of deposit for the reasons mentioned in the previous section, and are not considered in this report. In addition some 100 samples, randomly chosen, were ashed to determine their relative content of organic matter.

Zinc Distribution - The frequency distribution of Zn in the stream sediments is approximately log-normal, and therefore the data has been grouped into logarithmically based intervals, arbitrarily chosen. The intervals chosen for the subdivision of the Zn distribution are as follows:

>1380 ppm Zn	Greater than 3 std. dev. above the mean
490 - 1380 ppm Zn	Between 2 and 3 std. dev. above the mean
170 - 490 ppm Zn	Between 1 and 2 std. dev. above the mean
60 - 170 ppm Zn	Between the mean and 1 std. dev. above the mean
<60 ppm Zn	Less than the mean

In Figure 24 the main zone of mineralization six miles northeast of Daniel's Harbour is reflected by highly anomalous zinc values in the sediments of the stream draining south from the main body of mineralization with values generally in excess of 490 ppm Zn (greater than two standard deviations above the mean) and three values in excess of 1380 ppm Zn (greater than three standard deviations above the mean).

The highly anomalous zinc values persist in the stream sediments for nearly two miles down drainage from known mineralization where the stream flows over the upper part of the St. George Group. Where the stream course turns from southerly to southwesterly and flows over rocks of the Table Head Group, the zinc values in the sediments fall off to background levels in about three quarters of a mile. Anomalous zinc values occur in sediments farther down this stream, near the supposed location of the contact between the Table Head limestones and the overlying "clastic unit". Here, where several very small tributary streams join the main stream, six sediment samples contain zinc values greater than 500 ppm Zn. The zinc content of the sediments downstream from here to the coast remains high background or possibly anomalous. A stream system joins this main stream about a mile from the coast in which sediments also contain high background to anomalous zinc values. The anomalous sediment samples occur in two small streams flowing into a small lake about one mile east of the coastline, and also in the stream draining this lake.

Anomalous and high background zinc values occur in sediments in the streams to the west and north of the main zone of sulphide mineralization. Unfortunately lake levels were fairly high at the time of sampling, and many of the stream channels shown in Figure 24 and 25 connecting the lakes within the mineralized area were flooded, which prevented the collection of stream sediment samples.

One anomalous sample (810 ppm Zn) and three high background samples occur in a stream about four miles west of Western Blue Pond. Zinc anomalies in soil and peat are also known in this area (Cominco 1970).

Other high background concentrations of zinc in stream sediments are present in the drainage system flowing southwards into Brian's Pond; in a stream about two and one half miles northeast of Brian's Pond where there is a small showing of sphalerite; and in the stream system about five miles northeast of Brian's Pond.

<u>Manganese Distribution</u> - Under certain physico-chemical conditions of the drainage environment the coprecipitation of zinc with manganese and iron hydroxides and oxides may lead to anomalous concentrations of zinc in drainage sediments. Such zinc anomalies are unrelated to zinc mineralization. In the stream sediments of the Daniel's Harbour study area it was found that their zinc content is significantly correlated with both their iron and manganese contents, indicating that the process of zinc coprecipitation with manganese and iron is operative in this area. Furthermore, the iron and manganese contents of the stream sediments are very highly correlated, indicating that the distributions of these two elements are very similar. There is no significant correlation between the zinc content and relative organic content of 104 randomly chosen samples.

The manganese distribution in the stream sediments, which is approximately log-normal, is shown in Figure 25. Stream sediments containing relatively high levels of manganese occur in the drainages between Brian's Pond and Western Blue Pond and in the drainage system flowing southwards into Brian's

Pond. The stream sediments in the area south of the zone of the main zinc mineralization are quite high in manganese, as are some south of River of Ponds Lake. The manganese content of the sediments from different sites from any particular stream is quite variable. The variability is to be expected if the manganese content of the sediments is controlled by the Eh/pH conditions of the stream waters.

Residual Zinc Distribution - The distribution of the residual zinc content of the stream sediments is shown in Figure 26. Comparing this with the actual zinc distribution in Figure 24, the following points are noteworthy. The sediments in the drainages in the vicinity of the main bodies of zinc mineralization are anomalous both in zinc and residual zinc content, although in detail there are minor differences. The anomaly in the small northward draining stream which is about four miles west of Western Blue Pond is more clearly defined by residual zinc values than by actual zinc contents of the sediments. Perhaps the most important difference between the two distributions is seen in the streams between Western Blue Pond and Brian's Pond, and the stream system flowing southwards into Brian's Pond. Sediment samples from these streams contained high background values of actual zinc, but rather lower residual zinc values. The sediments were also generally high in manganese (Fig. 25).

Thus the residual zinc distribution more clearly defines areas of zinc mineralization than does the actual zinc distribution. Although, in the field area the actual zinc distribution does define the main zone of mineralization, there are a number of other locations where the sediments contain high background values of actual zinc which are difficult to interpret unambiguously. Many areas of high background actual zinc content contain only background values of residual zinc. High background residual zinc content may warrant further investigation. The effect of Eh-pH conditions in the drainage environment in producing concentrations of zinc is largely removed by regressing the zinc values against manganese, and thus the confidence with which anomalous residual zinc values in sediments may be related to areas of mineralization is greatly increased.

COMPARISON OF ZINC DISTRIBUTIONS IN LAKE AND STREAM SEDIMENTS

In general, the correspondence between the locations of lake and stream sediment zinc anomalies is good. In many places, however, the stream sediment coverage in the vicinity of some lake sediment anomalies is sparse as for example in the area containing the most significant sphalerite mineralization. Thus for the purpose of a regional geochemical reconnaissance program in this terrain, a lake sediment survey will give a more uniform coverage than stream sediments. In addition a lake sediment survey is considerably quicker and cheaper per unit area to carry out.

The stream sediment survey does contribute further information and complement the lake sediment data. It provides a better definition of the source of anomalous zinc, and thus stream sediment sampling provides a useful means of following-up the source of lake sediment anomalies.

DISTRIBUTION OF ZINC IN SOIL AND TILL OVER MINERALIZATION

Figure 27 shows the locations of grids I and II and the road traverse, where soil and till samples were collected, in relation to some of the known locations of suboutcropping sphalerite mineralization and to the area underlain by "pseudobreccia" - the host rock of the mineralization. In addition, projections to surface of the main zones of mineralization are shown for reference.

Both B and C soil horizons, and basal till were sampled. The element distributions in the two soil horizons and both the minus 50 (<297μ) plus 230 (>63μ) heavy mineral fraction and the minus 230 mesh (<63μ) fraction of the basal till were determined. The zinc distribution best reflects the location of the zinc deposits in these media. The frequency distributions of zinc were examined graphically following the method of Lepelitier (1969) and in all four media they are log-normal and positively skewed, and show an excess of high values over normal background values. This type of distribution is to be expected where sampling is carried out in restricted areas of known mineralization, since a relatively large proportion of samples should have an anomalous metal content. The data are grouped, arbitrarily, using the following boundaries; the log-mean, and one, two and three standard deviations above the log-mean. For the B and C soil samples, and the

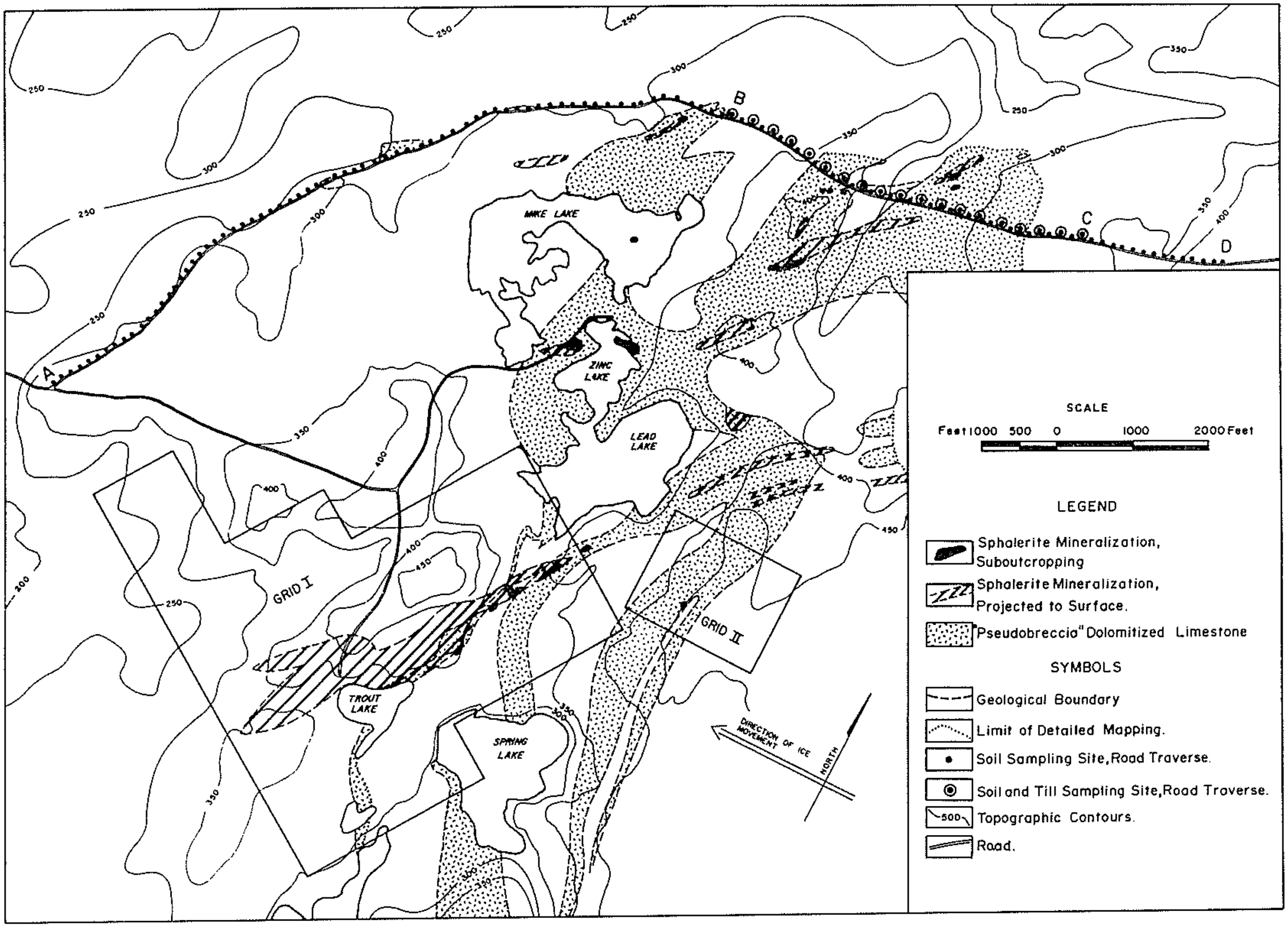

Figure 27 Soil grids and road traverse location map, Daniel's Harbour Area.

minus 230 mesh (<63μ) fraction of the basal till samples these boundaries are 125, 250, 500 and 1000 ppm Zn; for the heavy mineral fraction of the basal till samples these boundaries are 80, 125, 190 and 300 ppm Zn. The reason for generally lower zinc values in the heavy mineral fraction is not understood, but may be related to incomplete digestion of sphalerite by the rather weak acid attack used during analysis. Alternatively, groundwater leaching may have altered most of the sphalerite in the till, leading to a depletion of this mineral in the heavy mineral fraction. The till samples did not appear to be extensively leached.

Grid I - This grid lies over the largest zone of sphalerite mineralization (Fig. 28) with the base line being approximately parallel to the longitudinal axis of the zone. The generalized geology is shown in Figure 27. The zone plunges to the northwest, and suboutcrops on its eastern and southeastern margin. Mineralization does not outcrop, but diamond drill hole data provide a general indication of the areal extent of sphalerite in the suboutcrop (Fig. 28). Furthermore, the host rock of the mineralization, the "pseudobreccia unit" is present over a considerable proportion of the eastern part of the grid in suboutcrop and this unit may be sporadically mineralized with sphalerite.

The direction of ice-movement was to the west. The overburden is calcareous till, and ranges from 0 to 20 feet in depth, averaging 6 to 9 feet. Soil profiles, generally podzolic are developed in most places, except in swampy areas. The area is forested, and the topography undulating, with

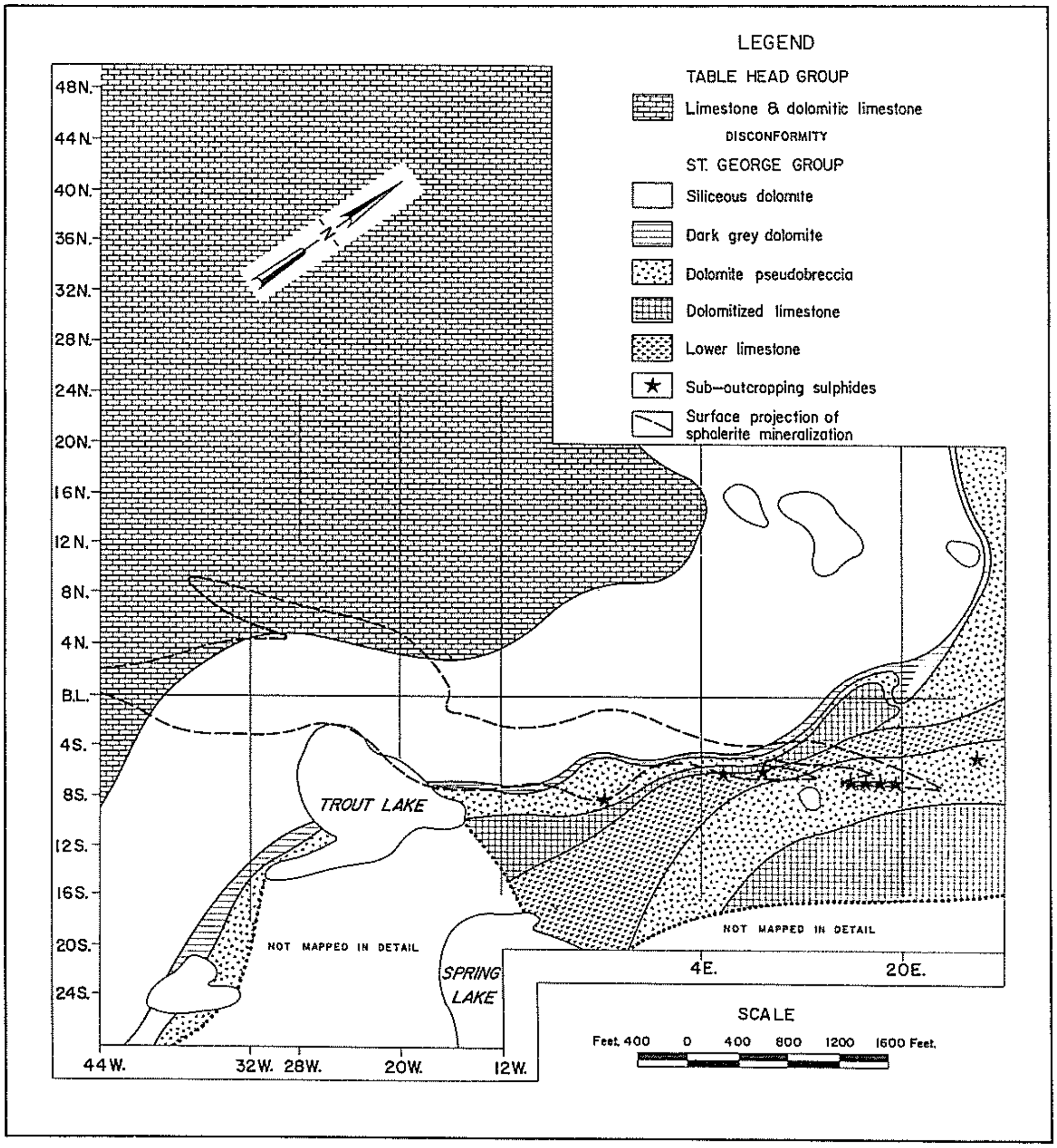

Figure 28 Geology of the grid I sample area, Daniel's Harbour Area.

elevations varying from about 300 to 450 feet.

The distribution of zinc in B horizon soils is shown in Figure 29. High zinc values are found in a strip approximately overlying the suboutcropping mineralization, from 12W/6S to 4E/8S and continuing to the highest value at 2E/4S (910 ppm Zn). High values also occur over a broad area to the west of this strip in the glacial down-ice direction.

The location of the suboutcropping sulphides is less well defined by the zinc distribution in C horizon soils (Fig. 30). Zinc values greater than 500 ppm are found at 20E/4S and 20E/8S, but the anomaly on lines 4E and 12W is displaced to the west, down-ice from its source. This difference between the zinc distributions in the B and C horizons may indicate that the anomaly in the B horizon directly over the mineralized suboutcrop is largely due to the movement of zinc from the sulphides vertically in groundwater, and its precipitation in the B horizon. The anomalous values in C horizon soils at 20E/8N and 20E/16N are in gleyed soils, where no B horizon is developed. In general the C horizon has a higher "geochemical relief" than the B horizon in its zinc content, probably reflecting the influence of hydromorphic dispersion and weathering processes in the latter.

The zinc distribution in the minus 230 mesh (<63μ) fraction of the basal till is shown in Figure 31. Two highly anomalous areas are defined. The first is centred on line 4E between 4E/0+00 and 4E/8S, and apparently extends to lines 12W and 20E. This anomaly lies over and down-ice from the suboutcrop

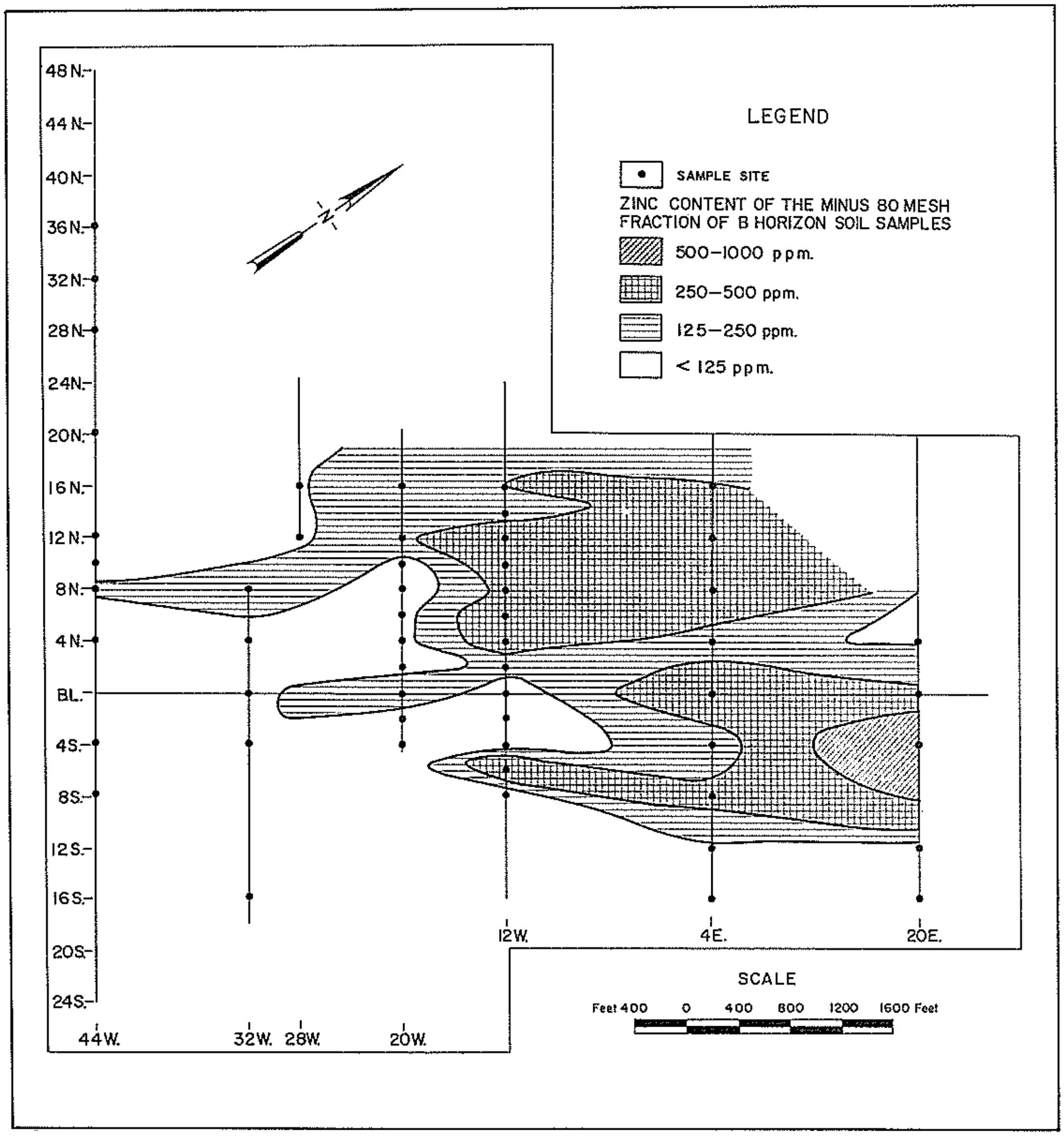

Figure 29 Zinc content of B horizon soil samples, grid I, Daniel's Harbour Area.

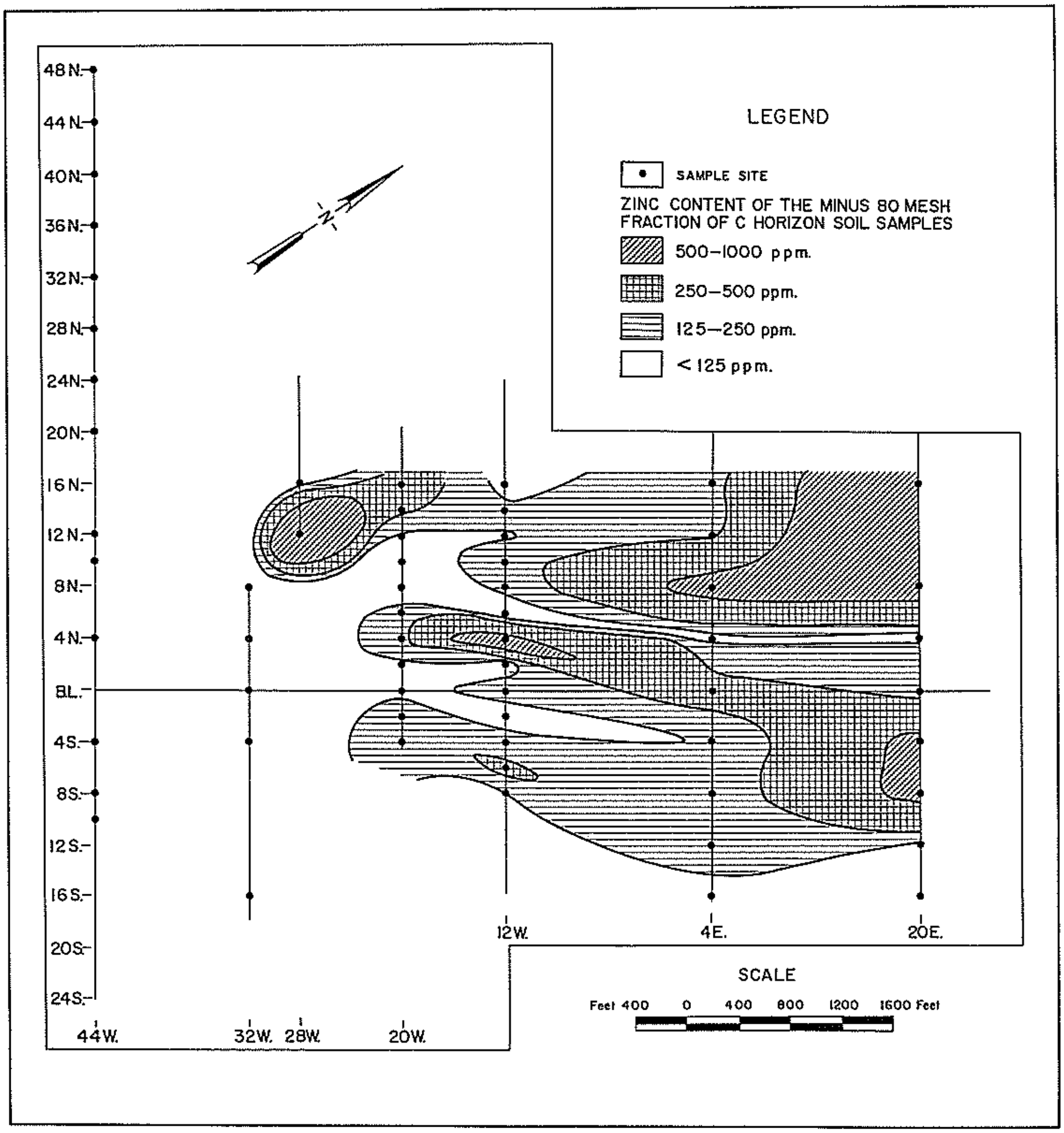

Figure 30 Zinc content of C horizon soil samples, grid I, Daniel's Harbour Area.

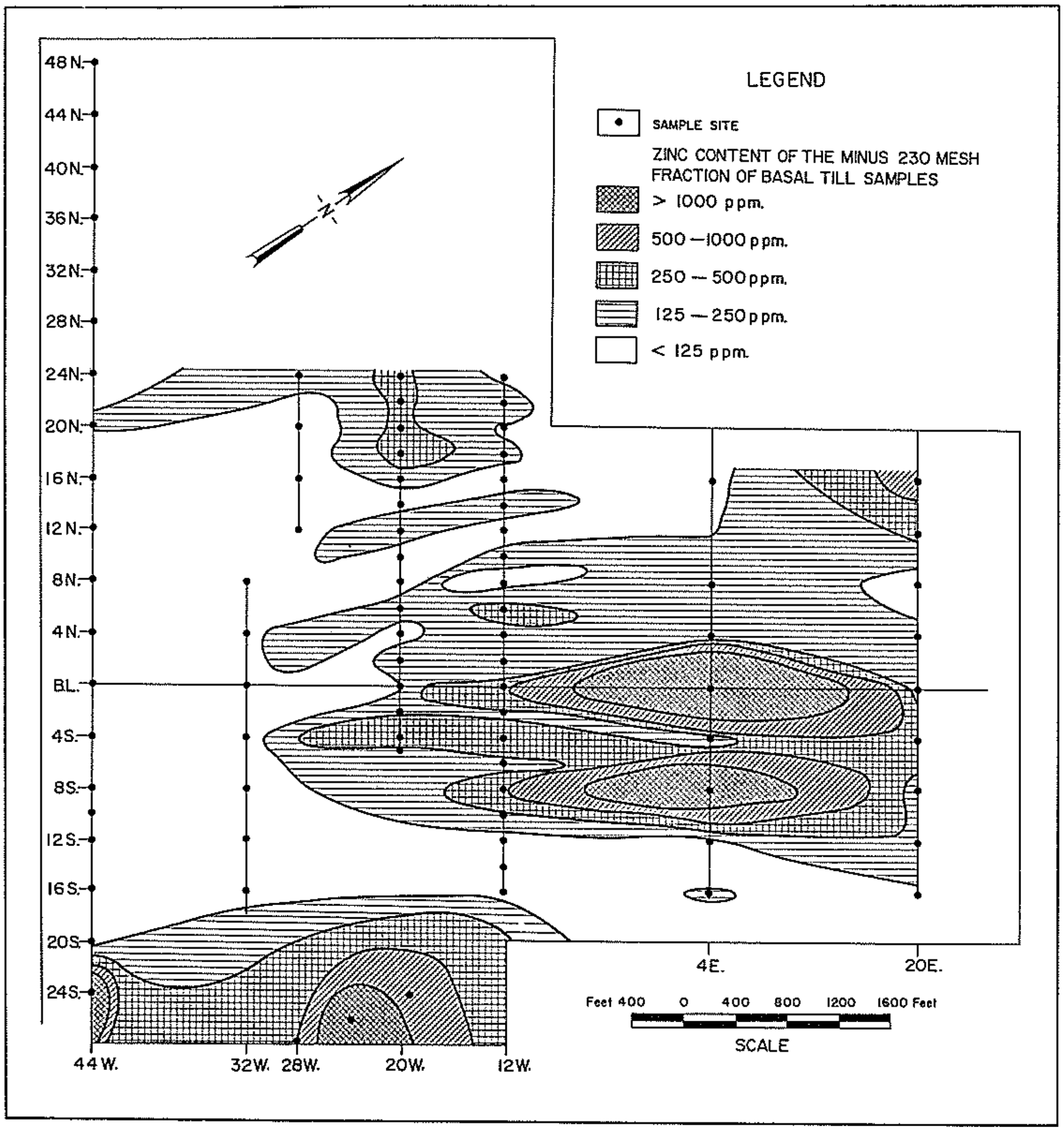

Figure 31 Zinc content of minus 230 mesh fraction of basal till samples, grid I, Daniel's Harbour Area.

of the sphalerite mineralization. This same anomalous area is also reflected in the B and C horizon soils, but is considerably better defined in the basal till. A second anomalous area is present at 44W/2S, and also in three samples taken at 28W/28S, 24W/26S, and 19+50W/24S. There is little outcrop in this area, and no diamond drill holes, so the source of the anomaly is unknown, and should be investigated.

Figure 32 shows the distribution of zinc in the minus 50 (<297μ) plus 230 mesh (>63μ) heavy mineral fraction of the basal till samples. Although the absolute zinc values are lower than in the minus 230 mesh (<63μ) fraction, the pattern developed is very similar. The distribution of metal in the heavy mineral fraction is controlled entirely by the mechanical transport of material during glaciation, whereas the metal distribution in the minus 230 mesh (<63μ) material may be subsequently modified by groundwater solution, transport and redeposition. In this case, however, there appears to be little evidence of lateral groundwater dispersion of zinc in the basal till.

From these results, several features are apparent. The presence of mineralization buried beneath the suboutcrop surface is not reflected by the zinc content of either the soils or till samples - i.e., there is no leakage anomaly upward through bedrock. The zinc anomaly in the soil and till at the centre and eastern end of the grid is related to the suboutcrop of sphalerite mineralization which lies up-ice from and beneath these anomalies.

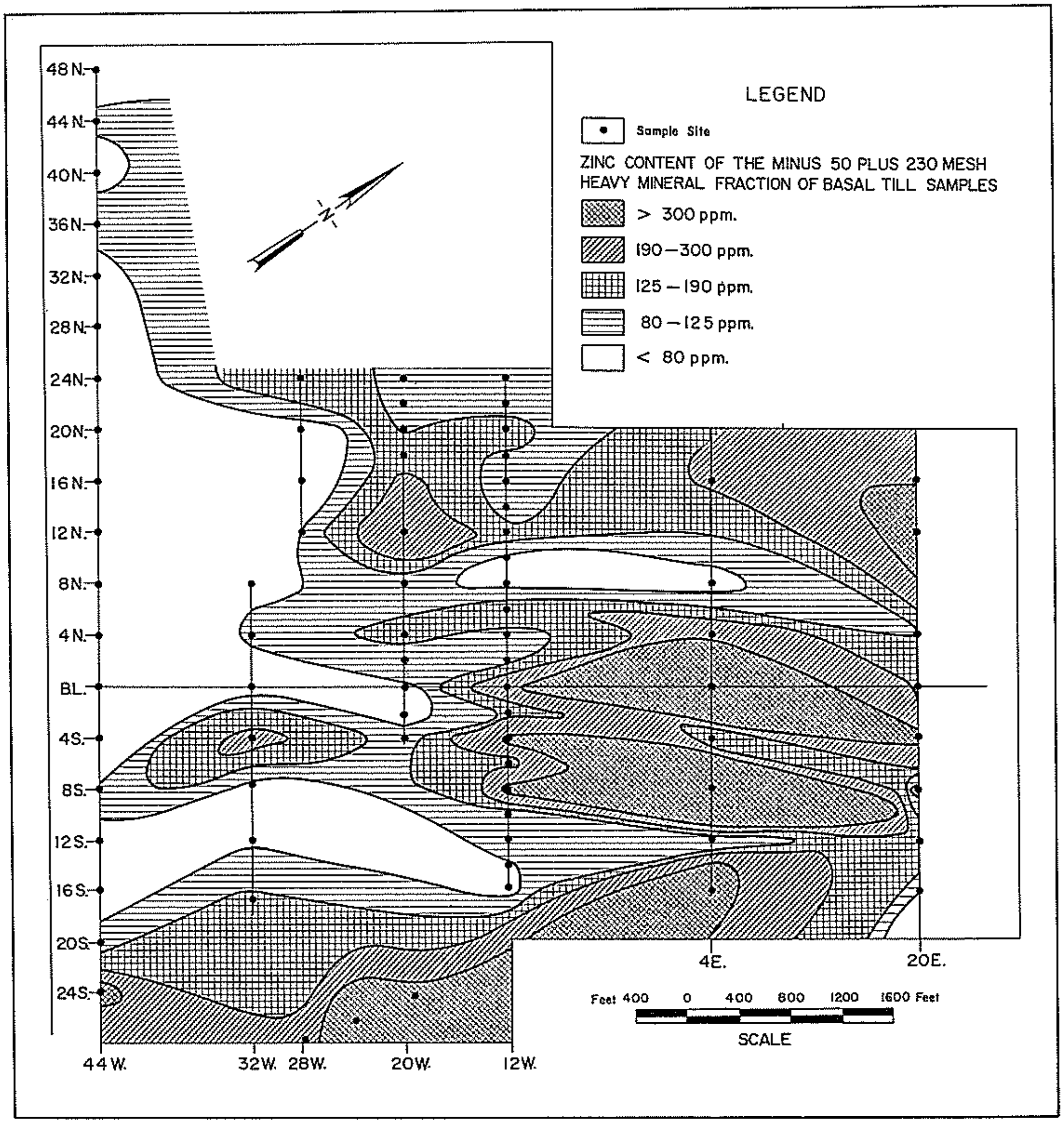

Figure 32 Zinc content of heavy mineral fraction of basal till samples, grid I, Daniel's Harbour Area.

By analogy therefore, the till anomaly at the southwestern margin of the grid is probably related to mineralization, either subjacent or immediately up-ice.

The zinc distributions in both B and C horizon soils define the anomaly related to the suboutcropping mineralization, but neither serve to accurately define the source. The zinc distribution in the basal till does define the location of the source of anomalous zinc more closely. The minus 230 mesh ($<63\mu$) fraction of the basal till samples alone give sufficient information on the zinc distribution in this medium. The zinc distribution in the heavy mineral fraction provides little additional information, and the cost of carrying out these separations is unnecessary in this area.

Road Traverse - To determine the extent of glacial dispersion of material from suboutcropping mineralization, soil samples were collected from a traverse 24,000 feet long extending generally down-ice from a number of mineralized zones. Both B and C horizon soils, where developed, were sampled at stations 200 feet apart, at least 20 feet off the road away from possible contamination. The location of the traverse A-D in relation to known suboutcropping mineralization and "pseudobreccia" is shown in Figure 27. In addition basal till samples were collected at 400-foot intervals over part of the traverse length (Fig. 33, section B-C). For convenience the sample site at A is taken at the origin, and the other sample sites will be referred to by their distance east of this origin.

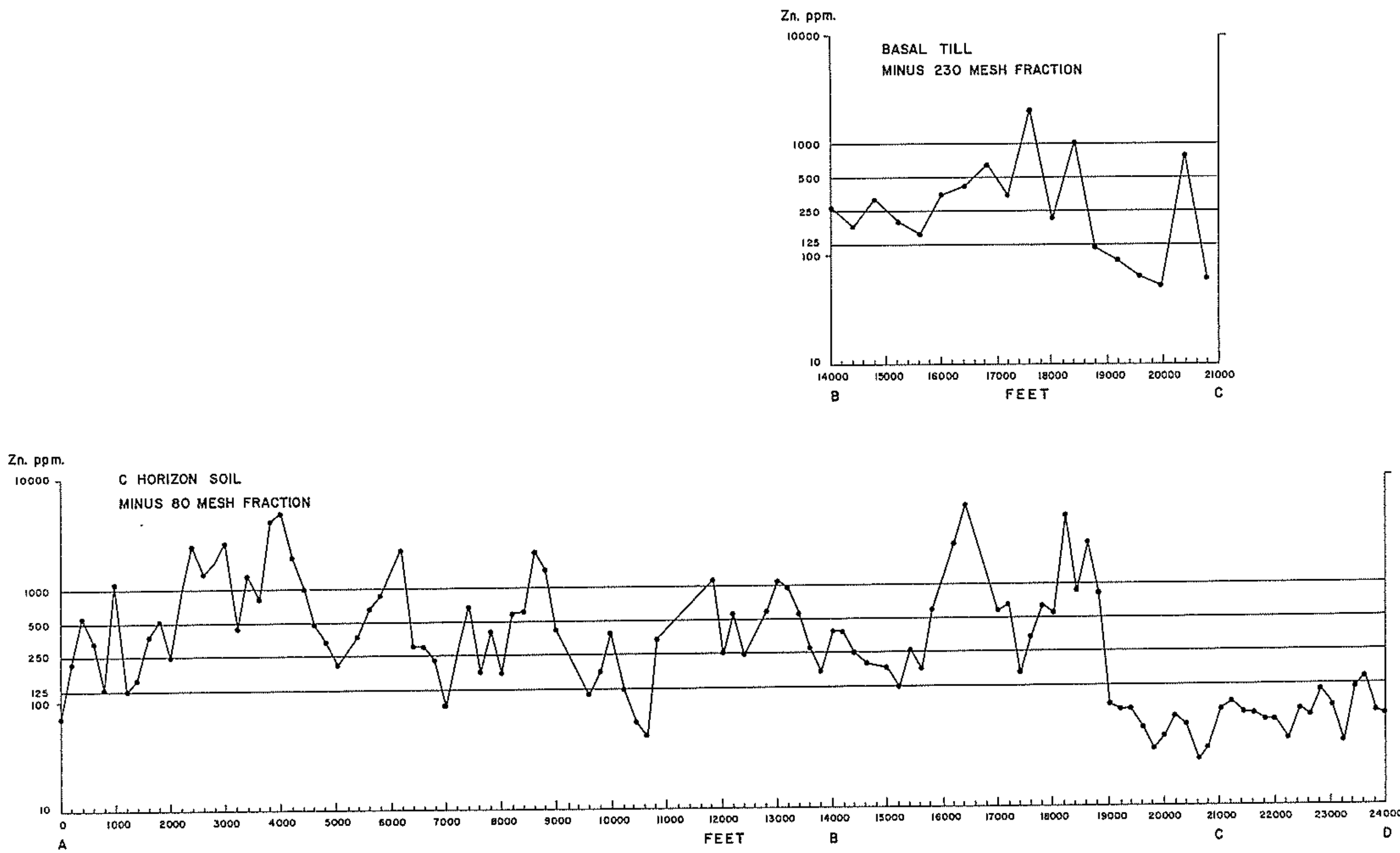

Figure 33 Distribution of zinc in C horizon soil along traverse A-D and basal till along traverse B-C in the Mike Lake - Trout Lake Area, Daniel's Harbour Area.

The distribution of zinc in the B and C horizon soils is essentially similar. Its distribution in the minus 230 mesh (<63μ) and heavy mineral fraction of basal till samples are also closely comparable, although the zinc content of the heavy mineral fraction of any particular sample is generally lower than the minus 230 mesh (<63μ) fraction. For this reason, only the zinc distribution in the C horizon soil samples along the traverse A-D, and in the minus 230 mesh (<63μ) fraction of the basal till samples along traverse B-C are shown in Figure 33.

The main direction of ice movement being essentially from east to west, it is convenient to consider the zinc distributions in this direction. The zinc content of the C horizon soils are within the background range (<125 ppm) from 24,000 feet east to 19,000 feet east. From 19,000 feet to 15,800 feet east the zinc values are highly anomalous, with peak values at 18,200 feet and 16,600 feet. This anomaly coincides with the suboutcrop of mineralized "pseudobreccia" (Fig. 27). Pods of sphalerite mineralization and associated mineralized haloes are present in the suboutcrop surface in this vicinity. From 16,600 feet to 13,600 feet east the zinc values fall off somewhat, but remain above background (125-400 ppm). Between 13,400 feet and 12,600 feet the zinc values are again clearly anomalous (400-1,100 ppm), over and down-ice from suboutcropping "pseudobreccia". This "pseudobreccia" contains a zone of sphalerite mineralization at depth (in excess of 100 feet), and may itself be mineralized at the suboutcrop surface. Alternatively, the anomaly could be due in part to mineralized material transported from mineralization 2,000 to

3,000 feet up-ice. The C horizon samples at 12,200 feet and 11,800 feet east are also anomalous, and do not have an apparent local source. From 11,600 to 11,000 feet the overburden is shallow, and B horizon soils directly overlie bedrock. Both the B horizon soils and the C horizons soils (where developed) between 11,600 and 9,000 feet contain background or possibly anomalous zinc values (50-400 ppm). Between 8,800 feet and 7,200 feet, 6,200 feet and 5,400 feet, 4,800 and 2,000 feet, and at 1,800 feet, 1,000 feet and 400 feet east anomalous zinc values are also present in the C horizon. A small area of suboutcropping pseudobreccia occurs between 8,600 feet and 7,700 feet (Fig. 27), but otherwise no local sources for these anomalies are known. The small zone of sphalerite mineralization between 7,000 and 6,500 feet east (Fig. 27) is present at depth (more than 250 feet below surface) and is unlikely to be reflected in the zinc content of the overburden. The source or sources of these anomalies most probably lies from 5,000 to 10,000 feet up-ice to the east and is represented by the suboutcropping sphalerite and mineralized pseudobreccia in the vicinity of Mike Lake, Zinc Lake and Lead Lake. A well developed boulder train extends westwards from these occurrences (Cooke, 1969). In particular, two zones of outcropping and suboutcropping sphalerite occur on the shores of Zinc Lake (Fig. 27).

The zinc distribution in the minus 230 mesh ($<63\mu$) fraction of the basal till along the traverse B-C (Fig. 33) is essentially similar to that in the C horizon soils. Westwards from C up to 18,800 feet east, the zinc values are background (<125 ppm), with the exception of one erratically high value at 20,400 feet east (the heavy mineral fraction of this sample was not anomalous). Between 18,600 and 16,000 feet east zinc values are anomalous (240-2000 ppm), corresponding with the anomalous C horizon values. In detail, however, the peaks of the anomaly in the basal till are at 18,400 and 17,600 feet east. As is the case of Grid I, the zinc anomaly in the C horizon is more diffuse than in the basal till, and shows more displacement in the down-ice direction.

From the zinc distribution in the C horizon soils along the traverse A-D (Fig. 33) it is evident that suboutcropping high grade mineralization in the Zinc Lake area has given rise to a very large dispersion pattern down-ice to the west. This is in contrast to the rather limited area anomalous in zinc in the soils of Grid I. Probably the main reason for this is the difference in the grade of mineralization in the suboutcrop, which is low in the suboutcropping "pseudobreccia" on Grid I. Consequently, with the general decrease in the amount of mineralized material in the overburden down-ice from a source of mineralization, the zinc values in the overburden from a low grade source will tend towards background much closer to the source than they will from a high grade source. In addition the mass of the mineralized material removed by glacial erosion from the suboutcropping zones on the shores of Zinc Lake has been estimated at about 100,000 tons of 10% Zn (Pegg 1964). The mass of the zinc removed from the weakly mineralized "pseudebreccia" on Grid I is probably several orders of magnitude less.

Grid II - The location of this grid, the base line of which lies north-south, is shown in Figure 27. The geology of the area sampled is shown in Figure 34. The local strike is roughly north-south, and a broad belt of the "pseudobreccia" unit occurs to the west of the base line. An induced polarization (I.P.) anomaly trends roughly north-south, at about 9E between lines 28N and 16N. This anomaly is not due to sphalerite mineralization. The "pseudobreccia" is known to be sporadically mineralized, with a small exposure of heavily disseminated sphalerite and galena at 16N/5W and of sphalerite at 19N/8W. Neither of these showings are of economic significance.

The reasons for sampling on this grid were to determine firstly, whether geochemistry could have been used to determine whether the I.P. anomaly was due to suboutcropping sphalerite mineralization, and, secondly to determine the magnitude of the geochemical response in both soil and basal till from the small showings of mineralization. The overburden cover is generally thin in this area, varying from 0 to 10 feet, and averaging 4 to 6 feet in depth.

C horizon soil samples were collected at 200-foot intervals along lines 400-feet apart. The zinc content of the minus 80 mesh (<177μ) fraction is shown in Figure 35. The zinc values to the east of the base line, and over the I.P. anomaly are all within the background range (<125 ppm). The area west of the base line which is underlain by the "pseudobreccia" unit is generally high background (125-250 ppm Zn), with two possibly anomalous values at 24N/6W and 20N/8W, the latter of which is near a zinc showing. The B horizon was also sampled, and shows a similar although more diffuse pattern.

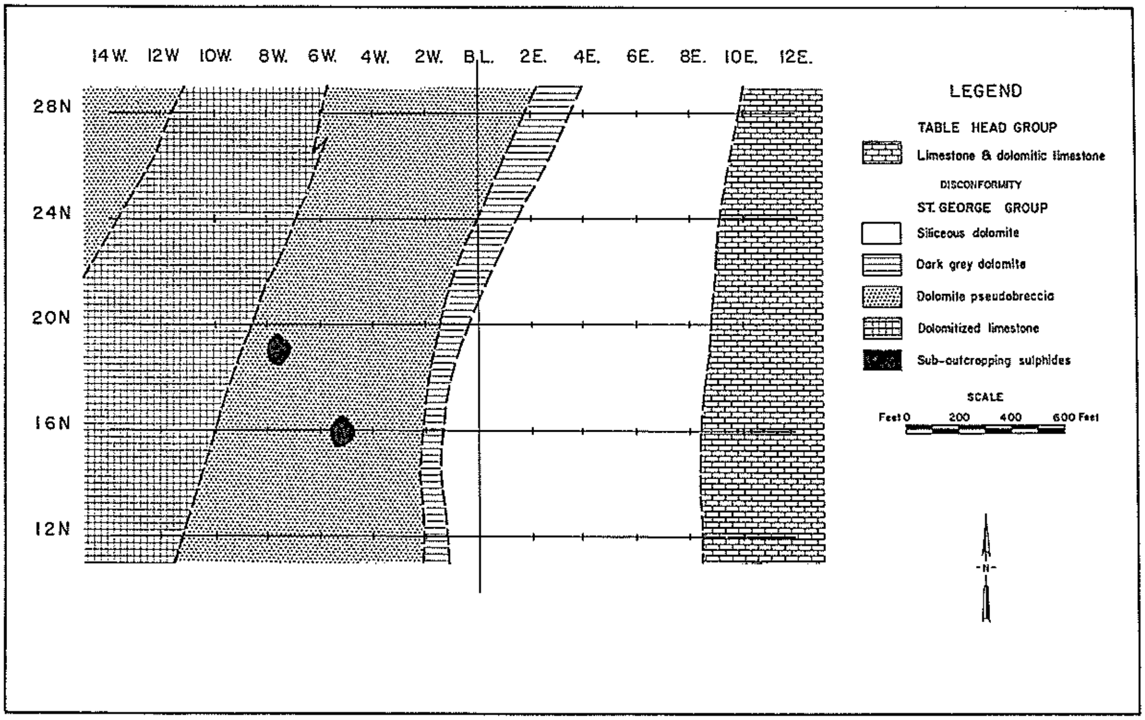

Figure 34 Geology of the grid II sample area, Daniel's Harbour Area.

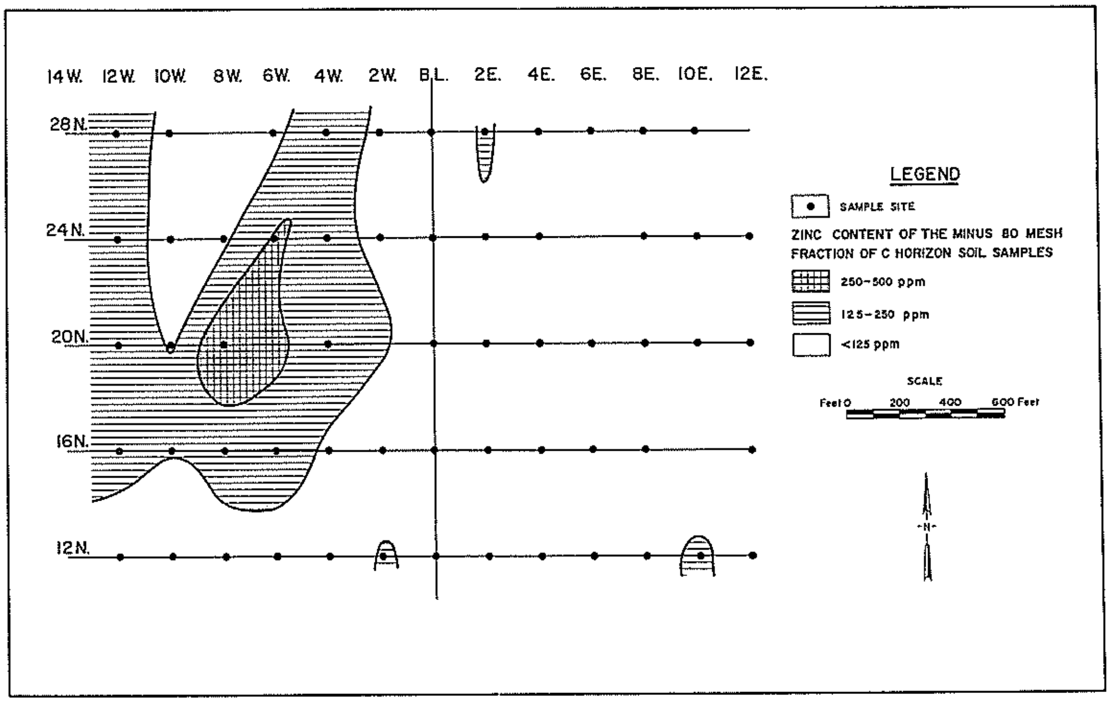

Figure 35 Zinc content of C horizon soils, grid II, Daniel's Harbour Area.

Basal till samples were collected at 200-foot intervals east of, and at 100-foot intervals west of 1W, along lines 28N, 24N, 20N, 16N and 12N. The zinc distribution in the minus 230 mesh (<63μ) fraction is shown in Figure 36. The zinc distribution in the minus 50 (<297μ) plus 230 mesh (>63μ) heavy mineral fraction is similar. Figure 36 shows that, as in the case of the C horizon soils, the zinc values of the basal till over the I.P. anomaly are well within the background range (<125 ppm Zn). The area underlain by the pseudobreccia is generally characterized by high background zinc values in the basal till, with two anomalous areas. One of these occurs on line 20N, between 6W and 7W, close to known sphalerite mineralization. The other occurs on line 28N at 13W and 14W. The mineralization outcropping at 16N/5W is not reflected by high zinc values in the immediately adjacent till samples. The local direction of the ice movement is not known exactly in this area, but the zinc distribution pattern suggest a local northwesterly movement.

These results demonstrate that either soil or till sampling would have strongly suggested that the I.P. anomaly is not due to suboutcropping sphalerite mineralization. Furthermore, the zinc distributions in these media focus attention on the area underlain by the "pseudobreccia" unit, which is mineralized in places. Although the extent of the till anomalies is less than those developed on Grid I, it does not necessarily follow that anything can be inferred as to the relative grade and tonnage of the mineralization on each grid. Qualitatively the size of anomalies may be related to the grade and area of suboutcropping sulphides only, since in a general way this will control the

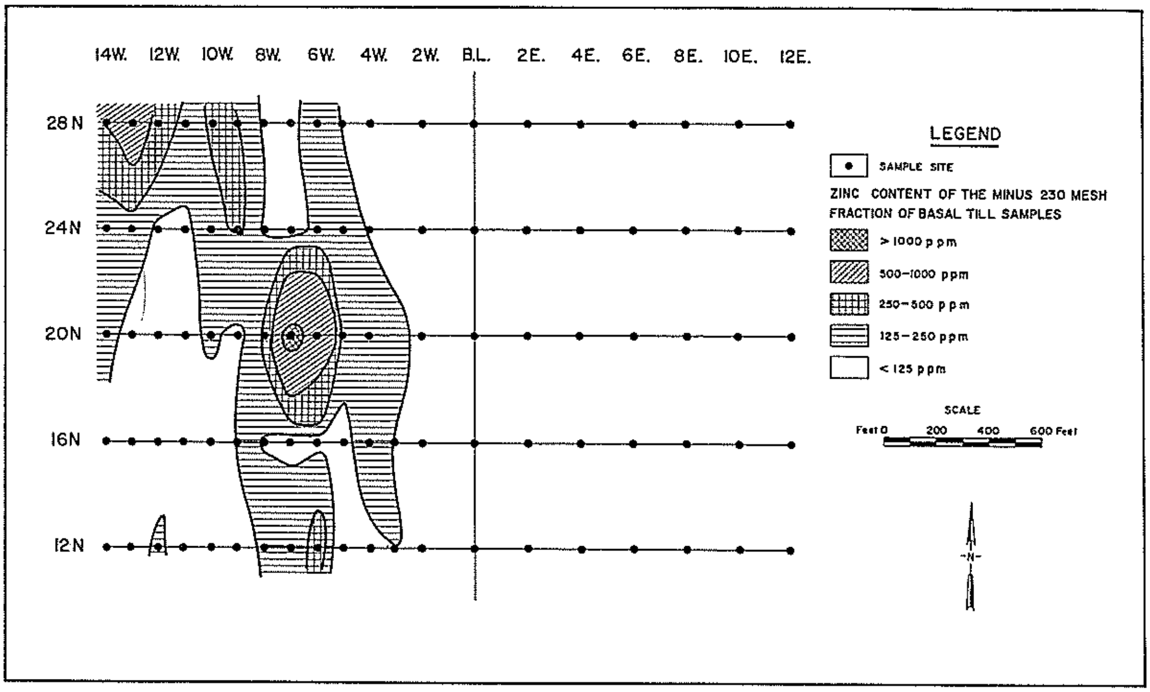

Figure 36 Zinc content of basal till samples, grid II, Daniel's Harbour Area.

mass of sphalerite incorporated into the overburden. This mass will, however, also be affected by the intensity of glacial erosion over the mineralization, and this intensity will have varied from place to place.

CONCLUSIONS AND RECOMMENDATIONS

From the results of this study, a number of conclusions as to the applicability of geochemical techniques at various stages of an exploration program may be drawn, and recommendations made for exploration programs in areas of similar geology and terrain. These conclusions and recommendations will be discussed within the framework of the various stages of an exploration program.

REGIONAL RECONNAISSANCE

Both stream sediment and more recently lake sediment surveys have been used in various parts of the world to assess the mineral potential of large areas. In the present study both types of survey are successful in defining areas of known sphalerite mineralization. Organic lake sediments are preferable, however, for a number of reasons. The sampling density of one sample per two square miles appears to be adequate, and it is generally possible to obtain an approximately random sampling distribution. Stream sediments, on the other hand, should be collected at a considerably higher density, since their zinc content, as expected, appears to reflect more local features of the bedrock and surficial environment. In addition, the distribution of stream systems is irregular in the study area, and in many places outside this area which are underlain by similar lithologies. Thus the distribution of stream sediment samples is not uniform. Lake sediment sampling therefore can be carried out more cheaply and quickly than stream sediment sampling, and will in general provide an approximately uniform sampling distribution. In areas where lakes are few, and streams are present, stream sediments may be employed to maintain coverage. They must, of course, be treated as a separate data set from the lake sediments.

The zinc distribution in the lake sediments is not strongly correlated with that of manganese, and only weakly so with iron and organic content. Thus there is little need for data processing involving regression. The zinc values may be related directly to the local geological envirionment.

In general the lake sediment zinc anomalies coincide closely with areas of known mineralization, and there is little evidence of displacement to the west (i.e., down-ice) at this scale. By far the greatest part of the area is covered by a thin veneer of moraine (Fig. 5), but substantial areas are covered by peat and by thin marine deposits, predominantly the winnowed coarse fraction of till. Both anomalous and background zinc values are found in sediments from lakes in peat-bog terrains. Most zinc values in sediments from lakes in areas of marine deposits (essentially confined to the coastal strip) are low background, although high background and anomalous values do occur. It is likely that the veneer of marine deposits is subduing the geochemical "relief" in places, and elsewhere is suppressing it entirely.

Thus low zinc values in these areas cannot necessarily be taken as evidence of lack of mineralization. Areas where other types of surficial deposits are dominant (Fig. 5), such as marine deltas and terraces are all of limited areal extent, and therefore will have little effect of lake sediment sampling at the density employed in this study.

PRELIMINARY FOLLOW-UP

Ideally all lakes whose sediments contain anomalous zinc concentrations should be resampled to confirm these anomalies. Commonly, however, logistical considerations preclude this step. To define more closely the source of the zinc mineralization giving rise to each lake sediment anomaly, stream sediment sampling of all the streams draining into the lake should be carried out at the preliminary follow-up stage.

Stream sediment samples should be collected at intervals of not more than 500 feet along the streams, and from all tributaries. Collection of organic-rich samples should be avoided as far as possible, since this type of sample may not be directly comparable to silt samples. In view of the correlation of the zinc content of stream sediment samples with manganese and iron, these two elements, or at least manganese, should also be determined. Linear regression of zinc against manganese, or preferably against both manganese and iron is desirable to eliminate the physicochemical effects of the surficial environment on the zinc distribution.

Ranking of the lake sediment anomalies in order for follow-up should be largely on the basis of their geological setting, as well as their magnitude and extent. Where there is little geological information, reconnaissance geological mapping should be carried out at the preliminary follow-up stage. The magnitude of a lake sediment (and also a stream sediment, soil or till)anomaly will be related not so much to the grade and size of the mineralization as to the amount of zinc moving from the mineralization into the sample medium. This will depend on factors such as the area and grade of the mineralization in the suboutcrop, the magnitude of any associated overburden anomaly, and the distance from the suboutcrop and overburden anomaly to the sample point, and so forth.

In glaciated areas, the source of metal giving rise to stream sediment anomalies may be mineralization in bedrock, or mineralization incorporated in the till, or a combination of both. In the present study, the sediments in a stream system, flowing in a northeasterly direction west of the area containing the main zones of mineralization, contain anomalous or high background residual zinc values (Fig. 26). These anomalies are probably related to mineralized till derived from the known sphalerite deposits, although they may also be related to unknown mineralization in the vicinity of the stream system, which is underlain by rocks of the upper part of the St. George Group.

In general, the zinc values found in sediments from streams draining areas of marine deposits do not appear to be notably different from those in streams draining areas covered by a veneer of moraine or areas of extensive outcrop. For example, the stream system draining the south end of the area of the main sphalerite mineralization has sediments anomalous in residual zinc not only immediately downstream from known mineralization, but also in two discrete areas downstream to the west (Fig. 26). Both of these latter anomalous zones are in areas covered predominantly by a veneer of marine deposits. Irrespective of whether the source of these anomalies is mineralized till or bedrock mineralization, the marine deposits do not interfere with the geochemical response in the stream sediments. Presumbably if the marine deposits are thicker, and especially if marine clays are present extensively elsewhere outside the area, then the geochemistry of the stream sediments may not reflect that of the underlying bedrock or till.

The residual zinc values of stream sediment samples from peat-bog terrains appear to be comparable to those collected from better drained terrains. Thus in general the surficial deposits of the study area do not appear to limit the usefulness of stream sediment sampling to any marked extent. Presumably this will be generally true in similar terrain in the coastal lowlands of the Great Northern Peninsula, although some areas may be found to be less favourable.

DETAILED FOLLOW-UP

Soil and basal till sampling comprise the last phase of the geochemical exploration program. It appears from the results of the present study that the main control over the magnitude of geochemical dispersion patterns in the overburden is the grade and areal extent of sphalerite mineralization in the suboutcrop. This controls the mass of sphalerite incorporated into the overburden during glacial erosion, although the local intensity of this erosion will also be a factor. Since weakly disseminated mineralization in the suboutcrop may or may not be related to higher grade mineralization beneath the suboutcrop surface, weak zinc anomalies in the overburden may or may not be related to significant mineralization. Sphalerite mineralization which does not intersect the suboutcrop surface will not be reflected in the zinc content of the overburden. Whilst the use of geochemical techniques is thus limited at this stage, and much emphasis must be placed on detailed geological mapping and diamond drilling, nevertheless the distribution of zinc in soil and basal till can provide useful additional information to aid in the direction of a diamond drilling program.

The great variations in the magnitude of soil and till anomalies in the present study make it difficult to categorically plan a standard sampling approach. On the choice of sample media, the C horizon appears to give better results than the B horizon soil, and the fine fraction, minus 230 mesh (<63μ), of the basal till samples gives similar results to the heavy mineral fraction, which is more costly to prepare. The location and orientation of a soil sampling grid will be determined by the geological strike and the dominant local direction of ice movement. In general, a soil sampling program should be designed to detect the weaker type of anomalies. Thus, sampling on a 400-foot square grid should be a sufficiently close interval. The sampling should be extended in the up-ice direction until background zinc values are encountered in the soil samples.

Where the till is shallow (on average less than six feet) basal till sampling is probably unnesessary, since the C horizon is commonly three to four feet deep. Additional fill-in samples may be required in anomalous areas on a 200-foot square grid pattern. In the present study on Grid II, the basal till and C horizon soil samples were collected in many places from the same depth. The greater definition of the anomalous zone in the minus 230 mesh (<63μ) fraction of the basal till samples compared with that in the minus 80 mesh (<177μ) fraction of the C horizon soil samples (Figs. 35 and 36) may thus be due mainly to the size fraction used. It may be preferable therefore to use a fraction finer than minus 80 mesh (<177μ) for the C horizon soils.

Where the overburden is deeper, basal till sampling over and adjacent to areas of anomalous C horizon soils may better define the source of the anomaly. This appears to be true in the present study in the case of Grid I (Figs. 30 and 31). A close inspection of Figure 31 shows that the sampling density is inadequate. For example on line 12W, anomalous zinc values are present in the basal till at 8S, 4S, 0 and 4N, whereas the zinc values at 10S, 6S, 2S and 2N are only background to high background. Thus to adequately define the source of basal till anomalies a 200-foot square grid pattern should be employed, and possibly even closer sampling may be required.

The area in which all the soil and till sampling was carried out in the present study is covered by a fairly thin veneer of moraine (Fig. 5), mainly lodgement till. Elsewhere in the area the surficial geology is in places more complex. In areas covered by outwash deposits, marine deposits or where the upper part of the till has been reworked by marine action soil sampling is unlikely to be successful. Commonly, however, these types of material are underlain by lodgement till, and in these cases basal till sampling may still be successful. Glacial meltwater channel deposits, characterized by well sorted and bedded sand and gravel and their linearity, should not be sampled.

Basal till sampling may also be readily carried out in bog areas, allowing an even sampling coverage regardless of the nature of the drainage of the terrain. Although no work on the distribution of zinc in peat bogs adjacent to sphalerite mineralization was done in the present study, this aspect was investigated by Gleeson and Coope (1967). They found that the zinc content of the upper clay layer immediately below the peat best reflects the presence of nearby mineralization.

REFERENCES[1]

Allan, R.J., Cameron, E.M., and Durham, C.C.
1973: Reconnaissance geochemistry using lake sediments of a 36,000-square-mile area of the Northwestern Canadian Shield; Geol. Surv. Can., Paper 72-50.

Baird, D.M.
1960: Observations on the nature and origin of the Cowhead Breccias of Newfoundland; Geol. Surv. Can., Paper 60-3.

Boyle, R.W., and Jonasson, I.R.
1973: The geochemistry of arsenic and its use as an indicator element in geochemical prospecting; Jour. Geochem. Explor. Vol. 2 No. 3, pp. 251-296.

Collins, J.A. and Smith, L.
1972: (a) Sphalerite as related to the tectonic movements, deposition, diagenesis and karstification of carbonate platform; Proc. 24th. Int. Geol. Cong. (Montreal), Sec. 6, pp. 208-215.

1972: (b) Lithostratigraphic controls of some Ordovician sphalerite; in Amstutz, G.C. and Bernard, A.J. (Eds.), Ores in Sediments, pp. 79-81, Published by Springer-Verlag, Berlin.

Cominco
1969: Unpublished geological map of the Newfoundland Zinc Mines Limited concession, Great Northern Peninsula, Newfoundland, scale 1:50,000. CONFIDENTIAL

1970: Yearly report on the Leitch concession area; unpub. rept., Cominco Ltd. CONFIDENTIAL

Cook, R.B.
1969: Report of work done by Cominco on the Leitch Concession, Daniel's Harbour, Newfoundland; Unpub. Company report, Cominco Limited. CONFIDENTIAL

Cumming, L.M.
1967: Platform and klippe tectonics of Western Newfoundland: a Review; in Clark, T.H. (Ed.), Appalachian Tectonics, Roy. Soc. Can., Spec. Pub. 10, pp. 10-17.

1968: St. George - Table Head disconformity and zinc mineralization, Western Newfoundland; Can. Inst. Min. Metall. Bull. Vol. 61, pp. 721-725.

[1]Unpublished company reports indicated to be confidential may be examined, with the permission of the company, in the offices of the Province of Newfoundland and Labrador Mineral Development Division, 95 Bonaventure Avenue, St. John's, Newfoundland.

Falconbridge Mines Limited
Geological Map of the Twin Lakes area, Newfoundland; unpub. map. CONFIDENTIAL

Fortescue, J.A.C. and Hornbrook, E.H.W.
1969: Progress report on biogeochemical research at the Geological Survey of Canada, 1963-1966; Geol. Surv. Can., Paper 67-23, Part II, pp. 39-64.

Garrett, R.G.
1971: The dispersion of copper and zinc in glacial overburden at the Louvem deposit, Val d'Or, Quebec; in Boyle, R.W. (Ed.), Can. Inst. Min. Metall. Special Vol. No. 11, pp. 157-165.

Geological Survey of Canada
1969: Aeromagnetic map of Roberts Arm Sheet, Newfoundland, Map No. 4460G.

Gleeson, C.F. and Coope, J.A.
1967: Some observation on the distribution of metals in swamps in Eastern Canada; Geol. Surv. Can., Paper 66-54, pp. 145-166.

Gleeson, C.F. and Cormier, R.
1971: Evaluation by geochemistry of geophysical anomalies and geological targets using overburden sampling at depth; in Boyle, R.W. (Ed.), Can. Inst. Min. Metall., Special Vol. No. 11, pp. 159-165.

Grant, D.R.
1969: (a) Late Pleistocene readvance of piedmont glaciers in western Newfoundland; Maritime Sediments, vol. 5, no. 3, pp. 126-128.

1969: (b) Surficial deposits, geomorphic features, and late Quaternary history of the terminus of the Northern Peninsula of Newfoundland, and adjacent Quebec-Labrador; Maritime Sediments, vol. 5, no. 3, pp. 123-125.

1972: (a) Surficial geology, western Newfoundland; Geol. Surv. Can. Paper 72-1, Part A, pp. 157-160.

1972: (b) Surficial geology reconnaissance, island of Newfoundland; Geol. Surv. Can., Paper 72-1, Part B, p. 100.

1972: (c) Postglacial emergence of northern Newfoundland; Geol. Surv. Can. Paper 72-1, Part B, pp. 100-102.

1973: (a) Canada-Newfoundland and Labrador Mineral Development Program, Project 6: Glacial geological - Geochemical survey (glacial geology phase); Geol. Surv. Can., Paper 73-1, Part A, pp. 196-198.

1973: (b) Terrain conditions, Gros Morne National Park; Geol. Surv. Can., Paper 73-1, Part B, pp. 121-125.

1973: (c) Surficial Geology of eleven map-areas, western Newfoundland Geol. Surv. Can., Open File, No. 180.

Hayes, J.J.
1951: Preliminary map of Marks Lake area, Newfoundland; Geol. Surv. Can., Paper 51-20.

Hornbrook, E.H.W. and Gleeson, C.F.
1972: Regional geochemical lake bottom sediment and till sampling in the Timmins-Val d'Or region of Ontario and Quebec: Geol. Surv. Can., Open File No. 112.

Hornbrook, E.H.W. and Jonasson, I.R.
1971: Mercury in permafrost regions: occurrence and distribution in the Kaminak Lake area, Northwest Territories; Geol. Surv. Can., Paper 71-43.

Horsnail, R.F., Nichol, I. and Webb, J.S.
1969: Influence of variations in the surface environment on metal distribution in drainage sediments; Colorado Sch. of Mines, Quart. Vol. 64, No. 1, pp. 307-322.

Jenness, S.E.
1960: Late Pleistocene Glaciation of Eastern Newfoundland; Bull. Geol. Soc. Am., 71, pp. 161-180.

Jonasson, I.R., Lynch, J.J. and Trip, L.J.
1973: Field and laboratory methods used by the Geological Survey of Canada in geochemical surveys, No. 12, mercury in ores, rocks, soils, sediments and waters; Geol. Surv. Can., Paper 73-21.

Lepeltier, C.
1969: A simplified statistical treatment of geochemical data by graphical representation; Econ. Geol. Vol. 64, pp. 538-550.

Nelson, S.J.
1955: Geology of the Portland Creek-Port Saunders area, West Coast, Newfoundland; Dept. Mines Res., Mines Branch, Geol. Surv. Rept. 7, 58p.

Noranda Exploration Company Limited
1972: Unpublished geological maps of the Roberts Arm area, Newfoundland. CONFIDENTIAL

Northern Miner
1974: Higher prices raise Teck. net: subsiduaries show potential; Vol. 59, No. 49, Feb. 7, 1974.

Pegg, C.W.
1964: Report on exploration and development carried out by Leitch Gold Mines Ltd., unpub. report, Leitch Gold Mines Ltd. CONFIDENTIAL

Poole, W.H., Kelley, D.G. and Neale, E.R.W.
1964: Age and correlation problems in the Appalachian region of Canada, in Osborne F.F. (Ed.), Geochronology in Canada, Roy. Soc. Can. Spec. Pub. 8, pp. 61-84.

Potter, R.R.
1956: Report on the Seal Bay-New Bay area; Unpublished company report to Newfoundland and Labrador Corporation. CONFIDENTIAL

Roedder, E.
1971: Fluid-inclusion evidence on the environment of formation of mineral deposits of the Southern Appalachian Valley; Econ. Geol. Vol. 66, pp. 777-791.

Rose, A.W. and Suhr, N.H.
1971: Major element content as a means of allowing for background variation in stream sediment geochemical exploration; in Boyle, R.W. (Ed.), Can. Inst. Min. Metall., International Geochemical Exploration Symposium, Special Vol. No. 11, pp. 587-593.

Sangster, D.F.
1968: Some chemical features of lead-zinc deposits in carbonate rocks; Geol. Surv. Can., Paper 68-39.

Schuchert, C. and Dunbar, C.D.
1934: Stratigraphy of Western Newfoundland; Geol. Soc. Am., Mem. 1, 123 p.

Shilts, W.W.
1973: Till indicator train formed by glacial transport of nickel and other ultrabasic components: a model for drift prospecting; Geol. Surv. Can., Paper 73-1, Part A, pp. 213-219.

Skinner, R.G.
1973: Drift prospecting in the Abitibi Clay Belt; Geol. Surv. Can., Open File No. 116.

Thomas, R.L., Kemp, A.L.W. and Lewis, C.F.M.
1972: Report on the surficial sediment distribution of the Great Lakes, Part 1, - Lake Ontario; Scientific series No. 10, Geol. Surv. Can., Paper 72-17.

Timperley, M.H., Jonasson, I.R. and Allan, R.J.
1973: Sub-aquatic gels: a medium for geochemical prospecting in the southern Canadian Shield; Geol. Surv. Can., Paper 73-1, Part A, pp. 58-62.

Wade, J.G.
1967: Newfoundland Zinc Mines Limited exploration rept.; unpub. company rept. CONFIDENTIAL

Williams, H.
1962: Botwood (west-half) map-area, Newfoundland; Geol. Surv. Can. Paper 62-9.

1967: Geology of Newfoundland; Geol. Surv. Can., Map 1231A.