Geochemical dispersal in till: Waterford area, New Brunswick

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Geochemical analyses of tills in the Waterford area indicate that till matrix closely reflects underlying bedrock. This is likely due to: (1) efficient glacial entrainment of local bedrock material, (2) limited transport distances, and (3) limited mixing prior to deposition as till. Dispersal patterns of chemical elements show elongated dispersal patterns parallel to south-southeastward ice-flow directions. Small (up-ice) source areas with unique lithology that lie at relatively high elevations impart readily identifiable geochemical dispersal trains. Train lengths generally vary from 2 km to about 8 km, but can be up to 18 km long for some elements. Dispersal patterns for till geochemistry are of similar size and shape to those found previously for till clasts, although extensive pre-glacial erosion and weathering of some friable mafic lithologies of the Mechanic Settlement Pluton has resulted in larger geochemical dispersal patterns relative to the dispersal pattern for mafic till clasts.

Our results confirm that, in New Brunswick, a 2 km sampling interval is effective for identification of significant geochemical anomalies in till matrix.

Des analyses géochimiques de tills de la région de Waterford révèlent que la matrice des tills correspond étroitement au substrat rocheux sous-jacent. Ce phénomène est probablement dû : (1) à une érosion glaciaire efficace de matériaux du substrat rocheux local; (2) à des distances de transport limitées; et (3) à un mélange limité avant la sédimentation sous forme de tills. Les distributions des éléments chimiques décrivent des tracés allongés parrallèles aux orientations sud/sud-est de l'écoulement des glaces. De petits secteurs d'origine (en amont de l'écoulement glaciaire) présentant une lithologie unique et se trouvant à des élévations relativement importantes impriment des traits de distribution géochimique facilement repérables. Les longueurs de ces traits varient généralement entre 2 et environ 8 km, mais ils peuvent avoir jusqu'à 18 km de longueur dans le cas de certains éléments. Les distributions de la structure géochimique des tills sont d'une dimension et d'une forme semblables à ceux auparavant relevés dans les clastes de tills, bien qu'une érosion préglaciaire prononcée et que l'altération atmosphérique de certaines lithologies mafiques friables de l'intrusion ignée de Mechanic Settlement aient produit des distributions géochimiques plus étendues que la distribution des clastes de tills mafiques.

Nos résultats confirment qu'il est efficace au Nouveau-Brunswick de recourir à un intervalle d'échantillonnage de 2 km pour le repérage des anomalies géochimiques déterminantes dans la matrice des tills.

[Traduit par la rédaction]

INTRODUCTION

During glacial erosion and transportation, rock fragments are reduced in size along the transport path. Dreimanis and Vagners (1971) have shown that two size groupings develop for each lithologic component being transported; one in the clast size portion of the glacial load (composed of rock fragments), and the other in the till matrix (composed of fine grained fragments <2 mm in diameter). Near the source the clast content should be much larger than locally derived matrix components and form larger dispersal trains (Balzer and Broster, 1994). The trains provide an expanded exploration target, sometimes hundreds or thousands of times larger than the actual source outcrop (DiLabio, 1990). Trains are recognized in spatial plots of concentration contours. Resulting patterns are commonly elongated with concentrations increasing in an up-glacial direction, which can be followed back (up-ice) to their source. This is one reason that till geochemistry surveys have been an integral part of numerous successful mineral exploration projects in Canada and Europe (Coker and DiLabio, 1989).

The areal distribution of till components is partly controlled by physiographic influences, number of source areas, elevation of the source area, and number of ice-flow events (Shilts, 1976; Hornibrook *et al.*, 1993). Because dispersal patterns are influenced by glacier dynamics, they can be used to infer glacial history and confirm ice-flow direction(s) (Broster and Huntley, 1995; Broster *et al.*, in press). Research from other areas of southern New Brunswick (Balzer and Broster, 1994; Hornibrook *et al.*, 1993) have shown that, in general, tills are locally derived and that distinctive trains are often less than 12 km for till clasts and 6 km for matrix components. However, dispersal trains in the order of 20 km for both till clast and martx components have been re-

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ported from southwestern New Brunswick (Seaman, 1995). Previous studies on clast dispersal in the Waterford area, (Munn, 1995; Broster *et al.*, in press) report that: (1) dispersal trains are elongated south-southeastwardly, and (2) train lengths generally varied from 4 to 10 km with the exception of a mudstone clast train of about 26 km in length.

The objective of the present study was to compare and contrast the fine grained geochemical matrix component with previous results on the coarse grained clast component.

LOCATION, PHYSIOGRAPHY AND BEDROCK

The study area is situated in southeastern New Brunswick, midway between the cities of Saint John and Moncton (Fig. 1). The area comprises the whole of the Waterford topographic map sheet (N.T.S. 21 H/11, scale 1:50 000) and is bounded to the south by the Bay of Fundy. The area lies within the Caledonia Highlands physiographic subdivision of the New Brunswick Highlands (Weeks, 1957; Bostock, 1970), which is further subdivided into: (a) a Central Plateau (Fig. 1) of mainly Precambrian rocks, and (b) the Anagance Ridges of folded and faulted Carboniferous sedimentary and metamorphic rocks (Rampton and Paradis, 1981a). Several distinctive lithologies and mineral occurrences provide "point-source" targets for delineation of dispersal trains.

The Central Plateau occupies about 80% of the study area. The plateau is characterized by a gently undulating to level surface with frequent hills typically 30 to 90 m high. Elevation of the plateau declines gently toward the southwest and ends abruptly along the Fundy coast, where bedrock cliffs are commonly more than 150 m high. Upper Precambrian metavolcanic and metasedimentary rocks underlie the plateau. The various units (Fig. 2) include felsic and mafic, pyroclastic, extrusive and intrusive units, locally intercalated with sedimentary rocks of limestone, siltstone, sandstone, arkosic sandstone, pebbly sandstone and rare conglomerate units (McLeod, 1987; McLeod *et al.*, 1994; Ruitenberg *et al.*, 1977, 1979).

The Anagance Ridges occupy the northwest corner, representing the remaining 20% of the study area (Fig. 1). This area is characterized by parallel northeast-southwest ridge-and-valley topography with relief varying from about 20 m to over 300 m. Local units consist of middle Paleozoic sedimentary rocks that were folded and faulted by northwest-southeast compression during the Carboniferous (Ruitenberg and McCutcheon, 1982). The dominant bedrock lithologies (Fig. 2) include: polymictic conglomerates, sandstones, arkosic sandstones, limestones, mudstones, oil shale and minor non-marine evaporites. Rare volcanic clasts and lesser amounts of granite, granodiorite and diorite clasts, derived from

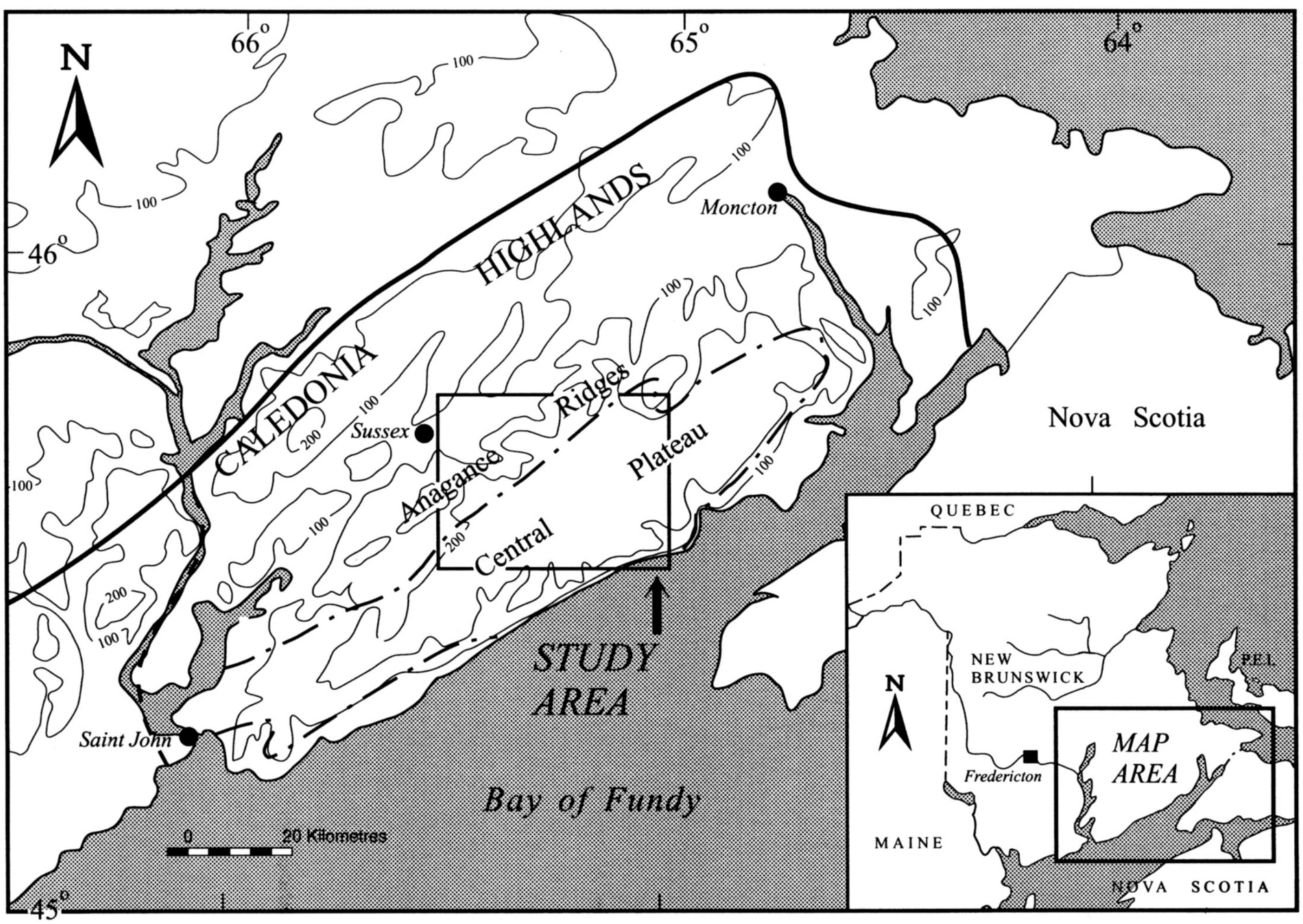

Fig. 1. Location of study area with physiographic subdivisions after Rampton *et al.* (1984).

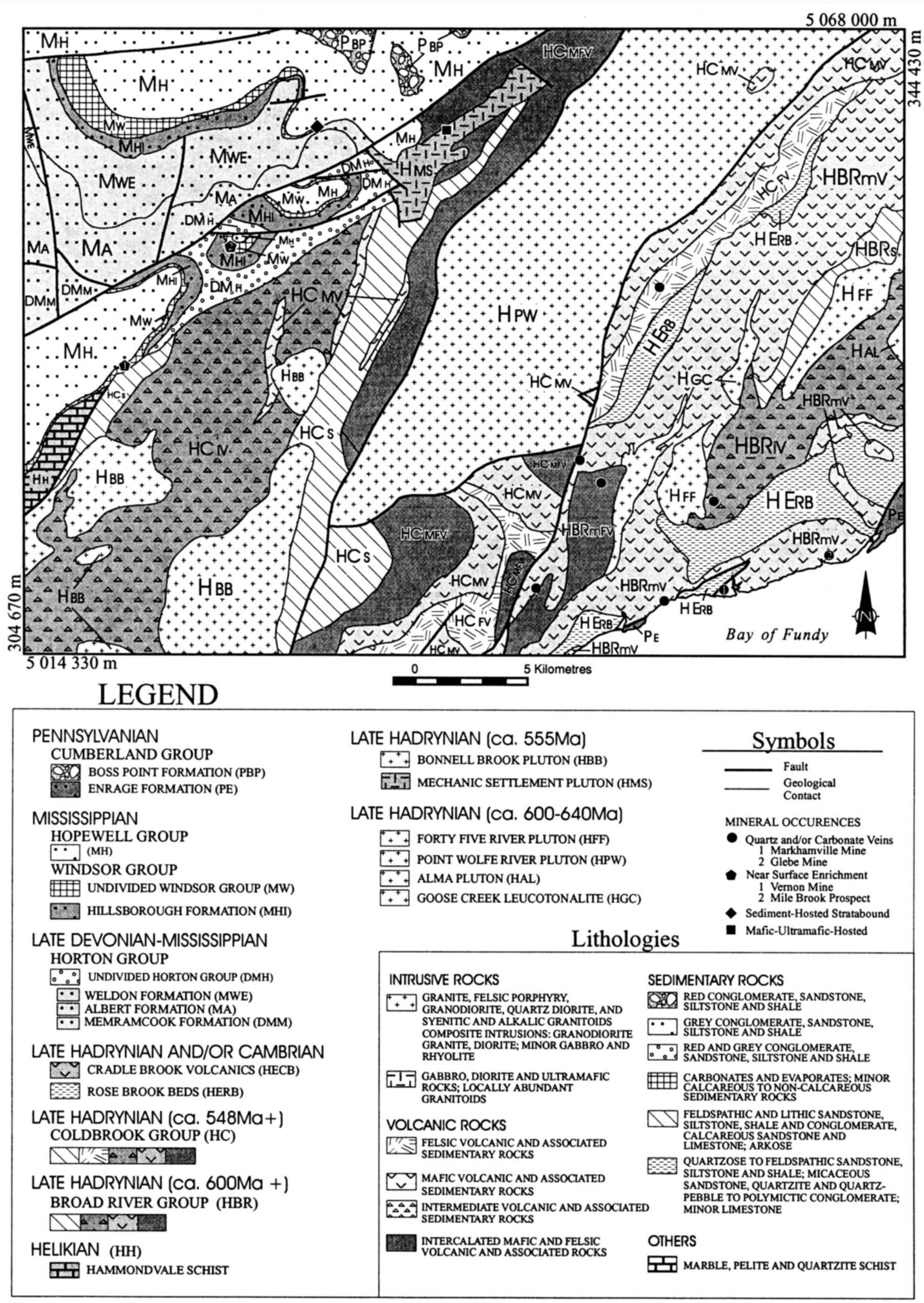

Fig. 2. Known mineral occurrences and bedrock geology of the Waterford area (from Broster *et al.*, in press; simplified from McLeod *et al.*, 1994).

Caledonia Zone source rocks (van de Poll, 1994), are found in the conglomerates.

MINERALIZATION

Twelve individual mineral occurrences of variable type and style have been identified in the study area (Fig. 2; after McLeod *et al.*, 1994). Some sulphide-bearing veins and stratiform, base metal sulphide occurrences were mined during the nineteenth century (Hind, 1865; Ells, 1882) and continue to be of interest (Ruitenberg *et al.*, 1979). In the northwestern part of the area (Fig. 2), base metal concentrations occur along the basal Horton-Windsor contact (van de Poll, 1995). Three sub-economic occurrences containing galena, sphalerite and minor barite (McCutcheon, 1981) have been identified in the Windsor Group (Gays River Formation, see McLeod *et al.*, 1994).

A vein-type deposit at Teahan Mine immediately east of the study area, is typical of deformed stratabound zones in the region (Ruitenberg *et al.*, 1979). The Teahan deposit occurs in mafic and felsic metatuffs, within a northeast trending shear zone, and contains dominant pyrite, sphalerite, and chalcopyrite with minor galena, telluride, and electrum (Barr, 1987; Barr and Moroz, 1994). Similar deposits (Ruitenberg *et al.*, 1979) occur in the study area near Goose Creek and Quiddy River (Fig. 2). In this area, quartz and quartz-calcite veins occur, bearing chalcopyrite, bornite, malachite, chalcocite, sphalerite and small amounts of gold (McLeod, 1987). Similarly, the Vernon Mine and Mile Brook Prospect (Fig. 2) host mineralization of this type (Smith, 1962).

An isolated mineral occurrence, east of the Point Wolfe River Pluton (Fig. 2), lies within the felsic volcanics of the Coldbrook Group and is a vein-type, disseminated, metallic sulphide deposit (e.g., McLeod, 1987). Another disseminated sulphide occurrence is hosted by the mafic-ultramafic Mechanic Settlement Pluton (Fig. 2) and contains copper, nickel, cobalt and zinc (Rose and Johnston, 1990).

Mineral occurrences in the southeast (Fig. 2) are mostly sulphide-bearing, quartz and quartz-carbonate veins, and some stratabound deposits, hosted by the Broad River Group (Ruitenberg *et al.*, 1979; McLeod, 1987). The Markhamville and Glebes mines (Fig. 2) were the largest producers of manganese in New Brunswick from 1862 to 1893 (Smith, 1962).

GLACIAL GEOLOGY

The nature and sequence of glacier ice-flow events in southeastern New Brunswick has long been of scientific interest (Matthew, 1872; Chalmers, 1890; Goldthwait, 1924; Rampton and Paradis, 1981a; Foisy, 1989). Due to the scarcity of datable materials, regional reconstructions of ice-flow have relied largely on observations of various bedrock erosional features (Rampton *et al.*, 1984; Foisy and Prichonnet, 1991; Seaman, 1989). Several studies have included cursory discussions of Wisconsinan glaciation of the study area (e.g., Matthew, 1872; Chalmers, 1890; Greiner, 1974; Rampton and Paradis, 1981a,b; Foisy and Seaman, 1989) and concluded that the area was glaciated by south-southeastward flowing ice, although the number and timing of these events are still controversial (see Rampton *et al.*, 1984; Munn, 1995). For example, Rampton and Paradis (1981a,b) suggest that southward flow is indicated by pervasive 120° to 155° striae and by the presence of Mississippian sandstone clasts in till south of its source area. However, the occurrence of boulders, seemingly displaced northward of their source area, and rare north-northwest rat tails on the northern flanks of the Caledonia Highlands, have been interpreted as evidence of northward flowing glaciers, possibly during the early Wisconsinan (Foisy and Prichonnet, 1991).

The origin of till clasts found at locations north of outcropping plutons on the Central Plateau was previously investigated (Munn, 1995; Broster *et al.*, in press) and attributed to glacial erosion of underlying conglomerate bedrock, which contains fragments from the Central Plateau to the south. The dispersal patterns for other clast lithologies were compared to source outcrops and used to confirm dominant south-southeastward glacial transport directions (Munn, 1995; Broster *et al.*, in press).

SAMPLE COLLECTION, PREPARATION AND STATISTICS

Till sampling was completed for New Brunswick Department of Natural Resources and Energy (NBDNRE), in conjunction with regional geochemical surveys and surficial mapping, during the summers of 1993 and 1994. Samples were collected using a 2 km sample-grid interval from natural exposures and hand-excavated pits. Only a single till sheet occurs in the area, although the colour and composition of the till changes with variation in underlying bedrock. The till commonly displayed a 0.7 m dense lower zone, interpreted to represent basal or englacial till, that graded upward into a loose diamicton interpreted as englacial and ablation till (see Dreimanis, 1976). We attempted to collect samples from unweathered basal till at natural exposures and from excavated sample pits, but as the till was often less than 1.5 m thick some samples were unavoidably collected from englacial till (*sensu stricto*, Dreimanis, 1976).

A total of 270 samples were obtained across a grid of 2 km spacing (Fig. 3); 194 samples during field mapping and 76 samples from NBDNRE archival samples. Samples were dry-sieved by New Brunswick Department of Natural Resources and Energy technicians and a representative clay and silt fraction (<0.063 mm) of about 30 g was obtained for each sample. Geochemical analyses were conducted by Activation Laboratories Limited (Ancaster, Ontario) using inductively coupled plasma emission spectrometry (I.C.P.) for Ag, Cd, Cu, Mn, Ni, Pb and Zn, cold vapour atomic absoption spectrometry for Hg, and induced neutron activation (I.N.A.A.) methods for 26 other elements. The complete data set is presented in Munn (1995), and only a few examples will be discussed here.

Contouring of geochemical data was accomplished using SURFER® computer software. The Kriging geostatistical method was used, which calculates an autocorrelation between irregularly spaced data points producing a minimum variance unbiased estimate. Grid nodes were established to

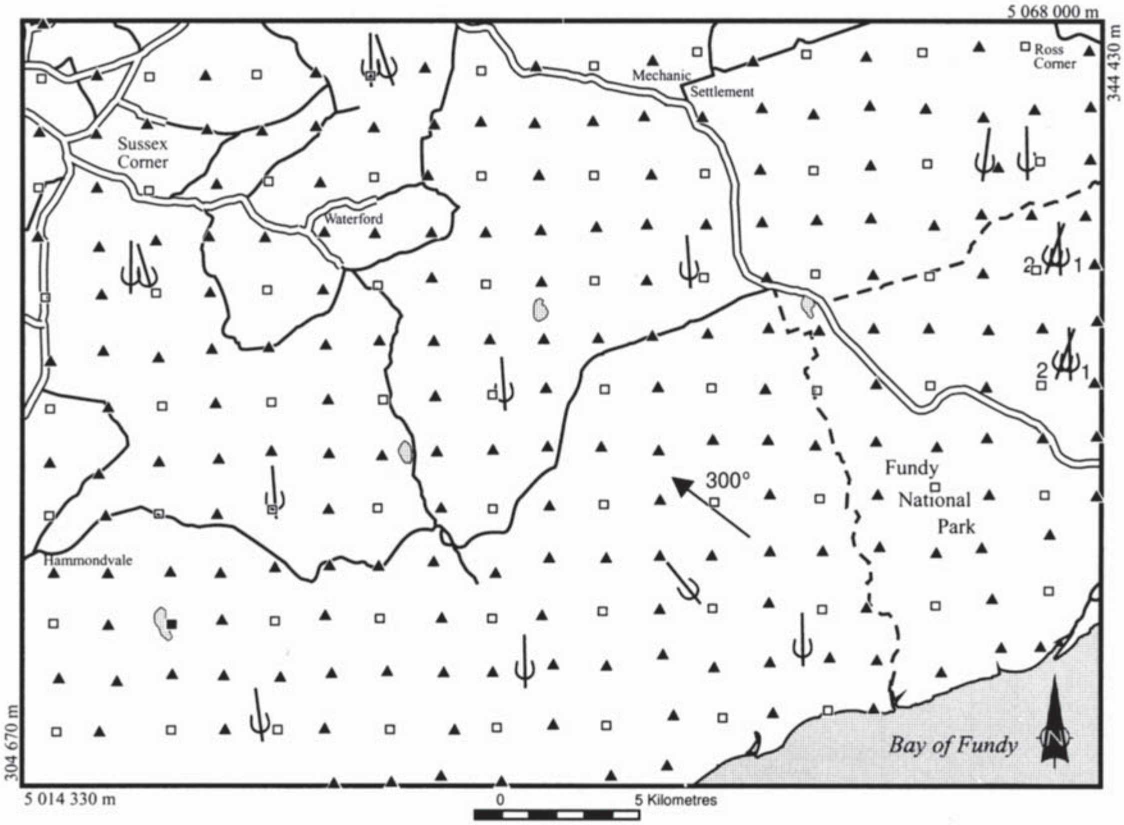

Fig. 3. Location of sample sites (▲ collected during this study; □ archival reference samples) and directions of major striae showing earlier (1) and later (2) erosive directions (from Foisy and Prichonnet, 1991), arrow indicates orientation of older striae reported by Foisy (1989).

be coincedent with sample locations and resulting contours were confirmed by comparison with original values. Pearson correlations between geochemical elements and clast lithologies were investigated using the Statistical Package for Social Sciences® (S.P.S.S.). Only those Pearson correlation coefficients (r) with an absolute value greater than r = .500 (Fig. 4) are discussed here.

Observations and interpretations

Most of the area is overlain by a blanket of till, that changes in colour with change in underlying bedrock. This similarity is likely due to the incorporation of highly weathered bedrock, as reported from other areas of New Brunswick (e.g., Balzer and Broster, 1994) and is not an indication of multiple tills. Locally the till sheet has undergone some degree of diagenetic alteration which can affect the till geochemistry (Broster, 1986). Chemical processes related to soil development are a major cause of significant variability in elemental concentrations (Shilts, 1975). Therefore, all tills were sampled below the "A" and "B" soil horizons.

For most elements, anomalous (highest) concentrations are dispersed with local and regional maximum values near known mineral occurrences and identifiable source bedrock units (e.g., Sm, Fig. 5), or parallel to local structural trends (e.g., Na, Fig. 6). Sodium occurs at relatively low concentration in tills overlying mainly Carboniferous rocks in the northwestern part of the study area and increases in concentration towards the southeast. Prominent increases in Na content occur southeast of the contact between the Devonian-Carboniferous rocks and the older rocks to the southeast (Fig. 6). Calcium is dispersed in a manner similar to Na (see Munn, 1995).

A few elements occur as isolated concentric concentrations (bulls-eye patterns), with no distinguishing elongation or fan-shaped down-ice dispersal pattern (e.g., Au, Munn, 1995). For most elements, however, dispersal patterns decrease in concentration in a south or southeasterly direction, parallel to the last glacier flow direction (see discussion in Broster *et al.*, in press).

The lanthanide elements, La, Ce, Nd, Sm, Eu, Yb, and Lu show common sources, demonstrated best by Sm dispersal (Fig. 5). The lanthanides occur at relatively low concentrations in tills across the study area and particularly over the Point Wolfe River Pluton. Maximum concentrations were detected north of the Markhamville Mine, at the edges of the Bonnell Brook Pluton and along the eastern edges of the Goose Creek Leucotonalite (Fig. 2). Concentrations higher than background values occur mainly as bull's eye patterns, less than 4 km in diameter, in the eastern and western parts of the study area (Fig. 5).

Maximum Cr till-concentrations are found, 1 to 2 km east and south of the Mechanic Settlement Pluton (Fig. 7). Chromium concentrations decrease progressively southward from this point, but extend as an elongated pattern for approximately 18 km. The major Cr dispersal pattern occurs

	La	Ce	Nd	Sm	Eu	Yb	Lu	As	Cs	% Na	Sb	Co	Cr	Sc	Ni	% Fe
La	1.00	.681	.758	.846	.719	.659	.623	-	-	-	-	-	-	-	-	-
Ce		1.00	.556	.667	.592	.638	.617	-	-	-	-	-	-	-	-	-
Nd			1.00	.825	.732	.615	.547	-	-	-	-	-	-	-	-	-
Sm				1.00	.934	.730	.663	-	-	-	-	-	-	-	-	-
Eu					1.00	.613	.523	-	-	-	-	-	-	-	-	-
Yb						1.00	.926	-	-	-	-	-	-	-	-	-
Lu							1.00	-	-	-	-	-	-	-	-	-
As								1.00	.598	-.591	.781	-	-	-	-	-
Cs									1.00	-	.576	-	-	-	-	-
Na (%)										1.00	-.552	-	-	-	-	-
Sb											1.00	-	-	-	-	-
Co												1.00	.720	.626	-	.581
Cr													1.00	-	.545	-
Sc														1.00	-	.674
Ni															1.00	-
Fe (%)																1.00

99.9% Significance Level
Minimum r = 0.211 (absolute value)
n = 193

Key : La = Lanthanum; Ce=Cerium; Nd=Neodynium; Sm=Samarium; Eu=Europium; Yb=Ytterbium; Lu=Lutetium; As=Arsenic; Cs=Cesium; Na=Sodium; Sb=Antimony; Co=Cobalt; Cr=Chromium; Sc=Scandium; Ni=Nickel; Fe=Iron

Fig. 4. Table of significant Parson correlations (> 0.5 ±) for till geochemistry.

over a distance of 6 to 8 km, parallel to, but 1 to 2 km eastward of the Mechanic Settlement Pluton (Fig. 7). Cobalt concentrations are highest in this same area (Fig. 8). The pattern of maximum Co dispersal mirrors the outcrop shape of the Mechanic Settlement Pluton, displaced 1 to 3 km eastward. Isolated Co and Cr bull's-eye anomalies (Figs. 7, 8) are characteristic of other point sources, rather than an extension of the main patterns.

Anomalous base metal concentrations (Cu, Pb, Zn, Ag, Ni, Mn, Cd, and Hg) are commonly found near known mineral occurrences (e.g., Ni, Fig. 9). Copper was an exception with maximum content (130 ppm) occurring in the northeastern part of the study area (not included). Maximum concentrations of Ni form a dispersal pattern, similar to the shape of the outcropping Mechanic Settlement Pluton but displaced 1 to 2 km southeastward (Fig. 9). The anomalous Ni concentrations are coincident with Co and Cr, although Ni concentrations also form a finger-shaped dispersion train that originates over the Point Wolfe River Pluton and extends southward for about 12 km.

Element Correlations

Only two modest correlations were found for the lithological data (not included); a positive correlation of r = 0.537 between Sb and sandstone clasts and a negative correlation of r = -0.505 between As and combined intrusive lithologies. Previous examinations indicated that clast lithology correlations had been compromised by entrainment from secondary sources and preferential preservation of felsic lithologies (Broster *et al.*, in press). Late Precambrian - early Cambrian, Hadrynian units occupy about 75% of the study area (Fig. 2). These igneous and metasedimentary units have been eroded over millions of years, and many of their lithologies occur as clasts within younger Carboniferous units to the northeast. Hence, during the last glaciation, south-southeastward ice-flow crossed both areas, resulting in some lithologies (especially felsic clasts) being entrained from multiple sources (Broster *et al.*, in press).

Although these multiple sources have compromised the lithological data some significant co-variance is apparent in the geochemical data (Fig. 4). Significant correlations among lanthanide elements reinforces the many common features recognized in their individual dispersion plots. The highest correlations occur amongst the lanthanide elements, particularly Sm with Eu (r = 0.934), and Yb with Lu (r = 0.926), with lesser correlations between these elements and La, Nd and Ce. These associations suggest a common source for the lanthanides. Positive associations are observed between Cr and Co (r = +0.720) and between As and Sb (r =

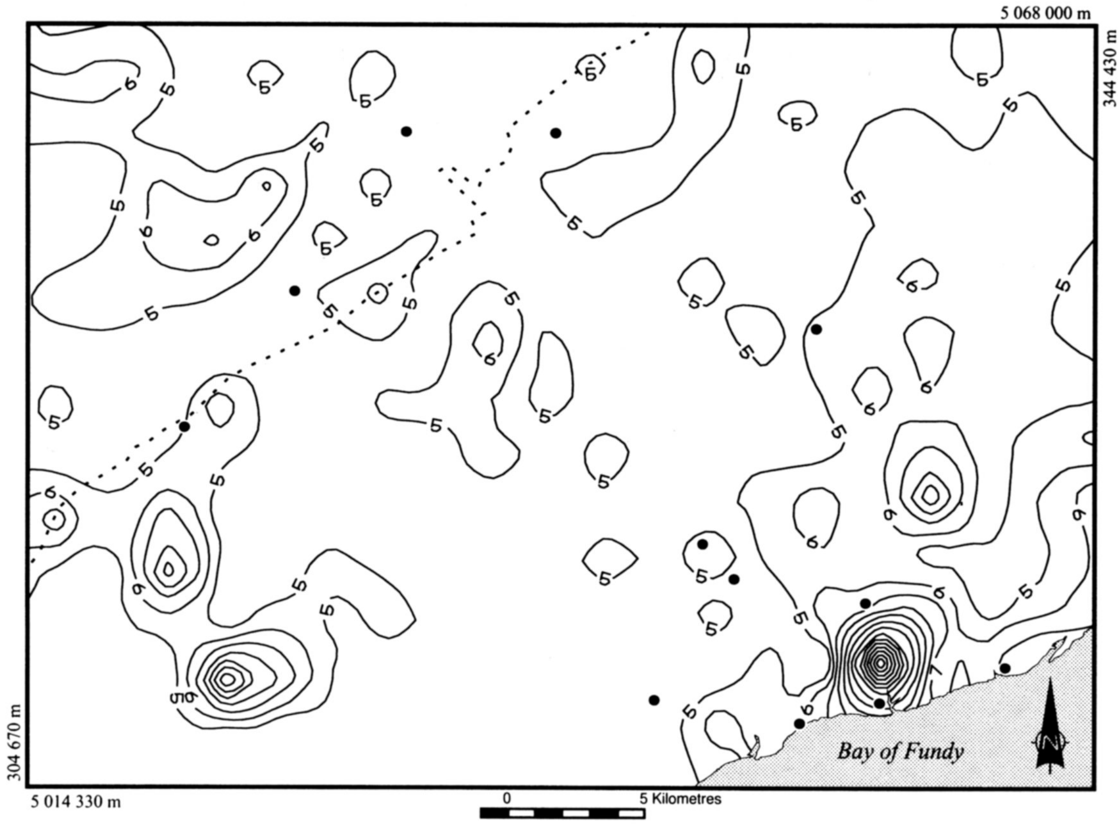

Fig. 5. Dispersal pattern for Sm ppm in till matrix with known mineral occurrences (•) from Figure 2. The dashed line designates the Carboniferous (northwest)/Hadrynian (southeast) contact.

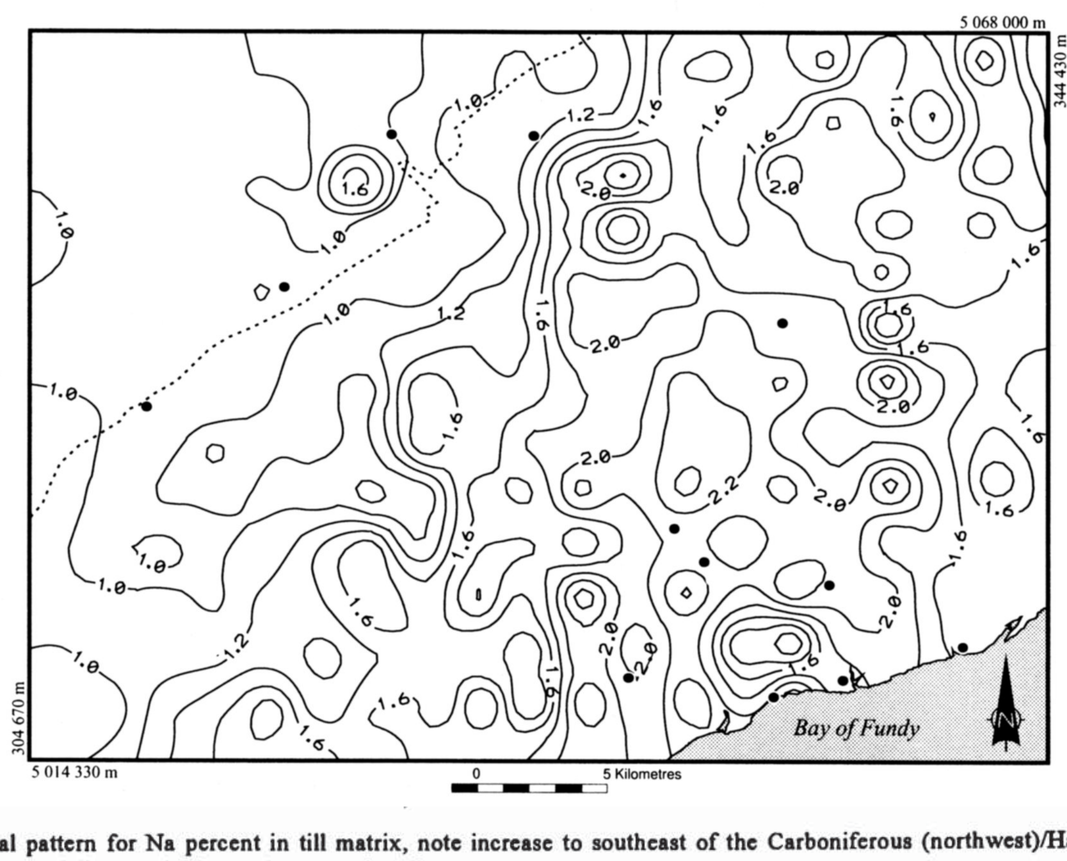

Fig. 6. Dispersal pattern for Na percent in till matrix, note increase to southeast of the Carboniferous (northwest)/Hadrynian (southeast) contact (dashed line); • indicates known mineral occurrences.

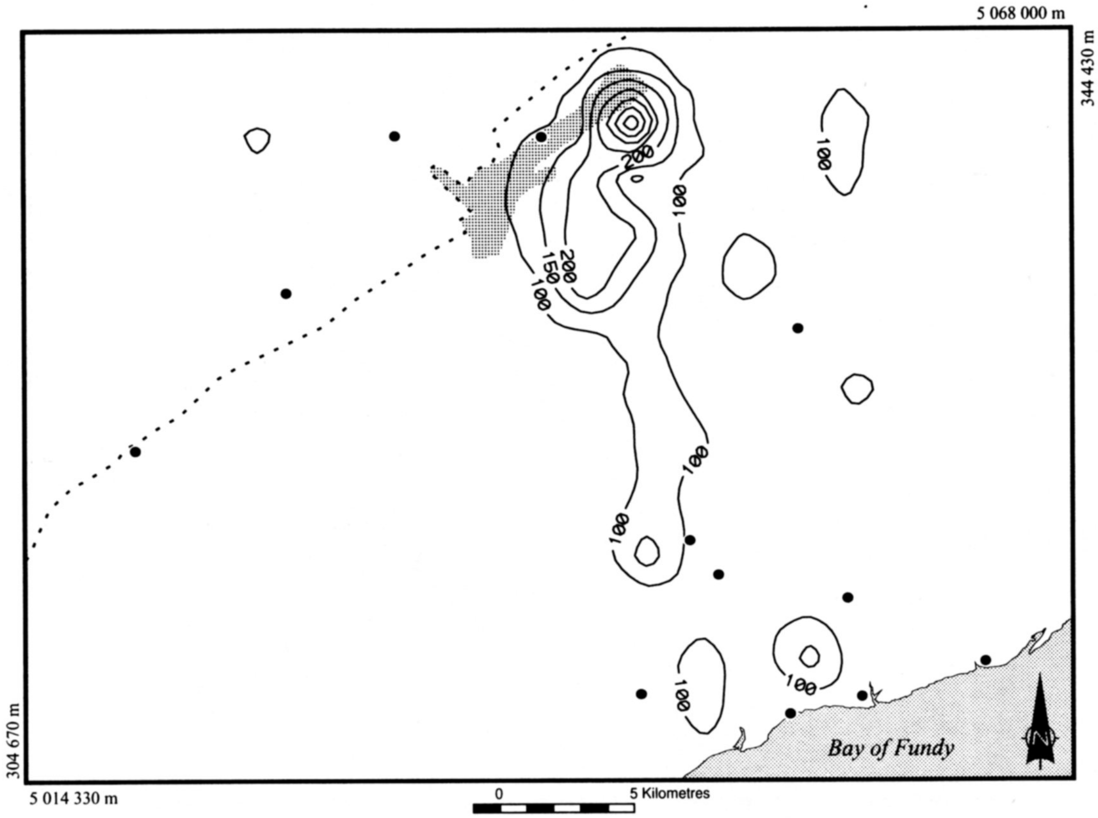

Fig. 7. Dispersal pattern for Cr ppm in till matrix indicating southward dispersal. The dashed line designates the Carboniferous (northwest)/Hadrynian (southeast) contact and • indicates known mineral occurrences. The Mechanic Settlement Pluton is indicated by shading (see Fig. 2).

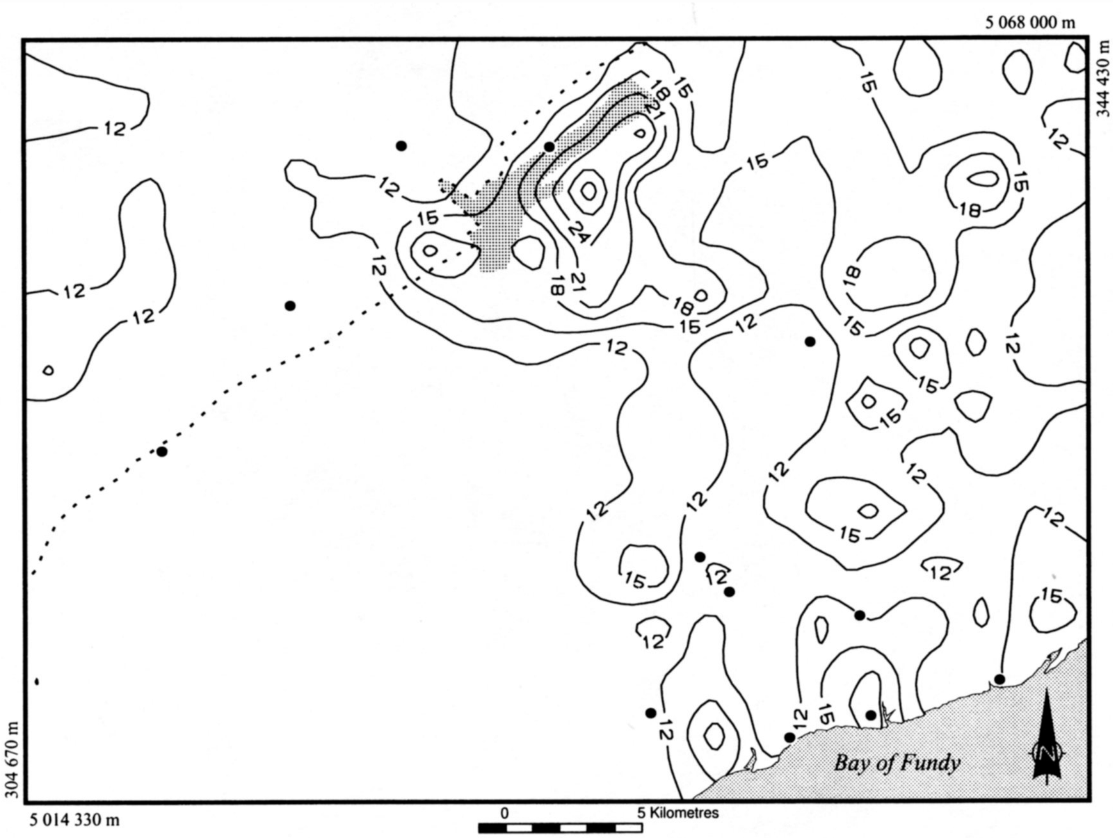

Fig. 8. Dispersal pattern for Co ppm in till matrix. Note eastward displacement of dispersal pattern and known mineral occurrences (•). The dashed line designates the Carboniferous (northwest)/Hadrynian (southeast) contact and the Mechanic Settlement Pluton is indicated by shading (see Fig. 2).

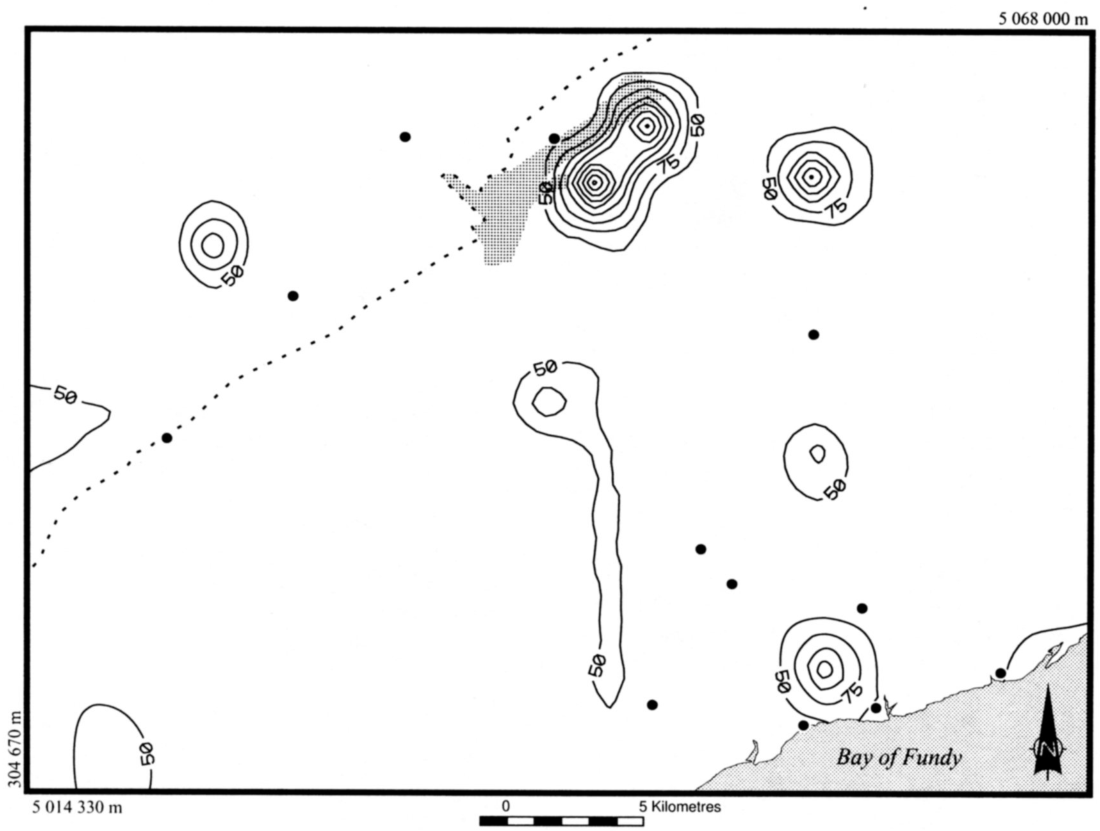

Fig. 9. Dispersal pattern for Ni ppm in till matrix suggesting eastward, followed by southward dispersal. The dashed line designates the Carboniferous (northwest)/Hadrynian (southeast) contact, the Mechanic Settlement Pluton is indicated by shading (see Fig. 2) and • indicates known mineral occurrences.

+0.781), probably due to common source areas. Negative associations between Na with As and Sb reflect a progressive increase in Na content and decreases in As and Sb content in bedrock units towards the southeast. Lesser correlations occur between Fe and Sc, Fe and Co, that are likely artifacts of coincidental occurrences.

Discussion and conclusions

The results of this study confirm that a 2 km sampling interval is sufficient for identification of significant dispersal features of matrix components. Dispersal patterns of chemical elements are elongated parallel to south-southeastward ice-flow directions. Train lengths generally vary from 2 km to about 8 km, but are up to 18 km long for Cr. Dispersal of clast lithologies were slightly longer, approximately 4 km to 10 km, with the exception of mudstone clast dispersal which extended over 26 km (Broster *et al.*, in press). The exceptionally long mudstone clast train occurred southward of the Mechanic Settlement Pluton and was attributed to transfer of material into higher ice positions during glacier flow on to the Central Plateau, 200 m higher in elevation (Broster *et al.*, in press).

The Mechanic Settlement intrusion is a relatively small pluton with unique lithologies, located at high up-ice elevations (Fig. 2). These attributes are favourable for tracing the dispersal of Mechanic Settlement clasts and related elemental constituents (Shilts, 1976; Hornibrook *et al.*, 1993). Gabbro and diabase clasts originating at the Mechanic Settlement Pluton, demonstrate a short transport distance of less than 7 km (see Munn, 1995), similar to dispersal patterns for Co, but less than Cr and Ni. These differences in transport lengths may be the result of several factors relating to source area or glacier dynamics. For example, the till clay and silt fraction can be relatively more far-travelled than the associated till clasts and can also be derived from preglacial sediments (Broster, 1986). For the most part, transport distances suggest that tills are locally derived, till components are thoroughly mixed and distinctive dispersal patterns lost, within 8 to 10 km of the source. Extraordinary long clast-dispersal patterns can be developed because of (englacial) entrainment from hill tops, or where topographic obstructions favour up-shearing of basal material into higher positions within the advancing glacier (Broster, 1986). Conversely, exceptionally limited clast-dispersal, can result from basal entrainment of lithologies easily comminuted to "terminal grade" (cf. Dreimanis and Vagners, 1971).

The Mechanic Settlement surficial units are presently highly weathered to grus and this condition likely existed at the time of initial glacial entrainment. The relatively incompetent clasts would have been rapidly comminuted and some weathered minerals may have been near "terminal grade" at the source area. These conditions are likely responsible for the limited mafic clast-dispersal and relatively longer geochemical dispersal patterns, and poor correlations between clast and geochemical data associated with this source unit. In addition, the elongated dispersal patterns of Co, Cr, and Ni (and mudstone) may indicate ice-streaming; a zone of localized high velocity flow within the ice mass at the time of glacial erosion. In such high velocity zones, glacial erosion is relatively greater causing elongated dispersal trains. This southward direction represents the last direction of ice flow. The eastward displacement of Co, Cr, and Ni dispersal patterns suggests that southward flow was preceded by an earlier phase in which glacier flow was directed eastward. This supports the observations of Foisy and Prichonnet (1991) who studied the adjoining map area to the east.

Long and narrow dispersal patterns like that for Cr and Ni (Figs. 7, 9) are normally considered to be indicators of a point-source. Long, thin distribution patterns can also result from the influence of topography on ice-flow which can trap trains in valleys (DiLabio, 1990), although the Cr and Ni patterns cross local valleys without any obvious deflections. Elongated dispersal patterns can also be due to overlapping contributions from erosion of a secondary source down-glacier (e.g., Hornibrook *et al.*, 1993). The finger-shaped Ni dispersal pattern originates from a point 7 km south of the Mechanic Settlement Pluton and appears to be distinctly separate from a Ni anomaly that overlies the pluton and extends 2 to 3 km southward. Chromium dispersal extends from the Mechanic Settlement Pluton to a small outcrop of mafic rocks that are part of the Coldbrook Group (Fig. 2), suggesting that this area may have been a secondary source of Cr (and Co) as it was for gabbro and diabase till clasts (Munn, 1995).

Entrainment from multiple sources for some clast lithologies has obscured many correlations. For instance, lanthanide minerals are primarily associated with alkalic and granitic rocks and with hydrothermal mineralization (Felsche and Hermann, 1978), yet only insignificant statistical correlations were calculated for these associations. High lanthanide concentrations do occur over the Bonnel Brook Pluton, likely related to the underlying bedrock unit. The regional lanthanide maxima occur over the primarily sedimentary Rose Brook Beds in the southeast. Since high lanthanide concentrations were detected at only one site over this large sedimentary unit, the source may be one of the numerous quartz and quartz-carbonate veins which intrude bedrock in this area (McLeod, 1987).

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