Chapter 10

EXPLORATION METHODS

10.1 Introduction

As previously noted, there has been sporadic mineral exploration for polymetallic mineralization in the South Mountain Batholith since the late 1800's. Initial activities consisted of prospecting and boulder tracing which led to the discovery of the New Ross Manganese Mines and numerous polymetallic occurrences, mainly near the village of New Ross. Recent exploration programmes, primarily since the mid 1970's, combined basic prospecting with a wide variety of geochemical and geophysical surveys, most notably till geochemistry and airborne gamma-ray spectrometric (i.e. "radiometric") surveys. This activity led to the discovery of the East Kemptville Sn-Zn-Cu-Ag and Millet Brook U-Cu-Ag deposits. This section summarizes the methodology used for mineral exploration to date and outlines a recommended strategy for future exploration surveys.

10.2 Geochemical Data

The basic premise for exploration geochemistry is that ore deposits are enriched in a suite of elements relative to host- or cover-rocks and that this enrichment is detectable in various sample media near, and over, the deposit. There are four mineralization types in the batholith, as outlined above, each with its own characteristic assemblage of ore, gangue and alteration minerals and subsequently its own elemental assemblage. These include: 1) Greisen - Sn, W, Mo, As, Cu, Pb, Zn, Bi, Au, Ag, B, F, P, Na and K; 2) Vein - U, Cu, Mn, P, F, Ag; 3) Breccia - Pb, Zn, Ba, Sn, W, Au and Ag; 4) Pegmatite - Mo, Sn, W, Cu, Nb, Ta, Be, B, F and Li. It is important to note that individual deposits may not be enriched in all of the elements associated with the particular style of mineralization. In addition to the detection of individual mineral deposits, geochemical data can also be used to delineate metallogenic domains (Chatterjee, 1983) and "specialized" leucogranites, both having characteristic enrichments and/or depletions in granophile elements that are variably reflected in the surficial sampling media (MacDonald et al., 1992b).

There have been several types of geochemical surveys conducted over the batholith since the 1950's (Rogers and Lombard, 1990). The following sections discuss some salient aspects of these surveys, with particular attention to their usefulness in exploring for granophile mineralization.

10.2.1 Stream Sediment Surveys

The first regional/reconnaissance geochemistry over the batholith consisted of a stream sediment survey conducted by the Geological Survey of Canada (Boyle et al., 1958). Samples collected during this survey were analyzed for Cu, Pb and Zn in the field using the organic reagent dithizone. The results from this survey are not particularly useful for granite related mineralization because of the limited suite of elements and the scarcity of samples from the interior regions that are dominated by granitic rocks.

In general, the physiography over much of the batholith is typified by low-lying or hummocky terrane with sluggish meandering streams that do not have abundant sediment. As a consequence this area is not conducive for stream sediment surveys. In contrast the northern margin of the batholith along the northern edge of the South Mountain is cut by incised streams which are well suited for stream sediment surveys.

10.2.2 Lake Sediment Surveys

In general, private-sector companies did not use lake sediment surveys when exploring for granite-hosted mineralization. Conversely the Nova Scotia Department of Mines and Energy conducted a centre lake-bottom survey over the entire Meguma Zone (Bingley and Richardson, 1978). Lake sediments reflect the collective response of the bedrock, and perhaps more importantly, the till in a catchment basin. Thus a single lake sediment sample may be representative of a large area. The chief advantage of lake sediment surveys, compared with other types of regional geochemical surveys, is that they are easy to conduct, particularly if helicopter support is available to the explorationist. Another advantage is the relatively uncomplicated sample preparation procedures consisting essentially of drying and sieving the sediment or gytjja prior to analysis. The elimination of complex and costly sample preparation procedures reduces the possibility of contamination. The chief drawback with lake sediment surveys is the lack of geological information that is available from the sample medium. For example it is not possible to establish the exact bedrock or till compositions within the catchment basin by examining collected samples.

The samples collected during the Bingley and Richardson (1978) survey were first analyzed for a suite of 15 elements including Cu, Pb, Zn, Ag, Fe, Mn, As, Mo, U, Cd, Ba, F, Sr, Ca, Mg and Loss On Ignition (LOI). With the exception of U, F and possibly Ba these elements are not particularly useful for detecting granophile mineralization. In light of this the entire sample set was re-analyzed for a suite of 16 elements including the "granophile elements" Sn, W, Li, Rb, F and Nb (Rogers et al., 1985). Figures 10.1 and 10.2 are plots of Sn and Cu for lake sediments over southwestern Nova Scotia. The boundaries of Stage I and II plutons and the metallogenic domains of Chatterjee (1983) have been plotted on these diagrams for comparison.

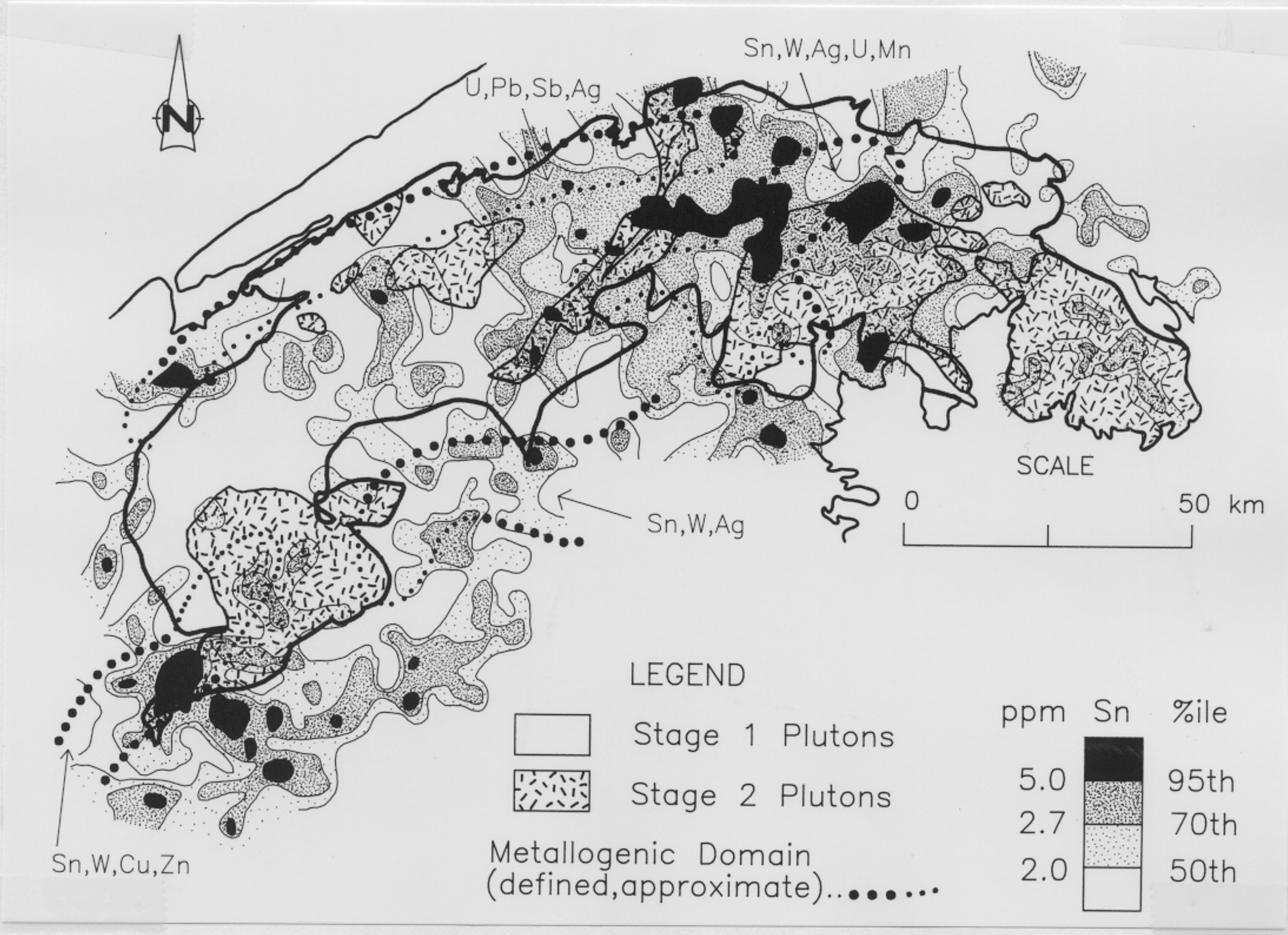

Figure 10.1 Contoured plot Sn in lake sediment data from southwestern Nova Scotia (modified after Lombard, 1991). Contour intervals based on percentile values for the entire Meguma Terrane data set and were arbitrarily selected at the 50th, 70th and 90th percentile levels. The metallogenic domains of Chatterjee (1983) and the Stage I and II pluton boundaries from this study have been plotted for comparison.

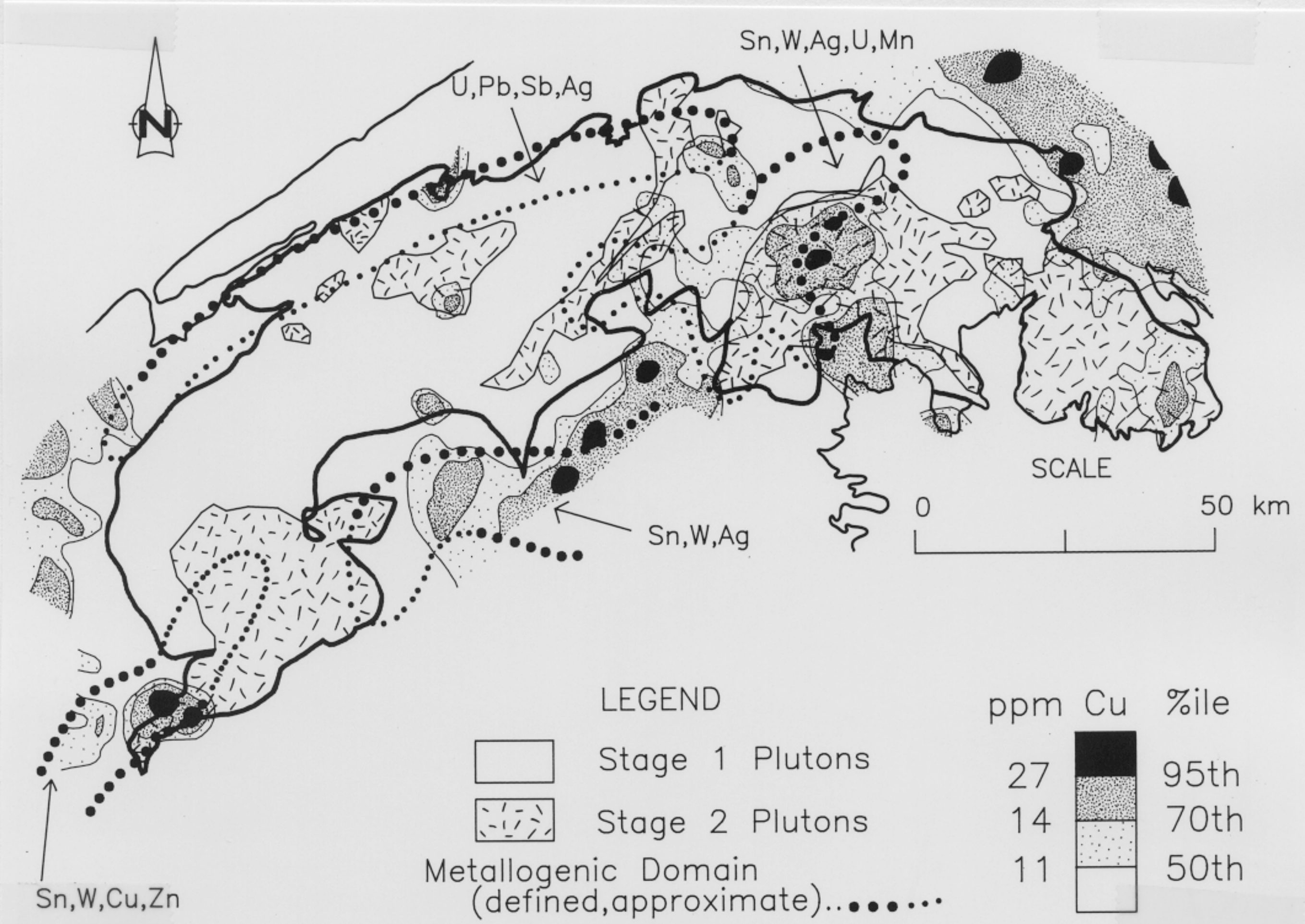

Figure 10.2 Contoured plot Cu in lake sediment data from southwestern Nova Scotia (modified after Lombard, 1991). Contour intervals based on percentile values for the entire Meguma Terrane data set and were arbitrarily selected at the 50th, 70th and 90th levels. The metallogenic domains of Chatterjee (1983) and the Stage I and II pluton boundaries from this study have been plotted for comparison.

An examination of the centre-lake bottom data (Rogers et al., 1985; Lombard, 1991) reveals large geochemical contrasts throughout the batholith, which may be attributed to several bedrock geological features. For example high Sn values are associated with granite-hosted mineralization at East Kemptville, as previously noted by Rogers and Garrett (1987), and near New Ross, an area that hosts numerous occurrences including Turner Tin and Grassy Brook.

In addition high Sn values are present in the Bezanson Lake area, which was flagged as having significant potential for granophile mineralization by Finck et al. (1988). In contrast, there are large portions of the batholith that have no known Sn occurrences and are outside the polymetallic Sn domains of Chatterjee (1983), that have high lake Sn values, such as the anomaly in the central part of the batholith (Fig. 10.1) that spans 3 Stage I and 2 Stage II plutons. The source for these high Sn values is unclear. The highest Cu values are mainly in lakes that overly the Meguma Group metasediments and Carboniferous cover rocks. Within the batholith, the highest Cu values are mainly in the New Ross area and near the East Kemptville and Long Lake deposits and, as such, there is an approximate correlation to metallogenic domains (Rogers et al., 1985). The distribution of Rb, Li, F and other "granophile" elements may be erratic, however, highest concentrations are primarily in lakes over Stage II plutons, particularly the New Ross Pluton, the southwestern portion of the Davis Lake Pluton and parts of the East Dalhousie Pluton.

Rogers et al. (1990) noted that multi-element lake sediment plots more accurately reflected the metallogenic domains defined by Chatterjee (1983) compared with single element lake sediment plots. The distribution of multi-element anomalies involving the granophile elements F-Li-Nb-Rb$\pm$Sn is shown in Figure 10.3. Clearly there is a good correlation with the domains of Chatterjee (1983).

10.2.3 Till Surveys

Till geochemical surveys were the most common exploration method employed by private-sector companies during the exploration "boom" of the 1970's and 1980's. The results of these surveys are contained in a plethora of assessment reports in the DNR library. Several till stratigraphy and till geochemical studies over the entire batholith were also conducted by the Nova Scotia Department of Mines and Energy during this same time period. The following section focuses only on the results from the government surveys.

The majority of the surface of the batholith is blanketed by glacial till which was formed by glacial erosion of local bedrock and, in some areas, previously deposited till sheets. Much of the batholith is overlain by a stony local till with up to >90% locally-derived clasts that were dispersed 1-4 km. Finck et al. (1989) concluded that the "renewal distances" in these "local" tills was as low as 100 m. Other parts of the batholith are overlain by more distally derived tills,

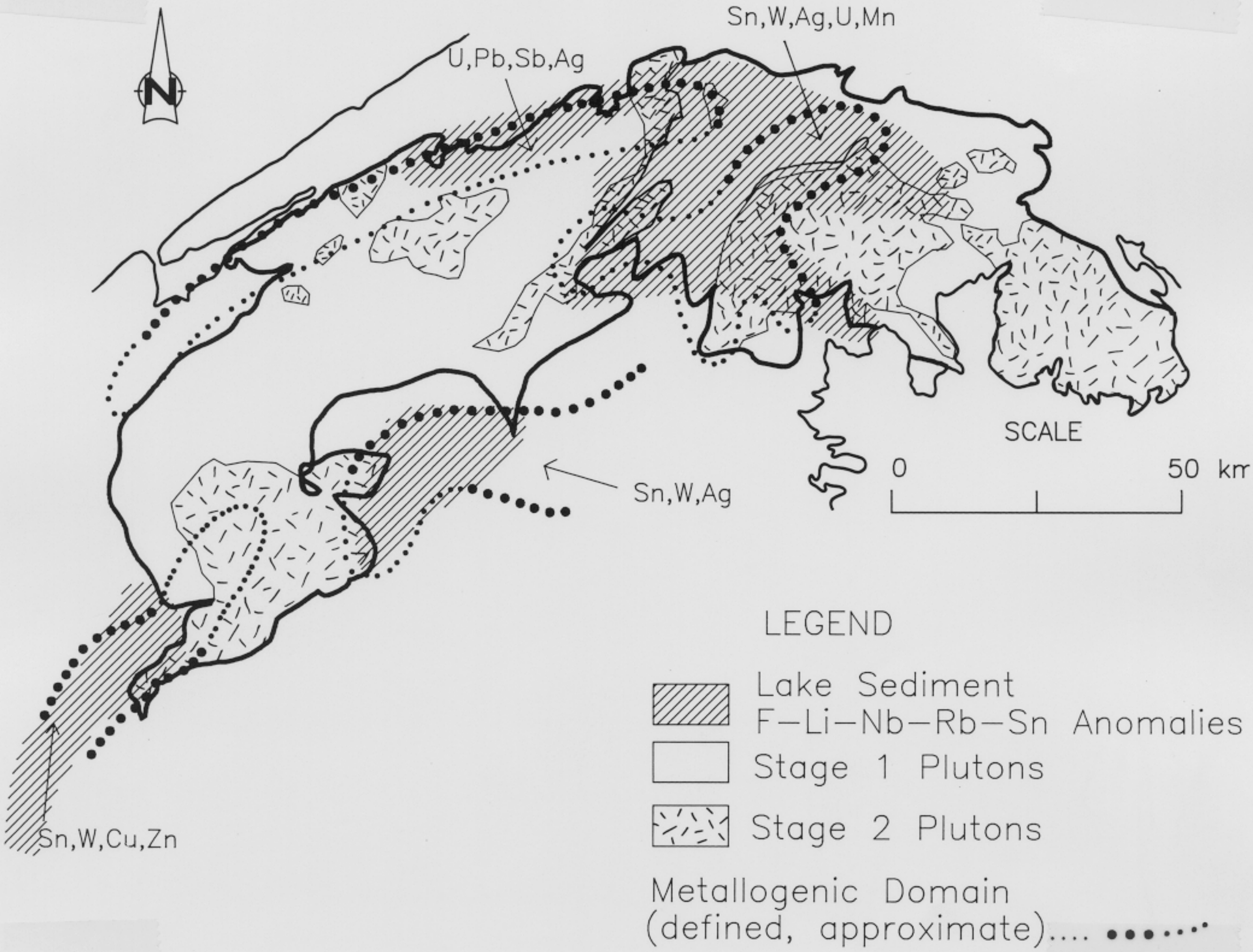

Figure 10.3 Plot of multi-element centre-lake bottom "anomalies" for the South Mountain Batholith. Only anomalies involving the granophile elements F-Li-Nb-Rb$\pm$Sn are plotted. The metallogenic domains of Chatterjee (1983) have been plotted for comparison. See text for discussion.

most notably the Lawrencetown till (Stea and Fowler, 1981), which may have clasts that originated in excess of 20-50 km north of the Meguma Terrane (Stea and O'Reilly, 1982) although these tills usually have small percentages of locally-derived (i.e. $<$ 1-2 km) clasts and matrix (Finck et al., 1989). Therefore the geochemical characteristics of the various till sheets that overly the batholith vary in response to their respective provenances. Thus caution should be exercised when using till geochemistry in mineral exploration as noted by Graves et al. (1988). The main advantage to till surveys is that, unlike lake sediment surveys, individual till samples contain clasts that provide information about the till source area (i.e. provenance). The chief disadvantage to till surveys is the increased sampling time and costly/complex sample preparation procedures that increase the possibility of contamination (MacDonald et al., 1992b).

Till surveys were first conducted over batholith by Stea (1983), Stea and Fowler (1981) and Stea and Grant (1982). These workers analyzed till samples for a suite of 13 elements including Cd, Ag, Cu, Pb, Zn, Ni, Co, Mg, As, U, Mo, Sn and W. Stea and O'Reilly (1982) noticed that there were significant chemical differences between the various till sheets. Furthermore, they noted that most Sn and W "anomalies" in the heavy mineral separates were situated at the margins of the batholith at the granite/metasedimentary rock contact. They also observed that most of the W anomalies were in the northern and eastern sections of the batholith whereas most Sn anomalies were in the southern part of the batholith which they regarded to reflect regional metallogenic zonation.

The entire South Mountain Batholith was covered by a till survey with a sampling density of 1 per 4 km^2 (Finck et al., 1990a,b). As noted above this survey was conducted in concert with the bedrock geological mapping and was designed to help define geological contacts and act as an aid to mineral exploration. Approximately 2100 till samples were analyzed for a suite of 16 elements including Ni, Cr, Ba, Th, Sc, As, Rb, Sb, Ta, U and W by neutron activation (INAA) and Pb, Zn, Cu, Fe and manganese by atomic absorption (AAS). Analytical results are given in Boner et al. (1990). In addition, tin (Sn) analyses for heavy mineral concentrates from the same suite of 2100 samples were given by Finck et al. (1990a,b). Despite the presence of several till sheets over the batholith, as noted above, there is a very good correlation between bedrock type and the relative abundances of several "granophile" elements. For example the concentration of Ta in tills derived from Stage II plutons is markedly higher than for Stage I plutons (Fig. 10.4). Conversely, the distribution of U and Th, which reside mainly in the accessory minerals zircon and monazite, does not reflect the type of underlying bedrock but rather can be correlated to the degree of bedrock weathering (Finck pers. comm.). The distribution of Cu, Pb, Zn and As generally do not reflect the distribution of Stage I and II plutons. These elements mainly reflect

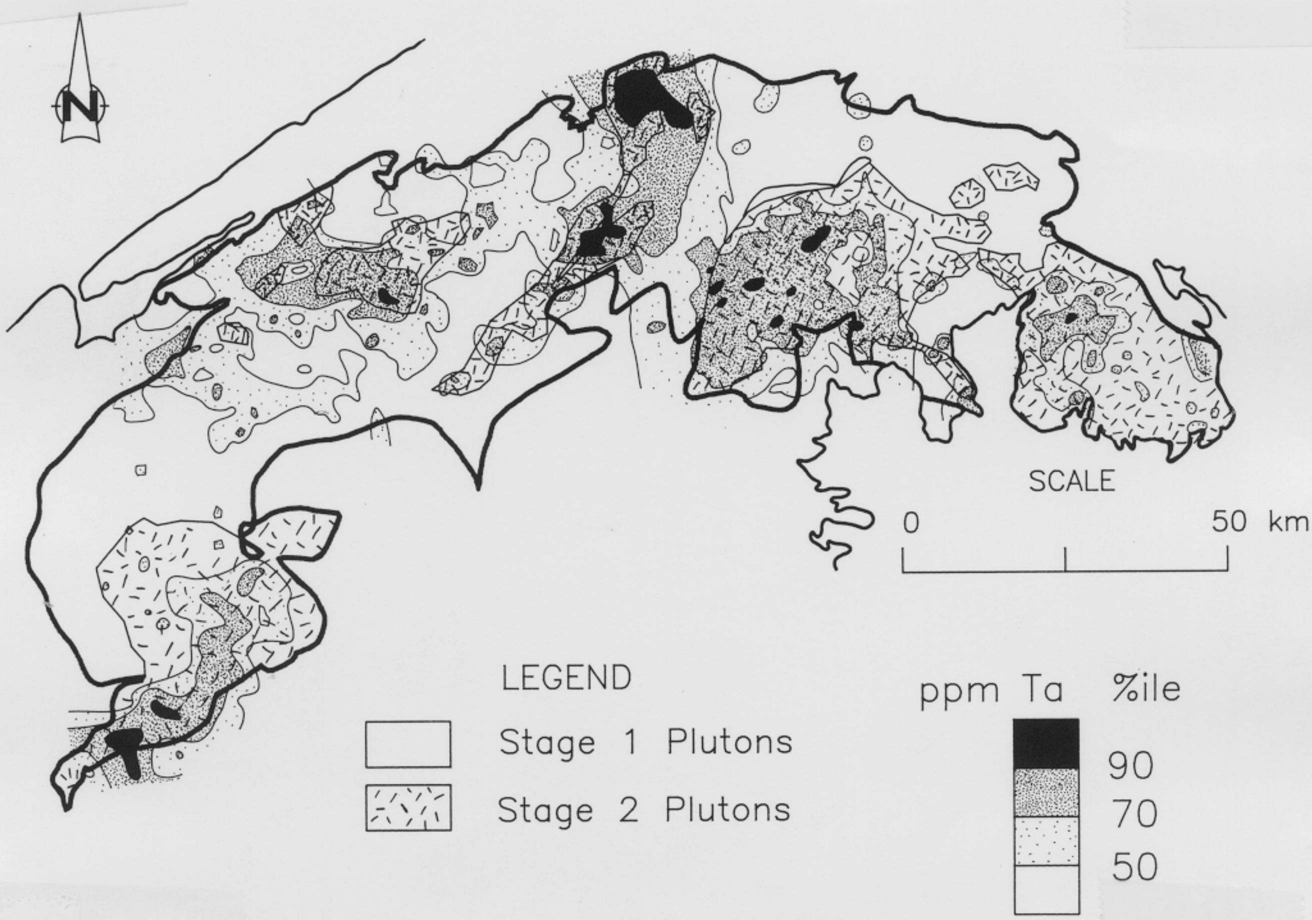

Figure 10.4 Plot of the distribution of Ta in the -230 (-62.5 μm) fraction of whole till for the South Mountain Batholith (data from Boner et al., 1990). Contour intervals calculated using the entire data set. Note the strong spatial association between high concentrations of Ta in till and the distribution of Stage II pluton rocks.

the presence of sulphide mineralization as noted for the Halifax Pluton (Graves et al., 1988) but may also reflect the degree of weathering of bedrock (Finck pers. comm. 1993).

Perhaps one of the most striking feature of the geochemistry of the tills over the batholith is the distribution of Sn in heavy mineral concentrates (Finck et al., 1990a,b). All of the areas with high concentrations of Sn (i.e. $>90^{th}$ percentile for entire data set), including the East Kemptville, East Dalhousie, New Ross, Long Lake and Bezanson Lake areas (Fig. 10.5), have associated polymetallic Sn occurrences or deposits. Till geochemistry is therefore considered to be a very effective exploration tool.

The East Kemptville area has concentrations of Sn that overshadow the remainder of the

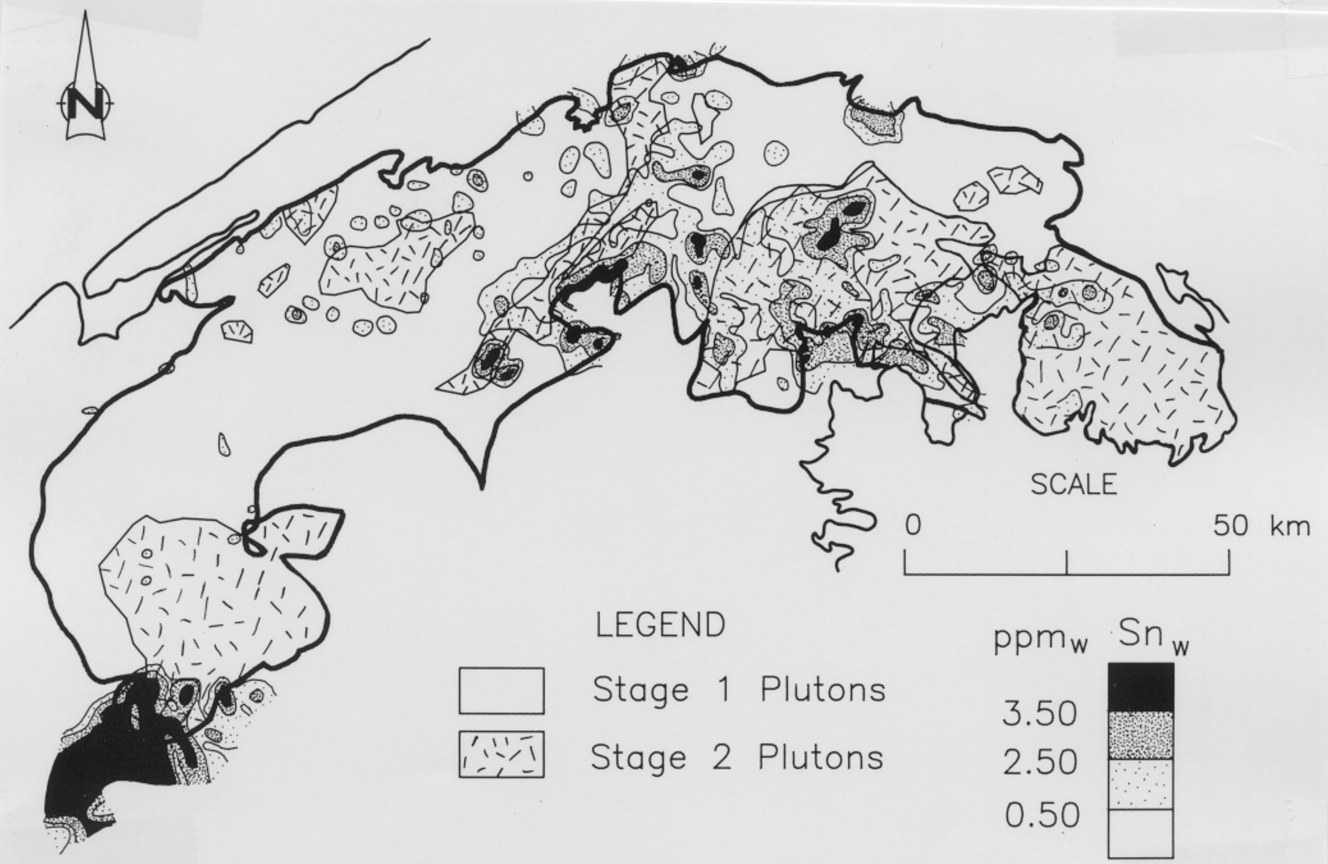

Figure 10.5 Plot of the distribution of "weighted" Sn values in heavy mineral separates from the -60 +230 (-250+62.5 μm) mesh fraction of till from the South Mountain Batholith (data and weighting method from Finck et al., 1990a; 1990b). Contour intervals calculated using the entire data set.

batholith. A detailed plot of the distribution of Sn in heavy mineral separates in till from the southwestern portion of the Davis Lake Pluton is given in Figure 10.6. Weighted Sn values are mainly >5 ppm with maximum values of >80 ppm compared with the rest of the batholith where the 98th percentile is 3.50 ppm$_w$ and the maximum value is 10.66 ppm$_w$. In fact if the percentile values were defined for the batholith using a subset of data from this region, none of the samples from the rest of the batholith would be "anomalous". The distribution of these high Sn values define the southwestern Nova Scotia Tin Domain as first described by Chatterjee (1983) and further investigated by Kontak et al. (1990). These extremely high Sn values near East Kemptville presumably reflect the presence of the East Kemptville Sn deposit, however, this deposit is situated on the top of a prominent ridge that presumably underwent significant erosion and glacial dispersion. The relatively low Sn values elsewhere in the batholith may not necessarily reflect

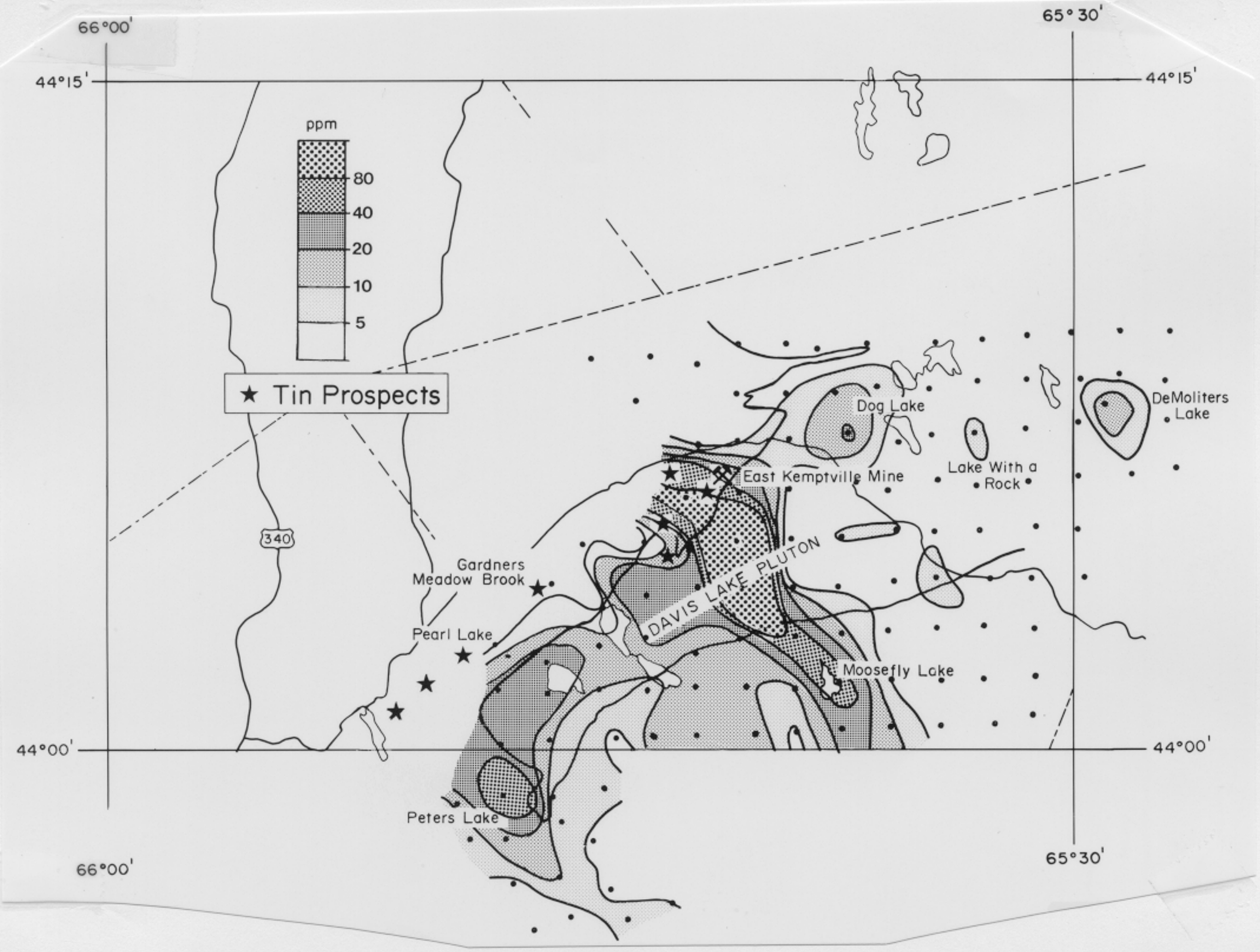

Figure 10.6 Plot of the distribution of "weighted" Sn values in heavy mineral separates from the -60+230 (-250+62.5 μm) mesh fraction of till from the southwestern portion of the Davis Lake Pluton (data and weighting method from Finck et al., 1990b). Contour intervals arbitrarily chosen to best display the entire data range.

low Sn potential but rather a lack of extensive glaciation of Sn mineralization.

In general, till geochemical data when interpreted with stratigraphic and provenance information can be used to define discrete exploration targets. In addition, follow-up surveys using a much closer spacing than 2 km can be used to define targets for trenching and diamond drilling as shown by the detailed work of MacDonald et al. (1992). Despite the presence of distally-derived tills the abundance of Ta and Rb and possibly other "granophile" elements can be used to define the extent of geochemically "specialized" granites.

10.2.4 Biogeochemical surveys

Biogeochemical surveys were not used to explore in the batholith by exploration companies. In fact, the applicability of biogeochemical methods for granite-hosted mineralization in the Meguma Zone was investigated only in the 1980's and 1990's. The chief advantages of biogeochemical surveys are their ease of sampling uncomplicated sample preparation procedures that reduce the risk of contamination. The main drawback to biogeochemical surveys is the lack of geological information that can be gleaned from samples as previously noted for lake sediment surveys.

The first biogeochemical study in the batholith was by Brooks et al. (1982) at the Millet Brook U-Cu-Ag vein-type deposit. They measured the U concentrations in Red Spruce and three species of hardwood trees over mineralized zones at the deposit. Results were then compared with U data for "B" horizon soils and scintillometer data over the same areas. They noted "anomalous" concentrations of U in Red Spruce that compared favourably with the scintillometer and bedrock geological information. Relatively poor analytical results were obtained for all investigated hardwood species. On the basis of the marked contrast between the U levels over mineralized/unmineralized biotite granodiorite Brooks et al. (1982) concluded that biogeochemical techniques could be successfully applied in U exploration.

Dunn et al. (1989) conducted a regional biogeochemical survey in eastern Nova Scotia. Their data confirmed the presence of known Au deposits and indicated that these techniques could be applied throughout the Meguma Zone. Therefore a regional biogeochemical survey was initiated over the southwestern part of the Meguma Zone (Dunn et al., 1992). The data from this survey revealed extreme enrichment in many "granophile" elements (e.g. Sn, W, Ta, Cs, Rb, Li) in the area from the East Kemptville deposit to the southern granite/metasediment contact. This enrichment is depicted in the plots of Sn and Rb in Red Spruce bark (Figures 10.7 and 10.8). Of particular interest is the discrepancy between the Sn patterns in Red Spruce and the distribution of Sn in the heavy mineral separates from till (Fig. 10.5). A detailed discussion of these differences is beyond the scope of this report.

MacDonald et al. (1992) analyzed Balsam Fir branches as part of a multi-media geochemical study of the Brazil Lake (Li, Be) pegmatites. They noted that branches from Balsam

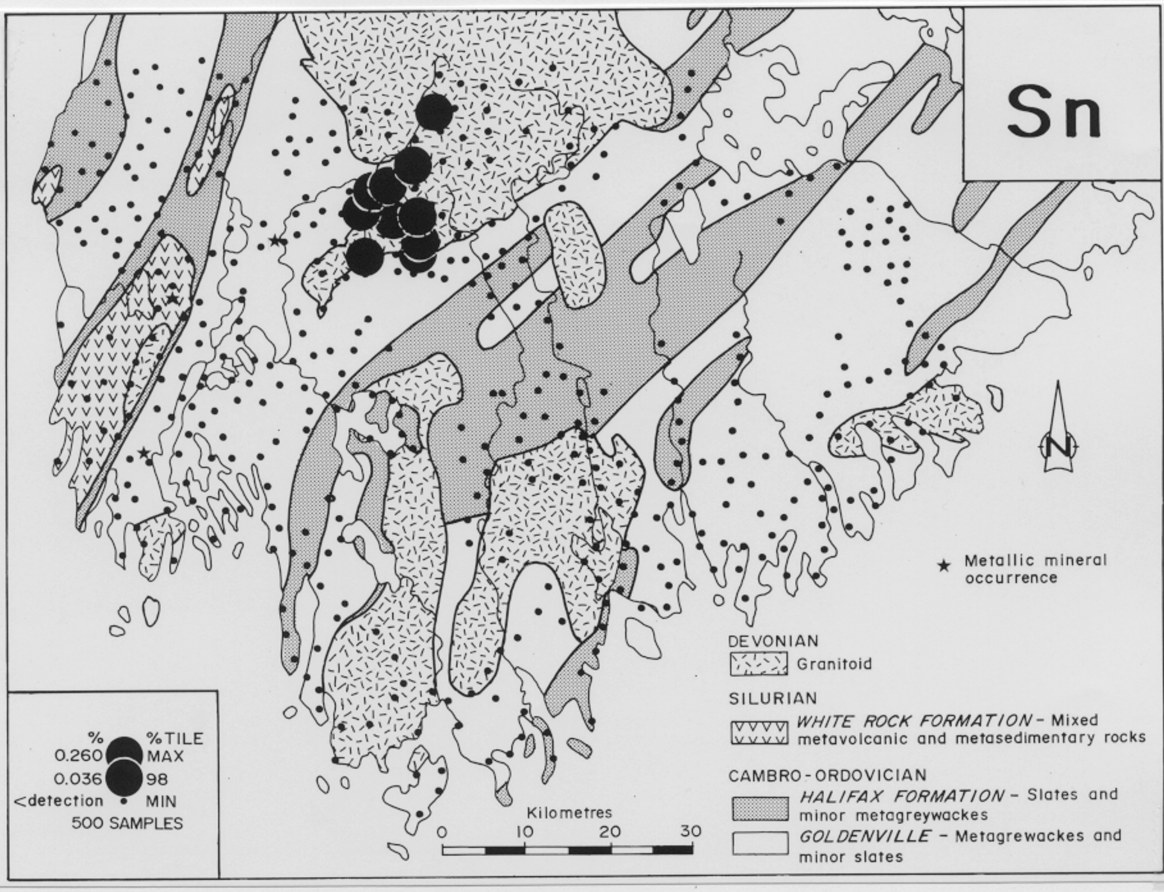

Figure 10.7 Proportional symbol plot showing the distribution of Sn in red spruce bark in southwestern Nova Scotia (modified from Dunn et al., 1992). The simplified geology for this area has been plotted for reference.

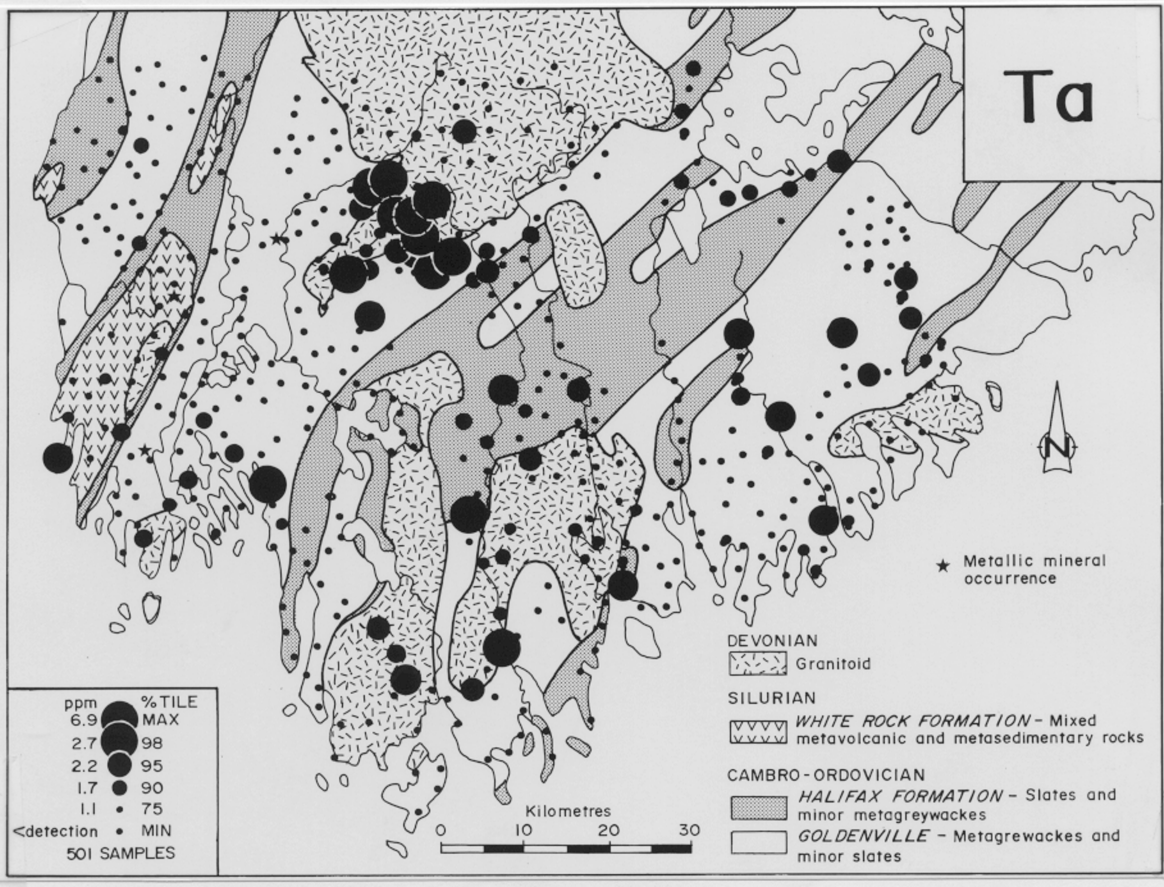

Figure 10.8 Proportional symbol plot showing the distribution of Rb in red spruce bark in southwestern Nova Scotia (modified from Dunn et al., 1992). The simplified geology for this area has been plotted for reference.

Fir trees collected near the pegmatite outcrop in the Brazil area generally had much higher values of Li±Cs±Ta±P±Sn±Nb±F than samples taken in other parts of the study area. They also noted different spatial distribution patterns for Li, Be and Cs which was tentatively attributed to primary zoning in the pegmatites.

It is apparent from the aforementioned studies that chemical analysis of plant tissues is an effective method for delineating areas of bedrock and overlying till that are enriched in "granophile", and indeed "chalcophile", elements. In addition these techniques have successfully confirmed the presence of known granite-hosted mineral deposits and metasediment-hosted rare-metal pegmatites in the southern Meguma Zone. Therefore biogeochemical techniques can be used in exploration programs for granite-hosted mineralization.

10.2.5 Lithogeochemical data

The South Mountain Batholith project has produced a large lithogeochemical database, as outlined in Chapter 5. Exploration companies routinely collected hand samples for geochemical analyses to measure the concentration of ore elements, or characteristic trace elements, that would suggest the potential for mineralization. However, to date there have not been any systematic exploration lithogeochemical studies for the batholith. Thus an evaluation of the potential for this type of exploration is warranted.

As previously noted in Chapter 5, lithogeochemical data can be used to define normal and/or reverse compositional zoning in most Stage I and II plutons. The central "highs" in normally zoned Stage II plutons generally have the highest concentrations of "granophile" elements and therefore are the most "specialized" granites exposed in the batholith. The detection of these rocks using lithogeochemical techniques is therefore a useful exploration method.

The remainder of this discussion will focus on the Davis Lake Pluton, however, all plutons can be investigated using lithogeochemistry. The Davis Lake Pluton displays very systematic normal zoning as previously noted in Chapter 5. For example K/Rb values (Fig. 5.10) decrease from >200 along the northern and eastern margin to <50 in the southeastern lobe which hosts the East Kemptville deposit. Detailed contour plots of F and Rb for the East Kemptville and western Davis Lake Pluton are given in Figures 10.9 and 10.10. These data indicate normal zoning in the Davis Lake Pluton with the least "evolved" rocks along the eastern and northern

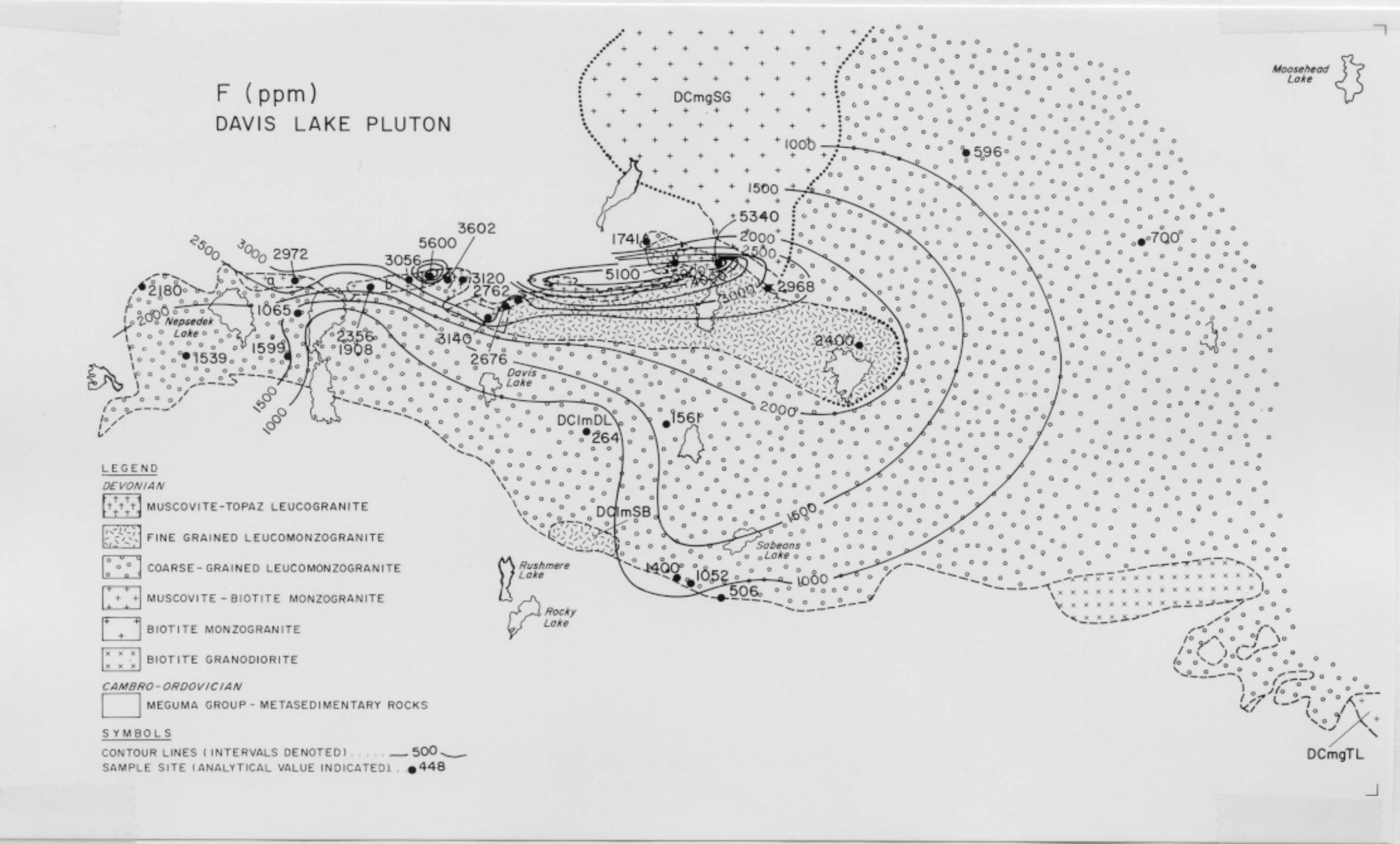

Figure 10.9 Distribution of F in the Davis Lake Pluton (data from Ham et al., 1990). Contouring was performed manually using contour intervals chosen to best display the entire data range.

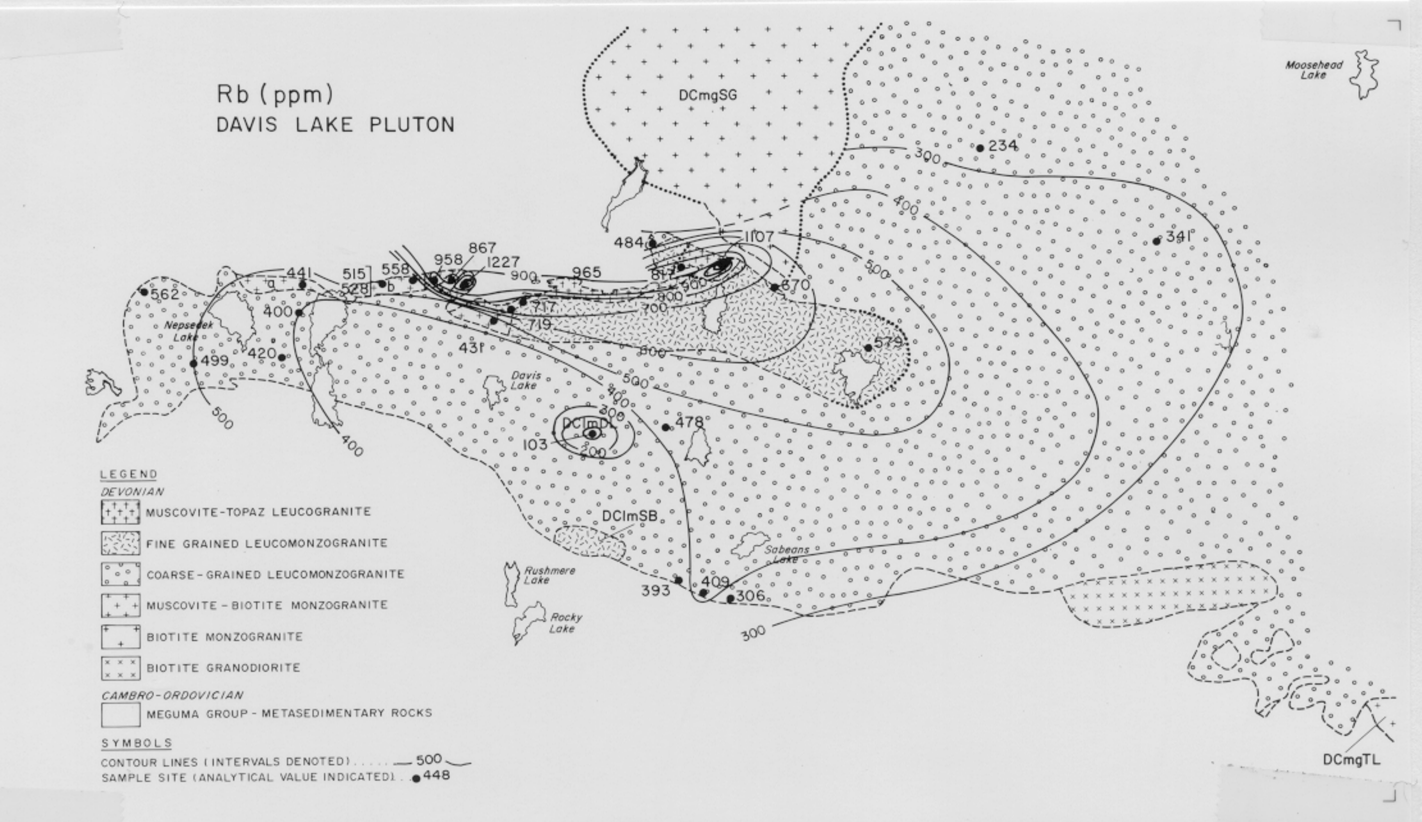

Figure 10.10 Distribution of Rb in the Davis Lake Pluton (data from Ham et al., 1990). Contouring was performed manually using contour intervals chosen to best display the entire data range.

margins having the lowest concentrations of F and Rb and the most evolved rocks with the highest levels of F and Rb residing in the southern lobe. In fact the contours for F and Rb have a pronounced "bulls-eye" pattern that is centred on the East Kemptville leucogranite and the greisen-type Sn-Zn-Cu-Ag mine. An exhaustive discussion of the exact processes that lead to the extreme enrichments of F and Rb and the pronounced lowering in K/Rb values over the Sn mine and host leucogranite is beyond the scope of this report. However, the key observation is that lithogeochemical analysis of the rocks of the Davis Lake Pluton accurately pin-point the East Kemptville deposit and thus should be considered as a viable "tool" when designing future exploration programmes, particularly for greisen-type mineralization which is spatially associated with "specialized" granitoid bodies.

10.2.6 Humus surveys

Organic humus or A_1 soil layer has not been used extensively for exploration for granophile mineralization. In fact the only published reference for humus data is MacDonald et al. (1992b) for the Brazil Lake pegmatites. They noted that levels of most elements including Li, Be, Cs, F, Rb and Sn varied significantly in the humus samples collected throughout their 600m x 600m sampling grid. They concluded that a large proportion of this variation in concentration correlated to the organic content of the samples which ranged from 5-90% and subsequently applied a correction factor to the raw analytical data, based on the percentages of organic material.

A plot of Li (corrected for organic content) in humus from the Brazil Lake survey is given in Figure 10.11a. Clearly the highest Li values are in humus samples collected directly over the known spodumene-bearing pegmatites. The results for Be, Cs and Ta (Figs. 11 b,c,d) are less definitive but also mirror the location of known pegmatite occurrences. High concentrations of these "granophile" elements elsewhere in the sample grid suggests that additional pegmatite dykes are also present. The most significant finding from this study, in terms of the implications for mineral exploration, is that anomaly/background contrast can be easily detected in samples of organic humus. The results from a previous multi-media geochemical study over the Yava Pb deposit in eastern Cape Breton Island (MacDonald et al., 1991) revealed that the distribution of Pb, Zn and other heavy metals in humus is strongly influenced by hydromorphic processes. Therefore, the applicability of humus sampling for the entire batholith is yet to be evaluated but merits further evaluation.

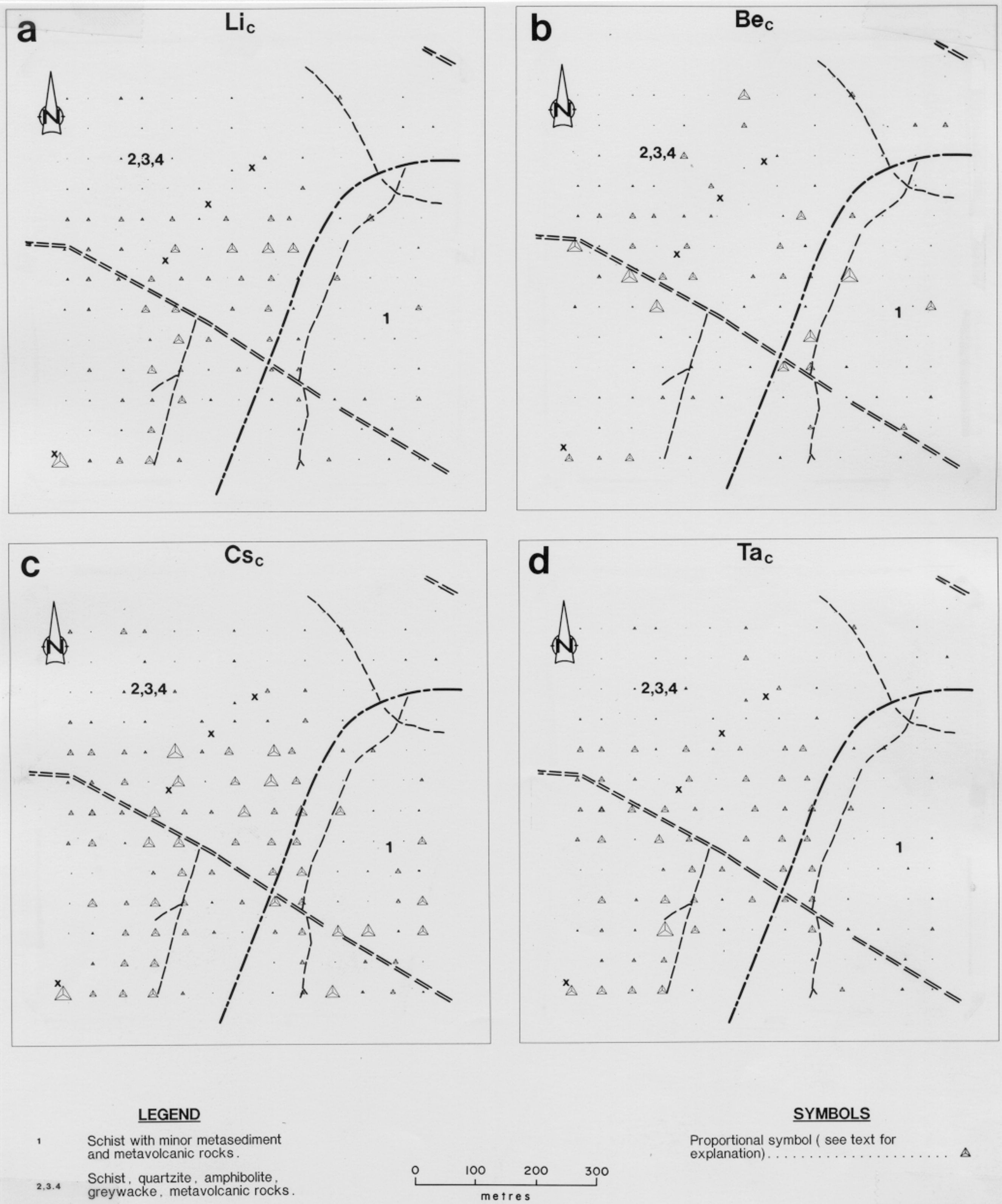

Figure 10.11 Proportional symbol plot for humus ash (corrected data from MacDonald et al., 1992b) from the Brazil Lake area that hosts spodumene±beryl-bearing pegmatites. Note the close spatial relationship between the high Li concentrations in humus and the outcrop of rare-metal pegmatites.

10.3 Geophysical Data

Several geophysical techniques have been used by explorationists and government organizations over the granitic rocks of the South Mountain Batholith and other plutons of the Meguma Zone. By far the most widely used geophysical methods have been airborne gamma-ray spectrometry, however, other methods have been employed with varying degrees of success. The following section summarizes some of the applications of geophysical methods in the batholith.

10.3.1 Airborne Gamma-ray Spectrometric Surveys

Airborne gamma-ray Spectrometric surveys were flown over the entire province between 1976 and 1990 (Ford et al., 1992). These surveys report responses both as total count (TC) and -as individual element components including equivalent uranium (eqU), equivalent thorium (eqTh) and equivalent potassium (eqK) and the various ratios of these components. The relationship between the results of these surveys and bedrock and surficial geology have been addressed in several studies including Chatterjee and Muecke (1982), Ford and Ballentine (1983), Ford and O'Reilly (1985), O'Reilly et al. (1988), and Finck et al. (1988). Spectrometric surveys over the granitic rocks of the Meguma Zone were also used by private sector companies, primarily in the search for U mineralization.

It is generally agreed by the above authors that the "radiometric" responses from the Geological Survey of Canada data can be explained by a combination of bedrock and surficial geological features. For example, most of the Stage II plutons, which are enriched in U and K compared with Stage I plutons, are clearly defined by several responses including eqU, eqK and eqU/eqTh. In addition, cryptic normal and reverse compositional zoning within both Stage I and II plutons, such as in the Halifax, Salmontail and New Ross plutons (MacDonald and Horne, 1988; Horne et al., 1989; MacDonald et al., 1992) are also evident in much of the "radiometric" data.

Complex "radiometric" patterns in some parts of the batholith and other Meguma Zone are difficult to explain in terms of the observed granitic rock types (O'Reilly et al., 1988). Some of these patterns reflect the presence of large scale alteration features including albitization and K-feldspathization or highly specialized leucogranite bodies (Chatterjee and Muecke, 1982; O'Reilly et al., 1988; Ford, 1993). In other areas observed radiometric patterns are best explained by the dispersion of granitic and non-granitic lithologies in the complex series of Pleistocene deposits that overlie the batholith (O'Reilly et al., 1988; Finck et al., 1988).

Spectrometric data can be used at various scales to interpret different bedrock and surficial features. On a large scale data can be used to define batholith- and pluton-scale compositional trends. On a more local scale it can also be used to define individual granite/granite or granite/metasediment geological contacts (MacDonald et al., 1992). These data can also be used as exploration tools to delineate high response areas with intense greisenization, albitization and K-feldspathization associated with greisen-type and U-bearing vein-type mineralized zones such as the Millet Brook deposit (Chatterjee et al., 1982). In addition radiometric response can be used to define "specialized" leucogranites that <u>may</u> host pegmatite-type mineralization. Finally, the presence of intense alteration zones at the New Ross Mn-Mines (O'Reilly, 1992) indicates that radiometric data may be useful in outlining these types of vein-style deposits.

The chief draw-back with airborne gamma-ray spectrometric surveys is the difficulty in distinguishing between the contribution from each of the various geological features outlined above. For example an area of very high eqU and eqU/eqTh may reflect the presence of a "specialized" granite that may or may not contain mineralized or intense alteration zones. In addition the actual shape of the "anomaly" may have been changed significantly by glacial dispersion. Data from "radiometric" surveys <u>must</u> be evaluated in light of all of these factors.

10.3.2 Other Geophysical Techniques

Several other geophysical techniques including electromagnetic (EM), very low frequency (VLF), resistivity, induced potential (IP) and gravity methods, have been employed, with varying degrees of success, over the batholith. Most techniques have been used by private-sector exploration companies, however, some government surveys have also been conducted.

Gravity data for the batholith mainly consists of the 6-km spaced regional data from the Geological survey of Canada (Miller and MacDonald, 1993). These data indicate the presence of two gravity "lows" centred over the Davis Lake and New Ross plutons which are interpreted as representing the thickest portions of the batholith. In general, detailed gravity surveys have not been used extensively in the batholith. The most notable exceptions include: 1) the delineation of a negative gravity "anomaly" near Caledonia by Billiton Canada (MacGillivray, 1982) which was interpreted as representing a buried granite "cupola". This interpretation is consistent with the presence of polymetallic W-Sn-bearing quartz-greisen veins and associated breccia pipes and mineralized skarns (O'Reilly, 1985) in this area; 2) the recognition of an "inflection" in the granite/metasediment contact north of the East Kemptville Sn deposit which was interpreted to be an essential factor in the formation of the Duck Pond Sn deposit by Pitre and Richardson (1989).

As previously noted, the batholith does not contain magnetite or significant quantities of other minerals with high magnetic susceptibility. Accordingly, regional magnetic and vertical gradiometer surveys outline the batholith as an area of "flat" magnetic response, particularly, compared with the highly responsive Meguma Group metasedimentary rocks (Miller and MacDonald, 1993). Detailed magnetic surveys have not been extensively used for exploration in the batholith. However, magnetic techniques could possibly be used to explore for mineral deposits containing high modal proportions of hematite, most notably the vein-type deposits, and pyrite, such as some of the greisen- and breccia-type deposits. Magnetic techniques will probably not be applicable for delineating pegmatite-type mineral deposits.

Electrical geophysical methods including induced polarization (IP) and self potential (SP) have been successfully utilized to define sulphide- and oxide-bearing zones within the batholith. An example is the use of IP to identify the extent of sulphide zones along the trace of the Tobeatic Fault Zone near Little Tobeatic Lake (Corey and Horne, 1989c). Another example is the detection of arsenopyrite-bearing albitite dikes in the Upper New Cornwall area (Corey, 1983).

Electromagnetic (EM), very low frequency (VLF) and resistivity techniques are sensitive to subsurface "conductors" such as sulphide- and graphite-bearing zones and have been used effectively in the batholith. For example Corey (1983) identified alteration zones (albitization, greisenization) in the Upper New Cornwall are using VLF and resistivity surveys. VLF and EM methods are also very useful for identifying clay-rich horizons, such as at Millet Brook and the New Ross Manganese mines and the Little Tobeatic Lake breccia-type occurrence (McKenzie, 1988). Resistivity surveys are particularly effective for outlining the presence of water-bearing zones including the vein-type mineralization and associated fracture zones at the Millet Brook U-Cu-Ag deposit (Chatterjee et al., 1985).

10.4 Discussion and Summary

Mineral exploration in the past several decades has focused principally on the potential for greisen- and vein-type mineralization throughout the batholith with sporadic exploration for breccia-type metal deposits along the southern margin of the Davis Lake Pluton (see discussion in Chapter 9). This activity has led to the discovery of the greisen-style polymetallic-Sn deposit at East Kemptville, the vein-type U-Cu-Ag deposit at Millet Brook, and numerous other occurrences. Most mineral occurrences have definitive geochemical and geophysical responses. The geochemical `signatures' of the four main deposit types have been noted to reflect their different mineralogy and associated alteration mineral assemblages, subsequently, future geochemical programmes should consider utilizing statistical techniques to establish multi-element anomalies. This procedure may assist in differentiating between styles of mineralization, for example, it may be possible to distinguish F anomalies associated with vein-type mineralization (U-Cu-Mn-P-**F**-Ag) from greisen (Sn-W-Mo-As-Cu-Pb-Zn-Bi-Au-Ag-B-**F**-P-Na-K) or pegmatite (Mo-Sn-W-Cu-Nb-Ta-Be-B-**F**) by looking at the associated elemental assemblages.

Lake sediment surveys have been shown to reflect large-scale bedrock (and presumably till) features including metallogenic `domains' (Rogers et al., 1990; Figure 10.3) and metal-rich regions of the batholith (e.g. New Ross, East Kemptville, Long Lake; Figures 10.1, 10.2). However, lake sediments will have limited application for detailed mineral exploration, owing to the relative size of the catchment basins and the nature of lake sediment depositional processes.

Till surveys have been shown to be an effective exploration method for pin-pointing the location of granite-hosted mineralization in the batholith, particularly when coupled with other geochemical and geophysical techniques (e.g. lake sediment geochemistry, Gamma-Ray Spectrometry). Explorationists have used detailed till surveys extensively to define trenching and drilling targets. Finck and Stea (1995) note that the surficial geology overlying the batholith comprises several till sheets with varying composition and proportions of distal (i.e. "foreign") and local components. It is critical that future till exploration programmes consider these factors into consideration, particularly when anomaly/background thresholds are established.

Biogeochemical techniques have not been used routinely for mineral exploration in the batholith, however, it is clear from initial studies and surveys that plant tissue can be used to detect several different types of mineralization. Consequently, the potential of using biogeochemical techniques should be considered in future programmes, particularly in light of their relative cost-effectiveness.

Lithogeochemical analyses provides detailed information regarding primary dispersion and degree of fractionation in both Stage I and II plutons. Accordingly, this information can be used to target areas with potential for vein-type mineralization (e.g. New Ross Mn Mines) or greisen-type mineralization (e.g. East Kemptville deposit) that have been demonstrated to occur in highly fractionated parts of normally zoned plutons. Similarly, lithogeochemical analyses can be used to define individual bodies of highly fractionated leucomonzogranite and leucogranite that commonly host pegmatite- and greisen-type mineral deposits (e.g. New Ross area). Lithogeochemistry is not particularly suited for establishing target areas for breccia-type mineralization, which is fault-controlled and may cross-cut less fractionated granites and/or metasedimetary host rocks.

Geochemical analysis of organic soil (i.e. humus) can provide a cost-effective exploration method granite-hosted mineralization. However, geochemical analysis of ashed humus is particularly susceptible to the organic content of samples (MacDonald et al., 1992).

Geochemical procedures are not particularly useful for vein-type Fe-Mn mineralization, such as at New Ross Manganese Mines, because these deposits are not strongly enriched in many of the "granophile" elements such as U, Ta, Rb. It is difficult to use both Mn and Fe as diagnostic exploration elements because these elements are strongly affected by surficial hydromorphic processes and commonly are enriched in low-lying, swampy areas. It may be possible to remove the hydromorphic effects by some data correction procedure, possibly entailing the Loss on Ignition values which indicate the amount of organic content in each sample. It is possible that indicator elements may be established for this type of mineralization. For example, ore zones at New Ross Mn Mines have high modal proportions of fluorapatite and subsequently high concentrations of F and P_2O_5. The possibility of using these and other elements as pathfinder elements for Mn-Fe mineralization warrants evaluation.

Airborne Gamma-ray Spectrometric techniques are especially useful for vein-type U-Cu-Ag mineralization and can also be utilized to delineate specialized bodies that commonly host greisen- and vein-type mineralization. Spectrometric surveys may also be used to detect hydrothermal alteration including potassic zones that routinely are associated with greisen-style mineral occurrences.

Vein- and breccia-type mineralization are localized along shear and fault zones, as evidenced by the Tobeatic Lake (Pb-Zn-Ba-Au-Ag) breccia occurrences, the Millet Brook U-Cu-Ag deposit and the New Ross Mn Mines deposits. Several geophysical techniques can be used to explore for these types of mineralization including VLF, IP, EM and SP.

Future exploration programs should employ a combination of geochemical and geophysical techniques and will assuredly benefit from the extensive datasets that have generated by both provincial and federal government surveys and organizations, along with mineral industry assessment work. Clearly, exploration programs that combine available bedrock and surficial geological information, geochemistry and geophysical data, and basic prospecting, should lead to the discovery of additional granite-related mineralization in or around the South Mountain Batholith.