*Current Research (86-1) Newfoundland Department of Mines and Energy,
Mineral Development Division, Report 86-1, pages 223-237*

REGIONAL GEOCHEMICAL PATTERNS IN THE EASTERN CENTRAL MINERAL BELT OF LABRADOR

Andrew Kerr
Labrador Mapping Section

and

Peter Davenport
Geochemistry and Geophysics Section

ABSTRACT

This report describes some preliminary results from an interpretation of lake sediment and water geochemical data for the Central Mineral Belt of Labrador using a range of multivariate statistical procedures. The most important steps in data analysis are multiple linear regression, calculation of residuals and R-mode factor analysis with VARIMAX rotation. The regression and calculation of residuals are used to selectively remove the effects of inter-element correlations which are considered to be related largely to environmental factors such as lake depth, topography, drainage and a variety of limnological processes. Factor analysis is used to both reduce the volume of data and to group elements into associations influenced mostly by single factors, which can perhaps be interpreted in terms of rock associations or geologic processes such as mineralization. Regional geochemical patterns are illustrated with factor score distribution maps for a five factor model explaining 66 percent of the total variance, and an attempt is made to interpret some of these patterns.

The results suggest that geological packages within the Central Mineral Belt have very distinct geochemical signatures, which can to some extent be correlated with what is known about their general geology and styles of mineralization. For example, the Archean gneisses show a signature suggesting enrichment in Ni,MgO and CaO, coupled with depletion in U and F, which is shared by Proterozoic granitoids that intrude, and were perhaps derived from these gneisses. In contrast, granitoid rocks of the younger Trans-Labrador batholith display enrichment in U, Mo, F, Pb and Zn, elements which are often indicators of granite-hosted mineralization.

On a more local scale, supracrustal rocks of the Moran Lake Group and perhaps also paragneisses within the Grenville Province are enriched in the base metals Cu, Co and Zn. This signature is not shared by the supracrustal sequences of the Bruce River Group and parts of the upper Aillik Group, which instead show enrichment in Ag, As and possibly Hg. The latter pattern is tentatively interpreted to indicate that these areas may have potential for precious metal mineralization. There appear also to be some differences between the geochemical signatures of the two separate outcrop areas of the upper Aillik Group. These may be due to the effects of late granites, but could also represent a difference in composition related to differences in tectonic setting or age.

INTRODUCTION

Project Description

Regional geochemical surveys in Labrador using lake sediment as a sample medium have been carried out over the last seven years under the Uranium Reconnaissance Program and several Canada- Newfoundland mineral development agreements. Analytical data for some of the more economically promising areas have only become available following the 1982 and 1983 programs. It is now possible for the first time to integrate data for entire structural or lithologic provinces, and it appears that Newfoundland and Labrador will be the first province to have complete reconnaissance geochemical coverage.

This report summarizes the results of an analysis of data for the eastern part of the Central Mineral Belt, an area which has been the focus of most past and present exploration work in Labrador. It was carried out as one of the initial stages of an ongoing project to investigate the petrology, geochemistry and mineral potential of granitoid rocks in this area, as a method of delineating areas that show favourable geochemical signatures within plutonic terranes. The results are, however, of interest also in terms of the regional geology of the Central Mineral Belt and its potential for a range of commodities, in particular Au and Ag.

General Geology

The Central Mineral Belt of Labrador (Greene,1974) was first defined by exploration geologists in the 1950's and consists of a west-trending zone of Aphebian and Helikian supracrustal sequences, which host a large number and variety of base-metal, uranium and rare-metal mineral occurrences. The Central Mineral Belt lies along the northern margin of

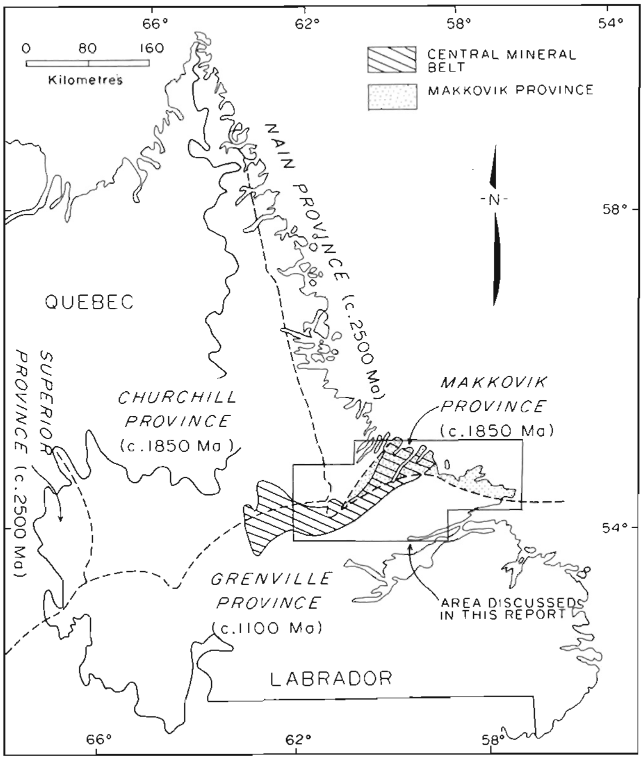

Figure 1: *Location of the Central Mineral Belt of Labrador and the area discussed in this report.*

the Grenville Province (c.1.1 Ga) , but also partly overlaps the older Nain, Makkovik and Churchill structural provinces (Figure 1). The geology of the eastern part of the belt has been recently described by Gower (1981), Gower *et al.* (1982) and Ryan (1984), and the northern edge of the study area by Ermanovics and Raudsepp (1979), Ermanovics and Korstgard (1981) and Emslie (1980). The generalized geological map shown in Figure 2 was compiled from all these sources. The geology of the area is dominated by four major subdivisions of basement and supracrustal rocks, and at least 3 discrete groups of intrusive rocks. The basement and supracrustal rocks are:

1. Archean basement gneisses exposed in the northern part of the area, and consisting of banded to massive gray orthogneisses with intercalated amphibolite and metasedimentary units, intruded by a variety of foliated to gneissic granitoid rocks. In the east, much of this Archean block has been variably remobilized during early Proterozoic orogenic events.
2. Aphebian supracrustal rocks (Moran Lake and Aillik groups). The Aillik Group (exposed in the east) consists of a lower mafic volcanic and metasedimentary sequence and an upper thick felsic volcanic pile; the lower and upper sequences may possibly be separated by an unconformity. The Moran Lake Group (in the west) is lithologically similar to the lower Aillik Group and may be correlative with it.
3. Paleohelikian supracrustal rocks (Bruce River Group) consisting of sandstones and conglomerates overlain by mafic to felsic volcanic rocks that are thought to be subaerial. Rb-Sr data suggest an age of c.1.5 Ga, but an unpublished U-Pb zircon age (Krogh, personal communication to R.J.Wardle, 1985) suggests 1.65 Ga as an alternative.
4. Neohelikian supracrustal rocks (Seal Lake Group) consisting of a shale-quartzite-conglomerate sedimentary sequence with intercalated mafic volcanic and plutonic rocks. Rb-Sr ages suggest that it is c.1.32 Ga in age.

The three main groups of post-Archean intrusive rocks are:

1. Foliated to gneissose granitoids emplaced between 1.9 and 1.8 Ga, coincident with early Proterozoic orogenic events affecting Archean basement and Aphebian supacrustal rocks.
2. A largely posttectonic polyphase granitoid batholith (Trans-Labrador batholith) dated at c.1.65 Ga, although some portions may be correlative with, or younger than, the Bruce River Group.
3. Anorthosites and related granitoid rocks of the c.1.45 Ga Harp Lake Complex. The complex postdates the Bruce River Group but predates the Seal Lake Group.

In addition to the supracrustal and intrusive rocks listed above, large areas south of the Grenville Front are underlain by orthogneisses and paragneisses which are rather poorly known. Some of the orthogneisses may be deformed equivalents of the Trans-Labrador batholith.

ANALYSIS OF GEOCHEMICAL DATA

Overview of Data

The areas discussed in this report include NTS map sheets 13J and 13K, together with portions of 13O and 13I, and were sampled in 1977,1978 and 1983. Descriptions of sampling methods, media and analytical techniques were described by the Geological Survey of Canada (1981, 1984) and have also been reviewed by Davenport (1982) and McConnell(1984). The subset of the data used in this examination was selected by using coded geological information, based on the geological map of Greene (1974), to select only those sample sites underlain by the geological subdivisions described in the preceding section, with the exception of the Seal Lake Group. This resulted in a data file containing 1512 observations with the following variables: depth, pH, LOI, Zn, Cu, Pb, Ni, Co, Ag, Mn, As, Mo, Fe, Hg, U, F, $U(H_2O)$, $F(H_2O)$, V and Cd. Values for V and Cd are available only for about 46 percent of the observations , and Hg values include a number of missing cases. For this reason, these variables have been omitted from some of the later steps in statistical analysis. U and F were also measured in water, e.g., $F(H_2O)$ and $U(H_2O)$.

In order to deal with this large volume of data and present it in the form of a small number of maps, a number of statistical analysis methods were employed. The methods are relatively commonplace statistical procedures in a variety of fields, but the combinations and sequences in which they are

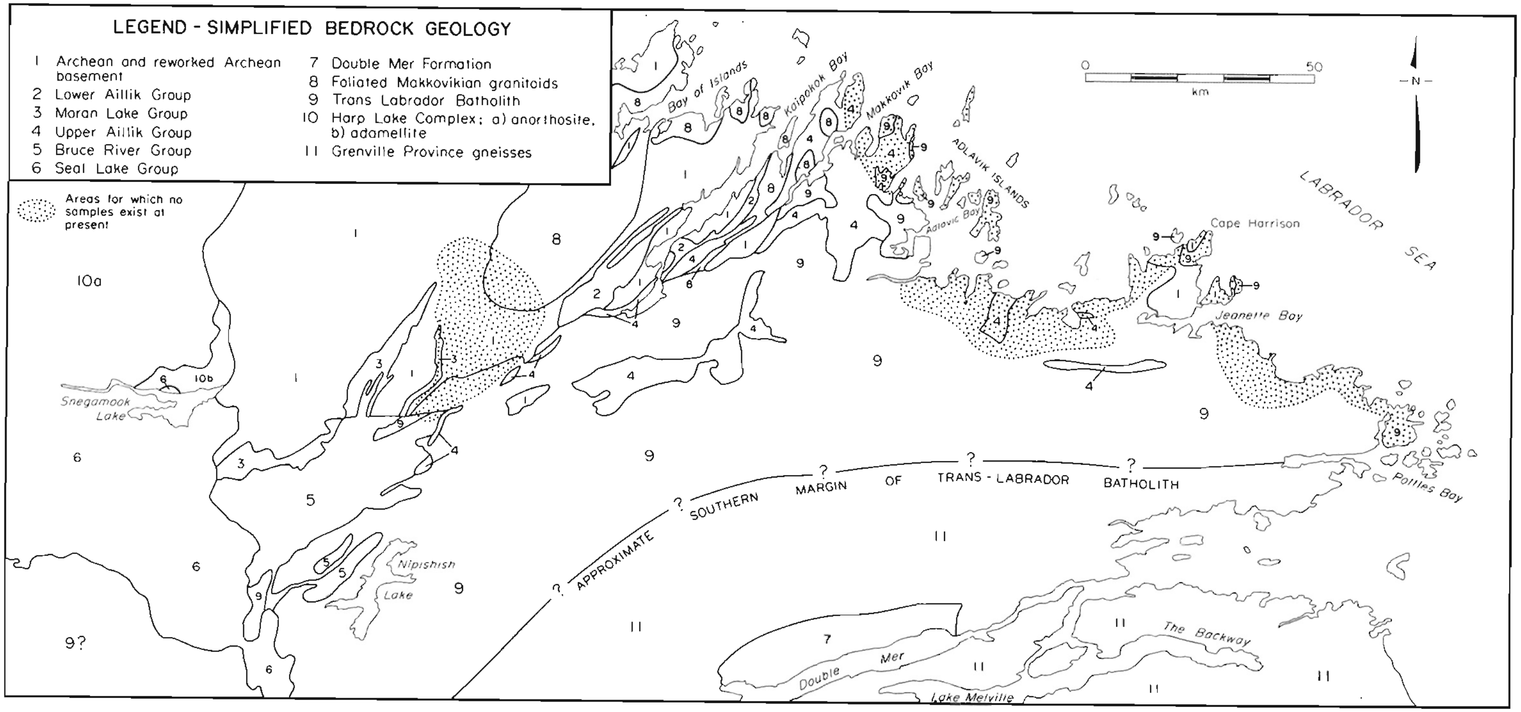

Figure 2: *Generalized geological map of the study area (after Gower, 1981; Gower et al., 1982; Emslie, 1980 and Ryan, 1984).*

applied were developed by P.H.Davenport and the geochemistry section as part of an overall project to produce geochemical atlases of the province (Davenport and Butler, 1983). Statistical calculations were performed using the SPSS computer package (Nie *et al.*, 1975). Maps that illustrate later portions of this report were produced initially as proportional symbol maps with a plotting program (MAPPLOT), and were subsequently hand contoured.

Data Analysis Methods

Data analysis can be divided into seven steps:

1. Generation of descriptive statistics (mean, minimum, maximum and standard deviation) to assess the characteristics of frequency distributions for all variables.
2. Log transformation of all variables where the standard deviation exceeds 0.5 of the mean value. This affects all variables except LOI and pH, which is already a logarithmic measurement.
3. Generation of a correlation matrix (Pearson type) to assess the magnitude and significance of inter-element correlations and, in particular, correlations that reflect the effects of variables whose distribution reflects mostly 'environmental', i.e., limnological, processes rather than the effects of bedrock geology.
4. Stepwise multiple linear regression analysis to generate equations relating the concentration of elements of economic interest to the concentration of these elements whose distribution reflects environmental factors.
5. Calculation of residuals for all elements whose regression equations suggest that a significant proportion of their variance is due to lacustrine environmental effects.
6. R-mode factor analysis[1] of regressed data, and assessment of factor models involving 4 to 7 factors (see explanation below).
7. Calculation of factor scores for all sample sites based on the preferred model, and generation of factor score distribution maps to represent the data.

The multivariate steps (4 and 6) have two main objectives. Step 4 allows the removal of variation which is considered largely to be of 'environmental' origin. Residuals represent the differences between the actual value of an element in samples and the values predicted by the regression equation. They are thus a much better indicator of bedrock effects than raw (unregressed) data. R-mode factor analysis seeks to group elements together on the basis of inter-element correlations and re-expresses the data in terms of a smaller number of new variables termed factors. This leads to a considerable reduction in the volume of data. The basic premise of the method is that variation in a multivariate data set is related to variations in the influence of a much smaller number of 'factors', which, in a geological context, could perhaps be thought of as particular rock types, mineralization styles or geological processes. It is possible, therefore, to use the results of factor analysis to identify the causes of variations in the data, but only by using subjective geological reasoning.

Although some of these concepts will be unfamiliar to many geologists, it is felt that the factor score maps can be understood and interpreted without detailed insight into the mathematics, and that the patterns themselves provide proof of the usefulness of the method in regional geochemical studies. A rigorous description of regression and factor analysis can be obtained from any comprehensive text on geostatistics, such as Davis (1973).

Analysis of Inter-Element Correlations

Table 1 is a correlation matrix showing Pearson correlation coefficients (R) for all variable pairs including Hg, V and Cd. The values of the coefficients may vary from 1.0 to -1.0 (such values reflect 'perfect' correlation, as for an element with itself) and indicate the magnitude and direction of correlation (negative values indicate antipathetic correlation). In the discussion that follows, correlations are categorized as strong where $R \geq 0.60$, moderate where R is between 0.45 and 0.60 and weak where R is between 0.30 and 0.45. Values less than 0.30 are not shown in Table 1 for the sake of clarity.

Several prominent associations can be discerned from Table 1:

1. Moderate correlations between depth and most other variables, with the exception of Pb,F, F(H_2O) and perhaps also As and Ag, which are marginal. A strong correlation, however, is present between depth and Mn.
2. Strong correlations (>0.80) between Fe and Mn, Fe and Co and Mn and Co. These are accompanied by moderate to strong correlations between many variables and one or more of these three elements. The notable exceptions are Ag, U(H_2O), F(H_2O), pH and LOI.
3. Moderate to strong correlations among the base metals Cu, Zn, Ni and Co. For Cu and Ni, these correlations are higher than those with Fe and Mn.

---

[1] In this report the term 'factor analysis' is used to describe procedures collectively contained in the FACTOR subprogram of SPSS (Nie *et al.*, 1975). The terms 'Principal Component Analysis' and 'Factor Analysis' are not interchangeable, but the methods are closely related and there is no clear concensus on terminology. Accordingly, those familiar with the methods should note that some statisticians would prefer the term 'Principal Component Analysis' for some of the techniques used here. For a full discussion of methods, see Nie *et al.*, 1975.

Table 1. Correlation Matrix for Central Mineral Belt Lake Sediment Data

	LOI	pH	DPTH	Zn	Cu	Pb	Ni	Co	Ag	Mn	As	Mo	Fe	U	F	U*	F*
LOI	1.00																
Ph	—	1.00															
DPTH	—	0.43	1.00														
Zn	—	0.38	0.52	1.00													
Cu	0.37	0.34	0.59	0.62	1.00												
Pb	—	—	0.32	0.40	—	1.00											
Ni	—	0.57	0.46	0.57	0.61	0.32	1.00										
Co	—	0.34	0.53	0.68	0.55	—	0.52	1.00									
Ag	0.40	—	0.42	—	0.43	0.32	—	—	1.00								
Mn	—	0.35	0.61	0.65	0.49	0.30	0.48	0.85	0.37	1.00							
As	—	0.46	0.43	0.40	0.42	0.35	0.45	0.44	0.32	0.52	1.00						
Mo	—	0.31	0.46	0.63	0.47	—	0.35	0.58	—	0.54	0.33	1.00					
Fe	—	—	0.52	0.69	0.47	—	0.36	0.84	—	0.83	0.37	0.61	1.00				
U	—	—	0.44	0.56	0.46	0.36	0.33	0.44	0.30	0.43	—	0.68	0.46	1.00			
F	-.34	—	—	0.42	—	0.42	0.33	0.42	—	0.44	0.33	0.33	0.45	0.38	1.00		
U*	—	—	—	—	—	—	—	—	—	—	—	—	—	0.48	—	1.00	
F*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.35	0.49	1.00
Hg	0.66	—	0.45	0.37	0.53	—	0.32	—	0.53	0.30	—	0.30	—	—	—	—	—
Cd	—	0.48	0.39	0.62	0.56	—	0.48	0.34	0.36	0.37	0.36	0.30	—	—	—	—	—
V	—	—	—	0.42	—	—	0.24	0.69	0.33	0.69	0.37	0.49	0.81	0.39	—	—	0.35

NOTE: Values between 0.30 and -0.30 have been omitted for the sake of clarity.
* Measured In Lake Water

4. Generally moderate correlations between (Cu, Zn, Co) and (Mo, U). The individual correlations of these elements with Fe and/or Mn are generally of similar magnitude or higher than their inter-correlation.

5. Strong correlations between U and Mo, and moderate correlations between U and U(H_2O) and U(H_2O) and F(H_2O). Other correlations within this group of "lithophile" elements are generally weak.

6. Moderate correlation between pH and Ni.

7. Generally weak correlations between Pb and almost all other elements. The highest values are with Zn and F.

8. Very poor correlation between U(H_2O), F(H_2O) and most other elements. The U(H_2O) - F(H_2O) correlation is stronger than either the U(H_2O) - U or F(H_2O) - F correlations.

In a general sense, these results resemble those of McConnell(1984), who analyzed data for areas of Labrador sampled prior to 1982, excluding data for As, Hg, V and Cd. The strong correlations dominated by Fe/Mn/Co and depth are present in both analyses, as are base metal and U-Mo-F-U(H_2O)-F(H_2O) associations. However, negative correlations between LOI and other variables are not as evident for the Central Mineral Belt data, and the pattern of correlations is somewhat more complex. The latter observation most likely reflects the contrast between an aggregated data set based on 100 km^2 cells (McConnell,1984) and the 'noisier' raw data used in this study. Of the correlations described above, we ascribe 1, 2, and 4 to 'environmental' factors, which are related mostly to lacustrine processes, rather than primary bedrock associations. The effect of (Fe, Mn) an other element distributions has been documented by Davenport (1982), McConnell (1984) and in a large number of exploration geochemistry programs elsewhere, and is widely considered to represent a coprecipitation effect caused by Fe-Mn oxides and hydroxides whose unusual surface properties give rise to a 'scavenging' effect. Depth is thought to be involved indirectly in this effect as it influences Eh-pH conditions at the sediment-water interface, which in turn control the stability fields of the various Fe-Mn compounds. McConnell(1984) also pointed out that depth may correlate with a finer sediment fraction containing clays, which have high ion exchange capacities. Correlations noted in 4 are interpreted mostly to be secondary effects of the depth-Fe-Mn control.

LOI is primarily a measure of the organic content of the samples and may exert some effect on metal concentrations via adsorption. It is correlated weakly with Cu, Ag, and F (Table 1) and strongly (0.61) with Hg. As LOI variation is without doubt related to limnological processes, it should be considered in the next step in analysis.

The remaining important correlations (3,5 and 6) are considered to reflect variations in bedrock geochemistry. The base-metal association probably reflects a common geological association and similar mobility during surface processes (c.f. McConnell,1984). The Mo-U-F association may perhaps relate to evolved igneous rocks, as these elements are commonly enriched in silicic magmas that have undergone extensive fractionation.

A correlation between pH and Ni may be a reflection of more basic rock types, which have higher Ni contents and tend to underlie lakes whose pH is buffered at about 7.0. A similar correlation was noted by McConnell (1984), but it was accompanied by a negative correlation with F(H_2O), which is not as marked in the Central Mineral Belt data. The lack of correlation between Pb and most other elements is less easily explained, but it is probably related to bedrock effects.

The above discussion suggests that 'environmental' effects are responsible for a significant amount of the variance in the Central Mineral Belt data. In order to 'see through' these effects to the underlying variations related to bedrock geology, their effects must be selectively removed by linear regression. The four variables Fe, Mn, depth and LOI are considered to be indicators of lacustrine environments and are thus chosen as the independant variables.

Regression Analysis and Calculation of Residuals

Results of regression analysis using Fe, Mn, depth, and LOI as independant variables suggest that a significant proportion of the variance of many other elements is of 'environmental' origin. The proportion is highest for Co and Zn, where over 50 percent of the variance is explicable via regression. Most other elements provide regression equations which account for 30 to 50 percent of their variance. For Ni, U, U(H_2O), F(H_2O) and Pb, less than 30 percent of the variance is explained by regression, and residuals were not calculated for these elements.

A *residual* is a measure of enrichment or depletion that is not explained by the regression, and hence (in these data) probably unrelated to environmental factors. For many elements, the residual populations are probably much better indicators of bedrock compositional variations than raw element data, and the significance of residuals is proportional to the amount of variance explained by the regression equations. The improvements offered by residuals can also be assessed by comparing maps showing raw and residual values for the area. In general, the latter are much smoother and easier to contour, and anomaly patterns commonly often differ significantly between the two, particularly with respect to the magnitude and size of anomalies. This tendency was also noted by McConnell (1984). In the discussions which follow, residual variables are indicated by a 'r' placed in front of the chemical symbol, e.g., rMo.

Factor Anlaysis

On the basis of the preceding steps in analysis, raw data for Co, Zn, Mo, Cu, As, F, and Ag were replaced by residual data. In order to group the elements for easier representation, the technique of R-mode factor analysis was used.

The most important result of factor analysis is a factor loading matrix, such as that shown in Table 2 for the Central Mineral Belt data. This shows the grouping of elements corresponding to particular factors, and indicates the magnitude and direction of their correlation. Definitions of 'strong',

Table 2. Factor Loading Matrix for 5-factor model with VARIMAX rotation.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	COMMUNALITY
U	0.80	—	—	—	—	0.74
rMo	0.78	—	—	—	—	0.66
U*	0.74	-.33	—	—	—	0.64
pH	—	0.82	—	—	—	0.75
Ni	—	0.71	—	0.39	—	0.75
F*	0.42	-.53	0.47	—	—	0.69
rF	—	—	0.79	—	—	0.66
Pb	—	—	0.72	—	—	0.63
rCu	—	—	—	0.80	—	0.73
rCo	—	—	—	0.67	—	0.53
rZn	—	—	0.35	0.65	—	0.59
rAg	—	—	—	—	0.85	0.75
rAs	—	0.34	—	—	0.53	0.47
% VE†	24.4	15.4	10.8	8.6	6.9	

NOTE: Values between 0.30 and -0.30 are omitted for the sake of clarity.
* Measured in lake water rather than sediment.
† Percentage of variance explained by this factor.

'moderate' and 'weak' are identical to those used for Table 1. The preferred model is the 5 factor model, which explains 66 percent of the total variance. Models with greater numbers of factors did not greatly improve this figure and started to generate factors which controlled single elements only. V, Cd and Hg were not included in factor analysis as the large number of missing cases causes problems in computation.

From the factor loading matrix , the factor scores for the sample sites can be calculated. The significance of scores for a particular factor can be assessed from the patterns in Table 2 . For example, a high score on factor 1 indicates that the sample is high in U, rMo, U(H_2O) and F(H_2O). High scores on factor 2 suggest depletion in U(H_2O) and F(H_2O) coupled with high pH and Ni values (negative loadings indicate antipathetic correlation). The immediate value of this step lies in a reduction of the *volume* of data involved, from 15 variables to only 5. A second advantage is that it is possible to ascribe geological significance to some or all of the derived factors and their score distributions.

DESCRIPTION AND INTERPRETATION OF REGIONAL GEOCHEMICAL PATTERNS

Figures 3 through 7 inclusive illustrate the distribution of factor scores for the 5 factors derived in Table 2. Factor scores are standardized variables, and are thus expressed in units of standard deviations. Contour intervals for each map are set at the 60th, 80th, 90th, and 95th percentiles and 'spot highs' (defined as single samples which are more than 2 contour intervals higher than all immediate neighbors) are eliminated for the sake of clarity at this scale. The simplified geological map in Figure 2 is at the same scale. It also illustrates the areas for which no sample data is available, including the mountainous areas along the coastal strip and swampy areas in major river valleys.

Implicit in the following discussion is the assumption that the characteristics of samples are influenced most strongly by the bedrock underlying the immediate drainage basin. Glaciation is also an important factor, as noted by McConnell (1984), but data on the Quaternary geology of Labrador is not yet sufficiently abundant to allow us to consider it in detail. However, we consider that bedrock effects are likely to be most important at the scale of this study, and the main effect of ice movements will be a 'blurring' of the relationship between geochemical response and bedrock units.

Factor 1 [U, U(H_2O), rMo, F(H_2O)]

Factor 1 shows strong positive loadings for three variables, U, rMo and U(H_2O) with lesser effects for F(H_2O). This general association is typical of fractionated silicic magmas enriched in large-ion lithophile elements and, for this reason, it is considered to be a 'granophile' factor. The general distribution of high factor 1 scores is in accordance with this conclusion. Most are along the northern margin of the Trans-Labrador batholith, and areas underlain by Archean gneisses, the Bruce River, Moran Lake and lower Aillik groups are generally low. The upper Aillik Group shows a more complex pattern. Some specific areas are discussed below.

The most prominent high forms a southeast-trending zone from Makkovik Bay to Adlavik Bay. This area is mostly underlain by upper Aillik Group volcanic rocks, but also contains a number of small granitoid bodies that host or are spatially related to Cu-Mo mineralization. A second high southwest of here shows a distribution that correlates generally with a coarse grained quartz-rich leucogranite defined as a major subunit of the Trans-Labrador batholith (Kerr, *this volume)*. Similar highs are also associated with granitic units to the southwest. In the Benedict Mountains area, there is a suggestion of a fairly extensive high, but there is no data available for the rugged area along the coastal strip.

The remaining major anomaly for this factor lies within the Archean terrane northeast of Snegamook Lake. This area is underlain mostly by Archean granitoid rocks that are dominated by tonalites and granodiorites, which do not usually display enrichment in these elements. It is, however, close to granitoid units associated with the Harp Lake Complex (Emslie,1980).

Factor 2 [pH, Ni, -F(H_2O), -U(H_2O), As]

Factor 2 shows strong positive loadings for pH and Ni, with a moderate negative loading for U(H_2O) and a weak negative loading for U(H_2O). Arsenic also has a small positive loading. This association suggests that it may reflect the opposite of factor 1, i.e., the influence of more basic or less evolved rock types containing more CaO and MgO (hence less acidic lake water) and Ni, but lower levels of U and F.

The most obvious feature of the factor 2 score distribution is that the Archean block, Moran Lake Group and parts of the Bruce River Group display moderate to strong enrichment, whereas all other units are low and generally below the 60th percentile. The most prominent highs appear to be associated with mafic volcanic units (not shown on Figure 2) in the Moran Lake Group and the Archean. However, areas within the Archean block that are underlain mostly by quartzofeldspathic gneisses still display moderate enrichment, as does a large early Proterozoic granitoid body that intrudes the Archean in the east. In contrast, granitoid rocks within the Trans-Labrador batholith are characterized by Factor 2 values below the 60th percentile, which is almost the exact inverse of the factor 1 pattern. This could have a number of explanations; it could reflect differences in crustal level, and perhaps even a contrast in source materials for these two areas of granitoid rocks and gneisses.

The edge of the exposed Archean block does not correspond exactly with that of the factor 2 high. This may reflect southward glacial transport from the Archean, but it might also reflect the influence of unseen Archean basement on the geochemical signatures of magmatic rocks derived from it, or acquired by passing through it.

Factor 3 [rF, Pb, F(H_2O), rZn]

Factor 3 is a rather peculiar association that shows strong positive loadings for rF and Pb, with lesser loadings for rZn and F(H_2O). The significance of such an association is uncertain, but it may be a reflection of alkaline or peralkaline

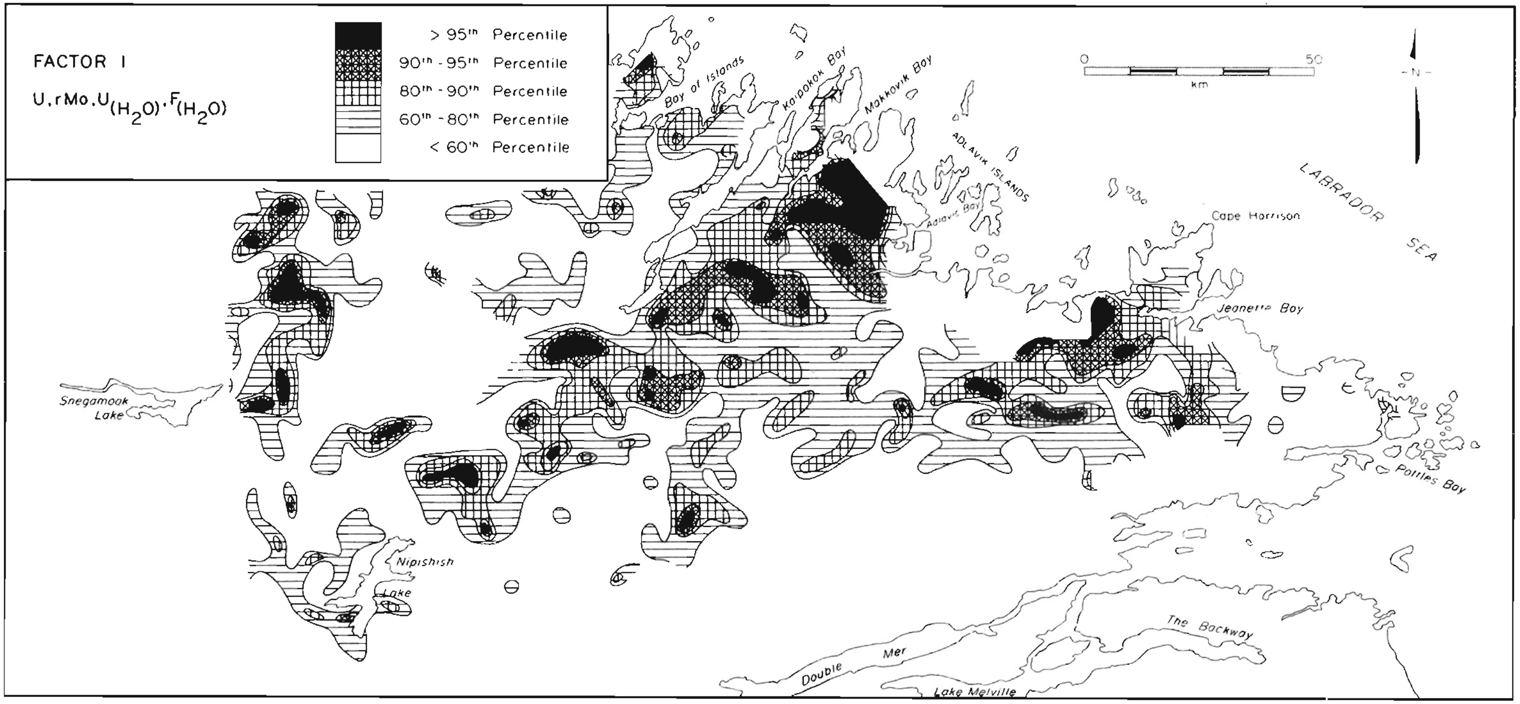

Figure 3: *Factor 1 score distribution map.*

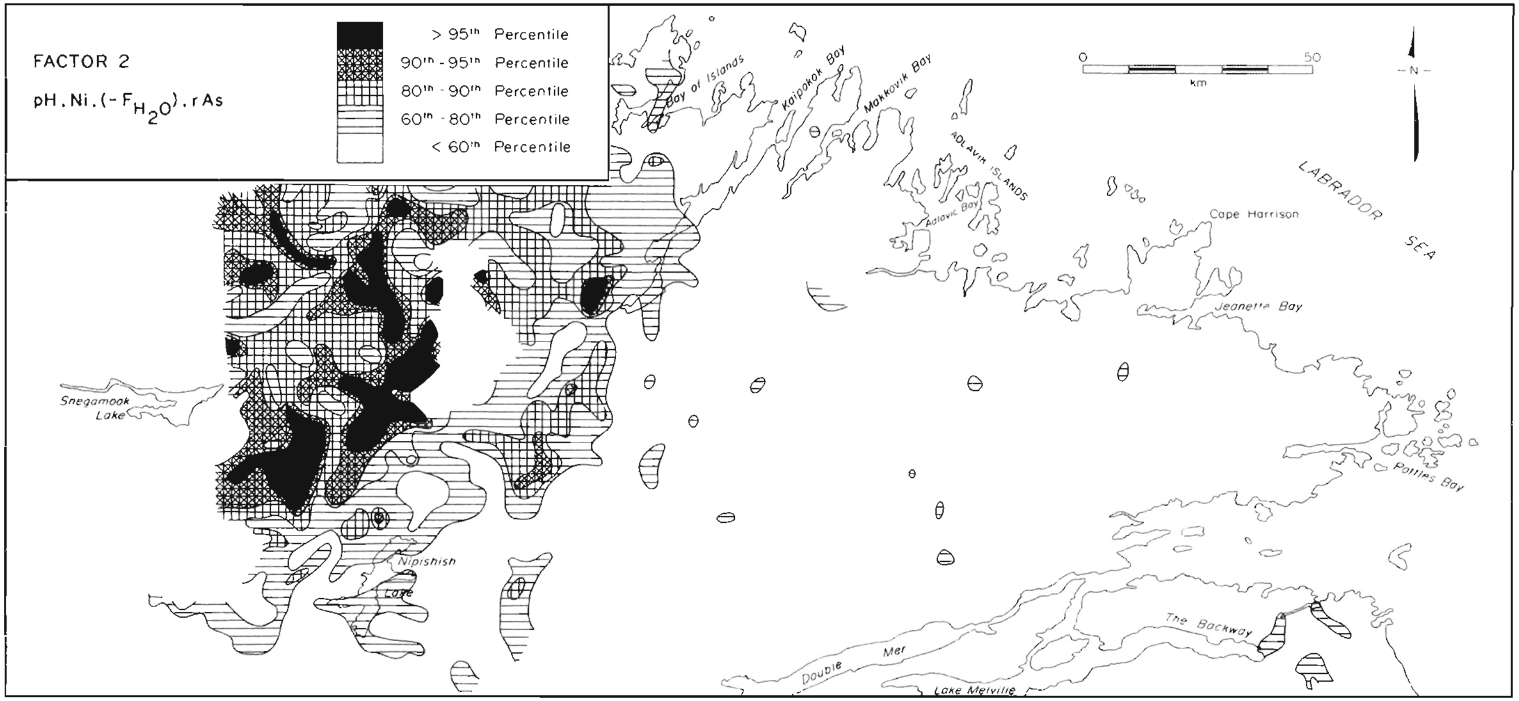

Figure 4: *Factor 2 score distribution map.*

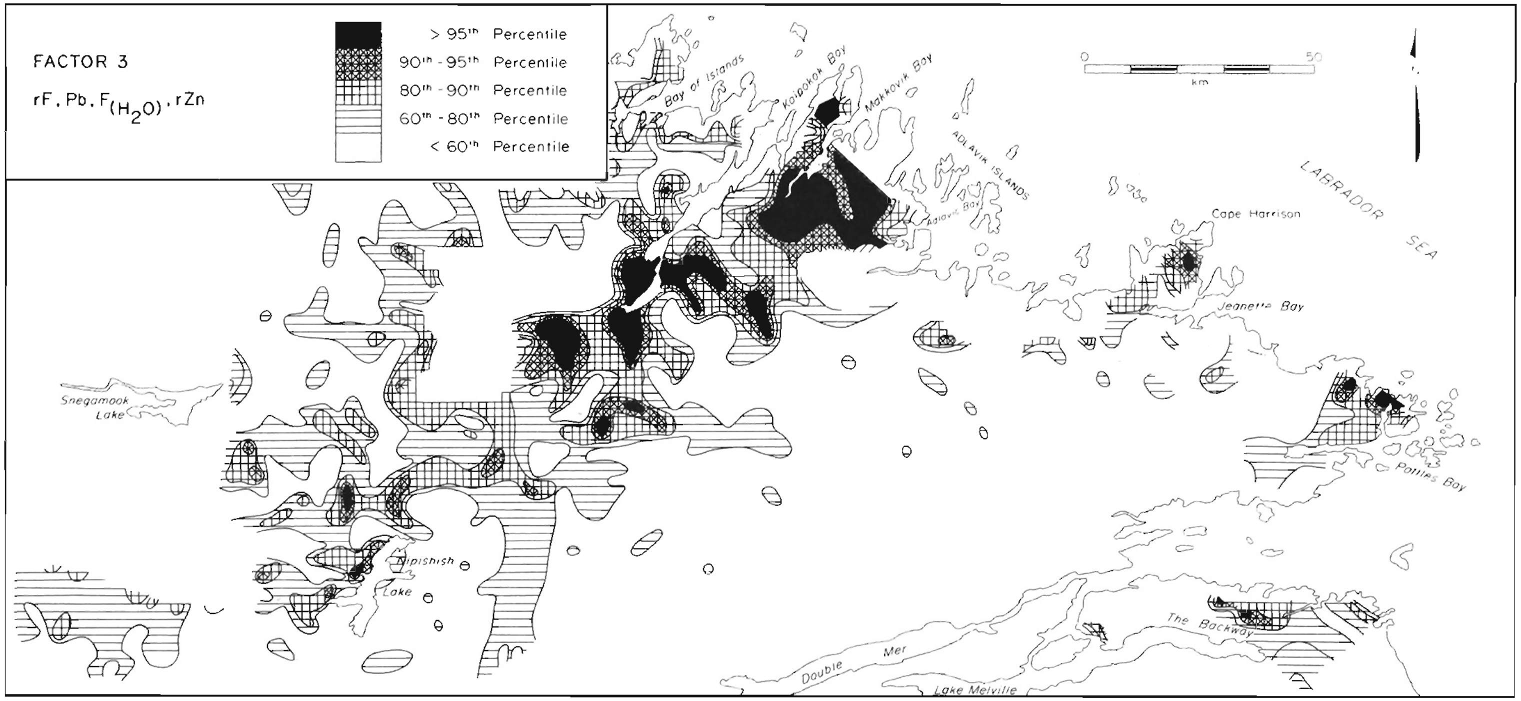

Figure 5: *Factor 3 score distribution map.*

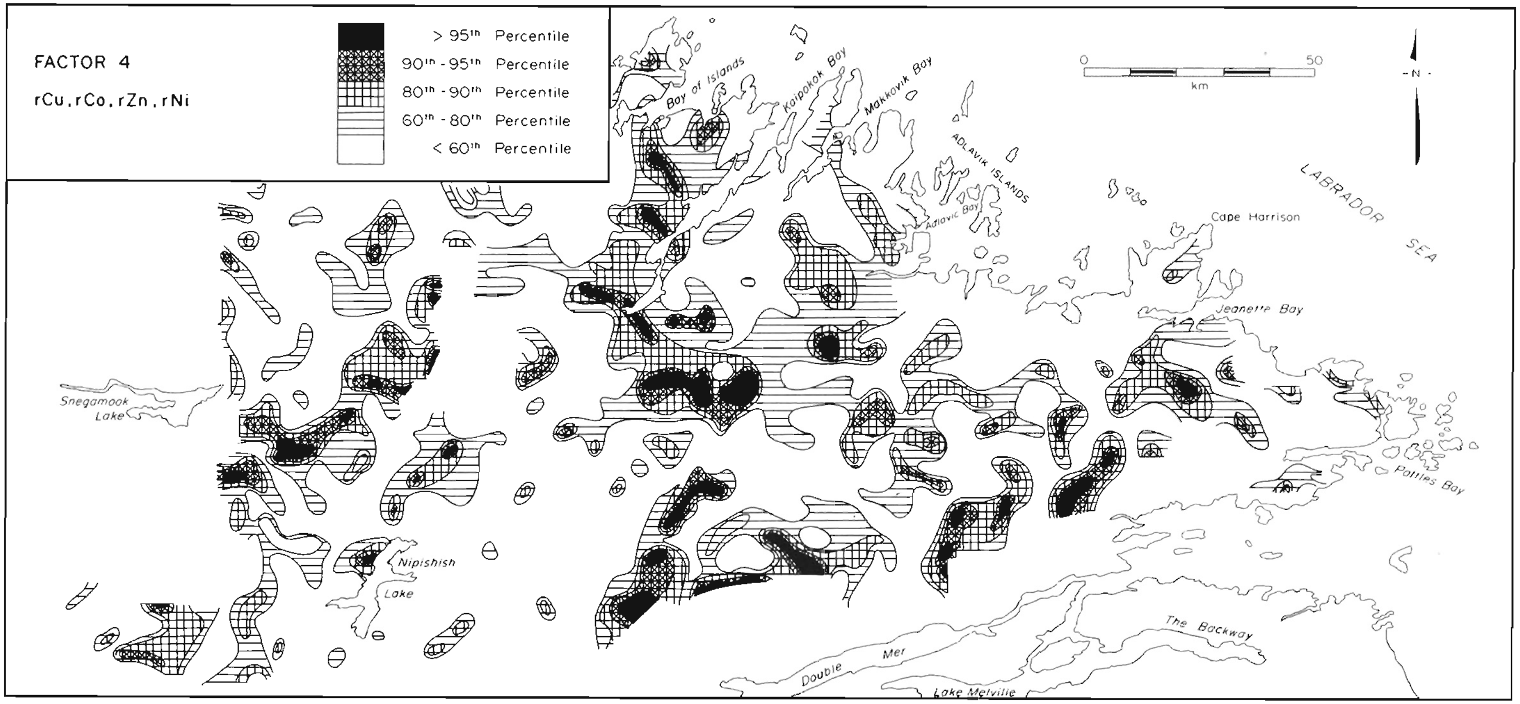

Figure 6: *Factor 4 score distribution map.*

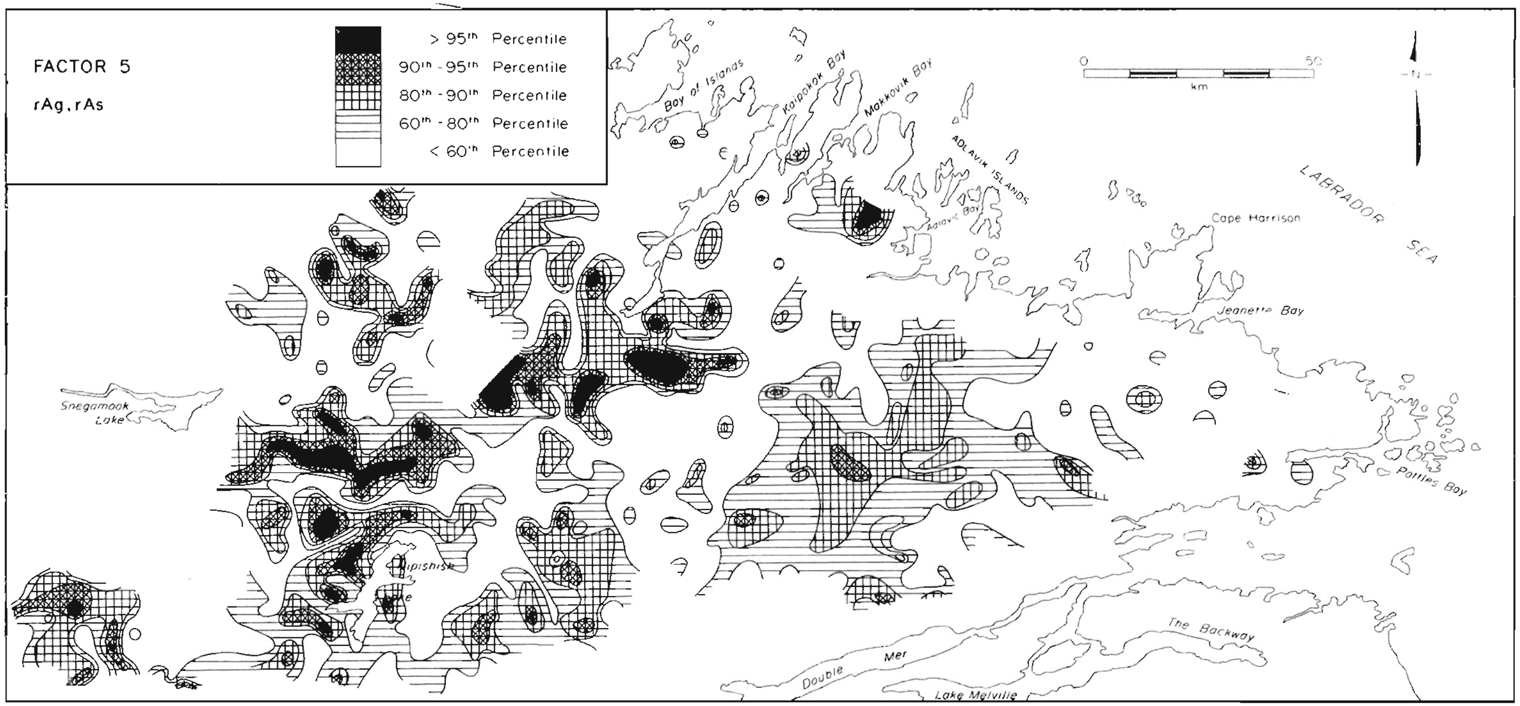

Figure 7: *Factor 5 score distribution map.*

magmatism. It resembles in many respects the signature of the Flowers River igneous suite in northern Labrador (McConnell, 1982,1984), but does not seem to be associated with high Mo. However, some areas high in factor 3 are also high in factor 1, which has a high loading for Mo (Table 2). The Pb-F-Zn association is associated with mineralized granitoid plutons in insular Newfoundland (Davenport, 1982b), and may reflect alteration processes related to epigenetic mineralization.

Factor 3 scores do not show a clear correspondance with any one geological unit, but the unit most commonly underlying anomalous areas is the upper Aillik Group, in particular the more northerly outcrop area. However, this area also contains a number of small granitoid plutons (as discussed above) and it is thus difficult to evaluate the precise bedrock unit responsible. If this signature does indeed represent the upper Aillik Group, it is certainly not shared by the more southerly outcrop area of this unit, which is generally low in factor 3.

The most prominent highs lie south of Makkovik in the same general area as the main factor 1 high. However, in detail it can be seen that the most anomalous areas flank the factor 1 high. Anomaly trends are once again northwest, almost at right angles to the dominant structural grain of the area. Similar trends are apparent in a complex anomaly pattern near the southern end of Kaipokok Bay. This is again slightly displaced from a similarly large but somewhat weaker factor 1 anomaly coinciding with a granitoid unit in the Trans-Labrador batholith. The presence of several smaller anomalous areas within the batholith suggests that this may also be a granitoid-related signature, rather than a signature related directly to the upper Aillik Group. The generally coincident, but slightly displaced positions of factor 1 and 3 highs may be indicative of a zoning effect similar to that noted by Davenport (1982b) around some mineralized granitoid bodies in southern Newfoundland.

Factor 4 [rCu, rCo, rZn, Ni]

Factor 4 is a base-metal association that shows high positive loadings for rCu, rCo and rZn, with a smaller loading for Ni. Interpretation of this association is difficult. The presence of Ni could indicate a correlation with igneous rocks of more mafic composition, which are commonly enriched in these elements, but the association might also reflect the presence of base metal mineralization. The factor 4 pattern is rather disorganized in general appearance, but some of the larger anomalies show a fairly good general correspondance with geologic units.

A series of linked highs in the west correspond generally with the outcrop area of the Moran Lake Group, which is known to contain minor base-metal mineralization (Ryan, 1984). A second prominent high corresponds with the Trans-Labrador batholith and the upper Aillik Group in the centre of the area, and is associated with the factor 1 and 3 highs discussed above. The large factor 1 high near Makkovik is not represented by an anomaly.

The most extensive anomalous areas form a confusing pattern in the Grenville Province south of the southern limit of the Trans-Labrador batholith. This area is underlain mostly by high-grade gneisses that are cut by minor gabbroic intrusions termed the Michael Gabbros. The highs might be related to the gabbro bodies, but might also correlate with regional paragneiss units mapped in this area by Gower (1984). The rather diffuse anomaly pattern and the location of these highs near the edge of the study area makes precise interpretation difficult.

A number of moderate highs in the Kaipokok Bay - Makkovik Bay areas show northwest-trends reminiscent of those shown in this area by factors 1 and 2.

Factor 5 [rAg, rAs]

Factor 5 shows a strong positive loading for rAg and a moderate positive loading for rAs. Both Ag and As are widely considered to be good indicators for Au mineralization. It is tentatively suggested that factor 5 may reflect the potential of various units for Au and Ag mineralization.

The score distribution pattern for factor 5 shows a very good correlation with the supracrustal sequences of the Bruce River Group and the southern outcrop area of the upper Aillik Group. The Moran Lake Group is generally low, as is much of the northern outcrop area of the upper Aillik Group, with the exception of a high south of Makkovik, which is generally coincident with a showing containing Ag (Wilton *et al.*, *in preparation)*. It should be noted, however, that the areas adjacent to Au-Ag showings northeast of Makkovik (Wardle and Wilton, 1984) are not covered by lake sediment samples, and this high could be considerably larger than that shown on the map.

Remaining factor 5 highs appear to correlate mostly with Archean metavolcanic units, which could also have potential for Au-Ag mineralization. However, there is a noticeable absence of response over the mafic volcanic rocks of the Moran Lake Group, which would appear to suggest that factor 5 represents more than a general response to volcanic sequences.

SUMMARY AND CONCLUSIONS

The statistical analysis techniques discussed in this report appear to have been effective tools in both reducing the volume of data under consideration and highlighting regional geochemical patterns within the eastern Central Mineral Belt. The factor score maps in Figures 3 to 7 show much smoother patterns than the 15 raw element maps that they replace, and also appear to show a clearer relationship to bedrock geological patterns. For some areas the correspondance is very striking indeed; as in the case of the factor 2 distribution over the Archean or the factor 5 distribution over the Bruce River Group. The results discussed in this report are necessarily preliminary, and more exhaustive examination of data is required to both substantiate and improve the interpretation of these results. Nevertheless, a number of inferences can be drawn from the patterns discussed in the preceding section:

1. The exposed Archean block has a very characteristic geochemical signature, illustrated mostly by the factor 2 distribution, which is attributed to a generally

higher Ni content and more intermediate quartzofeldspathic components compared to adjacent Proterozoic terranes. The depletion in U and F suggested by the loadings for factor 2 may perhaps be related to expulsion of such elements during repeated high-grade metamorphism. This signature is shared by a large Proterozoic granitoid body that intrudes the Archean block, but is lacking completely from the younger granitoids of the Trans-Labrador batholith.

2. Parts of the Trans-Labrador batholith, and particularly its northern margin, show geochemical signatures that suggest the presence of evolved granitoid rocks, which may have some potential for granophile mineralization (shown by factor 1 and factor 3 distributions). The area along the northern margin of the batholith is marked by a number of smaller granitoid plutons whose roof zones are cut by the erosion surface. If factor 3 also represents a granitoid association, there may well be multi-element zoning patterns in some areas of the type recognized by Davenport (1982b) in Newfoundland granites.
3. The supracrustal sequence of the Moran Lake Group is enriched in a base-metal association (factor 4) relative to the other supracrustal sequences, which may suggest that this package as a whole has some potential for base metal deposits (perhaps sediment hosted). This is in accordance with the presence of several minor Pb-Zn-Cu occurrences (Ryan, 1984). It is also possible that large diffuse anomalies in poorly exposed regions of the Grenville Province may be associated with paragneiss units, suggesting perhaps that these areas might be of some interest.
4. Ag and As appear to be associated together and both show high positive loadings on factor 5, which is generally anomalous in areas underlain by the Bruce River Group and also in the southern outcrop area of the upper Aillik Group. Both these areas contain felsic volcanic sequences, which might have potential for epithermal gold mineralization. Although recently recognized Au mineralization northeast of Makkovik is not covered by lake sediment data, an area south of Makkovik known to host silver-bearing showings is enriched in factor 5.
5. Although the signature of the northern outcrop area of the upper Aillik Group is difficult to assess due to the presence of late granitoid rocks, the patterns for factor 3 and factor 5 may indicate that it differs somewhat from the southern area. This could represent a difference in tectonic setting or perhaps even an age difference. The factor 5 pattern may also suggest a geochemical affinity between the southern area and the adjacent Bruce River Group.

In general, the results of this analysis suggest that, in addition to a well established potential for uranium mineralization, the Central Mineral Belt might also hold some promise for sediment-hosted base-metal deposits, epithermal precious-metal mineralization and granite-hosted Mo, Cu, Sn, W, Nb, Ta and a range of other lithophile elements.

Possible avenues along which this investigation could be expanded include the enlargement of the data set to include other geological subdivisions within the Central Mineral Belt, in particular the Seal Lake Group and Letitia Lake area, both of which host types of mineralization not recognized in the current study area. An examination of patterns over these areas might aid in interpretation of the factor patterns discussed in this report. Curvilinear regression models might offer an improvement on the linear models used here. A third possibility is to move from examination of single element variables to basing the entire analysis on elemental ratios. Geochemical dispersion patterns related to mineralizing events are commonly multi-element, and it may be worthwhile to adopt an *additive* approach, where areas enriched in 2 or more factors are accorded the highest priority.

In conclusion, it apperas that a logical step in regional geological studies in this province should be toward presentation of regional geochemical data in a reduced and processed form. It is hoped that this preliminary account will illustrate the potential of such a step, and perhaps also prompt some discussion of the suitability and usefulness of these and other methods.

ACKNOWLEDGEMENTS

This report has benefited greatly from discussions with a number of persons interested in geochemistry, data processing and Labrador geology. In particular, we wish to thank A.B.Ryan, R.J.Wardle and J.McConnell for reviewing the manuscript, and also D.J.Furey of Memorial University for providing a thorough review of our interpretation of statistical data. Gerry Squires is thanked for his patience in contouring numerous maps, and Lyne Houle for adding the finishing touches by coloring them.

REFERENCES

Davenport, P.H.

1982a: Regional geochemical mapping in Newfoundland —the use of lake sediment as a sample medium in a glaciated landscape. *In* Prospecting in areas of Glaciated Terrain. *Edited by* P.H. Davenport. Canadian Institute of Mining and Metallurgy, Geology Division, pages 57-82.

1982b: The identification of mineralized granitoid plutons from ore element distribution patterns in regional lake sediment geochemical data. Canadian Institute of Mining and Metallurgy Bulletin. May 1982, pages 1-12.

Davenport, P.H. and Butler, A.J.

1983: Regional geochemical surveys. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division. Report 83-1, pages 121-125.

Davis, J.C.

1973: Statistics and data analysis in geology. John Wiley. 550 pages.

Emslie, R.F.

1980: Geology and petrology of the Harp Lake Anorthosite Complex, central Labrador: an example of

Elsonian magmatism. Geological Survey of Canada, Bulletin 293, 136 pages.

Ermanovics, I. and Korstgard, J.A.
1981: Geology of Hopedale Block and adjacent areas, Labrador: Report 3. *In* Current Research, Part A. Geological Survey of Canada. Paper 81-1A, pages 169-76.

Ermanovics, I. and Raudsepp, M.
1979: Geology of the Hopedale Block of eastern Nain Province, Labrador. *In* Current Research, Part B. Geological Survey of Canada, Paper 79-1B, pages 341-348.

Geological Survey of Canada
1981: National geochemical reconnaissance, eastern and northern Labrador. 1:2,000,000 scale colored compilation map series. Geological Survey of Canada, Open File 749.

1984: Regional lake sediment and water geochemical reconnaissance data, Labrador 1984. Geological Survey of Canada, Open file 1102.

Gower, C.F.
1981: The Geology of the Benedict Mountains, Labrador. Newfoundland Department of Mines and Energy. Mineral Development Division, Report 81-3, 26 pages.

1984: Geology of the Double-Mer White Hills and Surrounding Region, Grenville Province, Eastern Labrador. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, pages 68-80.

Gower, C.F., Flanagan, M.J., Kerr, A. and Bailey, D.G.
1982: Geology of the Kaipokok Bay-Big River Area, Central Mineral Belt, Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-7, 77 pages.

Greene, B.A. 1974
1974: An outline of the Geology of Labrador. Newfoundland Department of Mines and Energy, Information Circular 15.

Kerr, A.
1985: Plutonic rocks of the eastern Central Mineral Belt, Labrador: general geology and description of regional granitoid units. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1.

McConnell, J.
1982: Regional lake sediment and water geochemistry as a guide to bedrock composition and mineralization in Labrador. *In* Prospecting in Areas of Glaciated Terrain. *Edited by* P.H. Davenport. Canadian Institute of Mining and Metallurgy, Geology Division, pages 105-132.

1984: Reconnaissance and detailed geochemical surveys for base metals in Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-2, 76 pages.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K. and Bent, D.H.
1975: SPSS. Statistical package for the social sciences. Second Edition, McGraw-Hill, 675 pages.

Ryan, A.B.
1984: Regional geology of the central part of the Central Mineral Belt, Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Memoir 3, 185 pages.

Wardle, R.J. and Wilton, D.H.C.
1984: Reconnaissance sampling for precious metals in the Kaipokok Bay-Big River area, Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Open File LAB 1679.