COMPUTER-AIDED ANALYSIS OF LITHOGEOCHEMICAL DATA FROM NEWFOUNDLAND GRANITES AND ITS ROLE IN MINERAL EXPLORATION

by

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Geochemistry, Mineral Deposits and Newfoundland Mapping Sections

Introduction

Geochemical indicators have been used by many workers to distinguish mineralized from barren granitoid plutons, e.g. Tischendorf et al., 1978; Mutschler et al., 1981. Some of these geochemical indicators have been regarded as of local or regional value, while others have been touted as having global significance. The first large scale attempt at assessing the mineral potential of some Newfoundland granitoids through their geochemistry was that of Strong et al. (1974). Subsequently, three studies have been made with a more systematic sampling approach by Elias (1980) of 14 plutons in the Bay D'Espoir area, by Dickson (1983) of the Ackley Granite, and by Blackwood and Green (1982) of the Middle Ridge Granite. In addition, there are several studies in progress which include granitoid geochemistry.

Granite Geochemistry Data File

To fully utilize these geochemical data to assess mineral potential, they are being organized into a computer file containing field observations as well as geological and chemical information. Currently, this file contains data from 1243 samples collected from 21 plutons. For all samples, the following information is recorded: sample number, pluton, U.T.M. coordinates, rock type, age, physical characteristics (color, grain size, texture, banding, alteration), fabric, composition of mafic minerals, presence or absence of sulfides, garnet, tourmaline, beryl, fluorite and muscovite, as well as major element data. The trace element suite for most samples is Li, Be, F, V, Cr, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Ba, Pb, Th and U. Sn and W have been determined on selected samples.

Uses of The Data File

Once the data are assembled into an organized computer file, it becomes very easy to apply to Newfoundland granites "geochemical indicators" of mineralization developed by other workers elsewhere. It is apparent, for example, that the concept of S and I type granites is not readily applicable to the granitoids of south-eastern Newfoundland (e.g. Dickson, 1983), so this concept is of little use as a guide to mineralization in the area. In addition, it is easy to carry out various multivariate statistical procedures on the data to gain a better understanding of the interrelationships present and, hence, to gain some insight into geochemical processes. Finally, computer graphics can be used to examine the data through both standard petrological diagrams and areal plots of the data and derived variables.

An illustration of the application of the analysis of a geochemical computer data file to mineral exploration can be provided for the Ackley Granite. This was systematically sampled on a 2 km x 2 km grid and geologically mapped by Dickson (1983). The geology and known mineral occurrences in the Ackley Granite are shown in Figure 1, and plots of Sr and Ba against SiO_2 for units 14, 14 a and 14b (which contains the known mineral prospects) are shown in Figures 2a and 2b. A large proportion of the samples in these units show moderate to extreme depletion in both Sr and Ba over an SiO_2 range of about 75 to 79%. Enrichments in F, Rb, U and Th in units 14, 14a and 14b relative to the rest of the granite are also apparent over the same range in SiO_2. To examine the spatial chemical variations within the granite, the data from all 357 sites were computer-plotted and hand-contoured using arbitrary contour levels derived from cumulative frequency plots. The distributions of Ba and Sr are shown in Figure 3, from which it is clear that the areas of extreme depletion of these elements are largely centered on the mineral occurrences in units 14a and 14b. Areal plots of a number of other major and trace elements and various ratios showed a variety of geochemically significant trends.

To try to summarize the trends of the 11 oxides, 20 trace elements and a number of element ratios, R-mode factor analysis was carried out. This mathematical procedure is also known as principal components analysis; in this application, the tech-

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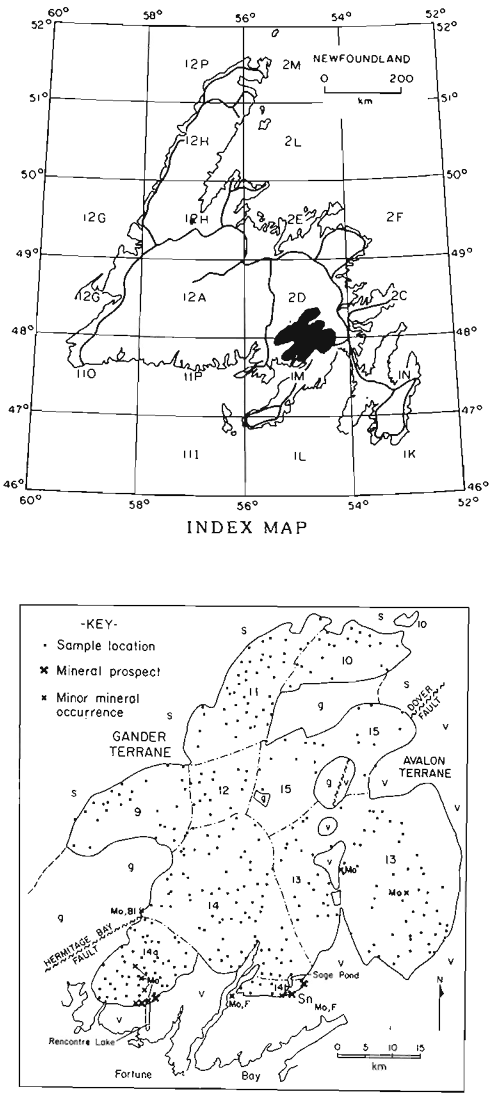


Figure 1: *Index map and geological map of the Ackley Granite (after Dickson, 1983) showing the main textural units of the granite, mineral occurrences and sample sites.*

nique is used to produce a relatively manageable number of variables from the 31 major oxides and trace elements. The first factor, or principal component, is a linear combination of these 31 variables chosen to account for more of the variance of the data than any other linear combination. The second factor is then chosen to account for more of the remaining data variance than any other combination of variables and so on. Each factor is chosen to be independent of (or orthogonal to) the previous factors. In theory a number of factors equal to the number of variables can be extracted, but the purpose of the method is

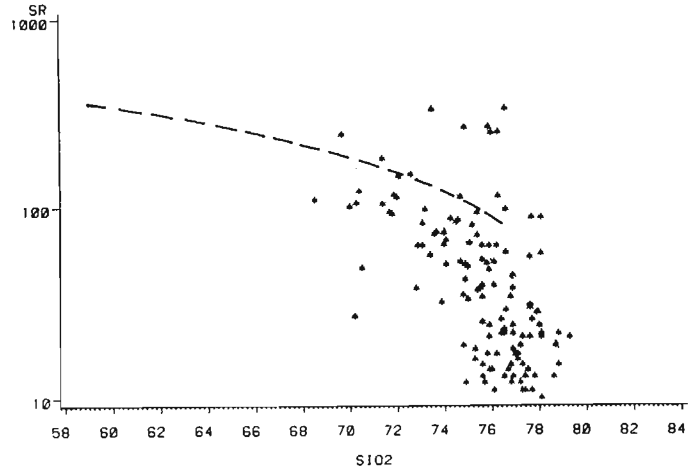


Figure 2a: *Plot of Sr (log scale in g/t) against SiO_2 (in percent) for units 14, 14a and 14b of the Ackley Granite. Dashed line is the best fit line for units 9-13 and 15.*

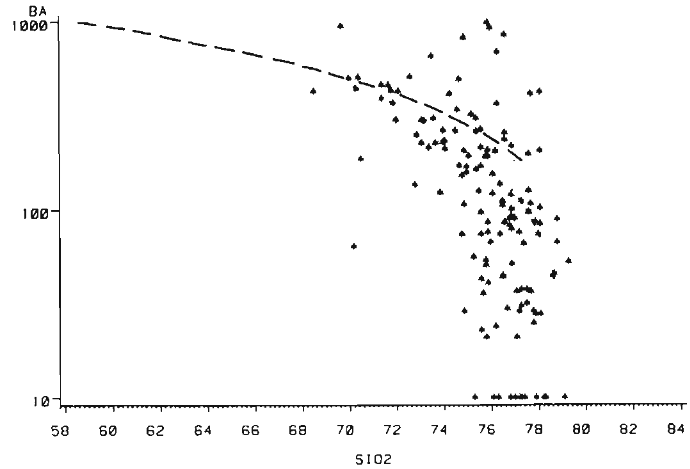


Figure 2b: *Plot of Ba (log scale in g/t) against SiO_2 (in percent) for units 14, 14a and 14b of the Ackley Granite. Dashed line is the best fit line for units 9-13 and 15.*

to account for most of the observed variation by means of a few (perhaps four to six) factors. The calculation of the factors is an objective mathematical process, but the selection of the model to use (i.e. the number of factors) is subjective. Table 1 gives an example of a four-factor model for the Ackley Granite. The importance of the contribution of each oxide or element to the factor is given by the factor loading. This may vary from -1.0 to 1.0 and can be thought of as a regression coefficient. In Table 1, only elements with loadings of a magnitude greater than 0.5 for any element are listed for each of the four factors. The first and second factors account for over 50% of the total data variance and are the most readily explained geologically. Factor 1 can be related to normal geochemical trends in a differ-

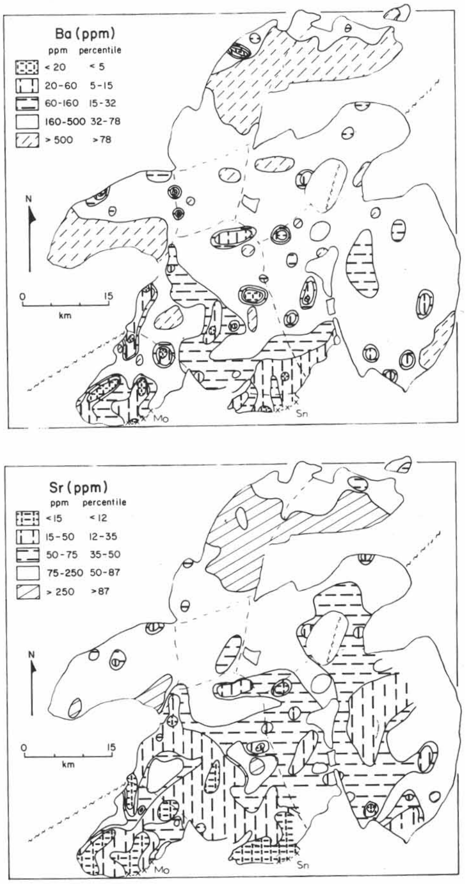


Figure 3: *Distribution of Ba and Sr in 357 samples of the Ackley Granite. The data were hand-contoured and no smoothing was applied.*

entiated comagmatic suite of rocks, with SiO_2 varying antipathetically with MgO, Al_2O_3, FeO, Fe_2O_3, TiO_2, MnO, P_2O_5 and the trace elements V, Sr, Ba and Zn. This factor accounts for over 38% of the total "geochemical variance" in the granite.

Factor 2 is a combination of the lithophile trace elements Nb, Rb, U, Th, Y, Be, Li, Sn, together with Ga and F. This factor also has negative loadings on Sr and Ba. Concentration of these elements is typical in the upper part of a silicic magma chamber (e.g. Hildreth, 1981; Strong, 1980), with depletions of Sr and Ba. In fact, in a qualitative way, it is possible to construct a pseudo-enrichment/depletion diagram to compare with the relative enrichment diagram for the Bishops Tuff of Hildreth (1981). The correspondence in sense of the elements' variations is striking (Figure 4). The other two factors in this model are of less interest.

From the element loadings a factor score can be calculated for each sample. Thus, for factor 1, a low, negative score will be generated for a sample high in SiO_2 and low in MgO, TiO_2, etc. (i.e. a highly differentiated granite), whereas high positive scores will be assigned to more mafic samples. Similarly, for factor 2, high positive scores will result in samples high in lithophile elements, Ga and F, and low in Ba and Sr. If the geochemical significance of factor 2 is related to the concentration of these elements at the top of the granite body, the high positive scores should form a coherent pattern which would delineate this zone of concentration.

Table 1: *Four-factor model for the 357 grid samples from the Ackley Granite. The factor model was subjected to a varimax rotation. Only factor loadings with a magnitude greater than 0.5 have been listed.*

	Factor 1	Factor 2	Factor 3	Factor 4
	SiO_2 (-0.88)	Nb (0.81)	Pb (0.76)	Na_2O (0.79)
	MgO (0.89)	Rb (0.79)	K_2O (0.60)	
	TiO_2 (0.88)	U (0.76)		
	P_2O_5 (0.87)	Th (0.73)		
	V (0.84)	Y (0.72)		
	MnO (0.82)	Be (0.64)		
	Al_2O_3 (0.81)	Ga (0.58)		
	Sr (0.71)	Li (0.55)		
	Ba (0.69)	F (0.55)		
	Zn (0.68)	Sn (0.54)		
	Zr (0.57)	- Sr (-0.55)		
	FeO (0.54)	- Ba (-0.57)		
	Fe_2O_3 (0.51)			
% of variance:	38.3	12.9	5.8	4.9

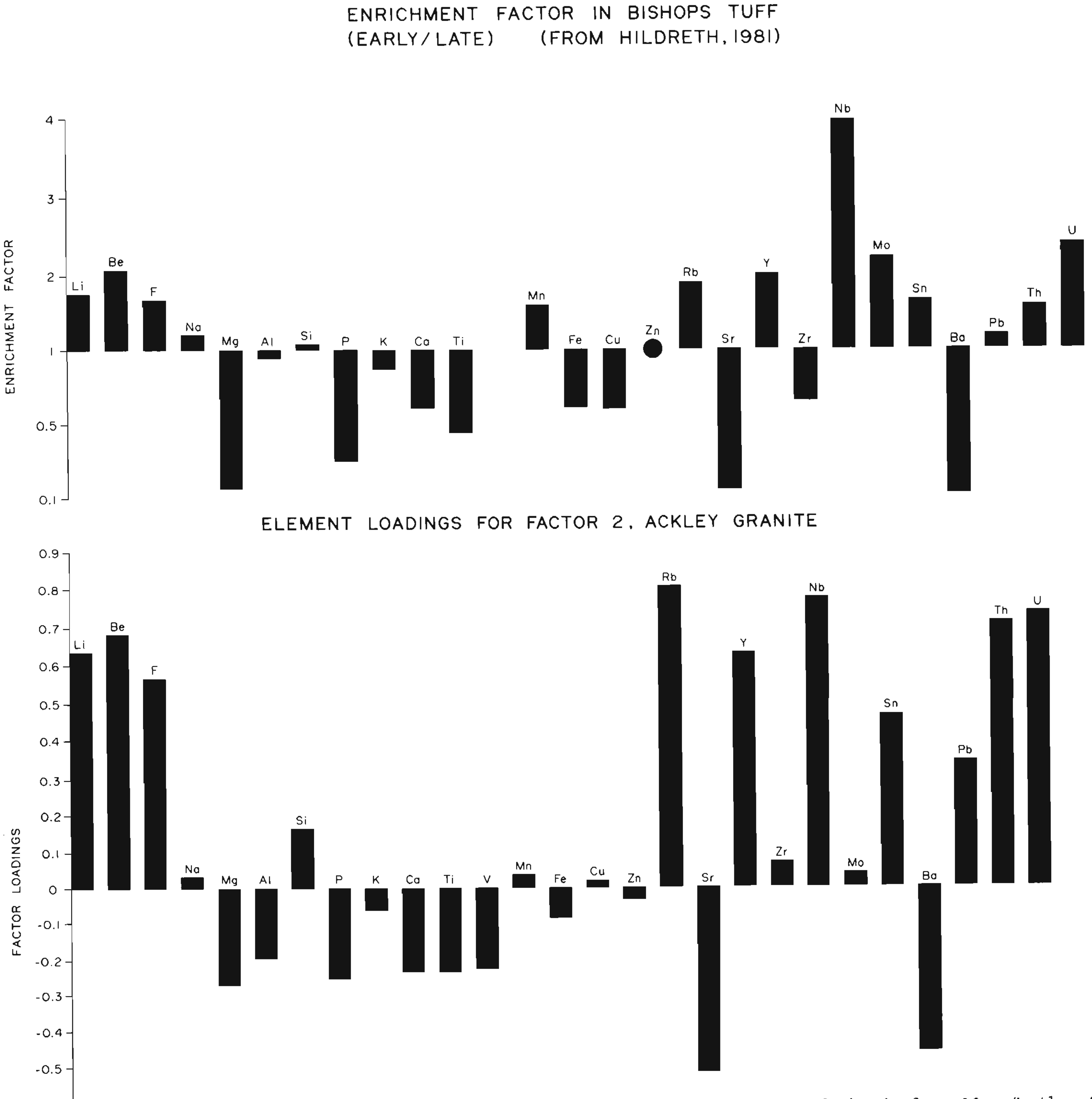


Figure 4: *Plot of factor 2 loadings for the Ackley Granite (below) for 28 of the 31 chemical variables (FeO, Fe_2O_3 and LOI omitted) compared with enrichment/depletion plot for Bishops Tuff (Hildreth, 1981). The factor loadings are correlation coefficients of the variables with the factor; elements having a large positive loading (0.5-1.0) contribute strongly and positively to the factor; loadings between 0.5 and -0.5 indicate modest to minimal contributions, and loadings in the range -0.5 to -1.0 are for those elements with a strong negative contribution. The correspondence in sign and relative magnitude between the factor 2 loadings for the Ackley Granite and the enrichment (+) and depletion (-) factors for the early (top of magma chamber) and lower (deeper in magma chamber) units of the Bishops Tuff are striking, and suggest similar processes were operative in both magma chambers.*

The factor scores from factors 1 and 2 are plotted in Figure 5. The following points are noteworthy:

(1) The factor scores do show coherent patterns.

(2) Factor 1 scores are lower (i.e. SiO_2 is higher and Al_2O_3, MgO, TiO_2, etc. are lower) in the southeastern half of the pluton. This may reflect an inherited compositional difference in source material since the two parts of the granite as defined by factor 1 are separated by a line which lies close to the projection of the Dover - Hermitage Bay fault zone, with the Gander Terrain lying to the northwest and the Avalon Terrain to the southeast.

(3) Factor 2 scores show a crosscutting north-south trend. High values of this factor (indicating enrichment in Sn as well as Nb, Rb, U, Th, Y, Be, Li, and F) surround the known Sn-bearing greisen zones, and extend in a west-northwest trend to include the Mo-Bi showing at Big Blue Hill Pond (line A-B in Figure 5). Small greisen veins were discovered within the central part of this trend near site C (see Tuach, *this volume*).

(4) The area of Mo showings west of Long Harbour shows only moderately high scores for factor 2, suggesting that this southwestern lobe of the granite is different from the Sn-bearing south-central margin of the granite. The mineralization in this southwestern lobe is not Sn-bearing, but it is reflected by a halo of Sr and Ba depletion. There are also differences in F content of the two marginal phases (unit 14a).

Conclusion

This simple example of a computer-aided analysis of the lithogeochemical data from the Ackley Granite shows the potential power of this approach. Such an analysis presupposes the existence of a sample suite from a well designed field sampling scheme, and the organization of the data in a computer file.

References

Blackwood, R.F. and Green, L.
1982: Rock geochemical data from the Middle Ridge Granite, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Open File 2D (127).

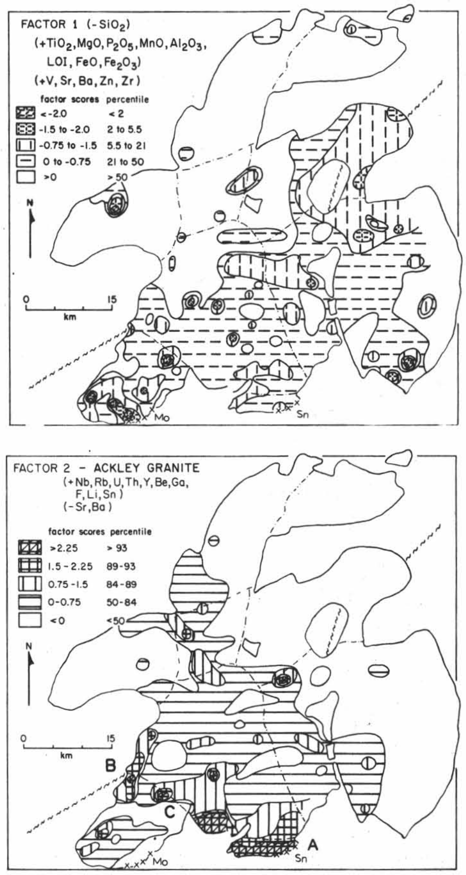


Figure 5: *Distribution of factor scores (hand-contoured, no smoothing) in the Ackley Granite.*

Dickson, W.L.
1983: Geology, geochemistry and mineral potential of the Ackley Granite and parts of the Northwest Brook and Eastern Meelpaeg Complexes, southeast Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-6, 129 pages.

Elias, P.
1980: Granite geochemistry project - Bay d'Espoir Area. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 80-1, pages 50-52.

Hildreth, W.
1981: Gradients in silicic magma chambers: Implications for lithospheric magmatism. Journal of Geophysical Research, Volume 86, pages 10153-10192.

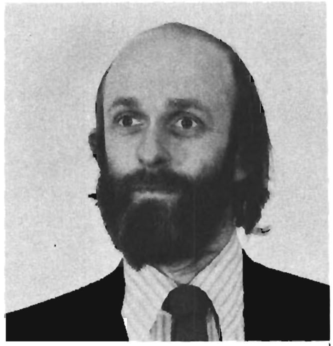
Mutschler, F.E., Wright, E.G., Ludington, S. and Abbott, J.T.
1981: Granite molybdenite systems. Economic Geology, Volume 76, Number 4, pages 874-897.

Strong, D.F.
1980: Granitoid rocks and associated mineral deposits of eastern Canada and western Europe. *In* The Continental Crust and Its Mineral Deposits. *Edited by* D.W. Strangway. Geological Association of Canada, Special Paper 20, pages 741-769.

Strong, D.F., Dickson, W.L., O'Driscoll, C.F. and Kean, B.F.
1974: Geochemistry of eastern Newfoundland granitoid rocks. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 74-3, 140 pages.

Tischendorf, G., Schust, F. and Lange, H.
1978: Relation between granites and tin deposits in the Erggebirge, G.D.R. *In* Metallization Association with Acid Magmatism. *Edited by* M. Stemprok, L. Burnol, and G. Tischendorf. Ustredni Ustrau Geologicky, Prague, Volume 3, pages 123-138.

Tuach, J.
1984: Metallogenic studies of granite-associated mineralization in the Ackley Granite and the Cross Hills Plutonic Complex, Fortune Bay area, Newfoundland *In* Current Research. Geological Survey of Canada, Paper 84-1, Also in this volume.



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