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DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA

PAPER 74-9

TRACE ELEMENT VARIATIONS IN PORPHYRY COPPER DEPOSITS, BABINE LAKE AREA, B.C.

J.L. JAMBOR

1974

ERRATUM

GSC PAPER 74-9

Page 6 Table 1: The asterisk after "69-29-550" should follow "70-21-1026".

Page 11 <u>North Newman Property</u>

"(Fig. 31)" should read "(Fig. 32)".
"Figures 33 to 37" should read "Figures 33 to 38".

Page 15 Table 4: footnote
"Figure 22" should read "Figure 23".

Page 17 Figure 24: caption
"Figures 23 to 28" should read "Figures 24 to 29".

Page 27 Figure 40: caption
"Figures 39 - 44" should read "Figures 40 to 45".

Page 29 Left column, line 4:
"values 3 ppm" should read "values > 3 ppm".

Left column, <u>Lead</u>: (b) Bell:
"highest values >20 ppm)" should read "highest values (>20 ppm)".

Page 30 Left column, line 22:
" (commonly >30 ppm)" should read " (commonly < 30 ppm)".

Energy, Mines and Resources Canada
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ABSTRACT

Trace element abundances in bedrock samples were obtained for five hydrothermally altered areas related to Tertiary biotite-feldspar porphyry intrusions in the northern Babine Lake area. Cu, Zn, Pb, Ag, Hg, and S were determined in samples from most of the properties (Granisle, Bell Copper, Dorothy, North Newman, and South Newman); Rb, Sr, TiO_2, Au, and Se were obtained for samples from Granisle and/or Bell Copper. Electron microprobe data are tabulated for primary (phenocryst) and secondary (hydrothermal) biotites from Granisle.

The results of the trace element analyses indicate that Pb, Ag, Hg, and several other elements are probably of limited value in routine bedrock geochemical exploration. However, copper and molybdenum form larger targets than ore zones, and peripheral zinc anomalies are common. Sulphur, largely present as hydrothermal pyrite, forms the largest target and is the element most systematically associated with copper mineralization in the Babine Lake area. Most of the other elements are only of secondary importance because their anomalies are largely confined within the pyrite haloes or copper zones.

RÉSUMÉ

L'analyse d'échantillons de roches de fond provenant de cinq régions modifiées hydrothermalement et prélevés dans des intrusions de porphyre biotite-feldspath tertiaire trouvées dans la zone nord du lac Babine, a révélé l'existence de traces abondantes d'éléments. Il s'agit en l'occurrence de traces de Cu, Zn, Pb, Ag, Hg et S relevées dans des échantillons de la plupart des terrains (Granisle, Bell Copper, Dorothy, North Newman et South Newman); des traces de Rb, Sr, TiO_2, Au et Se relevées à Granisle ou à Bell Copper, ou à ces deux en droits à la fois. Les données obtenues à l'aide d'une microsonde électronique sont disposées en tableaux pour les biotites primaires (phénocristal) et secondaires (hydrothermal) provenant de Granisle.

Les résultats de l'analyse des traces d'éléments indiquent que le Pb, l'Ag, le Hg et plusieurs autres éléments ont probablement une valeur réduite en ce qui concerne la prospection géochimique de routine de la roche de fond. Cependant le cuivre et le molybdène forment des cibles plus grandes que les zones à minerais et les anomalies du zinc situé à la périphérie sont courantes. Le soufre présent en grande quantité sous forme de pyrite hydrothermale, forme la cible la plus grande et est l'élément associé le plus systématiquement à la minéralisation du cuivre dans le secteur du lac Babine. Les autres éléments ne sont pour la plupart que d'importance secondaire, leurs anomalies se limitant en grande partie à l'intérieur des halos de pyrite ou des zones de cuivre.

TRACE ELEMENT VARIATIONS IN PORPHYRY COPPER DEPOSITS, BABINE LAKE AREA, B.C.

INTRODUCTION

More than a dozen porphyry copper deposits, all related to Tertiary biotite-feldspar porphyry intrusions, are known to occur in the northern Babine Lake area of British Columbia (Fig. 1). Seven hydrothermally altered areas (Fig. 2), six of which contain centrally-located copper zones, have been described in detail by Carson and Jambor (1974). Two of the areas (Granisle and Bell Copper) are being mined, but the others are currently of sub-economic grade.

The present report supplements a paper by Carson and Jambor (1974), and is concerned only with the presentation of chemical analyses that were obtained during the aforementioned hydrothermal alteration studies. Most of the data reported here are trace element analyses of the altered outcrop and drill core samples. Thus the present paper is essentially a recording of the bedrock geochemistry of the Granisle, Bell Copper, Dorothy, North Newman, and South Newman properties. The sampling distribution for four of these is shown in Figure 3.

Acknowledgments

It is a pleasure to acknowledge the property access and sampling privileges granted by the following mining and exploration companies that have been active in the Babine Lake area: Noranda Exploration Company Limited, Bell Copper Limited, Granisle Copper Limited, Twin Peak Resources Limited, and Phelps-Dodge Corporation of Canada, Limited. The writer is particularly grateful to D. J. Carson of Noranda Exploration, with whom most of the earlier work was carried out. The author's indebtedness for analytical services is readily apparent and it is thus a pleasure to acknowledge the contributions of the staffs of the Geochemistry Section, Analytical Chemistry Section, and Mineralogy Section, especially J. J. Lynch, S. Courville, and J. G. Gravelle. A. G. Plant and G. R. Lachance did the microprobe work on biotites, and I. Jonasson was responsible for the mercury analyses.

ANALYTICAL PROCEDURES

The outcrop and drill core samples were sliced with a diamond saw, washed in water, then alcohol, and ground to -150 mesh. Except for Au and Se, which were analyzed by Bondar-Clegg and Company Ltd., Ottawa, all other samples were analyzed in the Geological Survey laboratories. The complete rock analyses given in Table 3 were done by the Rapid Methods Group, Analytical Chemistry Section, using X-ray fluorescence methods for SiO_2, Al_2O_3, total iron, CaO, K_2O, TiO_2, and MnO. Rapid chemical methods were used for FeO, Na_2O, P_2O_5, and H_2O; S was determined by conventional chemical methods, and MgO by atomic absorption.

The trace element analyses were done in the Geochemistry Section laboratories using atomic absorption for Cu, Ag, Pb, and Zn, and a zinc dithiol colorimetric method for Mo. Additional X-ray fluorescence analyses of the -150 mesh powders were done by the Mineralogy Section for Rb, Sr, TiO_2, CuO, and S.

For the A. A. and colorimetric analyses, a control sample (Bear-Slave control SS No. 26) gave the following mean ppm values and standard deviations (s.d. in brackets): Ag 0.6(0.17), Pb 30(2.0), Cu 54(1.6), Zn 116(3.8), Mo 1.40(0.32). A comparison of the Granisle chemical and XRF sulphur analyses indicates that there is good agreement in the critical lower range (<0.3%S), but above this the XRF values are about 50% lower than the chemical.

The mercury analyses (Jonasson <u>et al.</u>, 1973) were done in two batches submitted at different dates. During this interval adjustments were made in the analytical

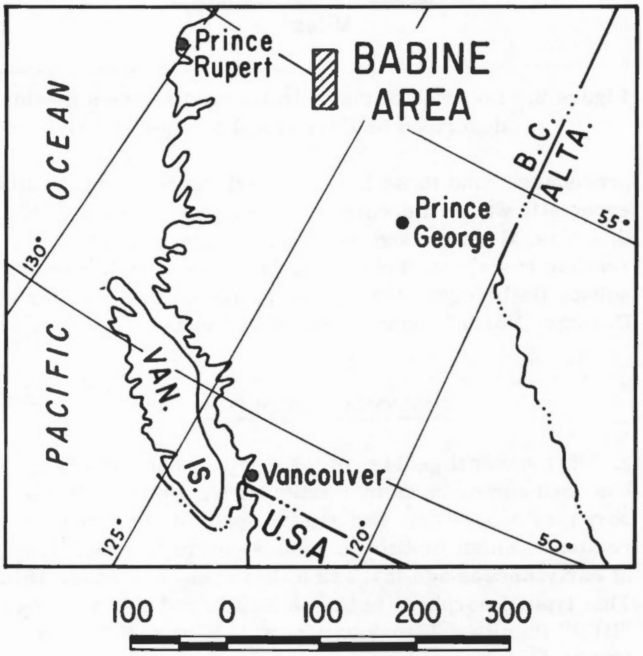

Figure 1. Index map.

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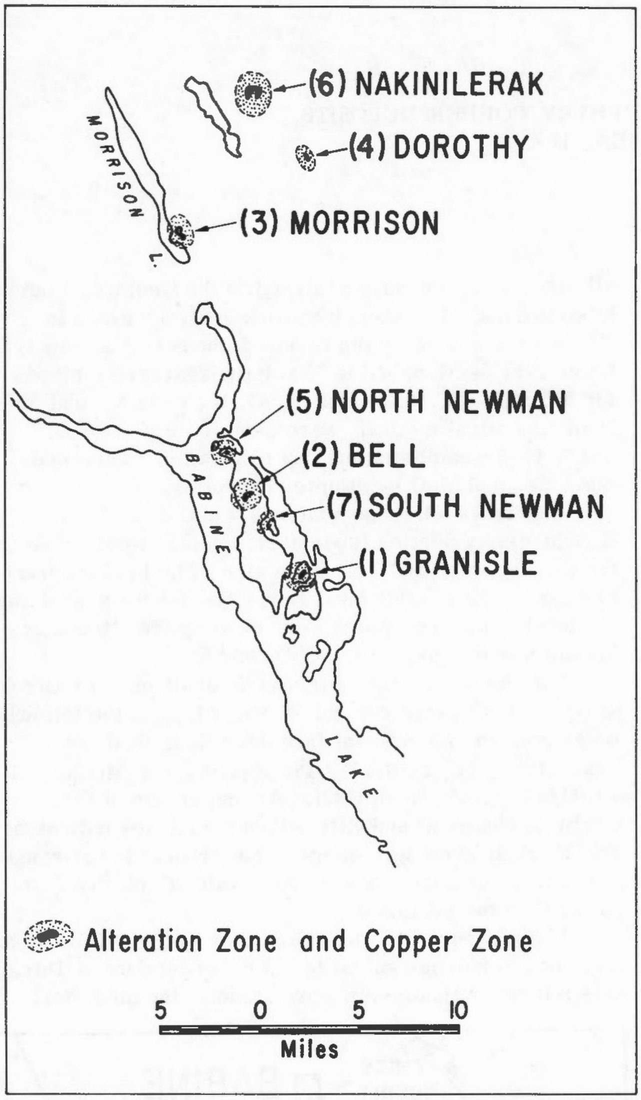

Figure 2. Location of the hydrothermal alteration haloes described by Carson and Jambor (1974).

procedures, and these have affected the reported results, especially where mercury values are low. Because of this bias, Granisle and Bell may be compared on a relative basis, but their background mercury levels are substantially higher than the more recent analyses for the Dorothy, North Newman, and South Newman samples.

REGIONAL GEOLOGY

The general geology of the Babine Lake area (Fig. 4) has been summarized by Carter (1972, 1973). All the porphyry copper deposits and prospects in the area are related to small biotite-plagioclase porphyry intrusions of early Eocene age (51.2±2 million years; Carter, 1972). This type of porphyry is known locally and informally as "BFP" (biotite-feldspar porphyry). Host rocks for the biotite-feldspar porphyry intrusions are mainly Jurassic Hazelton Group andesitic, dacitic, and rhyolitic flows,

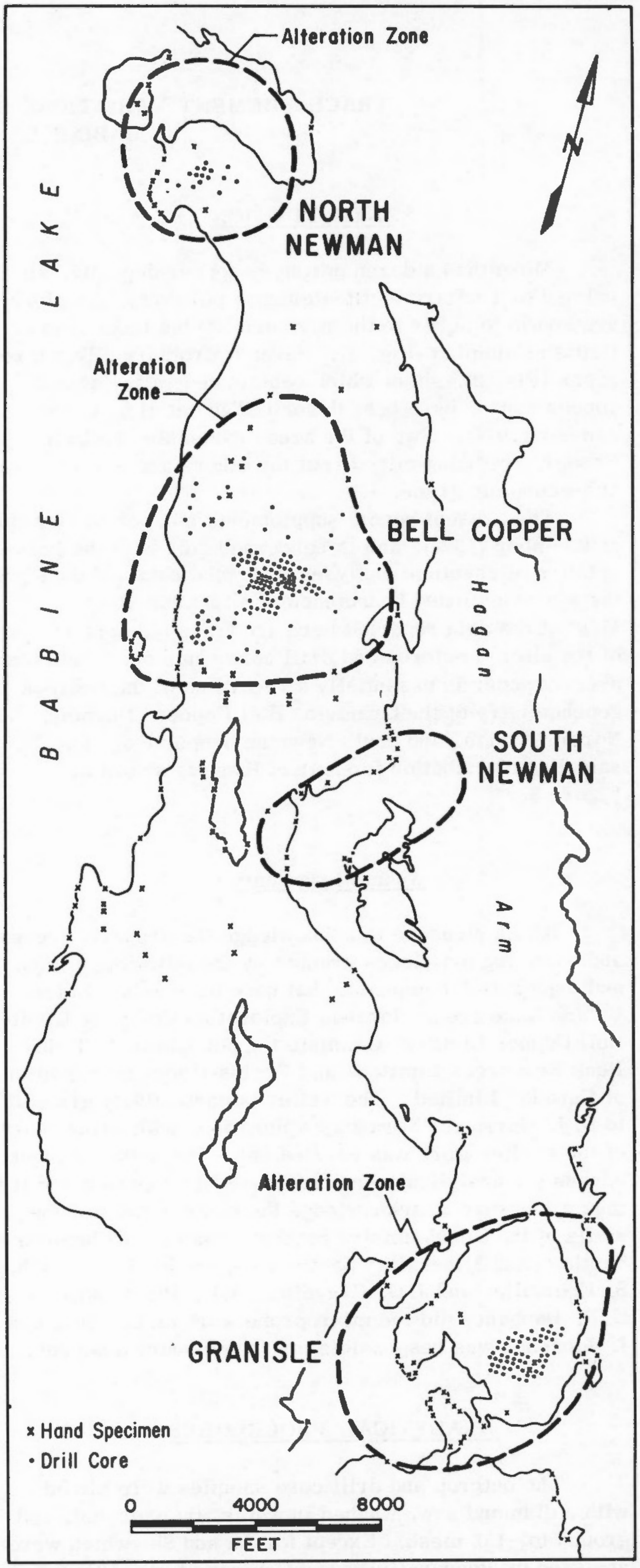

Figure 3. Distribution of samples, analyzed by microscopic and/or chemical methods, at four of the five areas covered in this report (see Figure 2 for the fifth–Morrison).

plugs (?), and fragmentals, and marine siltstones, sandstones, and conglomerates that are mainly of volcanic derivation. Late Triassic sedimentary and volcanic rocks have been identified in the southwestern part of the map-area, and continental sediments believed to belong to the Cretaceous Sustut Group have been preserved within two linear grabens in the northeast.

Major faults trending north-northwest appear to have been the loci of emplacement of the Tertiary intrusions. Subsidiary northeast-trending faults may also be present. The rocks are gently to moderately folded along north-northwesterly axes.

The form of the biotite-feldspar porphyry intrusions varies – stocks, dykes, and possibly sills being present. They have a distinctive light to dark grey and white speckled appearance and are characterized by ¼-5 mm phenocrysts of biotite, plagioclase, and hornblende in a fine-grained to aphanitic matrix of the same minerals plus quartz and K-feldspar. Extensive differences in the appearance of the porphyry result from highly variable grain sizes and phenocryst contents, and the effects of several types of hydrothermal alteration. The compositions of fresh specimens straddle the boundary between quartz diorite and granodiorite. Many of the intrusions, including those at Granisle (Kirkham, 1971) are multiphase. Breccias, believed by Carson and Jambor (1974) to include both intrusive varieties and diatremes, are known to be present at Granisle, Bell Copper and Dorothy.

The copper-bearing zones range from a few hundred to a few thousand feet in diameter. They are centrally

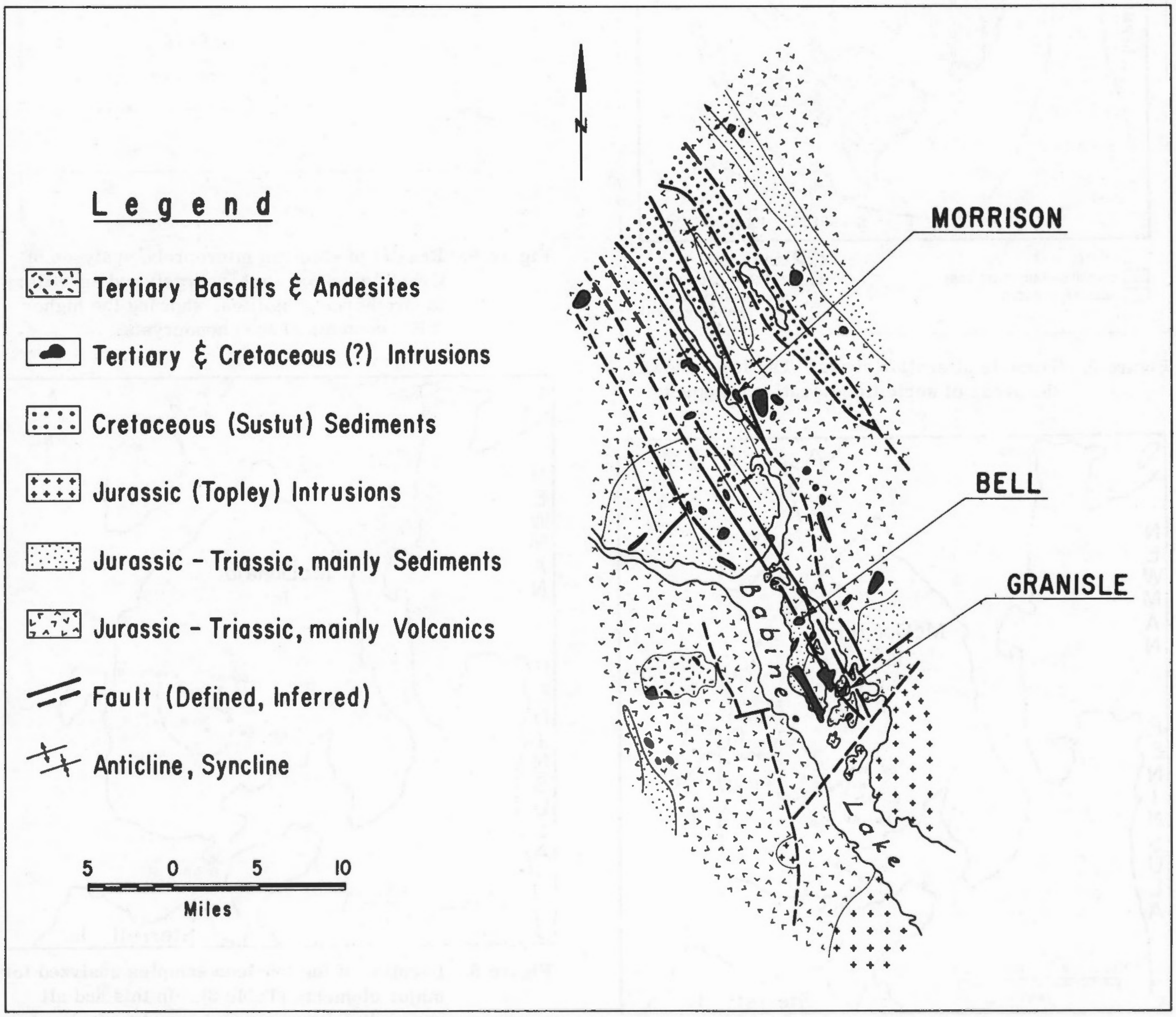

Figure 4. Geology of the Babine Lake area (modified after Carter and Kirkham, 1969, with minor additions and deletions).

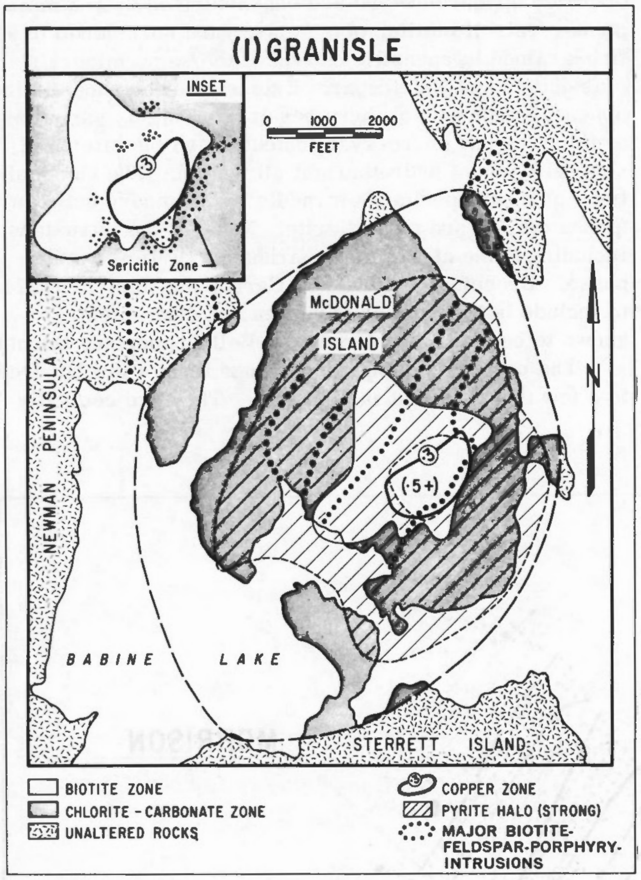

Figure 5. Granisle alteration zones. The inset shows the areas of sericitic alteration (stippled).

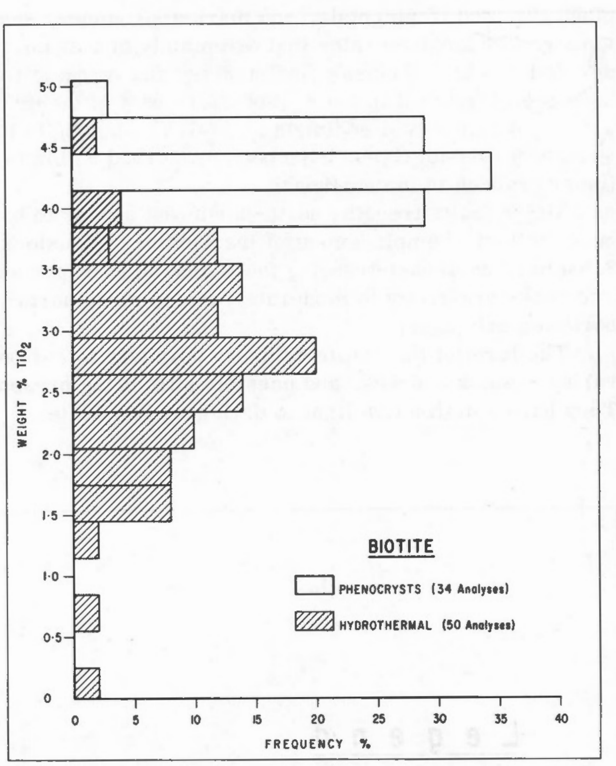

Figure 6. Results of electron microprobe analyses of Granisle primary (phenocryst) and secondary (hydrothermal) biotites, showing the higher TiO_2 contents of the phenocrysts.

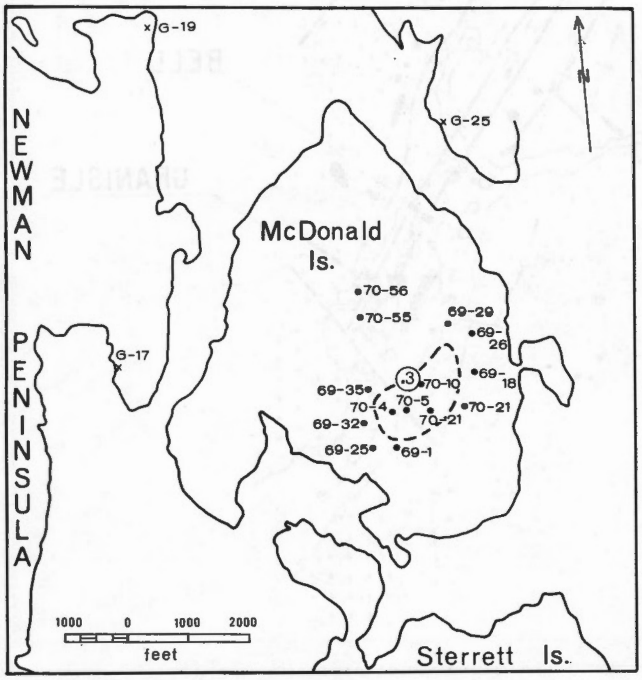

Figure 7. Location of the biotite samples analyzed with the microprobe.

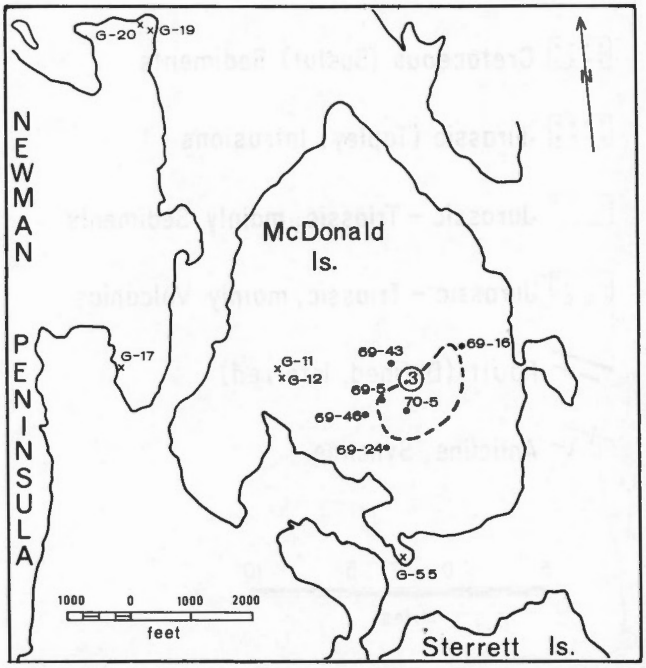

Figure 8. Location of the fourteen samples analyzed for major elements (Table 3). In this and all succeeding figures an x is used to designate a hand specimen and a dot to designate a diamond-drill hole.

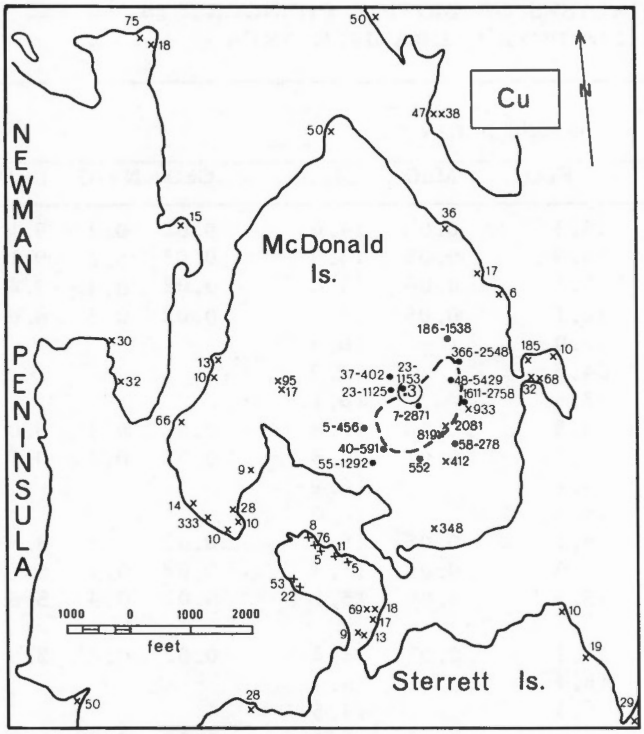

Figure 9. Cu (ppm) at Granisle. Ranges are given where multiple samples from a diamond-drill hole were analyzed. Figures 9-20 show the limits of the 0.3% Cu zone as estimated by Carson and Jambor (1974).

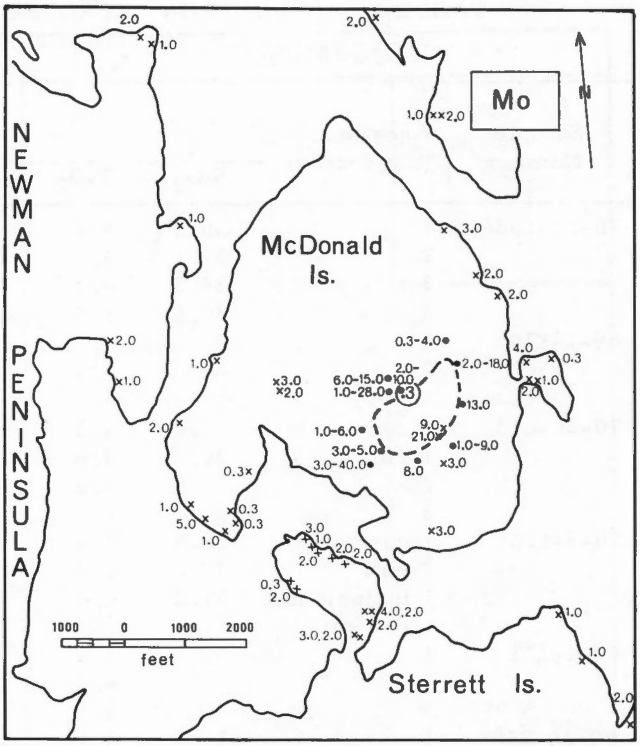

Figure 10. Mo (ppm) at Granisle. Ranges are given where multiple samples from a diamond-drill hole were analyzed.

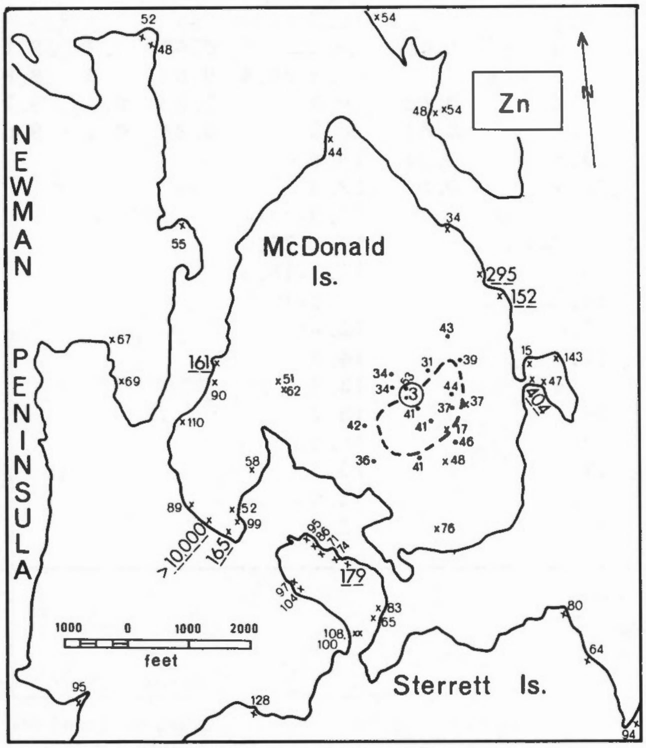

Figure 11. Zn (ppm) at Granisle. Averages are given where multiple samples from a diamond-drill hole were analyzed. (The maximum Zn in all the drill cores analyzed is 74 ppm).

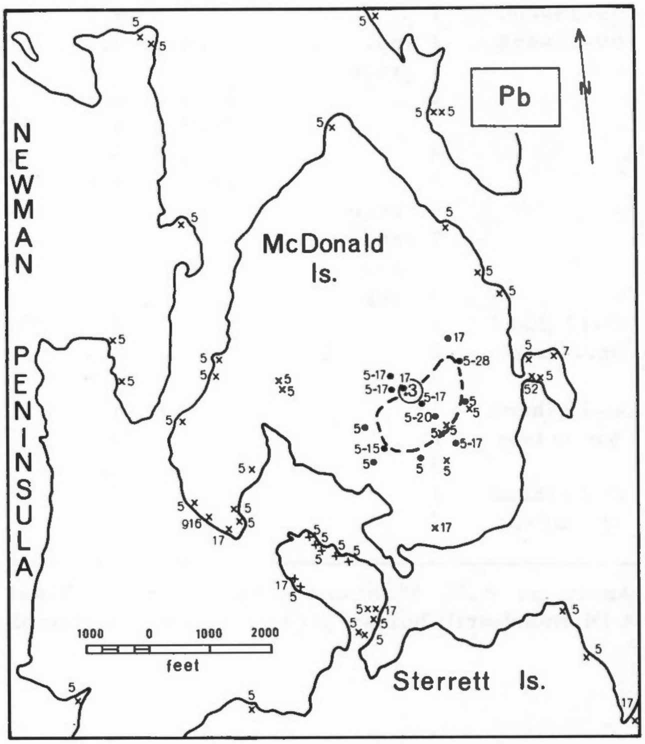

Figure 12. Pb (ppm) at Granisle. Ranges are given where multiple samples from a diamond-drill hole were analyzed.

TABLE 1. ELECTRON MICROPROBE ANALYSES OF BIOTITE PHENOCRYSTS IN BIOTITE-FELDSPAR PORPHYRY, GRANISLE AREA

Sample Number	Area in thin section	weight per cent								
		SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
70-21-1026	1	36.9	4.2	14.7	15.3	0.05	14.6	0.02	0.2	9.1
	2	37.1	4.1	14.3	15.9	0.05	13.9	0.03	0.2	9.1
	3	37.3	4.2	14.5	16.1	0.04	13.8	0.02	0.4	9.2
	4	36.6	3.7	14.4	16.1	0.05	13.5	0.02	0.3	8.6
69-1-140	1		4.5		13.0		16.5			
	2		4.3		14.5		14.9			
	3		4.5		13.6		15.1			
70-20-675	1 core	36.6	4.3	13.6	14.8	0.08	16.8	0.02	0.2	9.0
	1 rim	36.6	4.8	14.0	15.1	0.07	16.5	0.02	0.2	9.1
	2		4.0		14.7		16.9			
	3		4.1		15.8		16.0			
70-5-120	1 core	36.9	4.4	14.2	15.1	0.05	15.3	0.02	0.3	8.8
	1 rim	37.2	4.4	13.8	15.0	0.05	15.4	0.02	0.3	8.7
	1 inclusions in rim	37.2	4.4	14.3	15.5	0.06	15.1	0.02	0.4	8.8
70-4-773	1	36.1	4.4	14.0	15.4	0.07	15.2	0.02	0.2	8.9
	2		4.2		16.4		14.9			
	3		4.3		16.3		14.5			
69-29-550*	1	36.6	4.5	13.6	15.8	0.07	15.0	0.03	0.2	8.8
	2 core	37.8	4.5	13.8	14.9	0.08	15.9	0.02	0.2	8.9
	2 rim	38.3	4.5	14.3	15.1	0.03	15.7	0.03	0.2	9.0
	3 -	39.1	4.5	14.5	15.5	0.08	15.8	0.03	0.2	9.1
69-26-157	1		4.1		15.4		15.2			
	2		4.1		15.0		14.5			
69-35-200	1		4.1		10.1		18.9			
69-32-258	1 spot	39.4	4.7	15.5	9.8	0.03	19.6	0.02	0.3	9.1
	1 range				13.0- 8.8		18.2-20.4	0.03	0.3	8.8
	2	38.9	4.6	14.6	10.2	0.02	19.0	0.02	0.4	9.7
	3	39.5	4.6	15.0	7.1	0.01	20.6	0.03	0.3	9.6
	4	37.8	4.3	14.6	14.2	0.04	15.8			
	5	38.2	4.8	15.0	12.4	0.04	18.0			
	6 range				12.1-9.0		17.9-20.1			
	7 range				9.7-4.5		19.0-23.0			
	8 range				14.6-13.2		15.2-16.9			
	9 range				14.6-13.2		16.2-19.1			
G-17 (hand specimen)	1		4.0		17.6		12.4			
	2		4.2		17.4		14.2			
	3		4.0		17.6		13.5			
G-19 (hand specimen)	1		4.1		15.5		15.7			
	2		4.5		13.8		16.9			
	3		4.3		17.2		15.4			
G-25 (hand specimen)	1		4.3		19.4		12.4			
	2		4.0		17.0		13.3			

Analysts: A.G. Plant and G.R. Lachance. Total Fe as FeO.
* Diamond-drill holes: year, number, and sample footage.

TABLE 2. ELECTRON MICROPROBE ANALYSES OF SECONDARY BIOTITES, GRANISLE

Sample number	Description	weight per cent									
		SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
69-29-550*	pseudomorph** No. 1	39.3	2.6	14.8	14.0	0.01	15.6	0.05	0.2	9.0	95.6
	pseudomorph No. 2	40.7	2.4	15.1	14.7	0.01	15.3	0.05	0.2	9.3	97.8
	pseudomorph No. 3	41.3	2.5	16.5	13.8	0.02	14.7	0.05	0.1	8.9	97.9
69-26-157	pseudomorph		2.7		14.4		15.8				
	greenish, in matrix		2.3		15.3		15.2				
69-18-213	pseudomorph No. 1		1.4		10.8		10.2				
	pseudomorph No. 2		1.5		13.5		13.0				
	in matrix		2.0		15.4		14.6				
70-21-1026	pseudomorph No. 1	37.4	2.9	14.6	16.0	0.05	15.0	0.03	0.2	9.3	95.5
	second area in No. 1	38.4	2.9	13.8	15.2	0.03	14.9	0.02	0.2	8.9	94.4
	pseudomorph No. 2	37.9	2.8	13.9	16.0	0.04	15.1	0.02	0.2	8.6	94.6
69-1-140	pseudomorph No. 1		2.5		13.2		16.8				
	pseudomorph No. 2		2.6		13.7		14.7				
	second area in No. 2		2.3		12.7		12.9				
69-25-345	pseudomorph		3.5		15.1		14.2				
	in matrix		2.5		12.8		13.3				
70-27-441	pseudomorph		3.4		14.6		17.7				
	coarse, in matrix		4.1		15.7		15.4				
	greenish, in matrix		0.1		12.6		17.9				
70-20-204	pseudomorph?	37.7	2.3	14.4	13.1	0.05	18.9	0.02	0.2	9.6	96.3
	greenish, in matrix	36.3	0.7	19.2	12.8	0.05	18.1	0.02	0.1	9.7	97.0
	brown, in matrix	36.3	4.6	18.0	14.5	0.07	15.7	0.03	0.2	9.9	99.3
	brown, in matrix	38.9	3.7	13.7	13.9	0.04	17.5	0.05	0.2	9.5	97.5
70-20-675	pseudomorph	34.5	3.5	13.5	16.0	0.03	18.8	0.20	0.2	7.0	93.7
70-20-900		40.5	3.0	13.8	13.9	0.02	17.7	0.02	0.1	9.3	98.3
		41.0	2.8	14.3	14.0	0.03	17.8	0.03	0.1	9.2	99.3
		39.5	3.0	14.7	13.7	0.03	17.6	0.03	0.1	9.0	97.7
		39.6	3.0	13.8	14.1	0.03	17.8	0.02	0.1	9.5	98.0
		39.7	3.0	13.2	13.8	0.02	18.0	0.02	0.1	9.4	97.2
70-5-120	in matrix	39.0	3.8	14.0	14.7	0.03	15.7	0.03	0.3	9.0	96.6
	in matrix	37.3	3.5	14.0	14.7	0.02	15.5	0.03	0.3	8.9	94.3
	pseudomorph	38.0	3.9	13.3	14.6	0.04	16.2	0.02	0.4	9.0	95.5
69-32-83	matrix	43.3	2.3	19.0	12.9	0.04	9.9	0.1	0.2	8.8	96.5
	greenish, in matrix	39.3	1.8	17.8	13.5	0.03	15.0	0.07	0.2	9.2	96.9
	greenish, in matrix	38.3	2.3	16.2	16.5	0.07	11.9	0.07	0.2	9.4	94.9
	reddish, in matrix	39.8	3.5	16.9	8.0	0.03	18.5	0.1	0.2	9.5	96.5
69-32-258	in matrix	40.2	3.7	14.2	15.9	0.01	14.8	0.03	0.2	8.8	97.8
	pseudomorph No. 1	38.8	3.8	15.2	17.0	0.03	14.3	0.05	0.2	8.9	98.3
	pseudomorph No. 2	36.5	3.6	15.5	16.3	0.01	15.7	0.05	0.2	8.9	96.8
	in plagioclase	40.6	3.3	14.6	15.3	0.03	13.6	0.25	0.3	9.2	97.2
69-35-354	pseudomorph		2.8		12.4		16.5				
	in matrix		2.4		11.9		16.7				
70-10-816	pseudomorph No. 1		3.0		13.2		16.7				
	pseudomorph No. 2		3.1		13.5		16.9				
	second area No. 2		3.0		13.5		15.4				
	third area No. 2		2.9		13.4		17.1				
70-4-773	pseudomorph No. 1	40.2	3.6	12.7	13.8	0.03	17.3	0.02	0.1		96.7
	pseudomorph No. 2	39.2	3.3	13.6	13.5	0.04	16.8	0.02	0.2		95.7
G-204(hand specimen)	in vein-near wall rock		1.8		13.3		19.3				
	-near vein centre		2.2		13.6		17.7				
70-55-260		34.0	1.7	16.4	18.2	0.13	11.5	0.02	0.1	7.6	89.7
***		37.6	2.0	15.8	17.5	0.11	10.7	0.02	0.1	8.7	92.5
70-56-249		36.0	1.5	15.5	19.3	0.2	11.1	0.02	0.2	8.0	91.8
***		36.4	1.7	16.2	17.8	0.2	11.9	0.03	0.2	8.3	92.7

* Diamond-drill hole: year, drill hole number, and sampling footage.

** Pseudomorphous after amphibole.

*** Probably partly chloritized.

Analyst: A. G. Plant. Total Fe as FeO.

TABLE 3. CHEMICAL ANALYSES OF BIOTITE-FELDSPAR PORPHYRY FROM GRANISLE

Wt. %	G-19	G-20	G-17	G-55	G-11	G-12	69-46-283**	69-46-407	69-24-482	69-16-276	69-16-414	69-43-362	69-5-451	70-5 120
SiO_2	60.8	58.8	58.0	63.1	63.9	62.7	60.2	62.9	61.6	63.5	62.3	62.2	65.6	63.3
Al_2O_3	17.6	16.8	16.3	17.1	16.5	16.4	16.8	17.3	17.6	17.7	18.0	18.8	17.7	17.8
Fe_2O_3	3.2	3.2	2.3	1.1	4.3*	4.9*	7.2*	1.0	-	2.1	1.6	<0.1	0.4	0.9
FeO	1.8	2.1	2.6	1.9	-	-	-	3.3	-	2.4	2.9	4.0	1.7	2.1
MnO	0.07	0.08	0.08	0.09	0.07	0.07	0.03	0.03	0.07	0.02	0.02	0.03	0.02	<0.01
MgO	2.9	3.6	3.4	1.7	1.5	1.6	1.8	2.3	1.0	2.5	2.7	2.1	1.6	2.0
CaO	4.9	5.5	5.0	3.0	2.3	2.2	2.5	3.0	2.8	3.0	2.7	2.9	2.8	2.6
Na_2O	4.4	3.8	3.4	2.8	2.6	2.0	3.4	3.3	2.6	4.0	4.3	4.4	4.3	4.4
K_2O	2.4	2.3	2.3	3.5	2.9	3.6	2.4	2.6	2.9	3.0	2.7	1.5	1.7	2.6
TiO_2	0.77	0.78	0.75	0.50	0.52	0.52	0.61	0.61	0.61	0.61	0.73	0.61	0.55	0.65
H_2O	1.4	1.6	2.8	1.9	2.3	2.4	2.2	2.2	3.0	1.7	1.2	1.5	1.7	0.9
CO_2	0.6	0.6	2.7	2.6	3.7	3.9	1.8	2.2	2.7	0.3	0.2	1.2	1.5	0.5
P_2O_5	0.33	0.31	0.32	0.22	0.21	0.22	0.27	0.25	0.25	0.22	0.27	0.24	0.19	0.17
S	0.02	0.03	0.03	<0.02	1.21	1.42	1.42	0.23	2.49	0.08	0.07	0.60	0.33	0.09
O=S	0.01	0.01	0.01	0.0	0.45	0.53	0.53	0.09	0.93	0.03	0.03	0.23	0.12	0.03
Total	101.2	99.5	100.0	99.5				100.1		100.7	99.5	99.9	99.9	98.0

* Total iron as Fe_2O_3. ** Diamond-drill hole number and footage.

Analyses by Rapid Methods Group, Analytical Chemistry Section, GSC. Sample locations are shown in Figure 8. G-19, G-20: unaltered biotite-feldspar porphyry outside the Granisle alteration zone (Figs. 5 and 8). G-17, G-55 in the outer edge of the chlorite-carbonate zone. G-11, G-12 from the chlorite-carbonate zone with minor sericitization. Remainder of samples from biotite zone. Except for 69-5-451, which contains a small quartz veinlet, samples with megascopic sulphide, quartz, or carbonate veinlets were avoided.

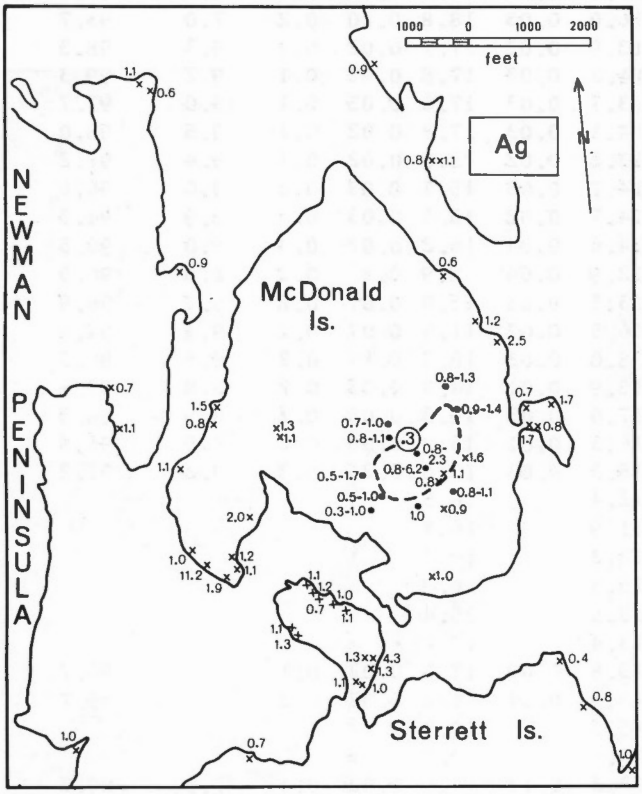

Figure 13. Ag (ppm) at Granisle. Ranges are given where multiple samples from a drill-hole were analyzed.

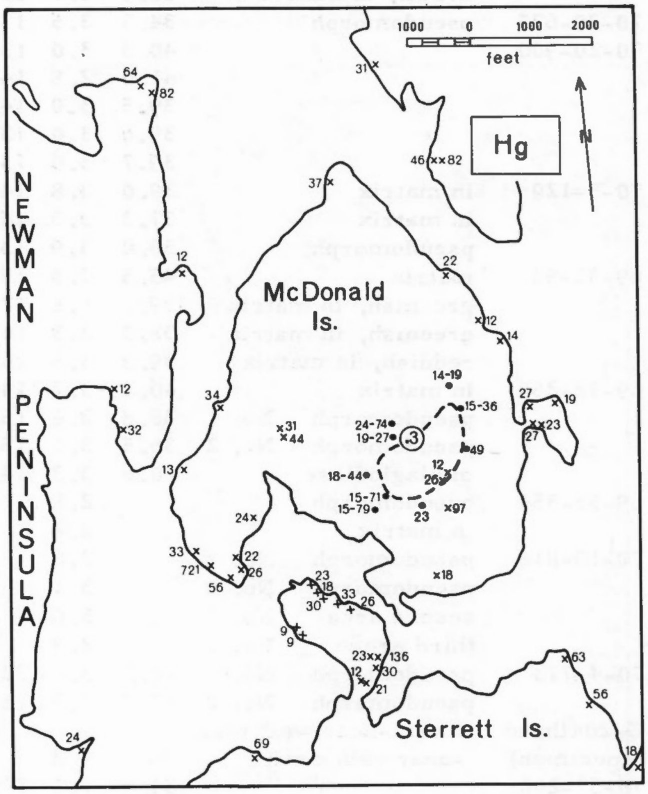

Figure 14. Hg (ppb) at Granisle. Ranges are given as stated for Figure 13.

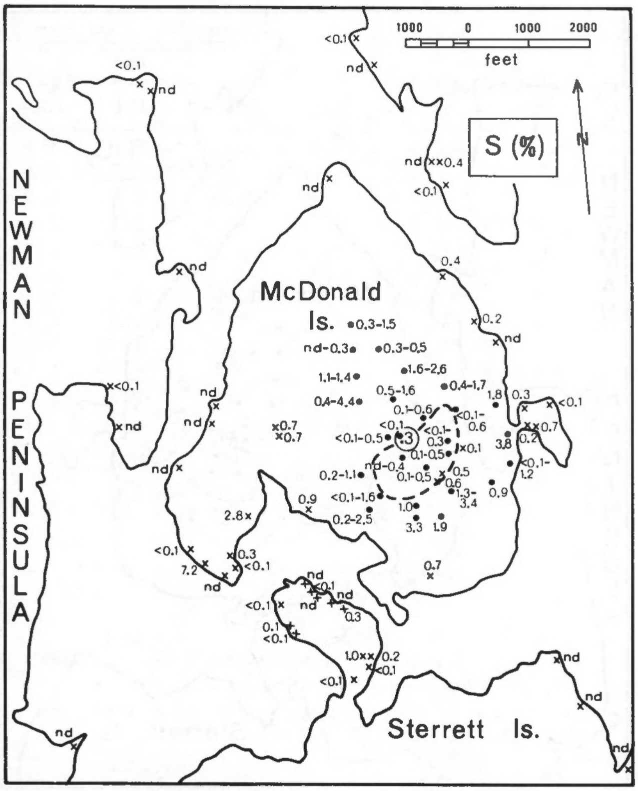

Figure 15. S(%) at Granisle. Ranges are given as stated for Figure 13. (n.d. = not detected).

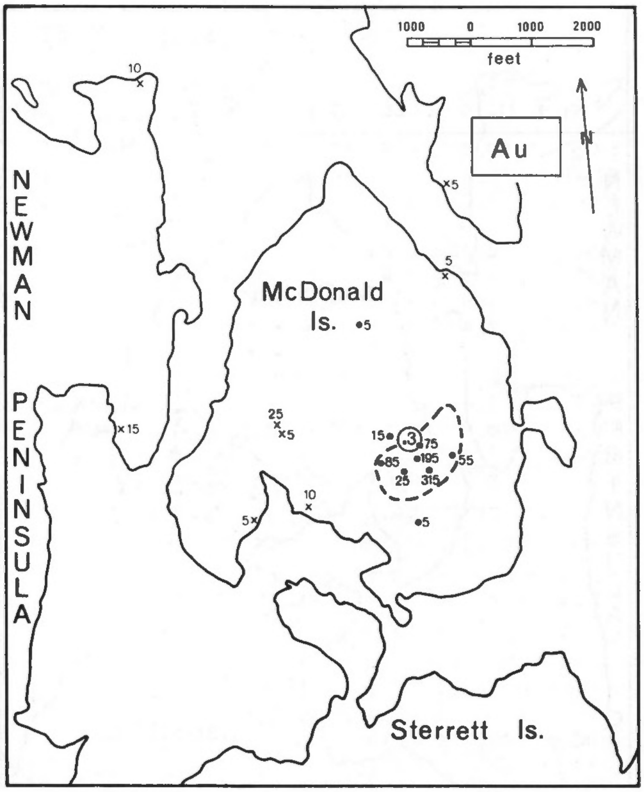

Figure 16. Au (ppb) at Granisle.

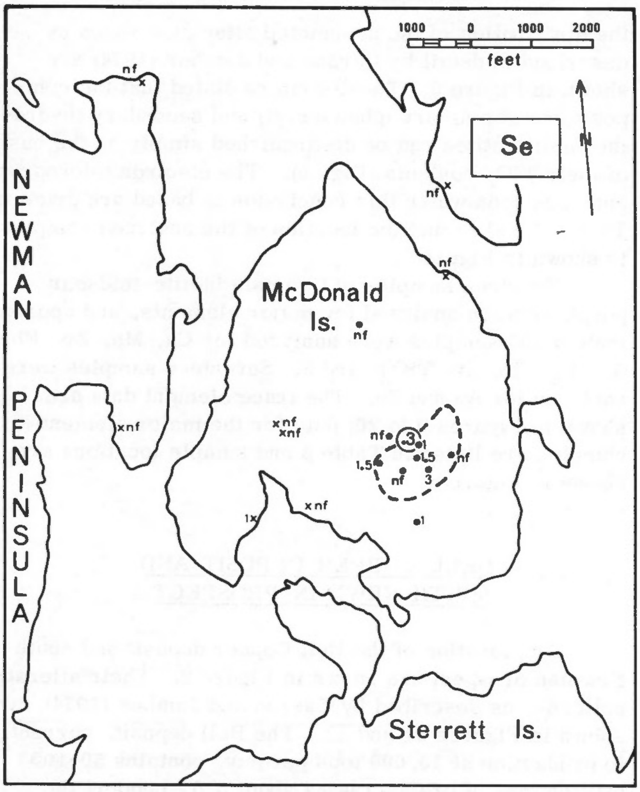

Figure 17. Se (ppm) at Granisle. (nf = not found).

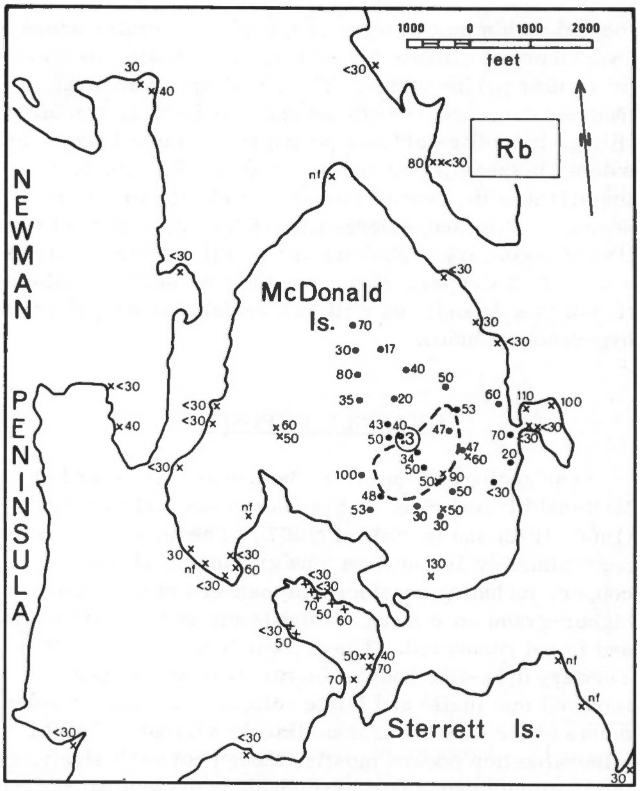

Figure 18. Rb (ppm) at Granisle. Averages are given where multiple samples from a drill-hole were analyzed. (<30 ppm taken as zero). (nf = not found).

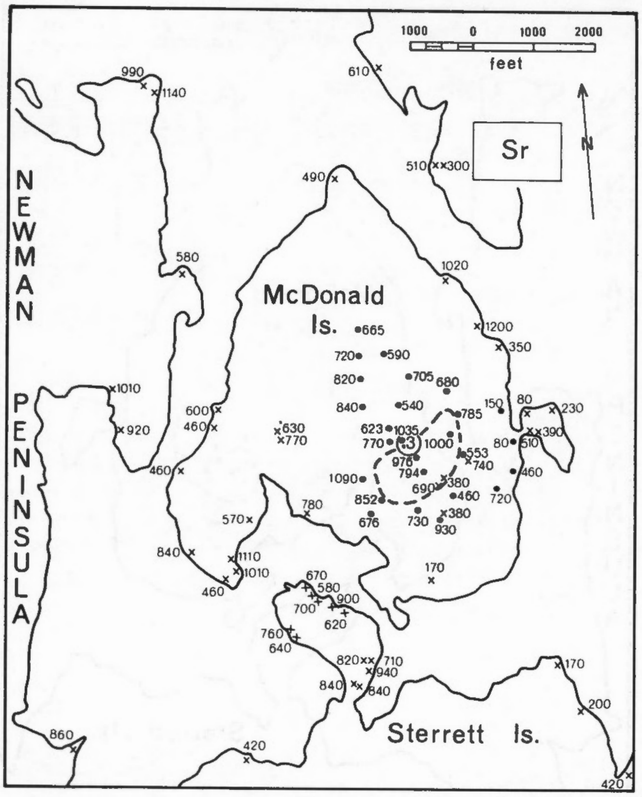

Figure 19. Sr (ppm) at Granisle. Drill hole averages are given as stated for Figure 18.

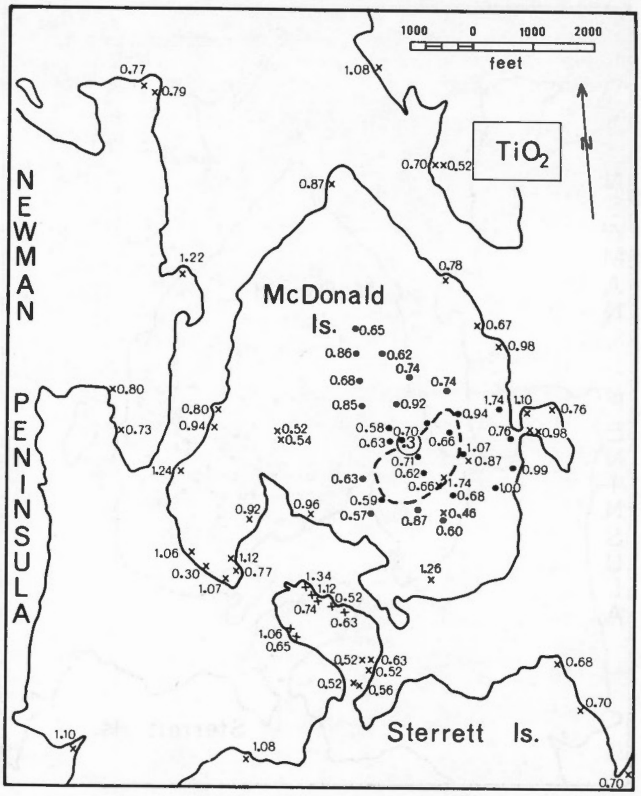

Figure 20. TiO_2 (%) at Granisle. Averages are given where multiple samples from drill hole were analyzed.

located within much larger elliptical or circular areas of hydrothermal silicate alteration, and are also encircled by annular pyrite haloes. The main copper mineral, chalcopyrite, occurs both disseminated and as fracture-fillings in biotite-feldspar porphyry, and to a lesser extent, in the adjacent country rocks. Bornite is important in the central portions of the higher-grade deposits. Limited supergene enrichment, with the formation of secondary chalcocite and covellite, has occurred only at Bell Copper. However, the commercial exploitation of this deposit, as well as Granisle, is dependent on hypogene sulphides.

GRANISLE DEPOSIT

The geology of the Granisle copper deposit and of McDonald Island (Fig. 5) has been described by Carter (1966, 1972) and by Fahrni (1967). The deposit contains approximately 100 million tons grading about 0.44% copper, including considerable tonnages of 0.6% Cu in a higher-grade core zone. Molybdenum is less than 0.01% and is not recovered. The deposit is associated with a Tertiary dyke-like body of biotite-feldspar porphyry intruded into mafic and felsic volcanics and minor sediments of the Lower Jurassic Hazelton Group. Copper mineralization occurs mostly, though not exclusively, in the biotite-feldspar porphyry, both as disseminated grains and as fracture fillings. The limits of the ore zone and the distribution of the associated alteration zones as described in detail by Carson and Jambor (1974) are shown in Figure 5. These writers stated that the compositions of primary (phenocryst) and secondary (hydrothermal) biotites can be distinguished simply on the basis of their TiO_2 contents (Fig. 6). The electron microprobe analyses upon which this conclusion is based are given in Tables 1 and 2, and the location of the analyzed samples is shown in Figure 7.

Fourteen samples of Granisle biotite-feldspar porphyry were analyzed for major elements, and approximately 125 samples were analyzed for Cu, Mo, Zn, Pb, Ag, Hg, Rb, Sr, TiO_2, and S. Seventeen samples were analyzed for Au and Se. The trace element data are shown in Figures 9 to 20; data for the major element samples are listed in Table 3 and sample locations are shown in Figure 8.

BELL COPPER DEPOSIT AND SOUTH NEWMAN PROSPECT

The location of the Bell Copper deposit and South Newman prospect are shown in Figure 2. Their alteration patterns, as described by Carson and Jambor (1974), are shown in Figures 21 and 22. The Bell deposit, currently in production at 10,000 tons per day, contains 50-100 million tons of ore averaging about 0.5% copper; the South Newman prospect does not have a definable copper zone.

The results of trace element analyses for Cu, Mo, Zn, Pb, Hg, S, Au, and Se are summarized in Figures 24 to 31 inclusive. Except for Au and Se, the sampling density around the Bell Copper deposit is too great to show individual values. Individual results are therefore listed in Table 5 and the corresponding sample locations are shown in Figure 23. Rock types and alteration zones may be deduced from Figures 21 and 22, and maps by Carter (1966, 1973).

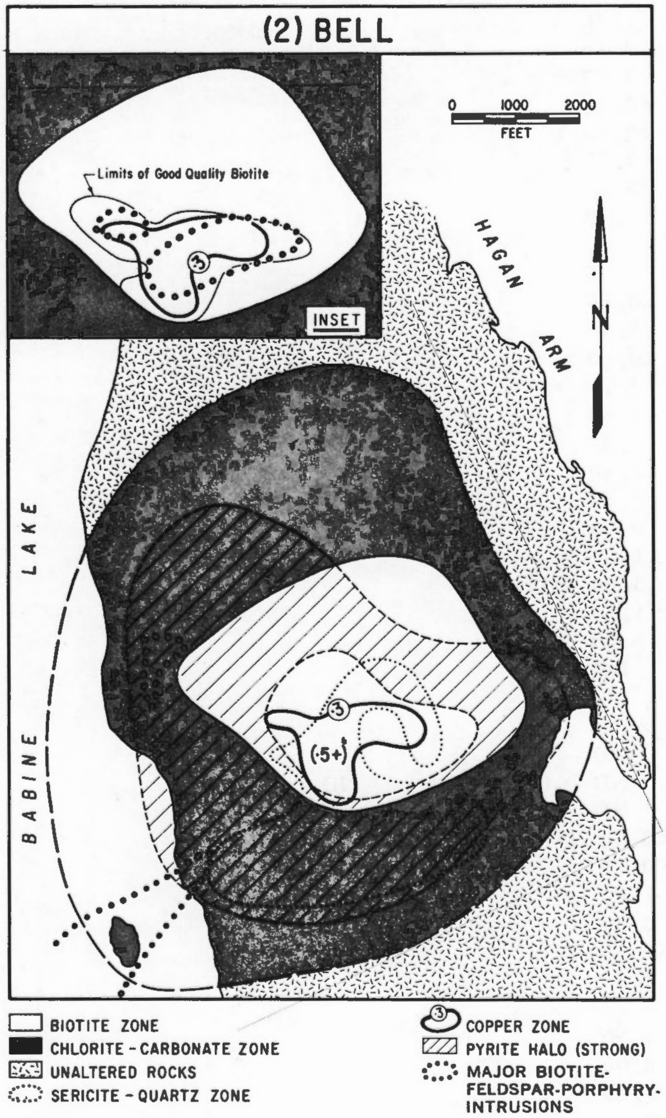

Figure 21. Alteration zones at Bell Copper. The inset shows the centrally-located biotite-feldspar porphyry intrusions, the total area in which hydrothermal biotite occurs, and the smaller area in which good quality hydrothermal biotite, as described by Carson and Jambor (1974), is present.

DOROTHY PROPERTY

The Dorothy property (Fig. 2) contains a large area in which copper grades are greater than 0.2%, but with no significantly higher-grade internal zone (Fig. 39). Although molybdenite is more than three times as abundant at Dorothy than at the other Babine deposits referred to in this paper, the Dorothy grades nevertheless average only about 0.03% Mo. The results of trace element analyses for Cu, Mo, Zn, Pb, Ag, and Hg are shown in Figures 40 to 45.

NORTH NEWMAN PROPERTY

The location of the North Newman property is shown in Figure 2. As was discussed by Carson and Jambor (1974), a relatively large alteration halo at North Newman is associated with a small, low-grade copper zone (Fig. 31). The results from trace element analyses of hand specimens and drill cores from this property are shown in Figures 33 to 37, inclusive.

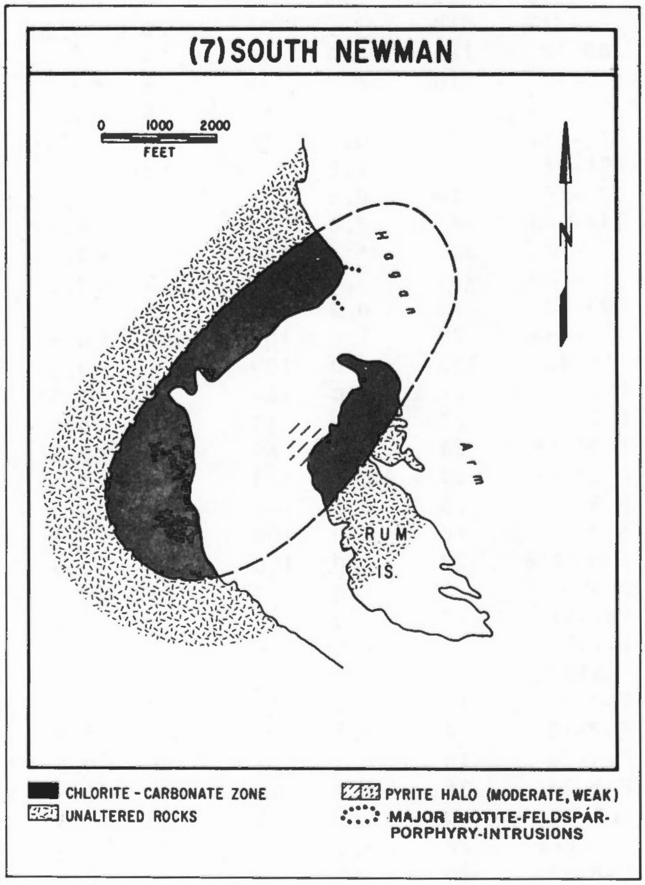

Figure 22. Alteration at the South Newman property.

TABLE 4. TRACE ELEMENTS IN BELL COPPER SAMPLES*

Sample Number	Cu ppm	Mo ppm	Zn ppm	Pb ppm	Ag ppm	Hg ppb	S %	Te ppm	Au ppb	Se ppm
D 12/7	23	1.0	22	5	<0.5	13	ND			
D 9/7/8	35	1.0	143	5	<0.5	53	0.10			
C 9/7/8	14	1.0	39	6	<0.5	13	0.75			
G 10/7/8	183	0.3	66	5	<0.5	11	ND			
F 12/7	185	14	261	18	<0.5	13	0.20			
139-240	48	1.0	41	5	<0.5	14	1.10			
-327	13	0.3	96	5	0.8	19				
138-100	15	2.0	1185	5	<0.5	19	0.40			
-190	22	1.0	44	5	<0.5	15	0.55			
-231	15	7.0	103	8	<0.5	11	1.40			
B 9/7/8	122	1.0	81	5	<0.5	18	0.25			
140-47	165	2.0	76	5	<0.5	11	0.40			
-56	90	1.0	97	5	<0.5	13	<0.10			
-200	19	1.0	125	5	<0.5	10	<0.10			
205-60	68	2.0	824	29	<0.5	36	0.70			
-96	14	2.0	58	5	<0.5	10	<0.10			
-147	6	1.0	46	5	<0.5	12	2.20			
141-90	41	2.0	80	16	0.5	38				
-113	326	0.3	84	5	<0.5	13	1.25			
-300	8	2.0	58	5	<0.5	12	<0.10			
204-140	12	2.0	65	122	<0.5	17	3.45			
-160	14	2.0	18	6	<0.5	13	<0.10			
-217	10	7	85	25	<0.5	16	3.10			
200-92	183	0.3	41	5	<0.5	28	1.50			
-141	10	0.5	47	5	<0.5	28	0.45			
-204	18	1.0	40	5	0.5	22	0.40			
-423	44	0.3	76	119	1.0	17	5.25			
201-31	58	1.0	38	5	<0.5	15	0.60			
-155	18	0.3	33	6	0.5	41	1.00			
142-113	347	3.0	67	5	<0.5	19	3.00			
-226	321	25	20	5	<0.5	8	1.10			
-228	453	3.0	34	5	<0.5	26	0.80			
203-62	15	0.3	22	5	<0.5	13	ND			
-143	30	1.0	102	33	<0.5	17				
16-42	383	1.0	109	5	<0.5					
N 1	17	3.0	156	5	<0.5	11	ND			
N 2	27	1.0	55	5	<0.5	25	ND	<0.2	5	ND
B 9/4/8	24	3.0	80	5	<0.5	48	ND			
G 8/7/8	27	20	174	14	<0.5	13	<0.10			
N 3	15	0.3	149	42	0.5	25	<0.10			
N 4	10	2.0	100	5	1.5	11	1.00			
a 10/4/8	32	2.0	100	25	<0.5	33	0.35			
N 5	8	1.0	102	19	0.5	10	<0.10			
127-52	17	2.0	66	5	0.5		7.5			
1-125	7	1.0	90	5	<0.5	12	ND			
-340	11	2.0	9	16	1.3	72	3.90			
F-1-9	10	1.0	40	5	<0.5	44	8.00			
F-2-13	14	2.0	630	73	<0.5	42	0.45			
F-4-10	16	1.0	93	5	<0.5	171	0.65			
F-5-23	36	2.0	158	5	<0.5	278	1.20			
217-99	15	1.0	73	13	<0.5	39	5.25			
-172	28	4.0	42	15	<0.5	36	1.20			
F-8-15	20	2.0	9	5	<0.5	68	0.75			
F-11-16	15	4.0	9	5	<0.5	34	3.20			
F-12-38	14	3.0	5	8	<0.5	47	1.15			
F-10-7	22	0.5	83	5	<0.5	10	ND			

TABLE 4. (cont'd)

Sample Number	Cu ppm	Mo ppm	Zn ppm	Pb ppm	Ag ppm	Hg ppb	S %	Te ppm	Au ppb	Se ppm
146-210	2286	1.0	20	5	<0.5	55	1.00	1.0	35	2
152-20	1255	3.0	77	5	<0.5	14	0.10			
18-373	3714	1.0	48	8	<0.5	34	1.70			
24-78							4.20			
82-495	6000	0.3	50	8	<0.5	18	1.25			
153-150	1657	10	170	30	<0.5	15	1.95			
100-1260	1714	8	66	16	<0.5	9	0.85			
4-664	6047	0.3	65	16	<0.5	47	2.05			
112-1008	3286	1.0	41	5	<0.5	150	1.50			
-1080	1489	3.0	45	8	<0.5	15	0.25			
102-55	987	2.0	40	22	<0.5	9	0.15			
29-313							2,60			
-910	4923	2.0	48	5	<0.5	14	2.60			
39-327							1.35			
80-150							<0.10			
-199	1000	2.0	83	5	<0.5	28	0.60			
46-124	947	2.0	42	15	<0.5	13	0.45			
-403	2429	1.0	38	9	0.5	119	1.35	0.5	115	1
19-97	1143	2.0	49	5	<0.5	13	0.85			
-313	3733	3.0	25	5	<0.5	39				
111-573	1723	9	31	5	<0.5	529	2.30	2.0	175	2.5
-809	6282	0.3	9	5	<0.5	36	1.90			
58-264	4154	5	64	5	<0.5	21	0.45	0.2	355	1.5
-500	9245	1.0	11	5	1.3	136	5.1			
-1908	8000	25	30	5	<0.5	10	1.35			
-1926	7833	3.0	32	5	<0.5	25	1.30	0.2	335	2.5
115-1172	5375	8	23	23	<0.5	91	2.80			
-1742	4140	2.0	34	5	<0.5	17	0.90	<0.2	355	2
113-554	2857	13	64	16	0.5	12	1.45			
-883	3733	4.0	27	5	2.5	20	7.0		355	10
-1193	3286	4.0	45	5	4.0	13	1.45			
-1704	12800	40	41	5	1.4	18	2.15			
109-240	3867	8	37	8	<0.5	187	1.90			
-665	4250	8	13	15	0.5	26	1.25			
-878	771	22	25	9	<0.5	18	1.15			
63-350	1286	1.0	80	8	0.5	23	0.10	<0.2	115	ND
77-336	43	37	6	8	<0.5	84	2.30		15	2
108-257							0.90			
-445							0.10			
56-125	298	20	57	8	<0.5	11	0.30			
-230	1075	48	106	5	0.6		0.70			
52-228	2533	60	81	8	<0.5	20	0.40			
-229	1142	9	84	5	1.4	15				
44-440	2000	35	56	8	0.5	15	0.35			
20-327							2.4			
36-1345	9283	23	39	5	1.8					
30-56	437	46	9	5	1.9		1.9			
-875							0.7			
187-145	960	10	91	5	<0.5	12	0.20		45	ND
64-330	2571	23	41	5	<0.5	12	0.40			
75-207	121	7	16	5	<0.5	64	1.20			
66-590	406	30	84	8	<0.5	11	1.20			
70-72	5375	1.0	20	5	0.5	50	2.45			
-558	6167	46	13	5	<0.5	23	2.10			
-787	8868	6	10	11	<0.5	76	2.10	<0.2	145	5
133-231							1.40			

TABLE 4. (cont'd)

Sample Number	Cu ppm	Mo ppm	Zn ppm	Pb ppm	Ag ppm	Hg ppb	S %	Te ppm	Au ppb	Se ppm
-13	58	2.0	30	5	<0.5	1570	0.35			
220-91	169	3.0	160	5	<0.5	29	0.45			
-165	61	3.0	143	23	<0.5	69	0.90			
218-60	29	12	59	19	<0.5	42	11.9			
-140	35	10	182	8	<0.5	16	2.35			
221-78	205	1.0	72	59	<0.5	102				
-200	88	1.0	97	5	0.5	225	0.65			
F-16-12	11	1.0	5	8	<0.5	37	1.20			
81-120	465	2.0	105	16	<0.5	25	0.65			
-190	99	1.0	107	6	<0.5	28	0.55			
219-220							2.90			
-276	18	2.0	65	5	<0.5	62	2.80			
F-13-22	11	2.0	33	5	<0.5	71	4.40			
F-17-6	13	9	7	13	<0.5	62	0.60			
F-14-12	92	0.3	161	9	<0.5	187	1.45			
-13	47	0.2	57	5	<0.5					
86-150	53	1.0	166	5	<0.5					
F 6/7	13	4.0	54	5	<0.5	13	< 0.10			
E 6/7	9	2.0	17	5	<0.5	184	< 0.10			
D 6/7	147	1.0	76	6	<0.5		< 0.10			
C 6/7	11	0.5	116	5	<0.5	13	ND			
92-27	98	1.0	67	5	0.8					
E 10/7	19	6	66	5	<0.5	11	< 0.10			
F 10/7	22	0.5	83	5	<0.5	10				
132-86	13	0.3	20	5	<0.5	19	3.35			
-194	59	2.0	64	15	<0.5	50	0.35			
-215	13	3.0	20	5	<0.5	10	1.75			
128-75	23	1.0	54	27	<0.5	15	2.70			
-160	109	1.0	38	5	<0.5	14	1.00			
-225	131	0.3	59	5	<0.5	18	0.45			
130-279	30	1.0	45	8	<0.5	14	3.75			
-292	50	2.0	32	5	<0.5	155	1.00			
B 6/7/8	20	1.0	231	5	<0.5	14	< 0.10			
A 6/7/8	30	2.0	71	5	0.5	59	< 0.10			
95-499	1809	2.0	39	5	3.2	15	0.30			
145-57							0.1			
209-92	993	2.0	55	5	<0.5		3.0			
-148	14	4.0	18	8	0.5	15	3.80			
-172	41	0.3	55	5	<0.5	18	1.30			
208-198	91	2.0	27	5	<0.5		0.5			
-273	97	1.0	30	5	<0.5	13	0.30			
-343	81	3.0	20	5	<0.5		0.50			
-437	64	3.0	39	5	<0.5	9	1.50			
Inset										
144-110	2845	3.0	40	5	<0.5	59	0.60			
-201	857	5	74	5	<0.5	25	1.90			
-208	1489	8	113	9	<0.5	50	2.40			
143-118	3714	6	57	8	<0.5	25	0.45			
-191	1082	45	45	5	<0.5	15	0.10			
-262	2133	1.0	57	23	<0.5	41	0.75			
17-74	704	15	94	5	<0.5	41	1.00			
150-125	508	10	50	5	0.5	14	0.10	<0.2	45	ND
-150	142	4.0	58	8	<0.5	50	0.10			
149-378	699	8	87	8	<0.5	12	0.10			
148-380	1500	8	75	5	0.5	15	0.50			
67-127	211	1.0	114	5	<0.5					

TABLE 4. (cont'd)

Sample Number	Cu ppm	Mo ppm	Zn ppm	Pb ppm	Ag ppm	Hg ppb	S %	Te ppm	Au ppb	Se ppm
-348	3714	6	83	8	< 0.5	20	0.40			
157-398	282	0.3	148	5	0.5	8	<0.10			
72-187	287	1.0	63	5	< 0.5	17	<0.10			
54-133	3914	2.5	61	8	0.5	68	1.75			
42-70	32	4.0	95	5	0.5	10	ND			
43-700	1082	13	76	16	< 0.5	12	<0.10			
129-220	19	1.0	36	12	< 0.5	21				
33-228	32	3.0	122	6	< 0.5	15	0.15			
158-704	7333	25	59	8	< 0.5	12	0.70			
161-95	482	12	65	5	< 0.5	12	<0.10			
172-321	1064	2.0	98	5	< 0.5	16	0.10			
-472	2533	9	133	11	< 0.5	18	0.25			
160-672	4000	50	47	5	1.9	51	0.50			
-745	5538	19	68	5	< 0.5	12	0.45			
-829	1857	8	61	5	< 0.5	18	0.10			
167-225	1340	3.0	90	5	2.2	20	<0.10			
-721	2448	33	42	5	0.8	37	0.75			
162-220	156	8	94	8	< 0.5	23	<0.10			
-448	210	4.0	78	8	0.5	54	<0.10			
210-116	2133	45	89	5	0.5	42	0.40			
-241	3286	15	49	8	1.3	28	9.2			
-395	2534	5	54	5	0.5	150	4.20			
170-149	1339	3.0	83	6	<0.5	91	0.15			
-180	583	1.0	85	5	<0.5	19	<0.10			
-319	4875	3.0	100	5	0.5	41	0.45			
-621	2000	1.0	71	5	< 0.5	15	0.10			
-735	5375	1.0	52	8	2.5	50	1.20			
168-393	5531	7	64	13	< 0.5	13	0.45			
-485	6806	3.0	71	5	< 0.5	39	0.70			
171-122	676	4.0	177	11	< 0.5	11	<0.10			
-293	6333	1.0	61	8	0.5	20	1.90			
180-833	1508	8	42	5	0.5	14	0.90			
-893	494	0.3	39	8	< 0.5	11	0.75			
181-447	173	1.0	95	5	< 0.5	12	0.70			
-740	1714	4.0	65	5	< 0.5	46	0.60			
-795	599	7	46	5	< 0.5	19	0.60			
184-519	21	2.0	32	5	< 0.5		1.30			
186-368	2534	1.0	34	5	< 0.5	15	0.25			
-618	1170	3.0	32	5	< 0.5	12	0.45			
93-190	135	7	29	5	< 0.5	7	0.90			
-398	929	30	23	5	< 0.5	12	0.20			

* Sample locations are given in Figure 22.

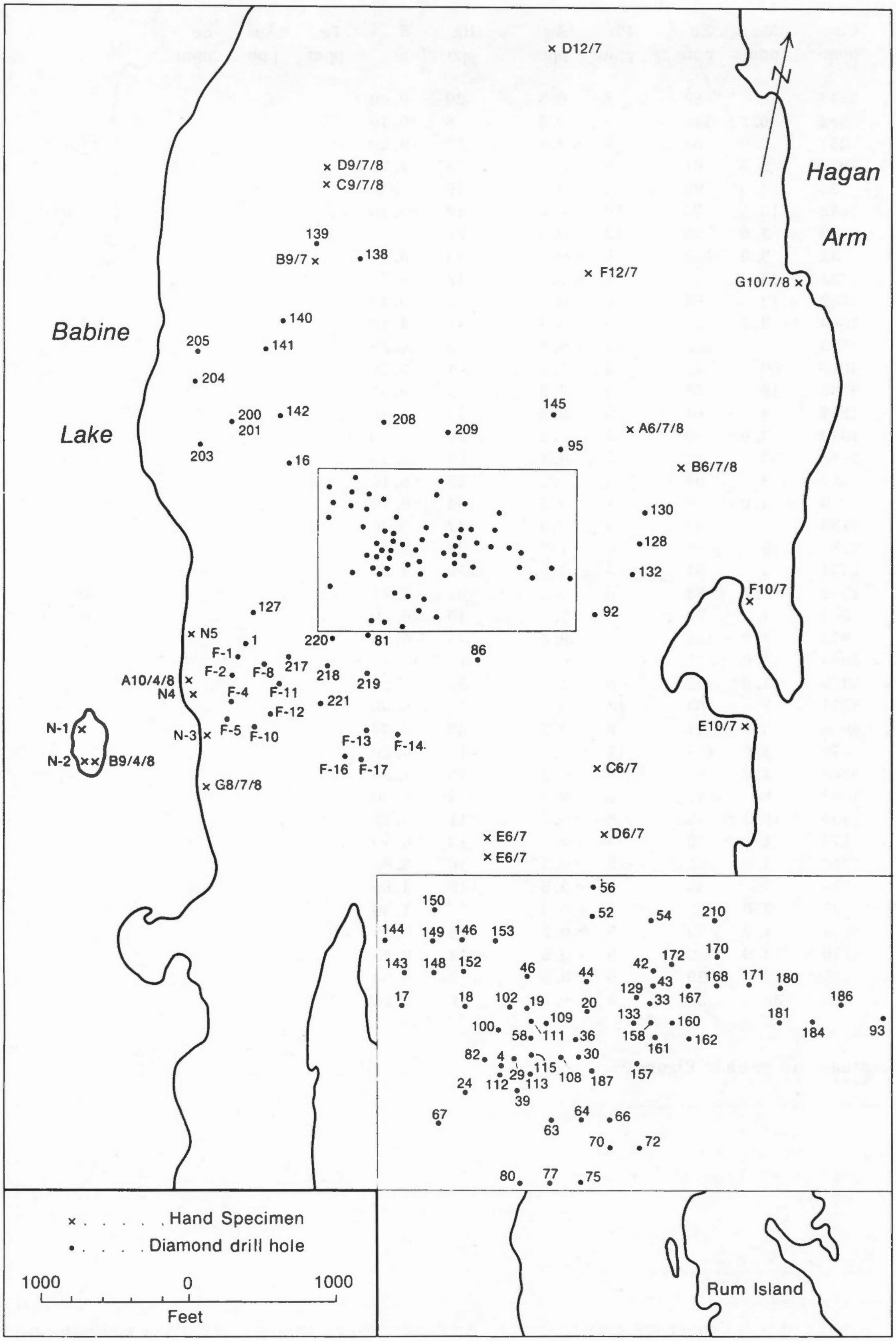

Figure 23. Location of the Bell Copper samples listed in Table 4.

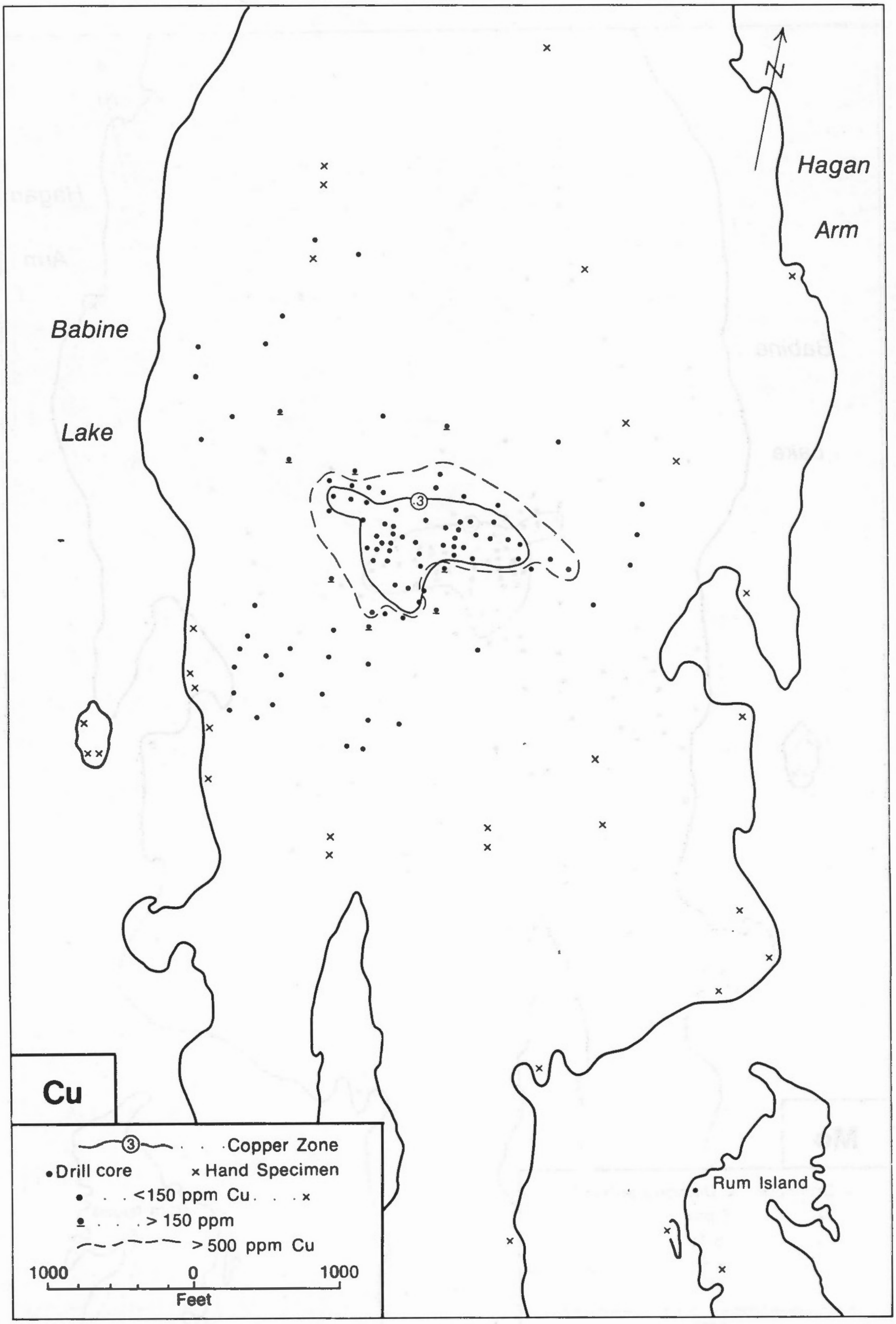

Figure 24. Cu (ppm) at Bell Copper and South Newman. Arithmetic averages were used where multiple samples from a drill hole were analyzed; this applies to Figures 23 to 28, inclusive.

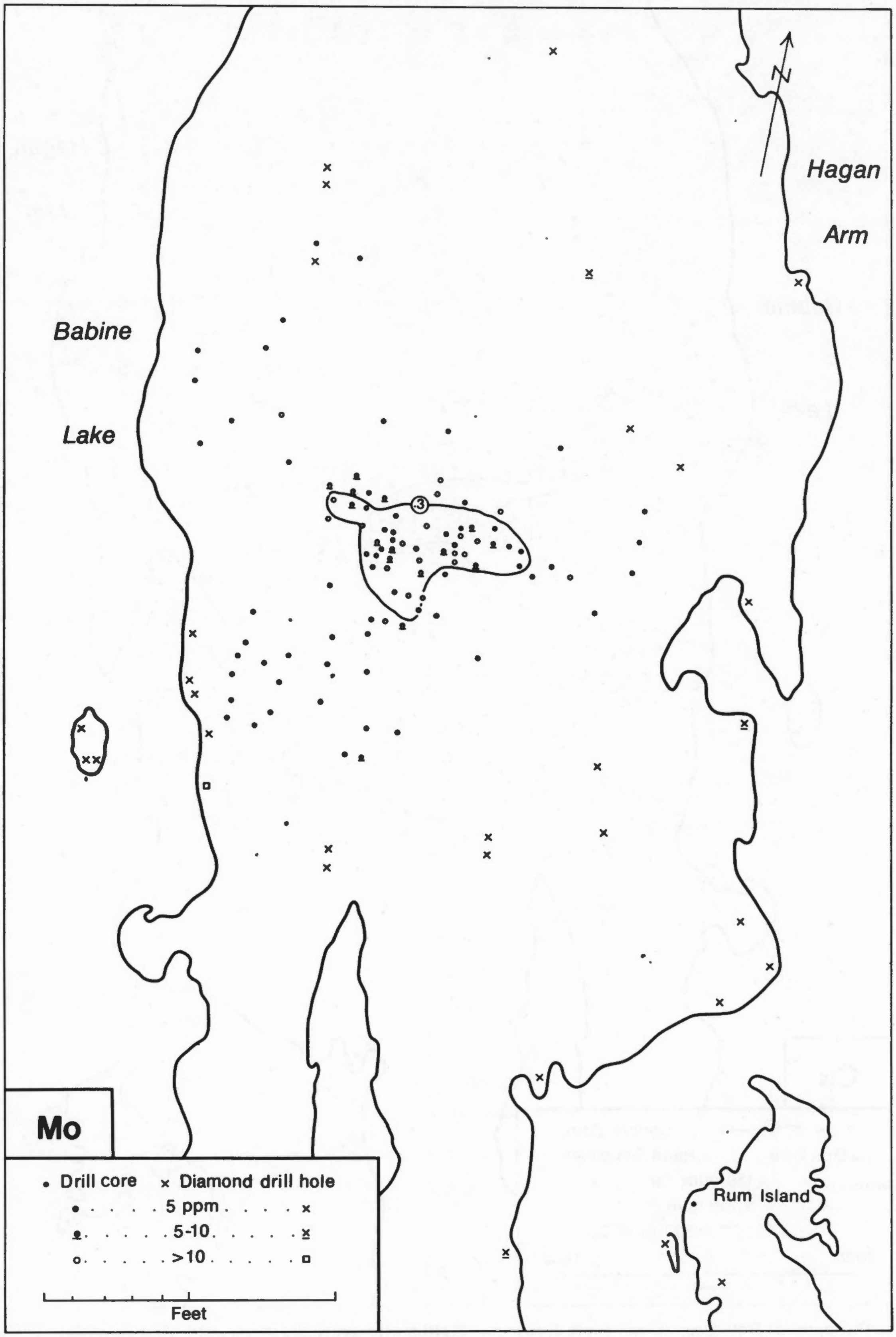

Figure 25. Mo (ppm) at Bell Copper and South Newman.

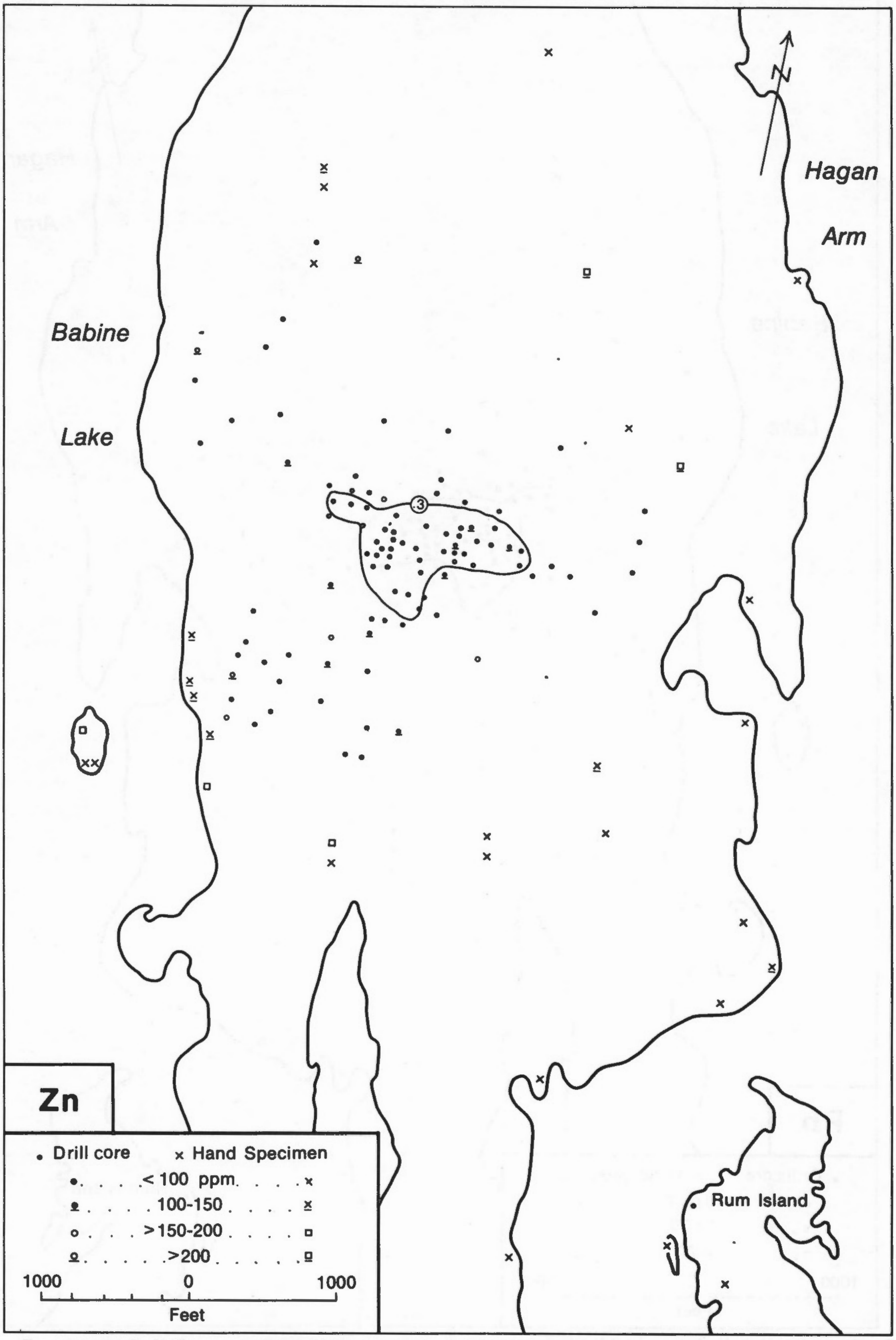

Figure 26. Zn (ppm) at Bell Copper and South Newman.

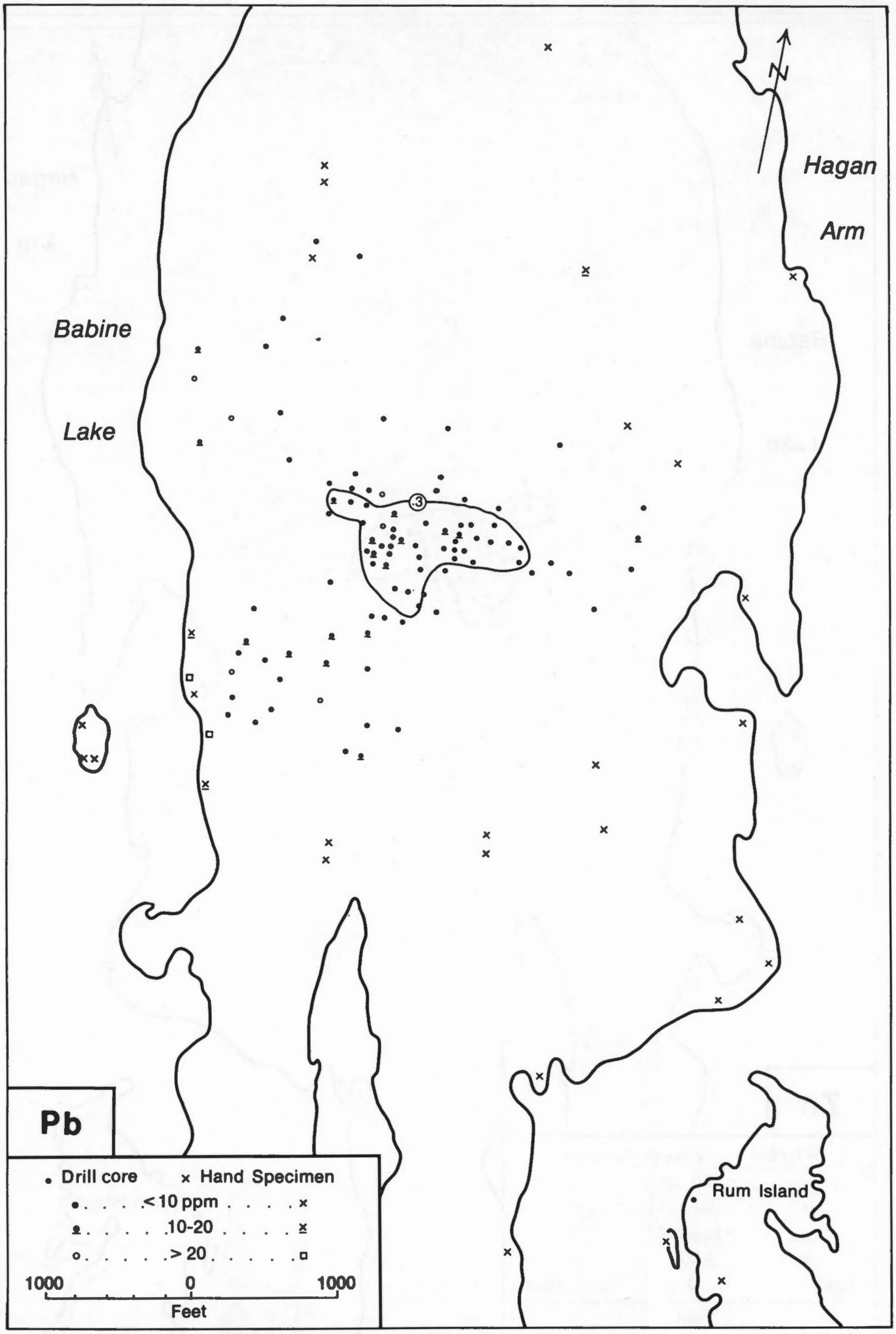

Figure 27. Pb (ppm) at Bell Copper and South Newman.

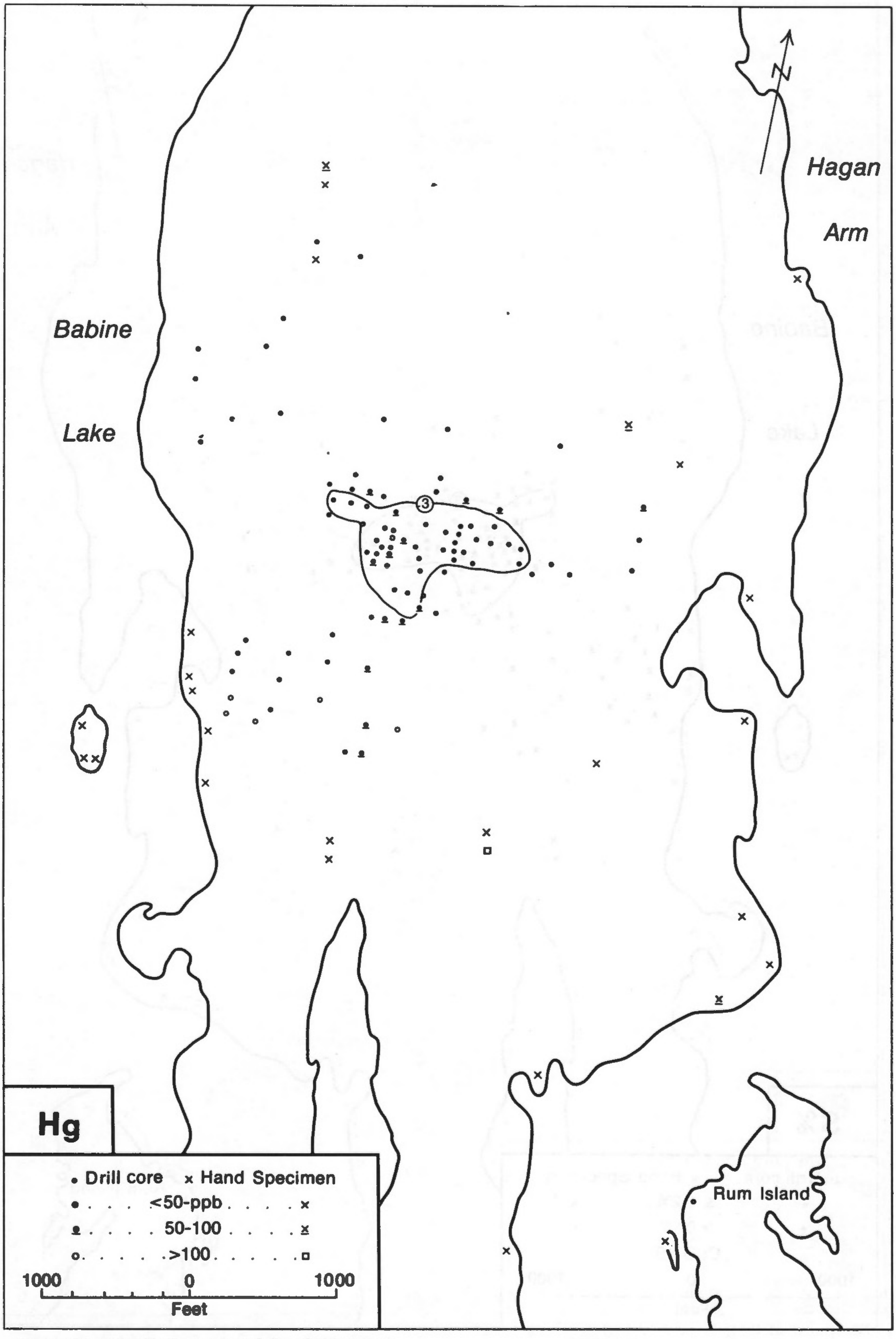

Figure 28. Hg (ppb) at Bell Copper and South Newman.

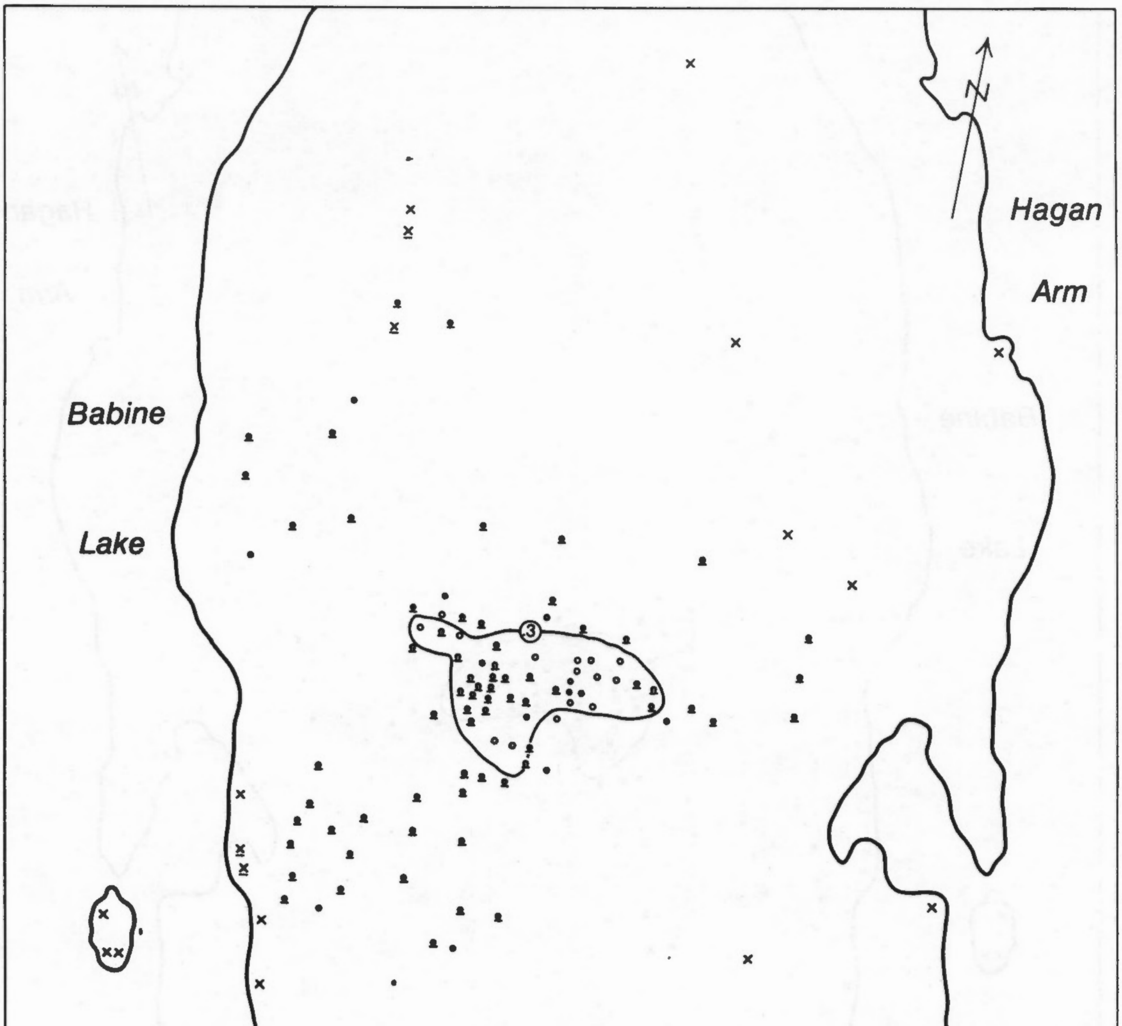

Figure 29. S (%) at Bell Copper and South Newman.

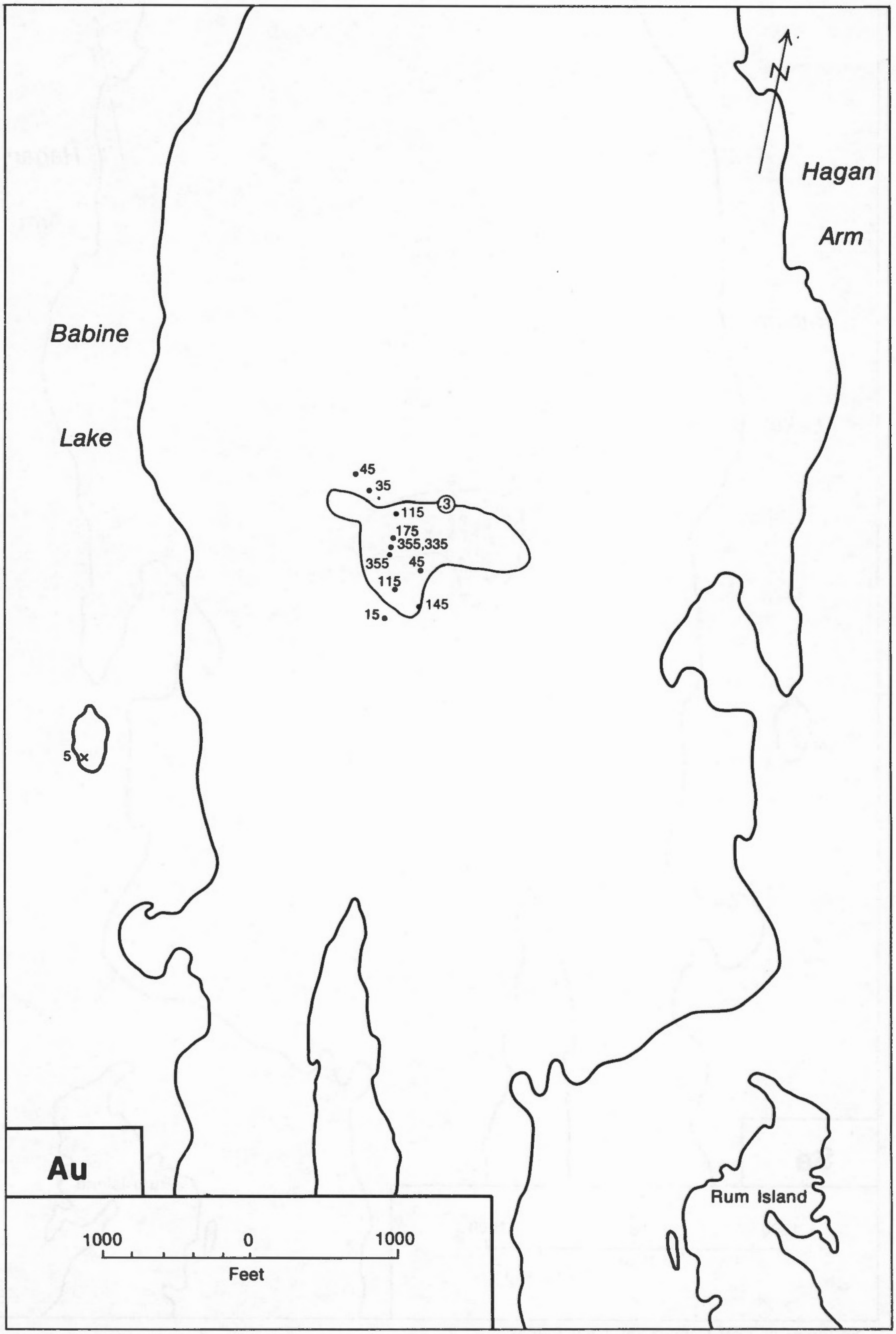

Figure 30. Au (ppb) at Bell Copper.

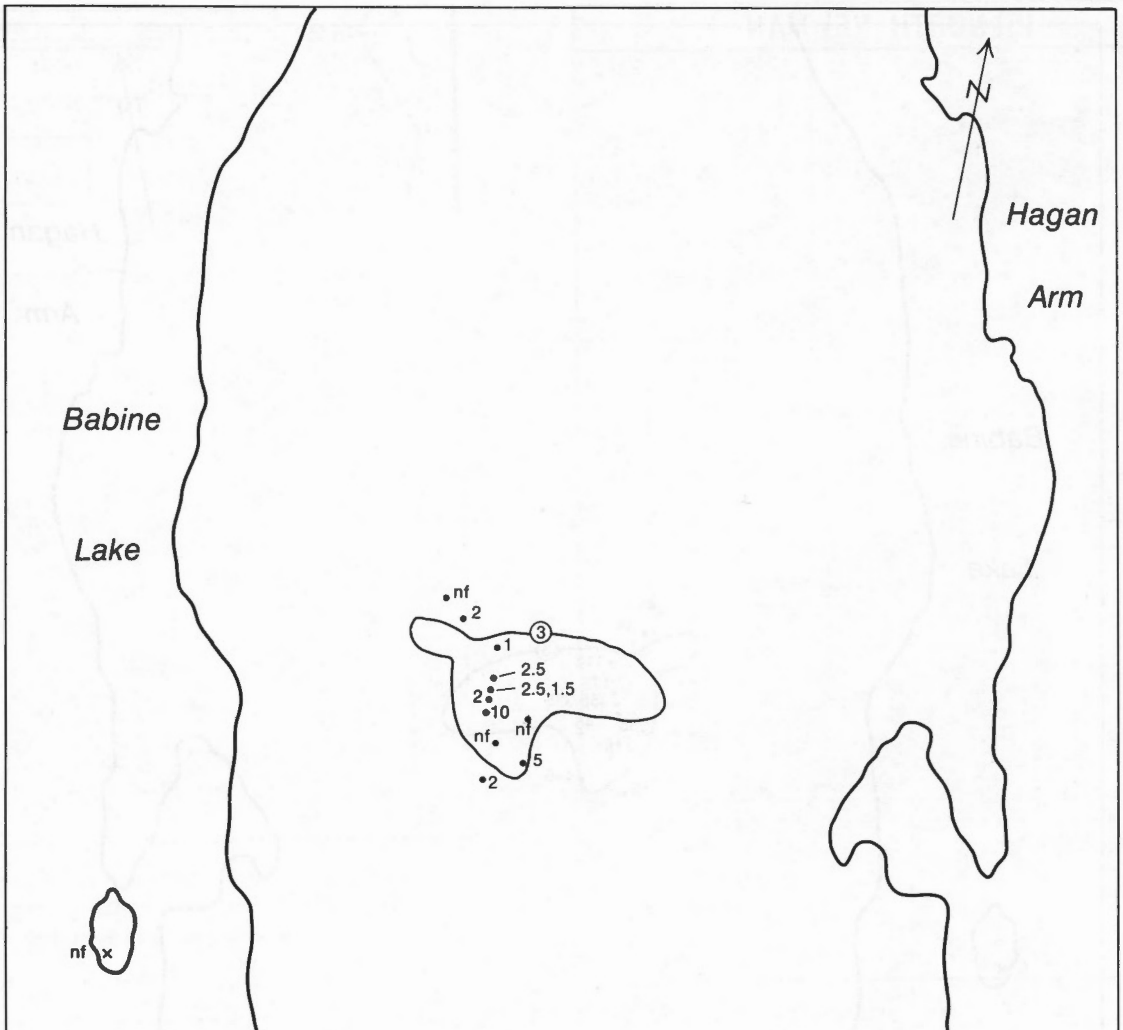

Figure 31. Se (ppm) at Bell Copper (nf = not found).

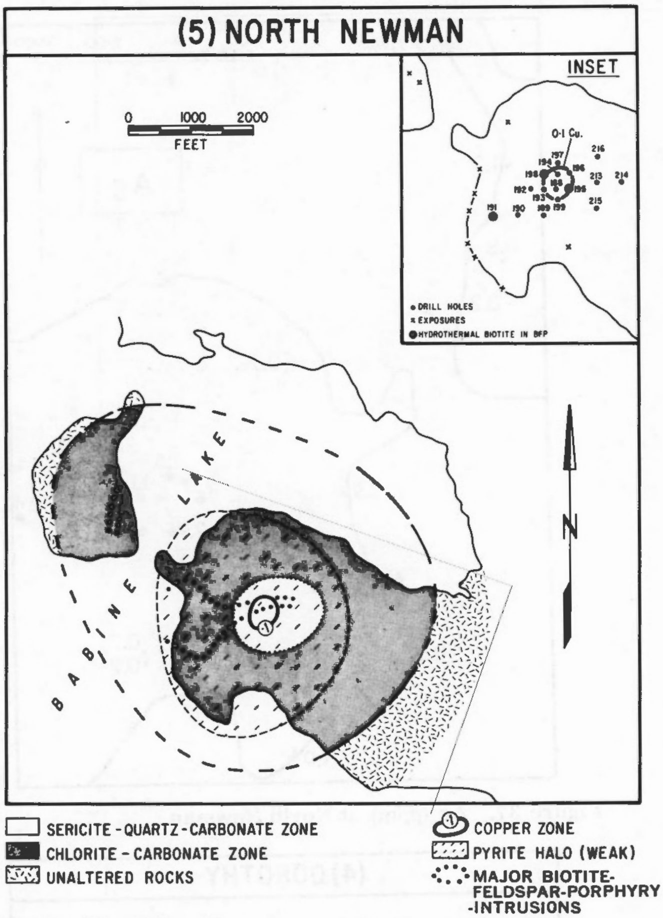

Figure 32. Alteration zones at the North Newman property.

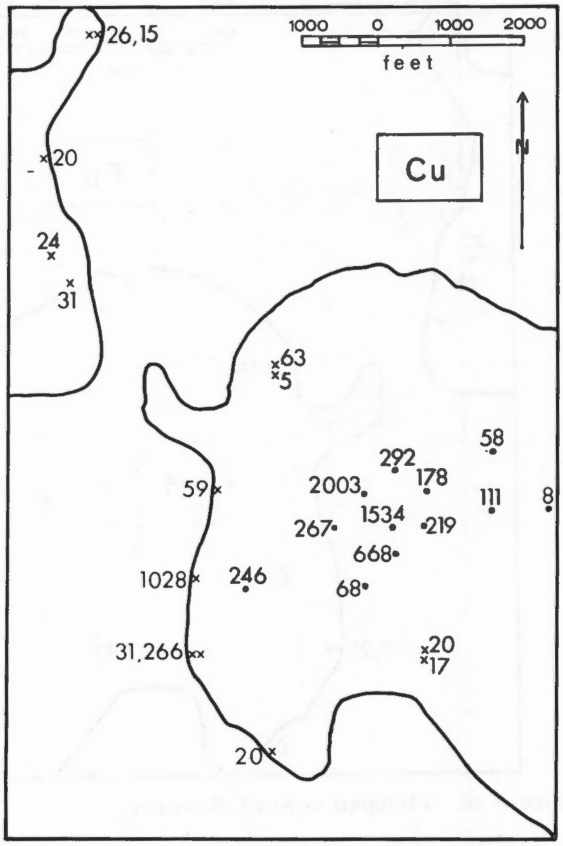

Figure 33. Cu (ppm) at North Newman. For Figures 32-38, inclusive, arithmetic averages are plotted where multiple samples from a drill hole were analyzed.

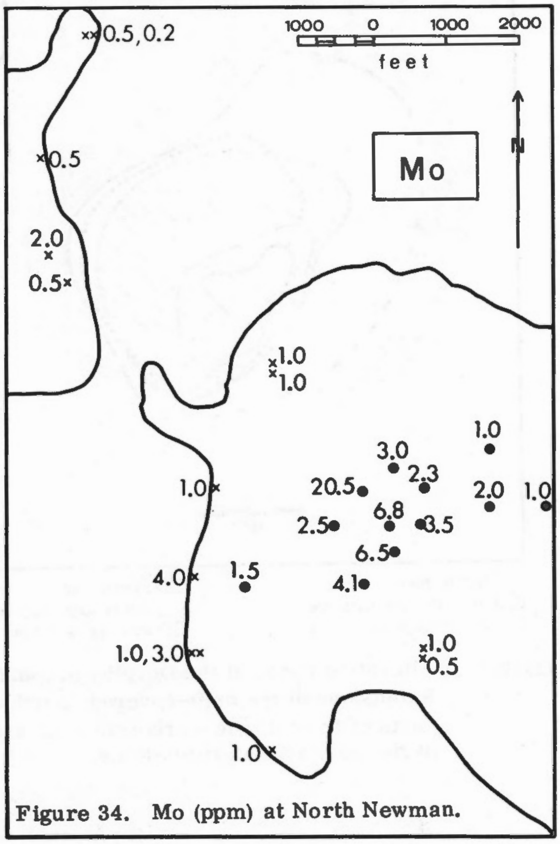

Figure 34. Mo (ppm) at North Newman.

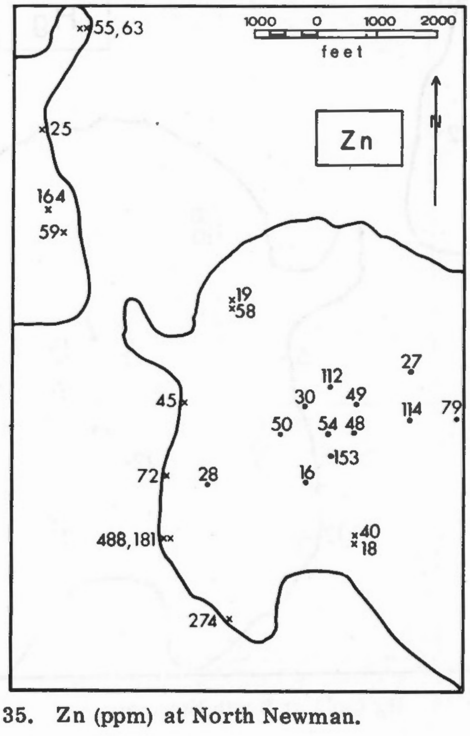

Figure 35. Zn (ppm) at North Newman.

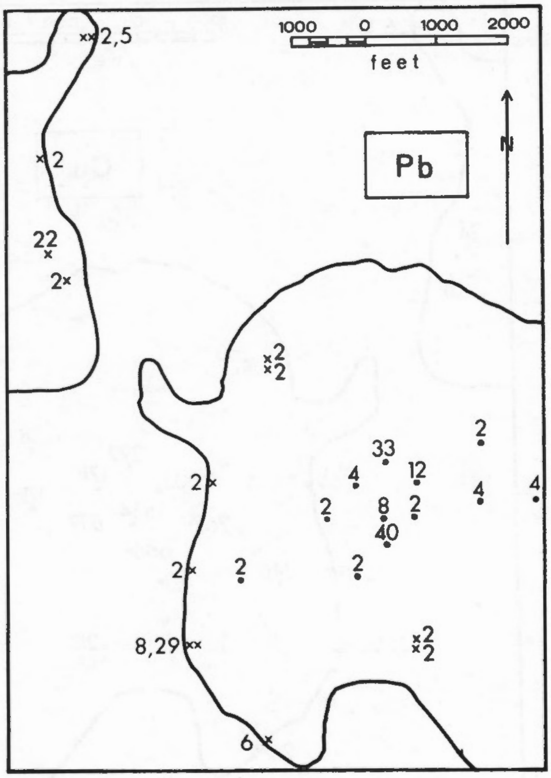

Figure 36. Pb (ppm) at North Newman.

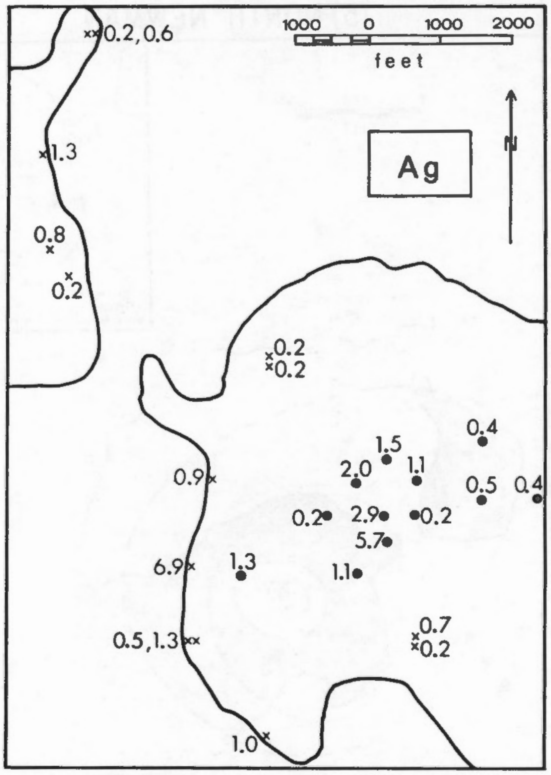

Figure 37. Ag (ppm) at North Newman.

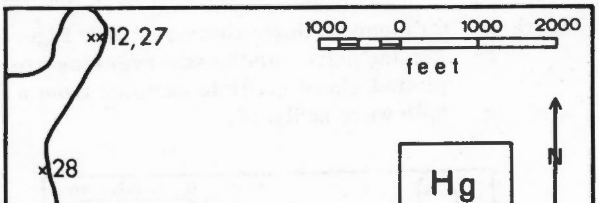

Figure 38. Hg (ppb) at North Newman.

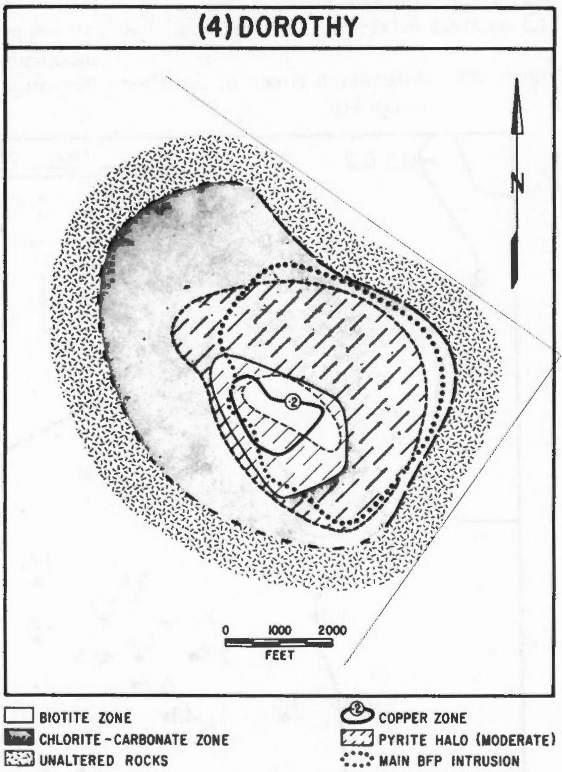

Figure 39. Alteration zones at the Dorothy property. Extensions of the drift-covered, northwestern parts of the chlorite-carbonate zone and pyrite halo are interpretations.

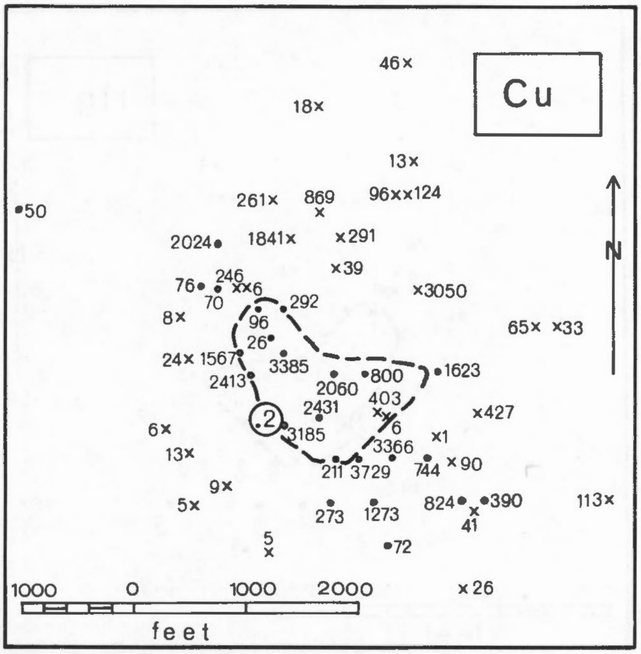

Figure 40. Cu (ppm) at the Dorothy property. For Figures 39-44, inclusive, arithmetic averages are plotted where multiple samples from a drill hole were analyzed.

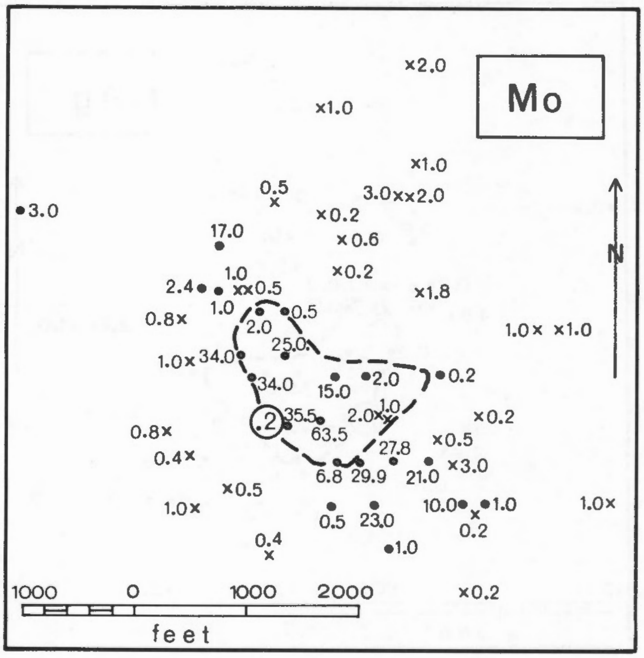

Figure 41. Mo (ppm) at Dorothy.

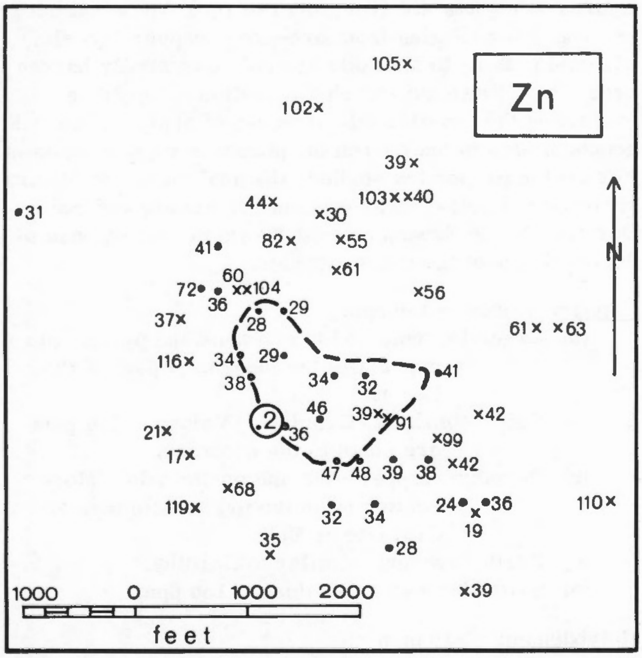

Figure 42. Zn (ppm) at Dorothy.

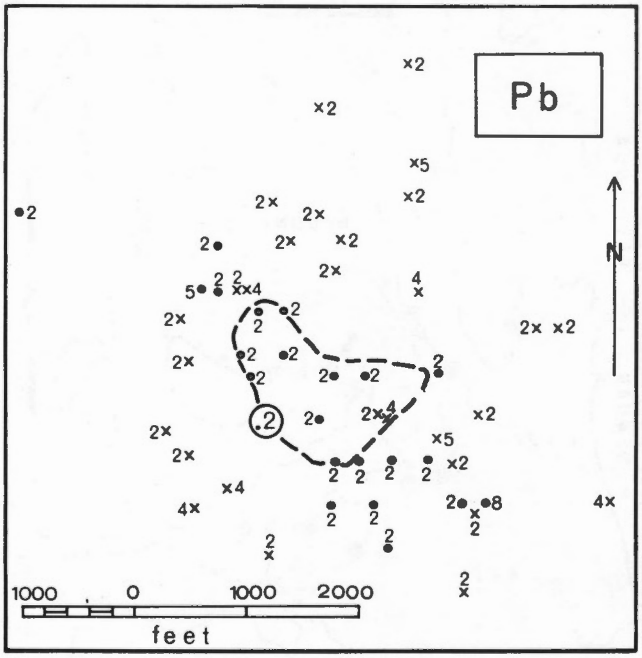

Figure 43. Pb (ppm) at Dorothy.

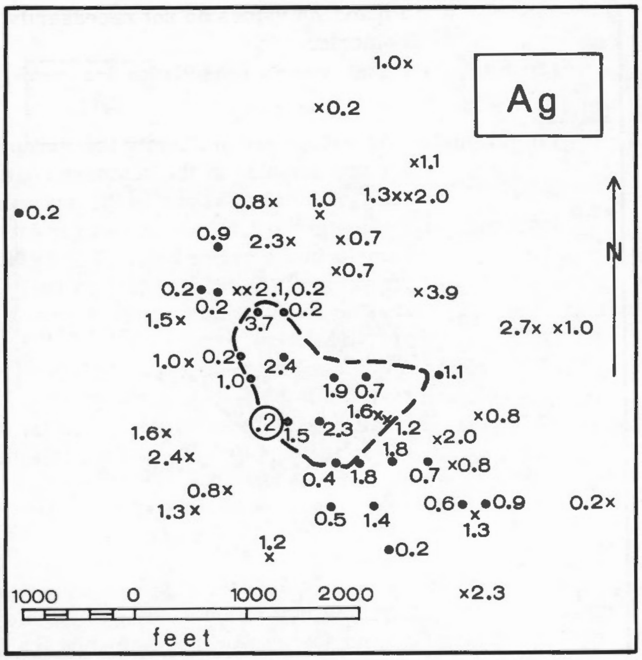

Figure 44. Ag (ppm) at Dorothy.

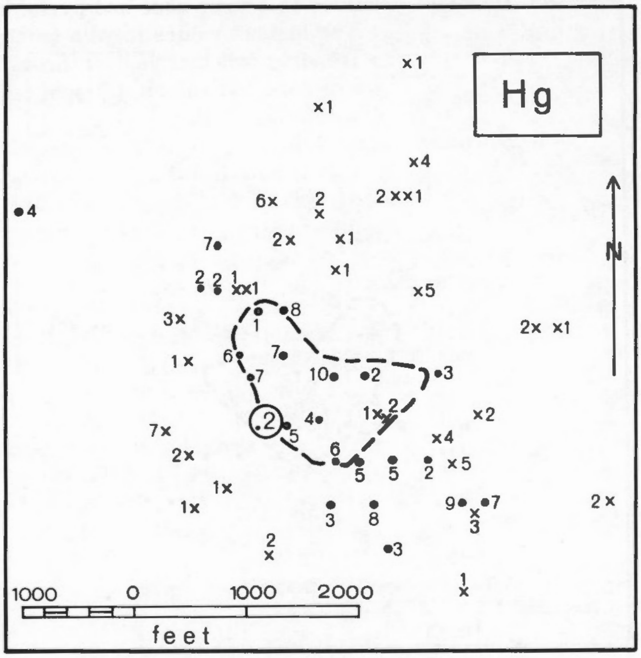

Figure 45. Hg (ppb) at Dorothy.

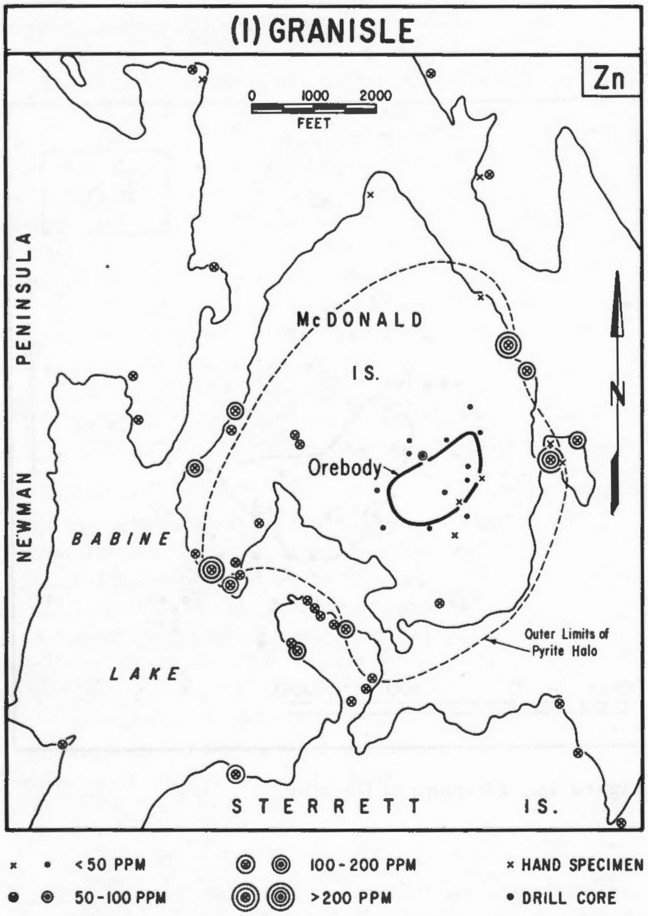

Figure 46. Zn (ppm) in Granisle rocks (see also Fig. 11). High values are concentrated at the outer limits of the pyrite halo.

SUMMARY AND DISCUSSION OF RESULTS

The trace element data shown in the preceding figures were obtained from diverse rock types that occur on properties ranging from ore-grade copper deposits (Granisle, Bell) to a weakly altered, essentially barren area (South Newman). Such a selection is useful in evaluating the possible effectiveness of applying bedrock geochemistry in the search for porphyry copper deposits. For all the properties studied, the analytical results are summarized below. The sequence (Granisle and Bell), Dorothy, North Newman, South Newman corresponds to decreasing average copper grades.

Copper: values >150 ppm

(a) Granisle: confined to ore zone and pyrite halo, especially the innermost part of the latter.
(b) Bell: similar to Granisle. Values >500 ppm are close to the ore zone.
(c) Dorothy: copper zone and pyrite halo. More scattering in the pyrite halo than at Granisle or Bell.
(d) North Newman: similar to Dorothy.
(e) South Newman: no values >150 ppm.

Molybdenum: >10 ppm

(a) Granisle: restricted to ore zone and adjacent pact of the pyrite halo. Values >5 ppm have an identical distribution.
(b) Bell: mostly in ore zone and adjacent pyrite halo, but some scattering. Values >5 ppm show a similar distribution.

(c) Dorothy: confined to copper zone and pyrite halo. The highest values form a northwest-trending belt that passes through the ore zone; all values 3 ppm fall within this belt.

(d) North Newman: values are < 10 ppm except for 1 drill hole in the 0.1% Cu zone. All values > 5 ppm also fall in this zone.

(e) South Newman: no values > 10 ppm.

Zinc:

(a) Granisle: the zinc distribution in relationship to the orebody and pyrite halo is shown in Figure 46. A distinct zinc low (< 50 ppm) coincides with the orebody whereas several anomalously high values occur in the outer part of the pyrite halo. The highest value, $> 10{,}000$ ppm Zn, is from a Zn-Pb vein.

(b) Bell: values > 50 ppm Zn are common within the ore zone. Although 11 of 12 high values (> 150 ppm) occur at substantial distances from the ore zone, segregation is not as well-defined as at Granisle.

(c) Dorothy: with one exception, values in the copper zone are low (< 50 ppm). Although the highest Zn value is only 119 ppm, most samples with > 100 ppm Zn are in the outer part of the pyrite halo.

(d) North Newman: no well-defined pattern is present, but the two highest values are near the outer edge of the pyrite halo.

(e) South Newman: one sample contains 107 ppm and all others are < 100 ppm.

Lead:

(a) Granisle: most analyses are in the 5-17 ppm range. The two highest lead anomalies (52 and 916 ppm) coincide with the two highest zinc values, but, unlike zinc, the ore zone is not depleted in lead.

(b) Bell: highest values > 20 ppm) occur in, but are not restricted to, the outer part of the pyrite halo. (The pattern is essentially the same whether 17 ppm or > 20 ppm levels are used).

(c) Dorothy: with one exception, samples in the 4-8 ppm range occur outside the copper zone; however, anomalous highs are not present. The lower background value compared to that at Granisle is considered to be an analytical distortion.

(d) North Newman: no obvious pattern is present. As is common at Bell, anomalous Pb and Zn values do not necessarily coincide.

(e) South Newman: values range from 2-8 ppm.

Silver:

(a) Granisle: Ag values are uniformly low except for two samples at the southern edge of the pyrite halo and one in the ore zone.

(b) Bell: all values are < 2.5 ppm except for one sample in the pyrite halo. The differences in silver values between Bell Copper and Granisle are attributed to analytical bias.

(c) Dorothy: the maximum is 3.9 ppm Ag. No systematic pattern is evident.

(d) North Newman: of the three highest results, two are in the copper zone and the other in the outer pyrite halo.

(e) South Newman: the range is 0.2-2.0 ppm.

Mercury:

(a) Granisle: values in the 50-100 ppb range extend from the inner part of the pyrite halo into unaltered rock. The highest value (721 ppb) is from the southwestern Zn-Pb vein.*

(b) Bell: the highest values (up to 1570 ppb) are in the ore zone and outer part of the pyrite halo.

(c) Dorothy: no pattern is present. The range (1-10 ppb) is much lower than at Granisle and Bell and is the result of an analytical bias as discussed in the Introduction. Because of this bias, comparisons may be made only among Dorothy, North Newman, and South Newman, or between Bell and Granisle.

(d) North Newman: the samples contain more mercury than those at Dorothy. (Average of 55 Dorothy samples is 3.5 ppb; average of 37 North Newman samples is 10 ppb).

(e) South Newman: the range is 1 to 50 ppb.

Sulphur:

(a) Granisle: background values average considerably less than 0.2%S so that the outer limit of the pyrite halo is well-defined. The orebody is relatively low in sulphur in comparison to the pyrite halo. X-ray fluorescence analyses for Cu and polished section studies indicate that most of the sulphur in the ore zone occurs in chalcopyrite and that in some places there is a gap between the inner edge of the pyrite halo and the 0.3% Cu zone.

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*Bornite, chalcopyrite, and a Cu concentrate from Granisle were found to contain 47, 248, and 610 ppb Hg respectively (I. Jonasson, pers. comm., August 1973).

(b) Bell: the inner part of the Bell pyrite halo is not as readily demarcated as that at Granisle, and this is also apparent from the sulphur analyses. Although pyrite commonly occurs in the Bell orebody, there is a well-defined clustering of samples near the 0.3% Cu zone in which CuO exceeds S (Fig. 29).*

Gold: the few analyses available for Bell and Granisle indicate that the gold is associated with copper rather than pyrite--relatively high values occur only within the 0.3% Cu zone. Carter (1972) reported that gold is recovered from the Granisle copper concentrates.

Selenium: despite the low values (maximum=10 ppm Se) and the few samples, the association at both Bell and Granisle seems to be as given above for gold.

Rubidium, strontium, and titanium: analyses were made only on material from Granisle. For rubidium, the volcanics and sediments are in general low in Rb (commonly >30 ppm) relative to BFP. The association of high Rb values with BFP regardless of the alteration facies present suggests that the predominant control is Rb substitution in the plagioclase feldspars. No similarly simple pattern is applicable to the results for strontium. Titanium is fairly well correlated with rock types (volcanics are generally high and sediments low in TiO_2), but there seems also to be a slight decrease in TiO_2 in BFP in the ore zones and parts of the pyrite halo. This decrease may reflect a mobilization and segregation of titanium into magnetite veinlets.

Exploration Applications

Bedrock geochemistry as an exploration tool in the Babine Lake area is severely limited by the general lack of outcrops in critical areas, i.e., above or adjacent to the zone of copper mineralization. The addition, in this study, of data from diamond-drill holes is thus a somewhat idealized situation, but even in these circumstances it is clear that Pb, Ag, Hg, and several other elements are useless in normal exploration practice in this region. Copper and molybdenum form larger targets than the ore zones, but visual inspection for chalcopyrite and malachite is probably just as adequate for exploration purposes. There are, however, indications from the trace element data that bedrock copper anomalies associated with weak deposits are considerably scattered.

Zinc is potentially useful in that anomalous highs generally surround the copper zone and reach peak abundances at substantial distances from it. A manifestation of such anomalies is the appearance of minor sphalerite-bearing veins that characteristically occur near the outer limits of the pyrite haloes of many porphyry copper deposits.

Aside from copper itself, the element most obviously useful is sulphur. Nearly all the sulphur is attributable to pyrite, and hence anomalies are mappable by the field geologist. Not only does pyrite present a very broad target area, but field mapping alone should indicate the approximate location of the copper zone. The outer limits of hydrothermal pyritization (pyrite > background pyrite) form an enclosure within which the copper mineralization is, more or less, centrally located. Where significant copper mineralization is present, be it economic or sub-economic, pyrite percentages increase inwards and define an annulus that encloses the copper zone. Moreover, the size and intensity of pyritization in Babine area prospects is indicative of the size and grade of the copper zone; as was shown by Carson and Jambor (1974), large, strong pyrite haloes occur only in association with relatively strong copper mineralization.

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*CuO and S as determined by XRF. Note that only colorimetric values have been plotted in the figures, and that if all Cu is present in chalcopyrite, then CuO should never exceed S. The latter fact suggests that the XRF values are not absolutely accurate, but are nevertheless sufficiently precise to clearly define the trend referred to above.