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MAPPING THE REGIONAL DISTRIBUTION OF GOLD IN NEWFOUNDLAND USING LAKE SEDIMENT GEOCHEMISTRY

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ABSTRACT

The determination of the Au distribution in organic lake sediment is an effective way of establishing the metal's regional distribution in Newfoundland. Although the abundance of Au is low (over 80 percent of samples are below the effective detection limit (2 mg/t) of the direct neutron activation analytical method) and the combined sampling and analytical errors are large, the errors can be diminished by averaging the data to produce smoothed regional distribution maps. The spatial distribution of Au averaged into 7- by 7-km cells, reflects well the main Au prospects of northeastern Newfoundland, and highlights extensive areas of Au enrichment, the largest of which extends over 40 km, north from Gander Lake to Dog Bay, and is now the focus of a very intense exploration program. Several elements are associated with some of the Au showings, e.g., Cr, Cu, Ni, Sb, Sc and Se, reflecting the metal associations of the mineralization and composition of the host rocks. Although no association is universal, Sb has the closest overall relationship, and its regional distribution reflects the surface expression of extensive hydrothermal systems that locally deposited Au mineralization, suggesting that heat from major plutons was the driving mechanism for these systems. The very large size of these hydrothermal systems suggests the possibility of major Au deposits in northeastern Newfoundland.

INTRODUCTION

Mineral exploration in Newfoundland is at record levels, with 1988 expenditures in excess of $40 million, mostly in the search for gold. This exploration effort has been focused, with some success, on two main areas: southwestern Newfoundland, around the Hope Brook Mine and the Cape Ray Prospect, and on the Baie Verte Peninsula, around the former Rambler and Betts Cove mines and prospects in the vicinity of Ming's Bight. These areas represent only two of the many geological environments within the province, some of which may have similar or greater potential for economic gold deposits. To maintain the exploration momentum, the challenge is to find a way to evaluate the gold potential of all favourable geological terrains in the province, thereby providing new exploration targets. As gold deposits worldwide occur in a great variety of geological settings, to be thorough, most of the province should be assessed for its gold potential.

Regional geochemical surveys would be one obvious way to provide this overview for gold, if an effective technique could be developed and demonstrated. Regional lake sediment surveys have been completed for the province at an average sample density of 1 site per 7 km² in Newfoundland and 1 site per 13 km² in Labrador. Thus, to investigate the characteristics of gold dispersion into organic-rich lake sediment, orientation studies around several gold prospects were carried out in 1984 and 1985. These showed that the measurement of gold in organic lake sediment is an effective exploration method, at least at a fairly detailed level, with a sample density of 1 site per 2 km² (McConnell, 1985, 1987; McConnell and Davenport, *in press*).

Further studies have refined the analytical technique used, have evaluated the usefulness of several pathfinder elements, and have demonstrated that the determination of gold in archived, regional lake sediment samples, collected at an average density of 1 site per 7 km², does provide an effective technique for assessing the gold potential of the island of Newfoundland on a regional scale at a very modest cost. In addition, mapping the distributions of Au and related elements, such as Sb, permits the broad scale relationships between these elements and the regional geology to be established, thereby providing unique evidence of the regional metallogeny of Au in Newfoundland. Results are presented, which show the generalized distribution of Au and several related elements in a 30,000-km² area of northeastern Newfoundland (Figure 1). The data have been released at 1:250,000 scale as open files (Davenport and Nolan, 1987, 1988; Davenport *et al.*, 1988).

Sampling and Analytical Methods

Samples of organic-rich, lake-centre sediment (profundal sediment) were collected systematically throughout Newfoundland at an average density of 1 site per 7 km² (Davenport, 1982). The samples were partially air dried in the field, with final drying in the laboratory, in ovens, at 40°C. The dried samples were disaggregated in a mortar and pestle prior to sieving through a 180 μm (80 mesh) stainless-steel sieve, and the fine fraction used for subsequent chemical analysis. Five percent of the samples were randomly selected to be split and included blind as duplicates, to monitor analytical precision.

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement, 1984–1989

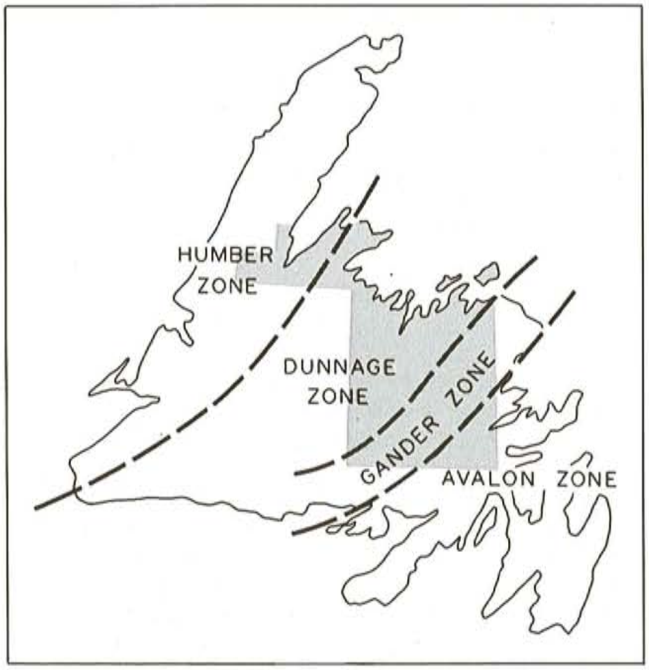


Figure 1. *Index map showing the area of northeastern Newfoundland in which the regional distribution of gold has been mapped using lake sediment geochemistry.*

Direct instrumental neutron activation analysis was used to determine Au, Sb, As, Se, W and Cr (together with Ba, Br, Ce, Cs, Eu, Hf, La, Lu, Rb, Sm, Sc, Na, Ta, Tb, Th, U, Yb and Zr, none of which are discussed in this paper). The average sample weight used was 10 g, but the actual weight varied from sample to sample, depending on the amount and density of material available. The characteristics of the results obtained by this method were discussed by Davenport (1988).

Atomic absorption spectrophotometry was used to determine Cu, Pb, Zn, Co, Ni, Ag, Fe and Mn following the digestion of 1 g of sample in a 4M HNO_3- 0.1 M HCl acid mixture. Loss-on-ignition (LOI) was determined as a measure of organic carbon content by ashing the samples during 3-hour-controlled temperature rise to 500°C. These techniques were described by Wagenbauer *et al.* (1983).

REGIONAL GEOCHEMICAL DISTRIBUTIONS

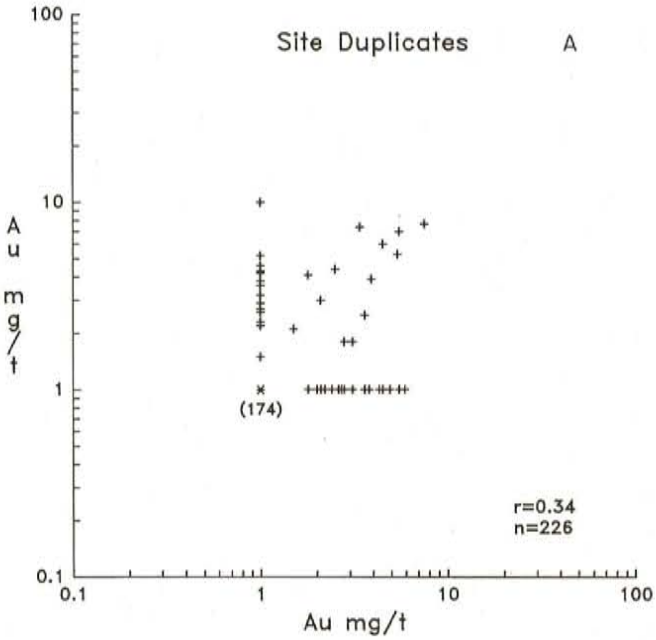
Enhancement of Regional Geochemical Variation

Gold in almost all geological materials, and at most scales, is characterized by low abundances, but a high proportion of the observed variation is due to sampling and analytical noise. The sampling noise is inherent for most media because of the nugget effect, i.e., the occurrence of gold as a major constituent of a very minor phase. Analytical precision can be improved by adopting more precise (and costly) analytical techniques, and sampling errors can be diminished by careful sample preparation and the use of large sample weights for analysis (also costly) but there are economic limits as to how far these steps can be taken.

The results discussed here are from archived samples where only a limited amount of sample material is available (generally about 10 g), and sample preparation had already been carried out. Fortunately, in organic-rich lake sediment gold has a relatively minor sampling variance when compared with many other media, but nonetheless its distribution in these lake sediments is much noisier than most of the other trace elements determined. This is illustrated in Figure 2 where replicate values for Au and Sb in site duplicates from northeastern Newfoundland are shown. Whereas Sb reproduces well ($r = 0.86$), Au does not ($r = 0.34$), at least not below about 5 mg/t. An analysis of variance to compare between site to within site variance (Garrett, 1973) reveals as expected that most of the variance of Sb occurs between sites, whereas for Au most of the variance is between site duplicates. Part of the problem with Au is that over 80 percent of the values are below the nominal analytical detection limit of 2 mg/t, and most of the rest of the data is only slightly higher (2 to 4 mg/t), where analytical precision is poor (± 100 percent).

In areas of Au enrichment, the site duplicate data for Au are much more reliable (McConnell, 1987), and the distribution of Au in lake sediment around known Au prospects suggests that anomalous Au values in lake sediment are both reproducible and geologically meaningful (McConnell, 1985, 1987; McConnell and Davenport, *in press*). On a regional scale, the Au data in lake sediment are too noisy to contour. When presented as symbol plot maps (Figure 3), however, fairly coherent patterns of anomalous Au values can be distinguished from areas of consistently low values, suggesting that there are real patterns in the data. Averaging Au values from several adjacent sites should improve the signal to noise ratio if indeed there are meaningful patterns present that are obscured by random sampling and analytical noise.

To emphasize regional geochemical patterns in Newfoundland, the geochemical data from individual lake sites have been averaged within 7- by 7-km cells (Davenport, 1982). This cell size was found to yield smoothed trace-element patterns that could be correlated well with the regional geology and the distribution of mineral deposits, and has therefore been adopted here. Because element distributions are positively skewed, geometric cell-means were calculated to diminish the effect of high outliers. The median could not be used for severely truncated data such as Au, as most cell medians were below the detection limit of 2 mg/t. The absolute value of the cell-means for Au is dependent on the value assigned to samples with a Au content below the detection limit (in this study, an abitrary value of 1 mg/t was used). The values for the cell-means for Au are not, therefore, accurate averages of actual Au abundance in lake sediment within each cell (they are probably too high), but they do reflect relative changes in average abundances from cell to cell.



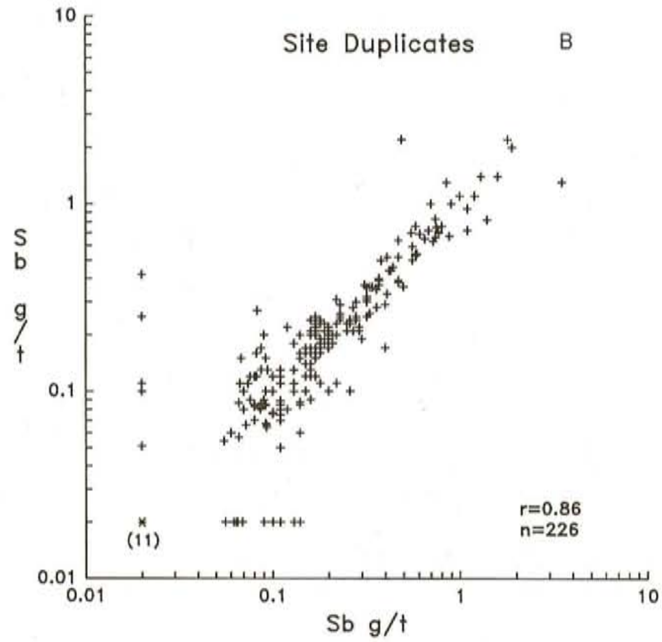


Figure 2. *Scatterplots of Au (A) and Sb (B) in site duplicate samples of lake sediment from northeastern Newfoundland.*

One indication that averaging the geochemical data has increased the geochemical signal relative to noise in the Au data is provided by the correlations between it and the other elements. Correlation matrices for the individual site data and the cell-averaged data is presented in Table 1. Correlations between Au and Sb, Cu, Ni, Cr, Se and Sc are all higher in the averaged data than in the site data, although there is little or no overall increase in the values of the correlation coefficients between elements in the cell-averaged data compared with the site data (Figure 4).

Distributions of Gold and Antimony

The spatial distributions of Au and Sb in the cell-averaged data are shown in Figures 5 and 6 in relation to the regional geology (after Williams *et al.*, 1988), and the main Au prospects in northeastern Newfoundland (from Tuach *et al.*, 1988). Contour intervals were chosen from cumulative frequency plots. For Au, there is a break in slope at the 87th percentile (1.6 mg/t), with about 5 percent of the cells having >2.0 mg/t. All of the significant Au prospects, except the Kim Lake showings (Occurrence 16 in Figures 5 and 6), coincide with Au in lake sediment values above the 69th percentile (>1.35 mg/t), and in most cases above 1.6 mg/t. The lack of response in Au in the Kim Lake area (Occurrence 13, Figures 5 and 6) is not understood—the prospects are, however, reflected by anomalous Sb levels. The most interesting feature of the regional Au distribution is the extensive area of high Au values between Gander Lake and the coast, in the northeast part of the area. This area is currently where the most active preliminary Au exploration in the province is taking place.

Antimony shows a change in background levels, increasing from west to east. Although not obvious, Sb does reflect well the known Au prospects (Occurrences 1 and 2, Figures 5 and 6) on the west side of White Bay and on the Baie Verte and Springdale peninsulas (Davenport and McConnell, 1988), but only relative to the local background. The highest Sb values are found in the eastern part of the area, in the south around the Kim Lake Au–Sb showings, northeast of Gander Lake, around the margins of the Mount Peyton gabbro–granodiorite pluton, and in a belt extending northeast from this intrusive body to Gander Bay. Most of these areas of high Sb in lake sediment are areas of active Au exploration programs, some initiated prior to the release of these data, but several subsequent to their release.

DISCUSSION AND CONCLUSION

The regional Au distribution in organic lake sediment does reflect the known Au prospects in northeastern Newfoundland, and perhaps more importantly, indicates extensive areas of Au enrichment that are only beginning to receive exploration interest. Several elements (As, Ba, Cr, Cu, Ni, Pb, Sb, Sc and Zn) are locally associated with Au in lake sediment, reflecting either the mineralization itself, or the composition of the host rocks to mineralization, with Sb being the single most generally useful pathfinder element in Newfoundland. Antimony reflects all the more significant gold prospects in northeastern Newfoundland, including the Kim Lake showing, which is not reflected by Au. In the Port aux Basques area, Sb was similarly effective in reflecting the Hope Brook and Cape Ray deposits, where again Au was not (Davenport and McConnell, 1988).

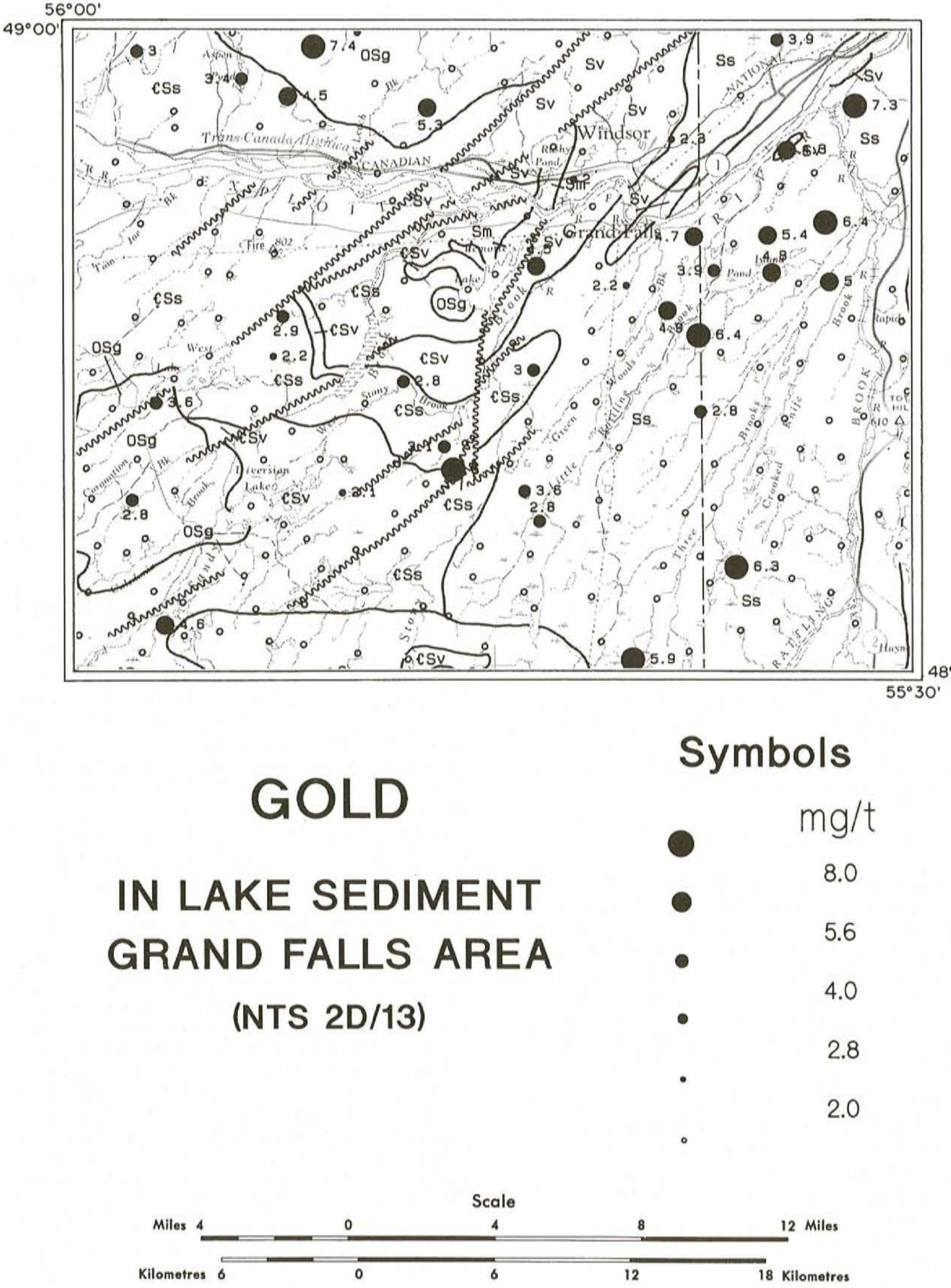


Figure 3. *Gold in lake sediment in the Grand Falls area, Newfoundland, presented as a symbol plot map.*

Table 1. Matrix of correlation coefficients for Au, Sb, As, Cu, Ni, Cr, Se, Ag, W, Ba, Sc, Pb, Mn, Fe, LOI, lake area and lake depth in individual sample sites (upper right, n=4023) and cell averaged data (lower right, n=685) in northeastern Newfoundland. Coefficients not significant at the 99 percent confidence level are shown as a dot.

SITES

	Au	Sb	As	Cu	Ni	Cr	Se	Ag	W	Ba	Sc	Pb	Mn	Fe	LOI	
Au		8	.	12	11	9	12	.	.	.	9	.	.	.	.	Au
Sb	13		52	21	40	39	7	-10	.	32	41	11	32	18	-17	Sb
As	.	57		.	37	31	9	-9	23	24	21	11	56	54	-27	As
Cu	19	18	.		59	39	22	27	-14	21	60	7	10	.	32	Cu
Ni	22	42	37	62		64	.	11	.	33	49	16	27	16	.	Ni
Cr	14	38	30	45	75		.	.	10	44	66	16	33	30	-12	Cr
Se	16	14	.	23	.	.		.	.	.	16	-8	10	9	16	Se
Ag	.	-16	.	15	.	.	.		.	11	9	16	.	.	14	Ag
W	.	.	20	-29	.	.	.	.		10	.	6	18	24	-22	W
Ba	12	23	.	27	31	38	.	13	.		56	22	44	42	-19	Ba
Sc	15	34	.	70	49	59	21	.	-18	50		6	39	35	.	Sc
Pb	.	.	.	.	19	19	.	27	.	27	.		25	20	-10	Pb
Mn	.	34	53	.	21	25	.	.	20	35	27	32		81	-27	Mn
Fe	.	.	39	.	.	18	.	.	30	35	22	27	76		-35	Fe
LOI	.	-18	-31	41	.	.	22	.	-31	.	.	.	-33	-40		LOI
	Au	Sb	As	Cu	Ni	Cr	Se	Ag	W	Ba	Sc	Pb	Mn	Fe	LOI	

CELLS

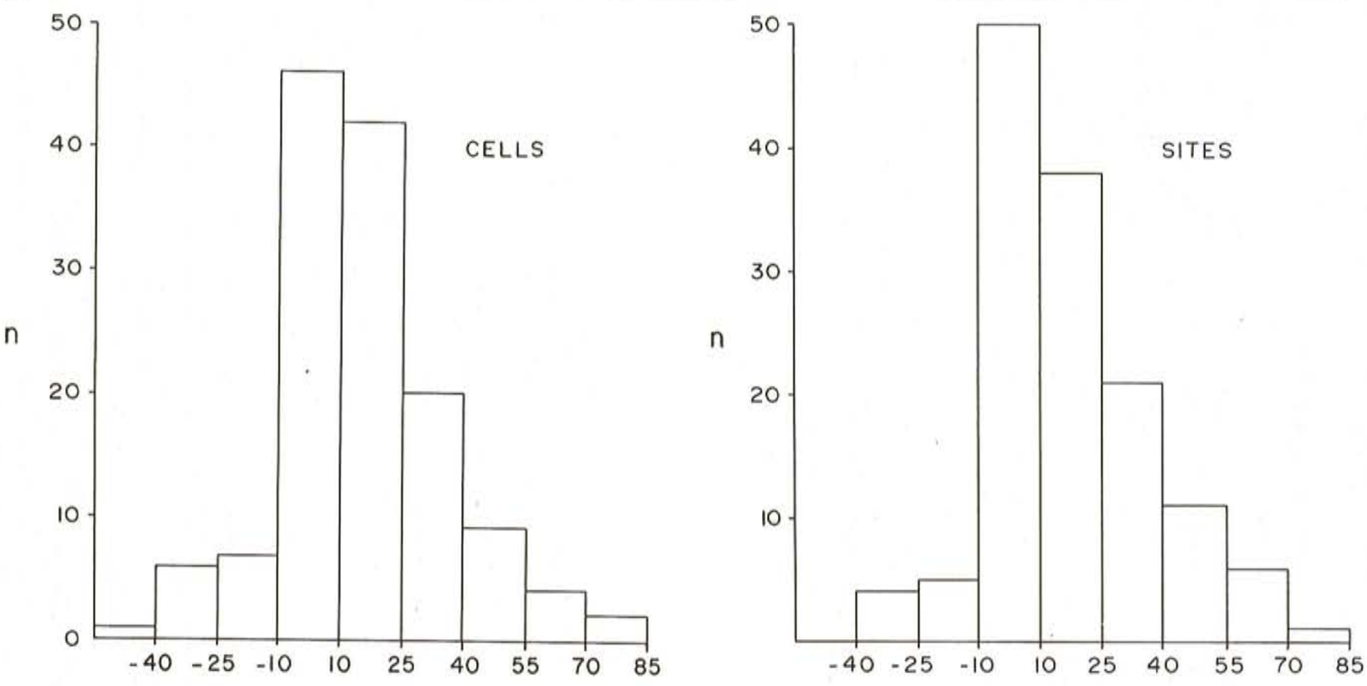


Figure 4. *Histograms of inter-element correlation coefficients in cell-averaged data and site data for lake sediments in northeastern Newfoundland.*

Antimony is distributed in an ovoid pattern surrounding the Mount Peyton gabbro–granodiorite pluton, a pattern that is extended along major, regional faults that trend northeast-southwest, away from the pluton. The pattern of Sb enrichment is developed over both marine (oceanic) sedimentary sequences as well as predominantly subaerial clastic rocks, and its form suggests that the pluton may have been the heat source that drove the hydrothermal system,

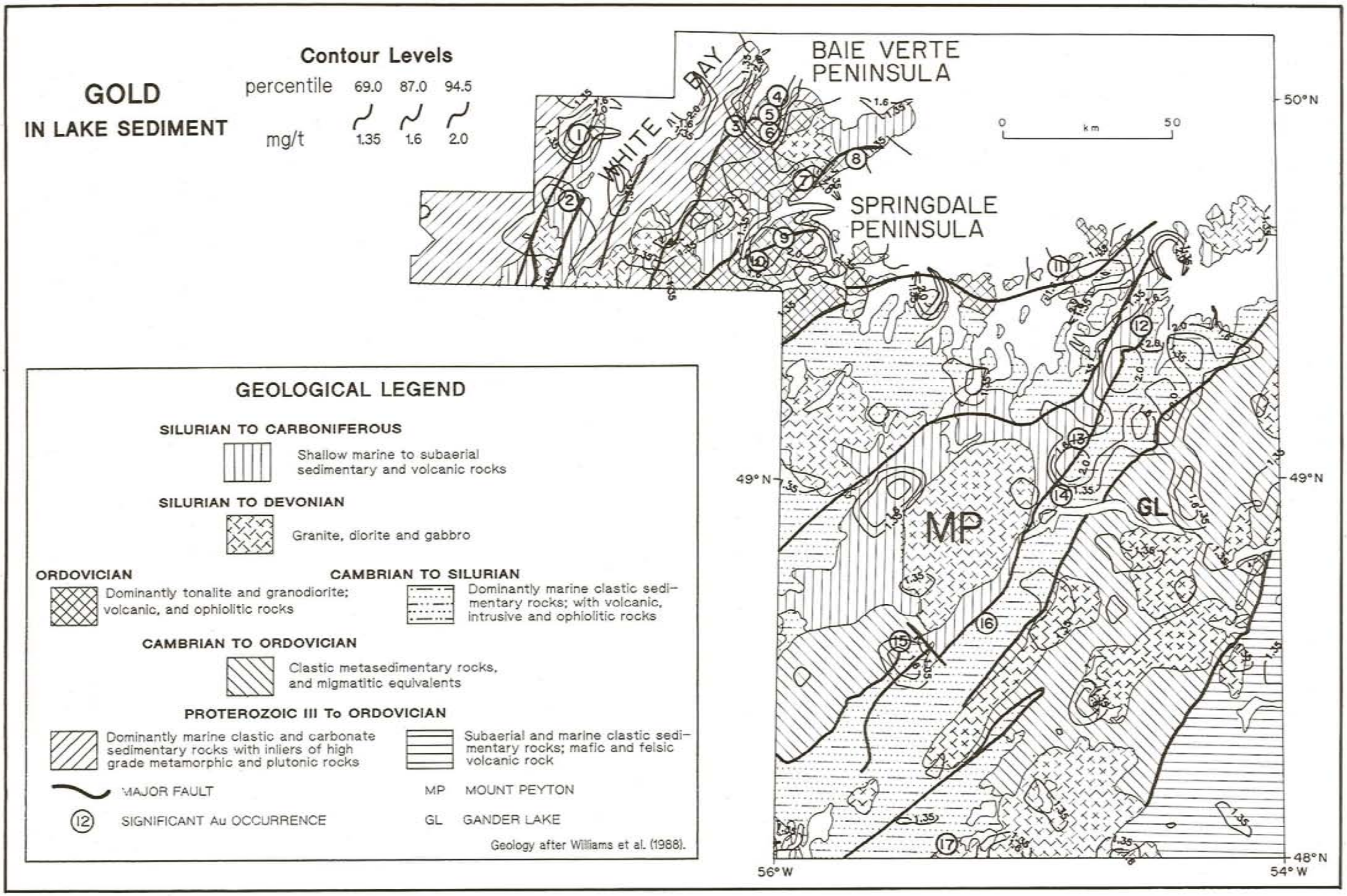


Figure 5. *Distribution of Au in organic-rich lake sediment in northeastern Newfoundland in relation to the regional geology and main Au prospects: 1) Apsy Zone; 2) Unknown Brook prospect, Browning Mine; 3) Terra Nova Mine; 4) Deer Cove Prospect; 5) Stoger Tight prospect, Goldenville Mine; 6) Rambler Mines; 7) Betts Cove Mine, Nugget Pond Prospect; 8) Tilt Cove Mine; 9) Little Bay Mine, Mine Brook prospect; 10) Randell–Jackman prospect; 11) Moretons Harbour prospects; 12) Clutha showing; 13) Blue Peter showing; 14) Mustang, Bullet and Bowater showings; 15) Great Bend prospect; 16) Aztec and Goose showings; 17) Kim Lake prospects.*

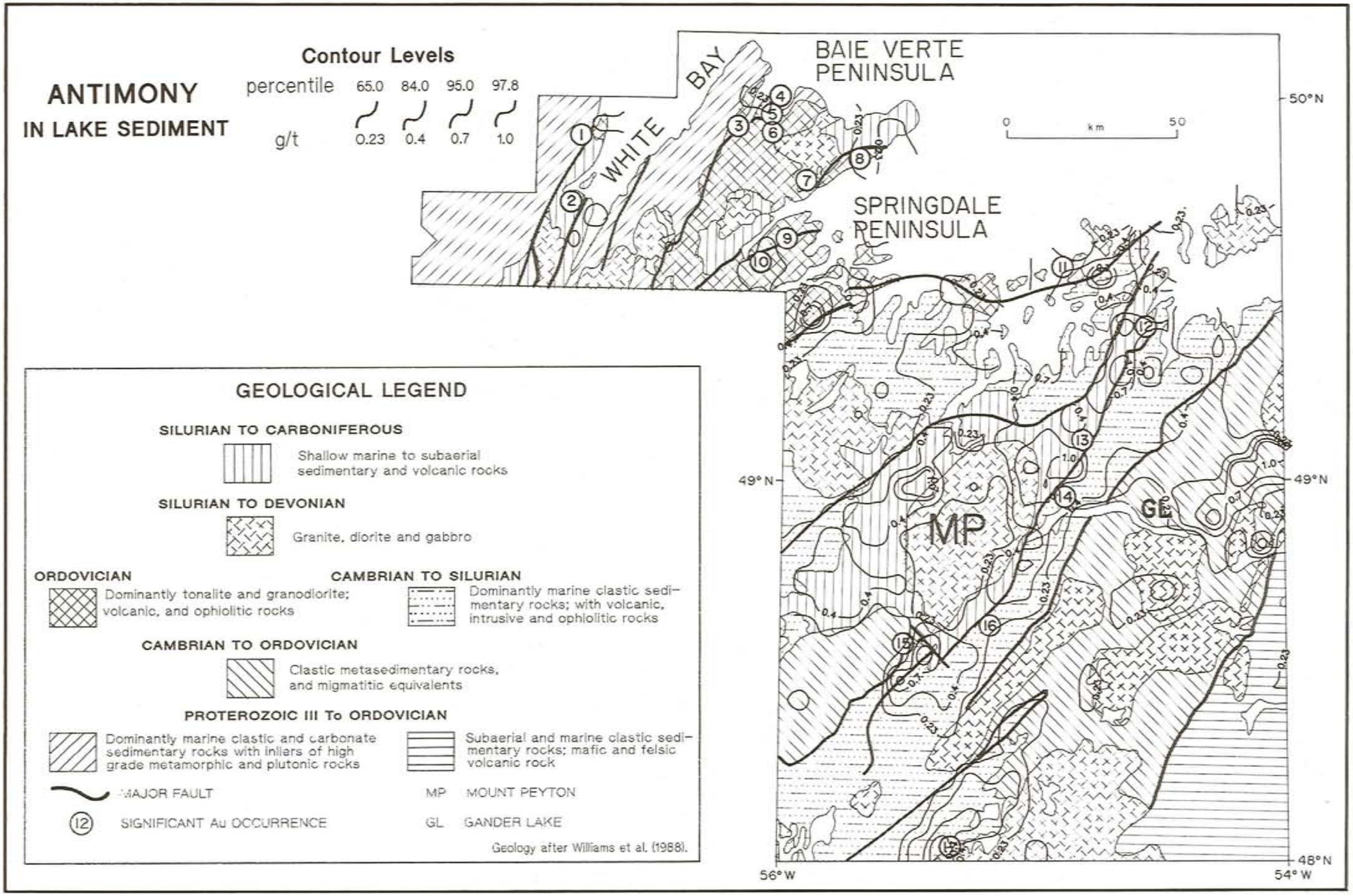


Figure 6. *Distribution of Sb in organic-rich lake sediment in northeastern Newfoundland in relation to the regional geology and main Au prospects (see Figure 5 for prospect names).*

which localized the Au mineralization. If this is so, it would represent a very major system involving very large fluid volumes affecting huge rock volumes, and which may well have produced large Au deposits.

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