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BRITISH COLUMBIA REGIONAL GEOCHEMICAL SURVEY

LARDEAU (NTS 82K)

STREAM SEDIMENT AND WATER GEOCHEMICAL DATA

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INTRODUCTION

Open File package BC RGS 31 / GSC 2356, a joint federal-provincial initiative, contains new data for gold and 25 other elements obtained by re-analyzing stream sediments collected in 1977 from the Lardeau map-sheet area (NTS 82K). Also included are the original analytical data from GSC Open File 515 published in 1979 for 13 elements in sediments, and uranium, fluoride and pH values in concomitant waters.

The original reconnaissance survey was undertaken in 1977 by the Geological Survey of Canada (GSC) in conjunction with the British Columbia Ministry of Energy, Mines and Petroleum Resources (MEMPR) under the Canada-British Columbia Uranium Reconnaissance Program. Funds for the determination of mercury were provided by Fisheries and Environment Canada. In 1990, under the MEMPR RGS Archive Program, the samples collected in 1977 were analysed by instrumental neutron activation (INAA). This initiative was funded in part by the Canada/British Columbia Mineral Development Agreement (1985-1990).

Analytical results and field observations from these regional geochemical surveys are used to build both a provincial and national geochemical database for resource assessment, mineral exploration, geological mapping and environmental studies. Sample collection, preparation and analytical methods are closely monitored to ensure consistency and conformance to national standards.

ACKNOWLEDGEMENTS

1977 STREAM SEDIMENT AND WATER SURVEY

E.H.W. Hornbrook directed GSC activities and *N.C. Carter* directed MEMPR activities.

Contracts were let to the following companies for sample collection, preparation and analysis and were managed by staff of the GSC or MEMPR.

COLLECTION : Stokes Exploration Management Ltd., Vancouver, B.C.
S.B. Ballantyne (GSC) and T.E. Kalnins (MEMPR)

PREPARATION : Golder Associates, Ottawa.
J.J. Lynch (GSC)

ANALYSIS : Chemex Laboratories Ltd., Vancouver. (Sediments / Waters)
Atomic Energy of Canada, Ltd., Ottawa. (U in Sediments)
J.J. Lynch (GSC) and W.M. Johnson (MEMPR)

1990 RGS ARCHIVE PROGRAM

The RGS Archive Program was managed by Geological Survey Branch staff of the British Columbia Ministry of Energy Mines and Petroleum Resources.

P.F. Matysek coordinated the operational activities of contract and MEMPR staff. *W. Jackaman* coordinated and prepared the production of the open-file. *S.J. Sibbick* and *J.L. Gravel* provided analysis and interpretation of the data. *S. Feulgen* provided computer processing support.

PREPARATION : Rob Phillips, Ottawa, Ont.

ANALYSIS : Becquerel Laboratories, Mississauga, Ont.

OPEN FILE FORMAT

Open File RGS 31 / GSC 2356 includes a data booklet, map booklet and a floppy diskette.

The data booklet provides details of the sample collection, preparation and analysis programs plus data listings, statistics and interpretations.

The map booklet consists of :

- 4 - 1: 100 000 scale sample location maps.
- 1 - 1: 500 000 scale sample location clear mylar overlay and map.
- 1 - 1: 500 000 scale bedrock geology clear mylar overlay and map.
- 1 - 1: 500 000 scale surficial geology map.
- 42 - 1: 500 000 scale symbol and value maps for individual elements in stream sediments and waters.
- 1 - 1: 500 000 base metal anomaly map.
- 1 - 1: 500 000 precious metal anomaly map.

A 5^{1/4}" 1.2 Mb (high density) floppy diskette containing data files in ASCII format.

SURVEY DESCRIPTION

PHYSIOGRAPHY, GEOLOGY AND MINERAL POTENTIAL

The Lardeau map sheet covers an area of approximately 15,700 square kilometres. The north-south trending Purcell trench, containing Kootenay Lake, roughly divides the region into two physiographic units: the Purcell Mountains to the east, and the Selkirk Mountains to the west (Holland, 1976).

Surficial materials (Map 3, after Fulton *et al.*, 1984) consist of widespread deposits of till and colluvium on slopes and till and glaciofluvial sediments within valleys.

In the eastern third of the Lardeau map sheet, the Rocky Mountain Trench separates mid-Proterozoic to Mesozoic miogeoclinal rocks of the Foreland Belt from the Purcell Anticlinorium, a north-plunging structure composed of Proterozoic sedimentary and carbonate rocks. To the west, merging with the Purcell Anticlinorium, is the Kootenay Arc, a north-trending arcuate structural zone developed in a succession of Hadrynian to Mesozoic age rocks. Mesozoic intrusives and high-grade metamorphic rocks of the Shuswap Complex are found to the west of the Kootenay Arc, along the western boundary of the mapsheet. The geological base map (Fig. 1 and Table A-1 in Appendix A) used for Open File RGS 31 is from Okulich and Woodsworth (1977).

Examples of mineral occurrences found within the survey area are:

- Skarn Au, Ag (Tillicum Mountain)
- Porphyry Mo (Trout Lake)
- Stratabound Pb, Zn (Duncan)
- Vein Ag, Pb, Zn (Lucky Boy)

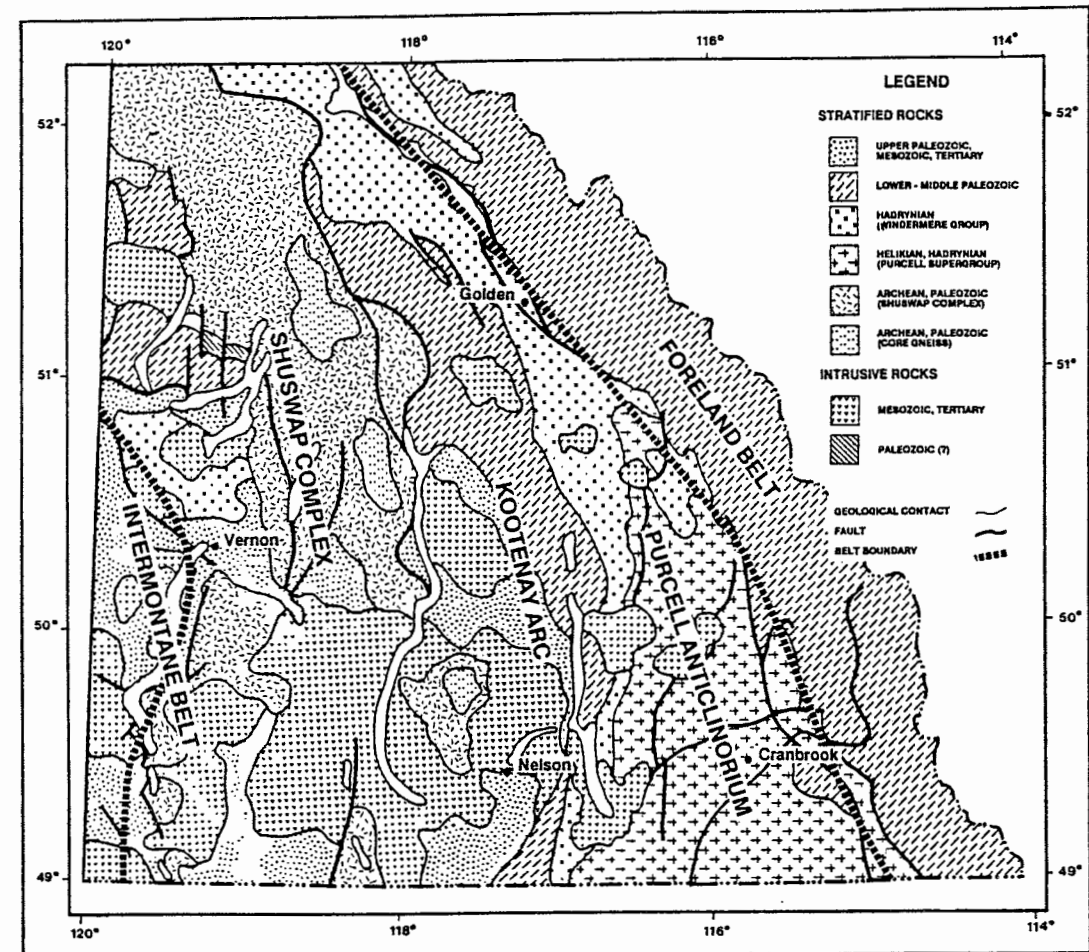


Figure 1 Generalized geology map of southeast British Columbia

SAMPLE COLLECTION - 1977

Helicopter and truck-supported sample collection was carried out during the summer of 1977 over the 15,700 square kilometre survey area. Stream sediment and water samples were systematically collected from 1224 sites for an average density of 1 site per 12.8 square kilometres. Field duplicate samples were routinely collected in each analytical block of twenty samples.

Fine grained stream sediments (< 1mm) weighing 1-2 kg were obtained from the active (subject to annual flooding) stream channel and placed in kraft bags. Unfiltered water samples were collected in 250 ml bottles, precautions were taken to exclude suspended solids when possible. Field observations regarding sample media, sample site and local terrain (Table A-2) were recorded.

SAMPLE PREPARATION - 1977

Field dried sediment samples were shipped to Golder Associates, in Ottawa, Ontario for final processing. The samples were air-dried and the -80 mesh (<177 microns) fraction was obtained and ball-milled for subsequent analyses. Quality control reference standards and blind duplicates were inserted into each analytical block of twenty sediment samples. Any -80 mesh sediment remaining after analyses was archived for future studies.

SAMPLE PREPARATION - 1990

The archived -80 mesh stream sediment pulps were retrieved for instrumental neutron activation analysis from the Geological Survey of Canada warehouse in Ottawa. New quality control reference standards were inserted into each analytical block of twenty samples. Existing analytical and field site duplicates contained within the samples sequences were checked and verified.

SAMPLE ANALYSIS - 1977

Chemex Laboratories (North Vancouver) analysed sediment samples for: copper, cobalt, iron, lead, manganese, mercury, molybdenum, nickel, silver, tin, tungsten and zinc. Uranium in stream sediments was determined by Atomic Energy of Canada (Ottawa). Water samples were analyzed for fluorine, uranium, and pH by Chemex Laboratories. Table A-3 summarizes analytical methods, specifications and reported detection limits for the various determinations. Concentrations below the reported detection limit were assigned a value equivalent to one-half of the detection limit.

SAMPLE ANALYSIS - 1990

Becquerel Laboratories (Mississauga), carried out instrumental neutron activation analysis (INAA) of archived stream sediment samples. Samples weighing 20 grams on average were epithermally irradiated for twenty minutes in a neutron flux of 10^{11} neutrons/cm²/sec. After a decay period of approximately one week, gamma-ray emissions for the elements of interest were measured using a gamma-ray spectrometer with a high resolution, coaxial germanium detector. Counting time was approximately fifteen minutes per sample. Counting data was compiled on a computer and later converted to concentrations. Numerous international reference samples were irradiated within each analytical batch. Sediments were analysed for antimony, arsenic, barium, bromine, cerium, cesium, chromium, cobalt, gold, hafnium, iron, lanthanum, lutetium, molybdenum, nickel, rubidium, samarium, scandium, sodium, tantalum, terbium, thorium, tungsten, uranium, ytterbium and zirconium. Concentrations below the reported detection limit were assigned a value equivalent to one-half of the detection limit.

RGS DATA EVALUATION

The ability to discriminate real trends related to geological and geochemical causes from those that result from spurious factors such as sampling and analytical errors is of considerable importance in the success of geochemical data interpretation. An estimate of the reproducibility (precision) allows the quantification of variation due to sampling and analysis, and is an integral part of the evaluation of geochemical data. Estimates of analytical precision and trace element variability within and between sample sites can be determined by utilizing analytical duplicate and field duplicate data.

In order to make these assessments, control reference standard materials and analytical duplicates are routinely inserted to monitor and assess precision and accuracy of analytical results. Each analytical batch of twenty sediment and water samples consists of :

- 17 - Routine samples
- 1 - Field duplicate sample collected adjacent to one of the 17 routine samples (Listed in Appendix A - Field observations and analytical data listings).
- 1 - Quality control reference standard sample containing sediment of certified element concentrations and known reproducibility.
- 1 - Analytical duplicate sample; a subsample from one of the 17 routine samples (Listed in Appendix B).

SUMMARY STATISTICS

Univariate statistics are presented in Appendix C for element concentrations within stream sediments and waters in order to establish some measure of the range of background levels and thresholds. Statistics were calculated for the total data set and on subsets (N>10) based on lithological units underlying the sample site.

Statistics determined include: minimum and maximum values; range; mode; median; arithmetic and logarithmic means, standard deviations and coefficients of variation; as well as percentile values. Depending upon the element the distribution of element values are also graphically displayed as logarithmic or arithmetic histograms. Please note, these calculations do not include the second values from analytical and field duplicate pairs.

PRECISION ESTIMATES OF SELECTED ELEMENTS

Precision estimates for selected elements were calculated using 211 analytical duplicate pairs from RGS 30, 31 and 33 (NTS 82F, 82K and 82M) using the Thompson and Howarth (1973, 1976, 1978) method. Analytical duplicate INAA data for 82K are listed in Appendix B.

Briefly, their method involves dividing 50 or more analytical duplicate pairs (x_1 , x_2) into groups with narrow concentration ranges. For each group, the median value of absolute differences between duplicate pairs ($|x_1 - x_2|$) is used as an estimation of the standard deviation (s), whereas the mean value of all the duplicate pair means $(x_1 + x_2)/2$ is used as an estimation of the average concentration. Repetition of this procedure for a successive group of concentration ranges obtains a set of corresponding mean concentration and standard deviation estimates for the entire range of data. Linear regression of the estimates provides slope and intercept values from which precision of the dataset can be calculated using the equation:

$$P_c = 200(K/c + S_o)$$

where S_o (coefficient of slope) is the standard deviation at zero concentration and K (intercept) is a constant. This linear function has been determined in many practical cases (Matysek and Sinclair, 1984) to be a satisfactory model for the expression of variation.

Precision estimates for INAA elements were calculated as follows:

- Step 1. A list of duplicate means and corresponding absolute differences were calculated.
- Step 2. The list was sorted in increasing order of concentration means.
- Step 3. The mean concentration and the median difference between pairs for the first group of 11* stream sediments were determined, respectively.
- Step 4. Step 3 was repeated for each successive group of 11 stream sediment analytical pairs ignoring any remainder less than 11*.
- Step 5. The linear regression of the median differences on the means was calculated. The resultant intercept and coefficient of the calculated line are multiplied by 1.048 and were used to estimate precision.

**Note: Groups of 9 and 13 pairs were used on occasion to improve the regression line fit.*

Precision estimates were determined for Ba, Ce, Fe, La, Rb, Sm, Sc, Th and U only. This particular suite of elements was selected on the following basis:

- Their distributions approximated a Gaussian (normal) curve
- The majority of their concentrations were well above their detection limits.

Precision estimates were not determined for elements characterized by non-Gaussian distributions. These distributions are recognized when the following conditions arise:

- Element abundances are dependent on rare grains
- Concentration levels are near or at the detection limit
- Data contains outliers

RESULTS

Precision estimates obtained from the Thompson and Howarth method are presented in Table 1. Only elements whose correlation coefficients (R-values) were significantly different from zero are listed. Precision estimates calculated by the Thompson and Howarth method for 9 different elements at different concentration levels averaged 16.8% at the 50th percentile, 16.1% at the 80th percentile and 15.6% at the 95th percentile (Table 1).

Studies tailored to the evaluation of error in stream sediment surveys such as Plant (1971), Chork (1977) and Fletcher (1981) generally concluded:

- The combined variability due to local variation and analytical error ranged from 10-25% of the total error.
- Precision ranges of 10-15% at the 95% confidence level are generally encountered and considered acceptable for laboratory variability in most exploration programmes.

Precision estimates determined for these elements are of similar magnitude to those observed from other regional geochemical surveys.

TABLE 1 Thompson and Howarth precision estimates

ELEMENT	MIN	MAX	INTER	SLOPE	R-VALUE	50TH	PREC	80TH	PREC	95TH	PREC
Barium	100	6120	15.833	0.0442	0.6058	660	14.29%	1000	12.58%	1500	11.48%
Cerium	10	1250	3.207	0.05811	0.7412	100	18.90%	170	16.13%	310	14.35%
Iron	0.2	18	0.053	0.071	0.7063	3.4	18.15%	4.6	17.30%	6.2	16.67%
Lanthanum	5	1160	1.244	0.0545	0.8309	60	15.77%	99	14.06%	180	12.87%
Rubidium	5	270	1.153	0.0668	0.6776	88	16.75%	120	16.02%	150	15.61%
Samarium	0.5	150	-0.12	0.0969	0.8973	8.7	17.42%	13.3	18.42%	22.5	19.19%
Scandium	0.6	63.1	0	0.0916	0.8229	11	19.20%	15	19.20%	21.3	19.20%
Thorium	0.5	488	0.252	0.0546	0.9113	15	14.97%	27.3	13.38%	60.4	12.32%
Uranium	0.5	452	-0.121	0.0943	0.9725	6.1	15.61%	14	17.95%	38.3	19.10%

ESTIMATION OF REGIONAL AND SAMPLE SITE ELEMENTAL CONCENTRATION VARIABILITY

INTRODUCTION

Variations in element concentrations of stream sediments are due to regional variation (ie. diverse lithologies, mineralization and influences of the surficial environment) and sample site variation (ie. sampling and analytical variability). Regional and sample site variance components were determined for 15 elements from 72 field duplicate pairs. Selected elements include Ag, Cu, Zn, Pb, Co, Ni, Fe, Mn (1977 data) and Au, As, Sb, Cr, Mo, W, U (1990 data).

METHOD

The estimate of variance components was based on field duplicate data. Since the RGS samples are derived from a variety of lithologies and drainages containing mineral occurrences, log transformation of the data was necessary to approximate normal distributions.

- 1) Calculate VC_{site} by taking the sum of the squared differences between samples in field duplicate pairs and average the sum over the number of pairs (Mean Sum of Squares).

$$(1) VC_{site} = MSQ_{site} = \sum (x_i - \mu_i)^2 / n$$

where
 x_i = 1st and 2nd samples of each field duplicate pair
 μ_i = mean for each duplicate pair
 n = number of duplicate pairs

- 2) Calculate the total variance (VC_{total}) by taking the sum of squared differences for all samples in field duplicate pairs and dividing by the number of samples less 1.

$$(2) VC_{total} = MSQ_{total} = \sum (x_j - \mu_j)^2 / N-1$$

where
 x_j = all samples in field duplicate pairs
 μ_j = mean of all samples in field duplicate pairs
 $N-1$ = number of samples in field duplicate pairs less 1

- 3) Calculate $VC_{regional}$ by subtracting VC_{site} from VC_{total} .

$$(3) VC_{regional} = VC_{total} - VC_{site}$$

4) Equate variance components to percentages by dividing each component (regional and site) by the total and multiply by 100.

$$(4) VC_{\text{regional}} = \frac{VC_{\text{regional}}}{VC_{\text{total}}} * 100$$

To determine if geochemical trends reflect actual regional variation or are an artifact of sample site variation, F ratios can be calculated between MSQ_{regional} and MSQ_{site} ;

$$F \text{ Ratio}(v1,v3) = \frac{MSQ_{\text{regional}}}{MSQ_{\text{site}}}$$

where $MSQ_{\text{regional}} = \sum \{ (x_i - \mu_i)^2 - (x_j - \mu_j)^2 \} / n - 1$

$$v1 = n - 1 = \text{degrees of freedom for } MSQ_{\text{regional}}$$

$$v3 = n = \text{degrees of freedom for } MSQ_{\text{site}}$$

Calculated F ratios greater than the critical F ratio (obtained from F tables at the 95% confidence level) indicate that regional variation exceeds sample site variation. Under these circumstances observed regional geochemical trends are not considered to be artefacts of sampling or analytical methods.

RESULTS

Figure 2a presents site and regional variation components . Some general similarities are noted:

- In general, most of the selected elements show low sample site variability (<10%). As a result a high measure of confidence is given to observed elemental regional trends.
- Elements displaying high sample site variance components (>10%) suffer from either nugget effect (Au, W) or characterized by numerous near detection limit values (Ag). Observed geochemical trends for these elements should be treated with less confidence.

Figure 2b presents F ratios for the selected elements, F_{crit} at the 95% confidence limit for given degrees of freedom is 1.50. All elements surpass this value.

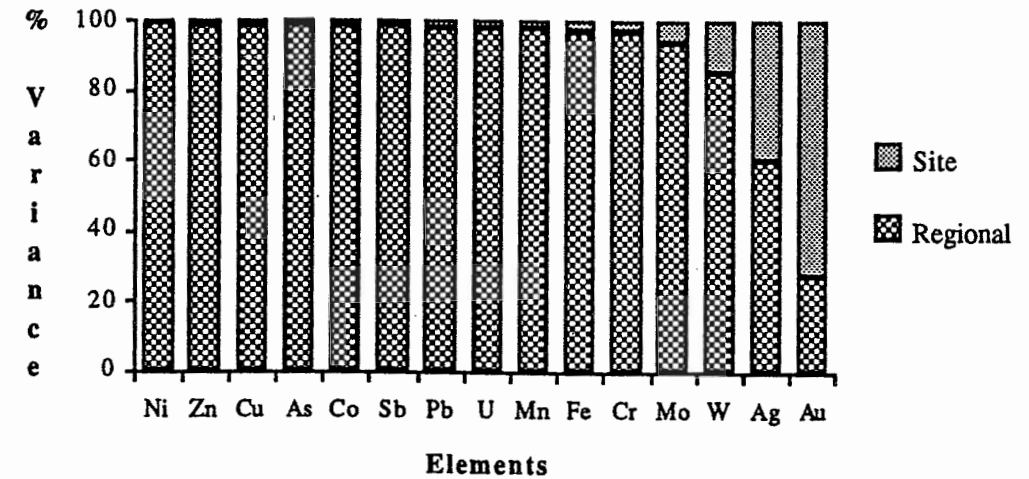


Figure 2a Variance Components for selected elements

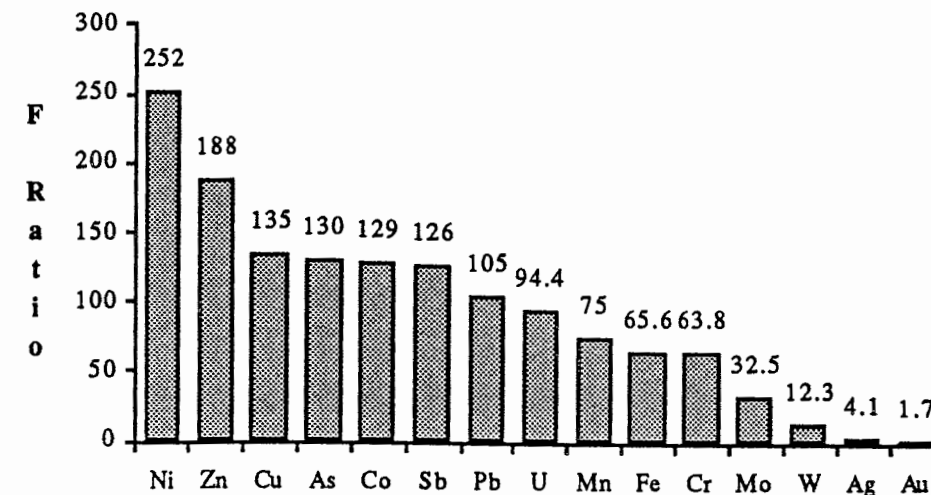


Figure 2b F ratios for selected elements

COMPARISON OF INAA VERSUS AAS TECHNIQUES

Several elements (Co, Fe, Mo and Ni) were determined by both atomic absorption spectroscopy (AAS) and by instrumental neutron activation analysis (INAA). Concentration variations observed between original (AAS) and subsequent (INAA) results are due largely to the analytical methods. AAS requires dissolution of the sample with acids prior to analysis. Aqua regia, a combination of hydrochloric and nitric acids, was primarily used to dissolve RGS sediment samples. Gold and sulphide minerals are dissolved, whereas silicates and some oxides (*ie.* magnetite) are only partially digested. Conversely, INAA does not require sample digestion prior to analysis. Concentrations determined by INAA generally represent the *total* content of that element in the sample. Due to this difference between methods, INAA generally reports slightly higher concentrations than *aqua regia* - AAS.

Figures 3a and 3b represent a comparison of the two techniques for iron and nickel, using data from RGS 30 (NTS 82F). In both cases, INAA gives higher results. A strong correlation is noted for nickel ($r = .958$); slightly higher INAA results are due to the presence of minute quantities of nickel within the lattices of silicates (*ie.* feldspars). Iron, however, demonstrates substantial concentration differences between analytical methods and a weaker correlation ($r = .646$), likely due to the presence of variable amounts of magnetite and hematite commonly found in stream sediment samples.

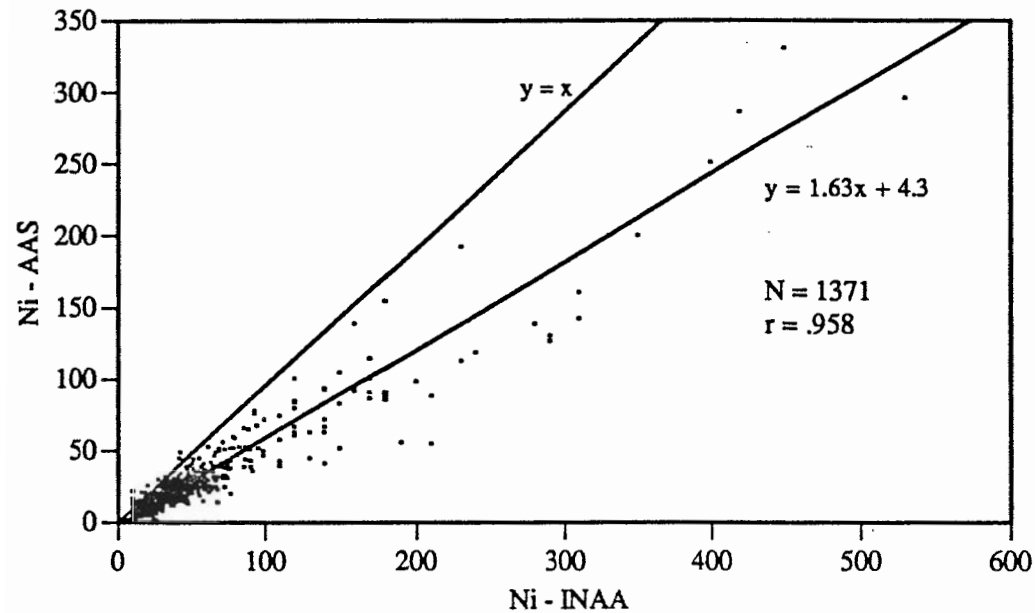


Figure 3a Scatterplot comparing INAA versus AAS results for Ni

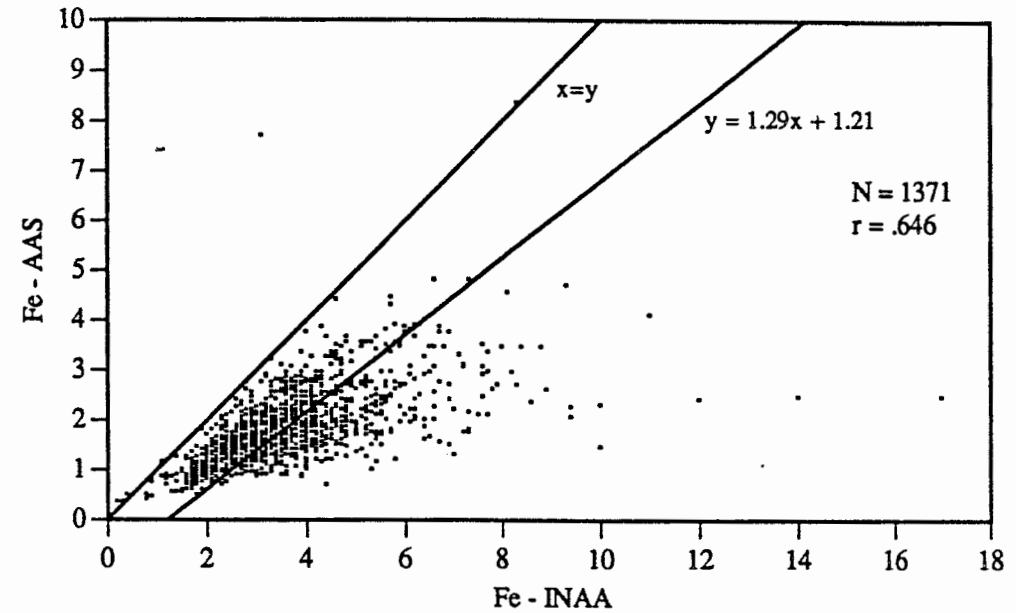


Figure 3b Scatterplot comparing INAA versus AAS results for Fe

BASE AND PRECIOUS METAL ANOMALY RATING PROCEDURE

INTRODUCTION

Stream sediments collected downstream from mineralized sources commonly exhibit enhanced concentrations for a particular suite of elements. An interpretive technique has been developed that reduces the data set and highlights stream sediment sites characterized by anomalous, multi-element signatures associated with particular mineral deposits. As an example of this methodology, sample evaluation charts and 1:500 000 scale anomaly maps have been produced which outline areas considered to have high base metal and precious metal potential.

METHODOLOGY

Data Subsetting on underlying geological formation

Analytical results for stream sediment samples typically reflect the underlying geology found within the drainage basins. Considerable variability in element concentrations exist between different lithologies. This variability must be considered in order to distinguish anomalous samples from background concentrations. Consequently, analytical data was initially subset on the basis of underlying lithology of the sample site. To better estimate element variability within lithologies, data from adjoining survey areas (RGS 27, 28, 29, 30, 31, 32, 33) were also included.

Threshold Calculations - Sample Evaluation Charts - Anomaly Maps

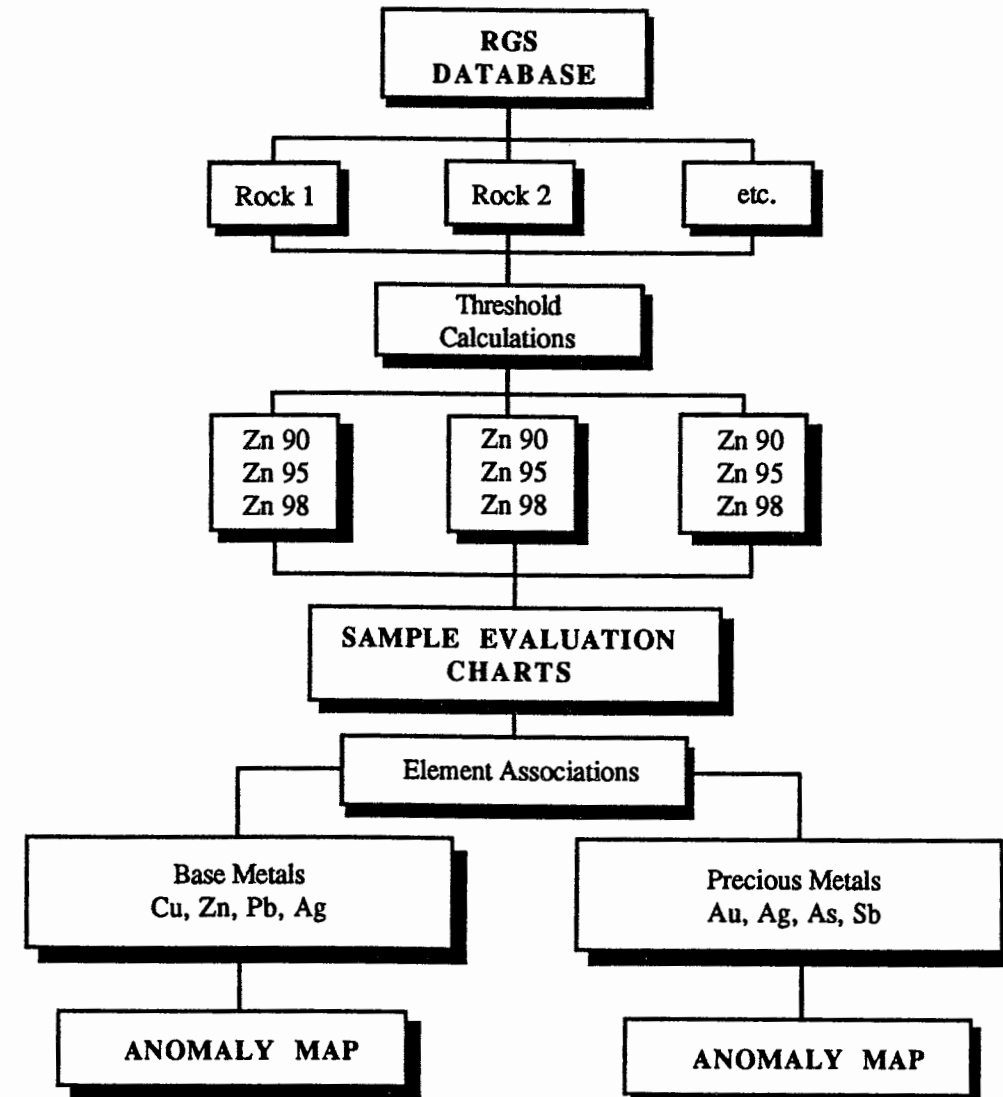
In order to assess the anomalous nature of individual samples, the 90th, 95th and 98th percentiles were calculated for lithologies having 10 or more sample sites and are provided in a threshold table (Appendix D).

Using the calculated thresholds, individual samples were assigned the following anomaly ratings :

- an anomaly rating of 1 for concentrations \geq 90th but $<$ 95th percentile,
- an anomaly rating of 2 for concentrations \geq 95th but $<$ 98th percentile,
- an anomaly rating of 3 for concentrations \geq 98th percentile.

Sample evaluation charts (Appendix D) graphically display the anomaly rating for individual elements. In addition, the summed element ratings provide a measure of the anomalous multi-element nature of each sample. Samples must have a minimum rating of 3 to be included in the chart. Anomaly maps produced from the sample evaluation charts highlight the spatial relationships between anomalous samples.

Utilizing the above technique, sample evaluation charts and anomaly maps have been generated to aid the user in identifying potential base metal and precious metal targets. The element suite used for the identification of base and precious metal multi-element anomalies include Cu - Zn - Pb - Ag and Au - Ag - As - Sb, respectively.



COMMENTS ON THE INTERPRETATION OF GOLD DATA

Understanding gold geochemical data from regional stream sediment surveys requires an understanding of the chemical and physical characteristics of gold in the surficial environment.

Gold is a soft, malleable element of high density (19.3 g/cm³). Under normal conditions it is chemically inert, most commonly occurring in native form (pure Au) or as electrum (alloyed with silver). Sub-micron sized gold is often bound to clays, adsorbed onto Fe-Mn oxides or contained within organic colloids. At normal surface temperatures, gold will dissolve under rare conditions of high oxidation potential and high acidity where ions such as chloride (Cl⁻), thiosulphate (S₂O₃⁻²) or cyanide (CN⁻) are present. Normal background concentrations for gold in bedrock vary, but are generally less than 5 ppb. Background levels encountered for stream sediments seldom exceed 10 ppb and commonly are near the detection limit of 1 ppb.

Under normal conditions, gold occurs as rare, discrete particles. In many instances a geochemical subsample may or may not contain a gold grain. This is known as the 'nugget effect'. Generally, larger geochemical sample sizes are required to minimize the nugget effect and more accurately represent gold concentrations. (Clifton *et al.*, 1969; Harris, 1982). Neutron activation analyses for the 1990 RGS Archive program utilized samples weighing on average 20 grams.

Follow-up investigations of gold anomalies should be based on careful consideration of related geological and geochemical information and an understanding of the variability of gold geochemical data. Once an anomalous area has been identified, field investigations should be designed to include detailed geochemical follow-up surveys and collection of large, representative samples. Analysis of field duplicates and blind (subsample) duplicates will increase the reliability of gold results, allowing for improved data interpretation.

Presentation of gold data within the map booklet differs from other elements as follows:

- Analytical duplicate pairs are listed in brackets following the initial determination.
- Results for field duplicate pairs are listed separated by a slash "/".
- Symbol size represents the highest value in field duplicate and blind duplicate analytical pairs.

• Possible variations in map format presentation:

- + Data < 50th percentile
- + 77..... Single analysis > 95th percentile
- + 103(42)... Analytical duplicate pair
- + 103/42.... Field duplicate pair

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APPENDIX A

Field Observations and Analytical Data

Notes : Values less than detection limit recorded as 1/2 detection limit value.

Table A-1 Reference Guide for Geological Formations (after Okulitch and Woodsworth, 1977)

Formation	Description	Formation	Description	Formation	Description
<u>STRATIFIED ROCKS</u>		<u>STRATIFIED ROCKS</u>		<u>STRATIFIED ROCKS</u>	
CENOZOIC		PALEOZOIC		PROTEROZOIC	
QUATERNARY AND RECENT		LOWER PALEOZOIC		HELIKIAN (BELT-PURCELL)	
Q	glacial deposits, recent alluvium	IPs	argillite, limestone, schist, phyllite, greenstone LARDEAU Group; BROADVIEW, EAGLE BAY, NELWAY, ACTIVE and METALINE Fms.; Ledbetter Slate, Grass Mtn. Sequence	HSL	quartzite, argillite, siltstone RAVALLI Group; CRESTON, ALDRIDGE, FORT STEELE, PRITCHARD, WATERTON, APPEKUNY, ALTYN, GRINNELL AND WERNER Pk. Fms.
MESOZOIC		LOWER CAMBRIAN		<u>INTRUSIVE ROCKS</u>	
TRIASSIC - JURASSIC		IEs		MESOZOIC	
TJs	shale, argillite, limestone, conglomerate, schist, sandstone NICOLA, SLOCAN, ROSSLAND and YMIR Groups; SICAMOUS and ARCHIBALD Fms.	quartzite, limestone, phyllite, argillite HAMILL and GOG Group; EAGER, BADSHOT, MOHICAN, DONALD, RENO, LAIB & QUARTZITE RANGE Fms.; Maitlen Phyllite, Emerald & Reeves Limestone Members		CRETACEOUS	
PALEOZOIC - MESOZOIC		PROTEROZOIC - PALEOZOIC		EARLY AND/OR MID-CRETACEOUS	
PERMIAN - TRIASSIC		PPNs		EKqm	
PTv	greenstone, basalt, andesite, lava, tuff, breccia, serpentinite KASLO Group; TSALKOM Fm.	paragneiss, schist, amphibolite, marble, orthogneiss, pegmatite SHUSWAP Metamorphic Complex		quartz monzonite, granite; lesser granodiorite, quartz diorite	
PALEOZOIC		PROTEROZOIC		EKgd	
CARBONIFEROUS - PERMIAN		HADRYNIAN (WINDERMERE)		granodiorite, quartz diorite; lesser quartz monzonite	
Ms	slate, argillite, chert, schist, conglomerate, limestone MILFORD Group; FLAGSTAFF MTN. Sequence	Hs		JURASSIC	
CAMBRIAN-DEVONIAN (PELITIC FACIES)		sandstone, conglomerate, limestone, grit, minor volcanic rocks MIETTE and HORSETHIEF Ck. Groups; TOBY, SHEDROOF and MONK Fms.; IRENE and LEOLA Volcanics; SILVER Ck. and CHASE Fms. near Shuswap Lake		MIDDLE AND/OR LATE JURASSIC	
EDp	Devonian: Limestone shale STARBIRD, Mt. FORSTER, HARROGATE and CEDARED Fms. Ordovician-Silurian: limestone BEAVERFOOT Fm. Ordovician: sandstone, shale Mt. WILSON and GLENOGLE Fms. Upper Cambrian-Ordovician: limestone, shale MCKAY Group Middle Cambrian: shale, limestone CANTON Ck., OTTERTAIL, JUBILEE and CHANCELLOR Fms.	HELIKIAN (BELT-PURCELL)		Jqm	
		HSU		quartz monzonite, lesser granodiorite	
		quartzite, argillite, dolomite, limestone, siltstone MISSOULA Grp.; Mt. NELSON, DUTCH Ck., GATEWAY, PHILLIPS & ROOSVILLE Fms.		Js	
		HSM		KUSKANAX BATHOLITH: syenite, leuco-monzonite leuco-quartz monzonite	
		limestone, argillite, quartzite, andesite, breccia, tuff SIYEH, KITCHENER, WALLACE, HELENA, and SHEPPARD Fms.; Purcell Lava		Jg	
				granodiorite, quartz diorite, lesser quartz monzonite	
				PALEOZOIC	
				DEVONIAN	
				Dg	
				gneissic granitic rocks MT. FOWLER Batholith, CLACHNACUDAINN Gneiss	

Table A-2 Reference Guide for Field Observations

Column	Definition and Descriptions	Column	Definition and Descriptions	Column	Definition and Descriptions
MAP	1:50 000 NTS map sheet number	SED COL	Sediment Colour: B = Black R = Red G = Grey-Blue T = Tan-Brown O = Olive-Green W = White-Buff P = Pink Y = Yellow	CHL PTN	Channel Pattern: S=Shoots-Pools M=Meandering B=Braided D=Disturbed
SAMPLE ID	Sample number			ELEV	Elevation: in metres
UTM ZONE	UTM Zone Number			PHY	Physiography: H=Hilly P=Plateau L=Lowland S=Swamp M=Mature Y=Youthful mountains
UTM EAST	UTM East Coordinate	DRN	Drainage Pattern: D=Dendritic H=Herringbone G=Glacially I=Interrupted deranged R=Rectangular		
UTM NORTH	UTM North Coordinate			TYP	Stream Type: P=Permanent S=Seasonal
STA	Replicate Sample Status: 0 = Routine Sample 1 = 1st Field Duplicate 2 = 2nd Field Duplicate 8 = Blind Duplicate 9 = Control Reference				
MED	Sample Media Collected: 1 = Stream Sediment only 6 = Stream Sediment & Water 7 = Moss-Mat Sediment only 8 = Moss-Mat Sediment & Water	SED COMP	Sediment Composition: estimate of Sand-Fines-Organic content 0 = Absent 1 = Minor (<1/3 of total) 2 = Moderate (>1/3 but <2/3) 3 = Major (>2/3 of total)	ODR	Stream Order: 1=Primary 3=Tertiary 2=Secondary 4=Quaternary
		STRM WPTH	Stream Width: in metres		
		STRM DPTH	Stream Depth: in centimetres		
FORMATION ROCK TYPE AGE	{ see Table A-1 }	BNK	Bank Composition: A = Alluvium R = Rock C = Colluvium S = Talus G = Outwash T = Till O = Organic U = Unknown	SRC	Stream Source: G=Groundwater S=Spring runoff M=Melt water U=Unknown
WAT COL	Water Colour: 0 = Colourless 2 = White Cloudy 1 = Brown Clear 3 = Brown Cloudy	BNK PPT	Bank Precipitate: N = None (otherwise same as SED COL)		
FLW	Water Flow Rate: 0 = Stagnant 3 = Fast 1 = Slow 4 = Torrent 2 = Moderate	CHL BED	Channel Bed: B = Boulders S = Gravel-Sand F = Silt-Clay O = Organics		

METHODS OF SAMPLE ANALYSIS

1977 Program

Co, Cu, Fe, Pb, Mn, Ni, Ag and Zn were determined as follows: a one gram sample was reacted with 3 ml of concentrated HNO₃ for 30 minutes at 90°C. 1 ml concentrated HCl was added and the digestion was continued at 90°C for an additional 90 minutes. The sample solution was then diluted to 20 ml with metal free water and mixed. Concentrations were determined by AAS using an air-acetylene flame. Background corrections were made for Pb, Ni, Co and Ag.

For **Hg**, a 0.5 gram sample was reacted with 20 ml concentrated HNO₃ and 1 ml concentrated HCl for 10 minutes at room temperature and for 2 hours at 90°C in a hot water bath. After digestion, the sample solutions was cooled and diluted to 100 ml with metal free water. Mercury present in the solution was reduced to the elemental state by the addition of 10 ml of 10% W/V SnSO₄ in H₂SO₄. Resultant mercury vapour was then flushed by a stream of air into an absorption cell mounted in the light path of an atomic absorption spectrometer. Absorption measurements were made at 253.7 NM.

Mo was determined by AAS using a nitrous oxide - acetylene flame. A 0.5 gram sample was reacted with 1.5 ml concentrated HNO₃ at 90°C for 30 minutes. At this point 0.5 ml concentrated HCl was added and the digestion continued for an additional 90 minutes. After cooling, 8 ml of 1250 ppm Al solution was added and the sample solution diluted to 10 ml before aspiration into the AAS.

For **Sn**, a 1 gram sample is heated with NH₄I in a modified pyropot furnace for 15 minutes at 500°C. This reaction converts the Sn in the sample to SnI₄. After cooling, the residue is leached with 20 ml of a solution which contains 5% V/V HCl and 6% W/V ascorbic acid. After leaching, the sample was cooled to room temperature and 5 ml of 4% W/V triethylphosphine oxide in methyl isobutyl ketone (MIBK) were added. The test tube was capped and shaken for 60 seconds. The solvent layer was then transferred to a small tube and centrifuged. Sn in the solvent layer was then determined by AAS using a nitrous-oxide acetylene flame at 2863 angstrom units.

W was determined as follows: a 0.2 gram sample was fused with 1 gram KHSO₄ in a rimless test tube at 575°C for 15 minutes. The cooled melt was then leached with 10 ml concentrated HCl in a water bath heated to 85°C. After the soluble material had completely dissolved, the insoluble material was allowed to settle and an aliquot of 5 ml was transferred to another test tube. 5 ml of 20% SnCl₂ solution was then added to the sample aliquot, mixed and heated for 10 minutes at 80°C in a hot water bath. A 1 ml aliquot of dithiol solution (1% dithiol in iso-amyl-acetate) was added to the solution and heated for 4-6 hours at 80-85°C in a hot water bath. The solution was then removed from the hot water bath and cooled; 2.5 ml of kerosene was added to dissolve the globule containing the tungsten-dithiol complex. W was measured by determining the absorbance of the kerosene solution at 630 nm using a spectrophotometer.

U in sediments was determined using instrumental neutron activation analysis (INAA) with delayed neutron counting. A 1 gram sample was sealed into a 7-dram polyethylene vial. Irradiation was provided by a Slowpoke Reactor with an operating flux of 10¹² neutrons/cm²/sec. Each sample was irradiated for 60 seconds. Following a 20-second delay, the sample was counted with 6 BF₃ detector tubes embedded in paraffin for 60 seconds.

U in water was determined by a fluorometric method. Uranium was initially preconcentrated by evaporation. The residue was fused with a mixture of Na₂CO₃, K₂CO₃ and NaF in a platinum dish. After cooling, the fluorescence of the fused pellet was measured using a Turner Fluorometer.

F in water was determined using a specific ion electrode. An aliquot of the sample was mixed with an equal volume of TISAB II solution (total ionic strength adjustment buffer). Fluoride content was measured using a Corning 101 Electrometer with an Orion Fluoride Electrode.

For the determination of **pH** an aliquot of water was transferred to a clean dry beaker. pH was measured using a Fisher Accumet pH Meter.

1990 Archive Program

Becquerel Laboratories (Mississauga), Ltd. carried out instrumental neutron activation analysis (INAA) of archived stream sediment sample splits. Samples weighing 20 grams on average were irradiated epithermally for twenty minutes in a neutron flux of 10¹¹ neutrons/cm²/sec. After a decay period of approximately one week, gamma-ray emissions for the elements of interest were measured using a gamma-ray spectrometer with a high resolution, coaxial germanium detector. Counting time was approximately fifteen minutes per sample. Counting data was compiled on a computer and later converted to concentrations. Numerous international reference samples were irradiated within each analytical batch.

Sediments were analyzed for antimony, arsenic, barium, bromine, cerium, cesium, chromium, cobalt, gold, hafnium, iron, lanthanum, lutetium, molybdenum, nickel, rubidium, samarium, scandium, sodium, tantalum, terbium, thorium, tungsten, uranium, ytterbium and zirconium. Concentrations below the reported detection limit were assigned a value equivalent to one-half of the detection limit. Detection limits for these elements are listed in Table A-4.

Element	Detection Limits	Sample Weight	Determination Method		
Cobalt	2 ppm	1 g	AAS		
Copper	2 ppm				
Iron	6.02 pct				
Lead	2 ppm				
Manganese	5 ppm				
Nickel	1 ppm				
Silver	0.2 ppm				
Zinc	2 ppm				
Molybdenum	2 ppm			0.5 g	Atomic Absorption Spectrophotometry
Tin	2 ppm			1 g	
Mercury	10 ppb	0.5 g			
Tungsten	4 ppm	0.2 g	COLOR Colorimetric		
Uranium	0.2 ppm	1 g	NADNC Neutron Activation		
pH - water	0.1 pH unit	25 ml	GCE Fisher Accumet pH meter		
U - water	0.05 ppb	5 ml	LIF Fluorometric Method		
F - water	20 ppb	25 ml	ION Fluoride Ion Specific Electrode		

Table A-3 1977 Routine RGS Analytical Methods

Element	Detection Limits	Element	Detection Limits
Gold	2 ppb	Molybdenum	1 ppm
Antimony	0.1 ppm	Nickel	10 ppm
Arsenic	0.5 ppm	Rubidium	6 ppm
Barium	100 ppm	Samarium	0.5 ppm
Bromine	0.5 ppm	Scandium	0.5 ppm
Cerium	10 ppm	Sodium	0.1 pct
Cesium	0.5 ppm	Tantalum	0.5 ppm
Chromium	5 ppm	Terbium	0.5 ppm
Cobalt	5 ppm	Thorium	0.5 ppm
Hafnium	1 ppm	Tungsten	2 ppm
Iron	0.2 pct	Uranium	0.2 ppm
Lanthanum	5 ppm	Ytterbium	2 ppm
Lutetium	0.2 ppm	Zirconium	200 ppm

Table A-4 1990 INAA Detection Limits



