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Applied Geochemistry



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Resource Geophysics and Geochemistry Division

# British Columbia Regional Geochemical Survey

## Stream Sediment and Water Geochemical Data

### Victoria / Cape Flattery - NTS 92B / 92C

*DATA BOOKLET*

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Canada - British Columbia  
Mineral Development Agreement (1985 - 1990)

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CANADA**

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## INTRODUCTION

Open File package BC RGS-24/GSC 2182 (Victoria - 92B & Cape Flattery - 92C) is one of three geochemical open files covering southern Vancouver Island and the Lower Mainland. Samples of moss-mat sediment and stream water were collected from June to August, 1989. This Open File presents the results of analyses for 21 elements, organic content and pH.

The reconnaissance scale survey was undertaken by the Geological Survey Branch of the Ministry of Energy, Mines and Petroleum Resources as part of its goal to provide a geochemical database for British Columbia. The Regional Geochemical Survey (RGS) program started in 1976. Employing national standards, they are part of the Geological Survey of Canada's National Geochemical Reconnaissance program. Survey objectives (Matysek, 1988) are to provide:

- High quality geochemical data at the reconnaissance level as a stimulus for mineral exploration in remote or under-explored areas,
- Geochemical sampling and interpretation methods specific to the needs of British Columbia,
- A geochemical database useful for environment, health and land-use issues.

Funding was supplied in part under the Canada/British Columbia Mineral Development Agreement (1985-1989).

## CREDITS

Sample collection, preparation and analysis were contracted to the following companies on a technically acceptable and competitive bid basis and were managed by the staff of the Applied Geochemistry Unit:

COLLECTION: MPH Consulting Services Ltd., Vancouver, B.C.  
PROCESSING: Rossbacher Laboratories Ltd., Burnaby, B.C.  
ANALYSIS: Barringer Laboratory (Alberta) Ltd., Calgary, Alberta  
(sediment and water)

APPLIED GEOCHEMISTRY UNIT (AGU) STAFF  
P.F. Matysek: Program Manager  
J.L. Gravel: Program Geochemist  
W. Jackaman: Program Coordinator  
S. Feulgen: Assistant Coordinator

## OPEN FILE FORMAT

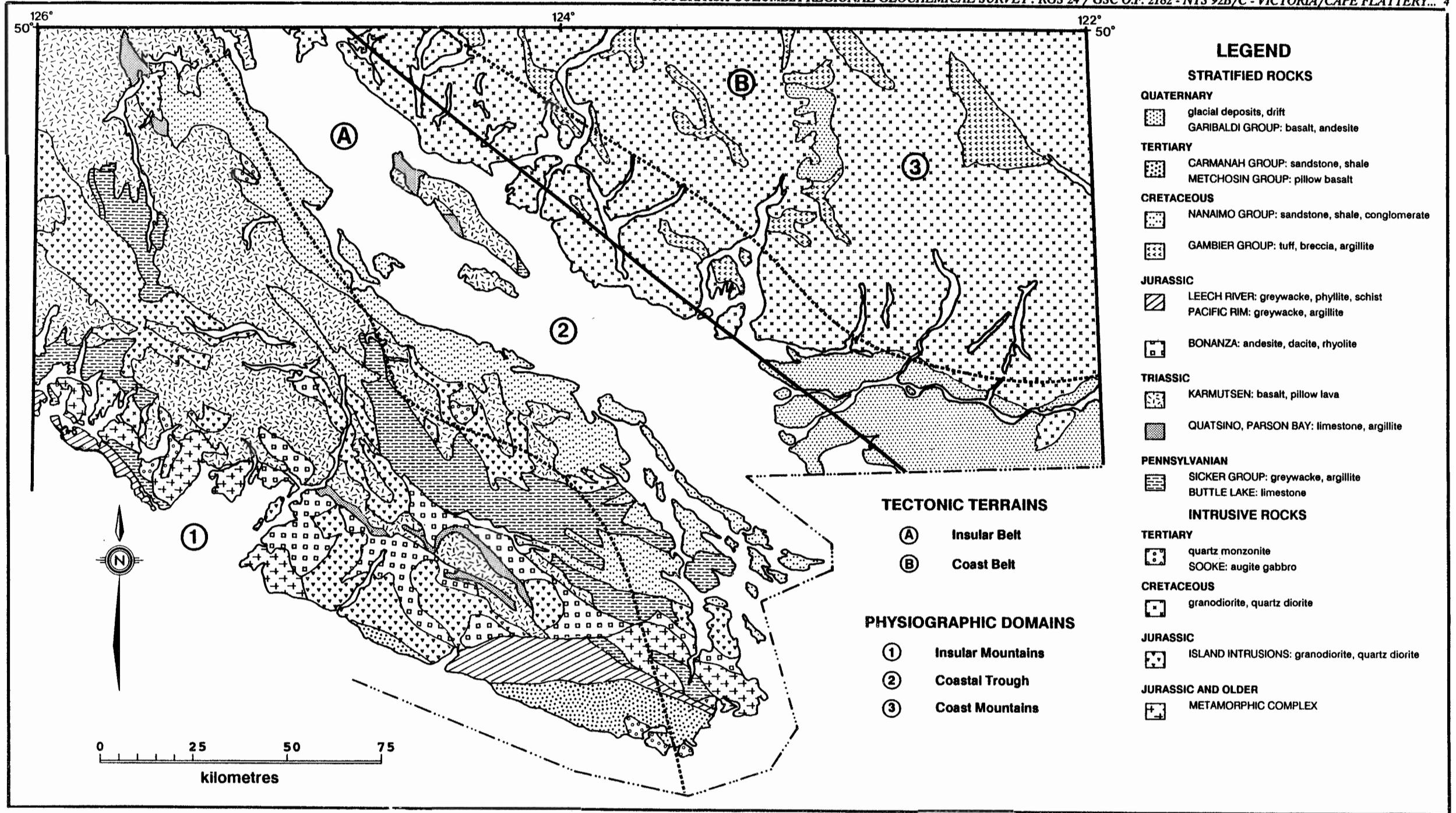
Open File BC RGS 24 contains:

- A data booklet providing descriptions of the 1990 RGS sampling and analysis program, data listings, statistics, analyses and interpretations.
- A map booklet which includes the following:
  - (26) 1:500 000 = scale symbol and value plots of element distributions, organic contents, pH and surficial geology,
  - (2) 1:500 000 = scale anomaly compilation maps,
  - (1) 1:500 000 = scale clear mylar sample location overlay, and
  - (2) 1:100 000 = scale sample location maps.

Raw data for Open File RGS 24 can be purchased in digital format on a standard 5¼" MS-DOS double sided, double density floppy diskette. A data file of analytical results, field observations and sample locations and two document files describing the nature and organization of the data have been stored on the diskette in ASCII format.

## 1990 RGS PROGRAM MODIFICATIONS

1. Collection of moss-mat sediments on Vancouver Island and stream sediments on the mainland.
2. 1:500 000 = scale symbol and value maps for each element are bound within a map booklet permitting greater ease in use.
3. 1:500 000 = scale anomaly maps based on sample evaluation chart results and elemental associations (base metal or precious metal).
4. Evaluation of analytical results in terms of precision and estimation of sampling variability.
5. Correlation matrices for major lithological packages.



**LEGEND**

**STRATIFIED ROCKS**

- QUATERNARY**  
 glacial deposits, drift  
 GARIBALDI GROUP: basalt, andesite
- TERTIARY**  
 CARMANAH GROUP: sandstone, shale  
 METCHOSIN GROUP: pillow basalt
- CRETACEOUS**  
 NANAIMO GROUP: sandstone, shale, conglomerate  
 GAMBIER GROUP: tuff, breccia, argillite
- JURASSIC**  
 LEECH RIVER: greywacke, phyllite, schist  
 PACIFIC RIM: greywacke, argillite  
 BONANZA: andesite, dacite, rhyolite
- TRIASSIC**  
 KARMUTSEN: basalt, pillow lava  
 QUATSINO, PARSON BAY: limestone, argillite
- PENNSYLVANIAN**  
 SICKER GROUP: greywacke, argillite  
 BUTTLE LAKE: limestone

**INTRUSIVE ROCKS**

- TERTIARY**  
 quartz monzonite  
 SOOKE: augite gabbro
- CRETACEOUS**  
 granodiorite, quartz diorite
- JURASSIC**  
 ISLAND INTRUSIONS: granodiorite, quartz diorite
- JURASSIC AND OLDER**  
 METAMORPHIC COMPLEX

**TECTONIC TERRAINS**

- (A) Insular Belt
- (B) Coast Belt

**PHYSIOGRAPHIC DOMAINS**

- (1) Insular Mountains
- (2) Coastal Trough
- (3) Coast Mountains



## SURVEY DESCRIPTION

### PHYSIOGRAPHY, GEOLOGY AND MINERAL POTENTIAL

The combined Victoria (92B) - Cape Flattery (92C) map sheet covers approximately 6200 km<sup>2</sup>. Physiography comprises rolling hills of the Nanaimo Lowlands along the eastern and southern margin, the Vancouver Island mountain range in the interior and fiord land along the western margin (Holland, 1964). Thick (> 10 metres) marine sediments (Fig. 1 in map booklet) are found within a variable width belt (up to 2 km) along the eastern coast. Further inland, moderate to thick till and colluvium blanket most areas. Thin till, residual soil, talus or barren rock are found on steeper mountain slopes or where bedrock has been stripped of overburden by glaciation (Fulton *et al.*, 1982; Jungen, J.R., 1985).

Mid-Paleozoic to mid-Tertiary Insular belt and Jurassic to Tertiary Pacific belt rocks underlay southern Vancouver Island (Fig. 1 and Table A-1 in Appendix A). Volcanics and sediments of the Insular Belt represent an island arc and back-arc basin sequence. Pacific belt trench and slope oceanic sediments and volcanics form an accreted wedge on the southwestern margin. Jurassic felsic plutons intrude Insular Belt rocks, Tertiary mafic intrusions are found within the Pacific belt. The geological base used for Open File RGS 24 is from Roddick (*et al.*, 1979).

Typical mineral occurrences found within the survey area are:

- Volcanogenic massive sulphides (Lara, Mt. Sicker),
- Gold in quartz vein shear zones (Debbie), and
- Skarn hosted iron ± copper (Blue Grouse).

A review of assessment reports over the past five years indicates a moderate level of exploration activity (208 reports filed) with emphasis on massive sulphide and gold in quartz shears hosted by Sicker Group volcanics (Gravel *et al.*, 1990).

### SAMPLING PROGRAM

A total of 599 sites were sampled for moss-mat sediment and stream water at an average density of 1 site per 10.3 km<sup>2</sup> (Table 1). Provincial parks were excluded from the sampling program. Although staking is not permitted within the Greater Victoria watershed (outlined on all symbol and value maps), samples collected will provide valuable data for exploration related statistical calculations and environmental research.

Samples were collected by truck, boat or helicopter depending on accessibility. Moss-mat sediment samples weighing 1 - 2 kg were scraped from logs and boulders found within the active (subject to annual flooding) stream channel and placed within kraft-paper bags.

**Table 1. Sample Distribution for 92B - Victoria and 92C Cape Flattery**

Map Sheet	Moss-Mat Samples	Stream Samples	Total Sites	Area km <sup>2</sup>	Density km <sup>2</sup> /Site
92B05	42	0	42	577	13.7
92B12	68	0	68	880	12.9
92B13	42	0	42	750	17.9
92B14	2	0	2	175	87.5
<b>Total</b>	<b>154</b>	<b>0</b>	<b>154</b>	<b>2382</b>	<b>15.5</b>
92C08	18	0	18	215	11.9
92C09	113	0	113	976	8.6
92C10	52	0	52	392	7.5
92C11	4	0	4	25	6.3
92C13	4	0	4	43	10.8
92C14	30	0	30	300	10.3
92C15	119	0	119	968	8.1
92C16	105	0	105	963	9.2
<b>Total</b>	<b>445</b>	<b>0</b>	<b>445</b>	<b>3882</b>	<b>8.7</b>

Weathered boulders, rotting logs and channel banks were avoided to prevent sample contamination. Unfiltered water samples were collected in 250 ml nalgene bottles, precautions were taken to exclude suspended solids when possible. Observations regarding sample media, sample site and local terrain (Table A-2 in Appendix A) were recorded. Aluminium sample site tags inscribed with a unique RGS sample number were affixed to permanent objects (tree, *etc.*) at each site to aid follow-up. Numerous field site checks (10%) were conducted by AGU staff to monitor, control and assess sample collection procedures.

## SAMPLE PREPARATION PROGRAM

### Field Processing

Samples collected on Vancouver Island were field processed by the sampling contractor at a central facility in Port Alberni. Samples from the mainland were processed at Rossbacher Laboratories in Burnaby, B.C.

- Sediment samples were dried for 2 - 3 days on paper lined trays in a heated (< 50°C) drying shed.
- Sediment was dislodged from moss mats by pounding the dried mat in a pyrex bowl with a wooden mallet.
- Sediment finer than 1 mm was recovered by sieving with an 18 mesh ASTM screen.

Samples were assessed for quality and fine grained sediment content. One sample in 20 was routinely sieved to -80 mesh (-177 microns). Organic rich or light samples (<40 grams of -80 mesh material) were re-collected.

### Lab Processing

All samples were sent to Rossbacher Laboratories in Burnaby, B.C. for final sample preparation involving:

- sieving all sediment samples to -80 mesh,
- weighing out sample splits for analysis (40 g of -80 mesh material) and archive storage (40 g of -80 mesh and 100 g of +80 mesh material),
- preparing analytical blind duplicates and inserting control reference standard material in each batch of twenty sediment samples, and
- inserting two control standards in each batch of twenty water samples.

## SAMPLE ANALYSIS PROGRAM

Barringer Laboratories (Alberta) Ltd. was selected to analyze water and sediment samples. Sediments were analyzed for: antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, fluorine, gold, iron, lead, manganese, mercury, molybdenum, nickel, silver, tin, tungsten, uranium, vanadium, zinc and organic matter. Water samples were analyzed for fluoride ions, uranium, and pH. Analytical methods and specifications for the various determinations (Table A-3) remain unchanged from last year except for two modifications;

- Vanadium was determined from the same dissolution as molybdenum, and
- Silver was analyzed by fire assay using a palladium inquart followed by atomic absorption.

\* \* \*

## QUALITY CONTROL

### INTRODUCTION

Foremost to the success of the Regional Geochemical Surveys is the need to maintain high quality in sample analysis. Control reference standard materials and analytical blind duplicates inserted amongst routine samples permit quality control monitoring throughout the duration of the analytical program. Each analytical batch of twenty samples comprises seventeen (17) routine samples, one (1) field duplicate sample, one (1) control reference standard material sample and one (1) analytical blind duplicate sample.

### CONTROL REFERENCE STANDARD MATERIALS

Control reference standard materials (CRSMs) are stream sediments and waters collected by AGU staff which exhibit two necessary traits;

- anomalous concentrations for various elements, and
- low variability between repeat analyses.

These materials serve the purpose of monitoring analytical accuracy and long-term precision. The RGS program presently uses three sediment CRSMs. Table 2 gives the Coefficients of Variation (CVs) of the RGS elemental suite for each CRSM. CVs are a measure of variability and are calculated in the following manner:

$$C.V. = \frac{SA}{\mu A} * 100$$

where SA = Standard deviation for CRSMA  
 $\mu A$  = mean of CRSMA

and are expressed in percentages. CVs of 20% are acceptable for elements with concentration ranges near their respective detection limits. CVs of 10% or less are expected for elements having moderate to high concentrations. CVs exceeding 20% are indicative of either detection limit concentrations (Cd, Ag, Sn) or severe nugget effects (W, Au).

In each analytical batch, a position has been left empty for the purpose of inserting a CRSM by the sample preparation contractor. For water samples, two spots are reserved for water CRSMs. The CRSM location for each analytical batch, chosen at random by the AGU during

**Table 2. Coefficients of Variation for RGS CRSMs**

Element	CRSMX	CRSMY	CRSMZ	Element	CRSMX	CRSMY	CRSMZ
Antimony	26.7	17.5	10.2	LOI	20.2	25.2	37.0
Arsenic	12.3	21.8	8.9	Manganese	7.2	5.3	5.4
Bismuth	16.2	49.2	19.0	Mercury	23.5	18.1	10.2
Cadmium	35.1	35.7	35.7	Molybdenum	7.4	36.0	4.0
Chromium	12.3	5.5	5.6	Nickel	9.8	6.4	5.6
Cobalt	8.8	8.5	5.6	Silver	60.8	72.1	33.0
Copper	4.6	6.2	3.6	Tin	-	-	-
Fluorine	22.8	20.1	18.2	Tungsten	44.4	35.7	37.2
Gold	24.1	296.0	28.2	Uranium	12.3	14.6	11.7
Iron	7.5	8.9	8.6	Vanadium	8.3	8.0	5.4
Lead	17.6	19.2	32.9	Zinc	5.5	6.1	5.2

program planning, is unknown to the analytical contractor. Within the analytical results of the first 500 samples (25 batches), sufficient numbers of CRSM samples have been analyzed to make a preliminary statistical assessment of the analytical performance. These results can be compared to historical means and standard deviations for the various elements based on similar methods of analysis. In this manner analytical problems unknown to the contractor (*i.e.* faulty AAS element lamps) can be corrected during the early stages of the program. After all samples are analyzed, analytical batches containing CRSM results for elements which exceed their mean by  $\pm 2.5$  standard deviations, are rejected and are re-analyzed.

### Future Modifications

The purpose for using three or more CRSMs is to provide sufficient concentration range, for a variety of elements, to permit monitoring accuracy across the ranges anticipated within the survey. As seen in Table 2, present standards give good coverage of the low to medium concentration range for most elements although each has its weak elements (Sb - Hg in CRSMX, Bi - Mo - Au in CRSMY, Pb and LOI in CRSMZ). Some elements (Cd, Ag, Sn) are poorly represented by all three. New standards are continually being sought to give better coverage of the RGS suite of elements.

## ANALYTICAL BLIND DUPLICATES

Analytical Blind Duplicates (ABDs) are sediment samples prepared by the processing contractor during final sample preparation. Results of analysis are listed in Appendix B. The purpose of these samples are:

- to measure short term precision within analytical batches,
- to determine elemental precision over a concentration range as measured by the Thompson and Howarth (1978) method, and
- to quantify analytical variability in relation to total variability (regional geochemical trends and sampling induced) as measured by the unbalanced ANOVA method.

After sieving each analytical batch to -80 mesh, the processing contractor selects the largest sample to be split in two. One half of the split is placed at the beginning of the analytical batch where a sample position was purposely left vacant. The choice of routine samples which were split are unknown to the analytical contractor. Assessment of analytical precision is possible upon receiving the first set of analyses. The absolute difference between ABD samples within an analytical batch is measured by:

$$\text{Abs.Dif.} = \frac{|X_1 - X_2|}{\mu_{1,2}} * 100$$

where  $X_1, X_2$  = ABD sample pair  
 $\mu_{1,2}$  = mean of  $X_1$  and  $X_2$

and expressed as a percentage. The result for each element in each analytical batch is compared against a table of acceptable tolerances at varying concentration ranges. Similar to CRSMs, initial ABD results may identify instrumental or digestion problems unknown to the analytical contractor that can be rectified early in the program. After completion of all analyses, analytical batches which are rejected for failing tolerance criteria for various elements are re-analyzed. Frequently elements within analytical batches which failed the CRSM criteria also fail the ABD criteria.

## Future Modifications

Tolerance levels presently used for the various elements are the same as those employed when the program began in 1976. Inspection of historical results for various elements analyzed by methods which remained constant over the years, indicates considerable tightening of tolerance levels are possible given current analytical technology and practices. The result will be greater precision and better ratios for variability due to regional geochemical trends compared to analytical variability.

\* \* \*

## 1989 - 1990 RGS PROGRAM COMPARISON

Eighty sediment samples from the previous RGS program analyzed by Chemex Labs of North Vancouver in 1988, B.C. were re-analyzed by Barringer in 1989 to establish relative differences between surveys.

- Cadmium, chromium, cobalt, copper, lead, LOI, manganese, molybdenum, nickel, uranium and zinc correlate very well between years exhibiting near 1:1 relationships for most elements. Some elements may have a marginal fixed bias related to calibration procedures and standards used at each lab.
- Antimony, bismuth, silver and tin cannot be correlated due to a predominance of detection limit values.
- Gold, mercury and tungsten exhibit moderate to poor correlations related to nugget effect problems.
- Vanadium can not be correlated due to different analytical techniques used between surveys.
- Iron (Fig. 2a) exhibits moderate to poor correlation between 1988 and 1989 results although analytical methods and specifications are the same for both years. Results from a referee laboratory agree with the 1989 dataset.
- Arsenic (Fig. 2b) exhibits a proportional bias towards higher values (up to 26%) in the 1988 data set. Users wanting to correlate arsenic trends across the 1988 and 1989 surveys will have to account for this bias.

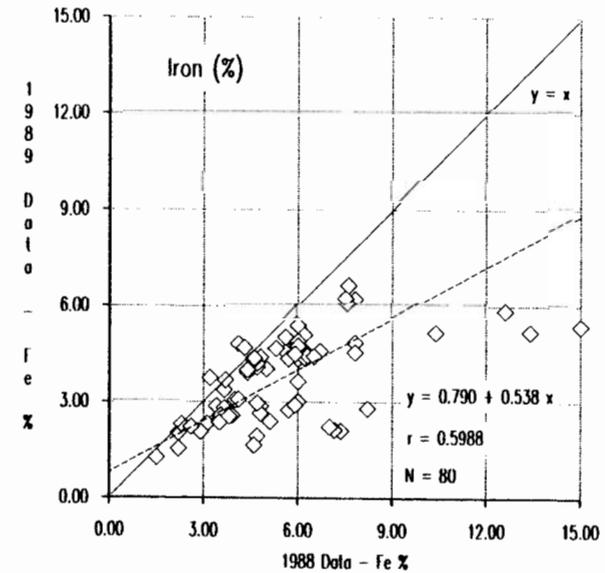


Figure 2a

Scatter diagram comparing analytical results for 80 moss-mat sediment samples analyzed in 1988 and again in 1989. Regression equation and correlation coefficient ( $r$ ) were calculated using the Reduced Major Axis Regression Analysis method. Correlation between years is moderate to poor ( $r = 0.5988$ ), with a very bias noted in the 1988 dataset. Analytical techniques and specifications were the same for both years. Results from a referee laboratory agreed with the 1989 dataset.

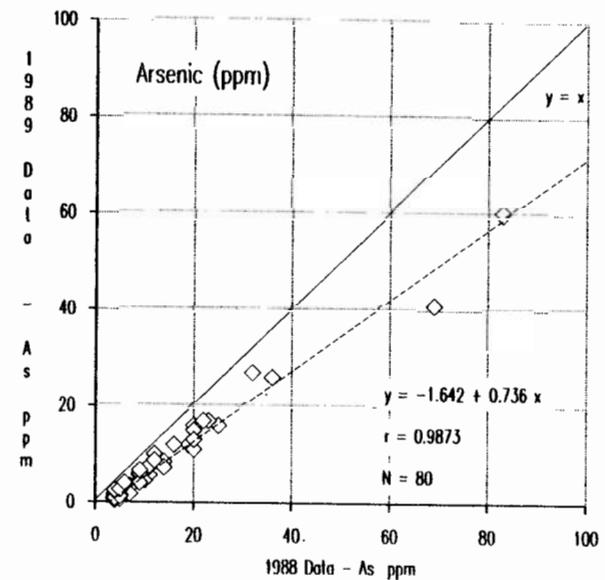


Figure 2b

Scatter diagram comparing analytical results for 80 moss-mat sediment samples analyzed in 1988 and again in 1989. Regression equation and correlation coefficient ( $r$ ) were calculated using Reduced Major Axis Regression Analysis method. Correlation between years is very good ( $r = 0.9873$ ), a proportional bias (up to 26%) is noted in the 1988 dataset. Analytical techniques and specifications are the same for both years, results from a referee laboratory agree with 1988 dataset.

## INTERPRETATION OF THE 1990 RGS DATABASE

### INTRODUCTION

Over the past three years modifications have been introduced into the RGS program at the sampling, analysis and interpretation stages to help the user identify exploration targets worthy of follow-up. The following section contains discussions of these modifications, how to interpret the resulting data and how the user may improve upon these methods.

### SAMPLE MEDIA: INTERPRETATION OF MOSS-MAT SEDIMENT RESULTS

#### Orientation Surveys

Conventional stream sediment sampling in cool, wet mountainous environments is severely hampered by the lack of fine sediment in high-energy streams. In these environments, 4 kilograms (or more) of coarse stream sediment must often be collected to provide sufficient -80 mesh sample material to satisfy RGS analytical requirements (minimum of 40 grams).

Orientation surveys (Matysek and Day, 1988; Matysek *et al.*, 1989) were conducted on Vancouver Island in 1987 and 1988 to address this concern. Several sample media types were evaluated to determine the sampling method which would optimize logistical and geochemical parameters such as time taken to collect a sample without compromising contrast and anomalous dispersion length.

Detailed studies were undertaken along several streams draining both mineralized and background areas to compare geochemical dispersion characteristics for moss-mat versus conventional stream sediments. For example, at McKay Creek which drains the Mt. Washington copper-gold deposit, paired moss-mat sediment and stream sediment samples were collected at 500 metre intervals along a 5½ kilometre reach of the stream (Fig. 3). Both media produced similar concentrations and dispersion patterns for copper, arsenic and other base metals. Gold however, displays a marked enrichment in moss-mat samples. At the sample station located furthest from the mineral occurrence (5½ km), moss-mat sediment contained 3 orders of magnitude more gold than the paired stream sediment. Similar trends were seen in other creeks draining gold bearing deposits.

In addition, moss-mat sediment samples contained 4-5 times the amount of -80 mesh material relative to their companion stream sediment samples. A typical 1-2 kilograms moss-mat sample produced a minimum of 100 grams of sieved material.

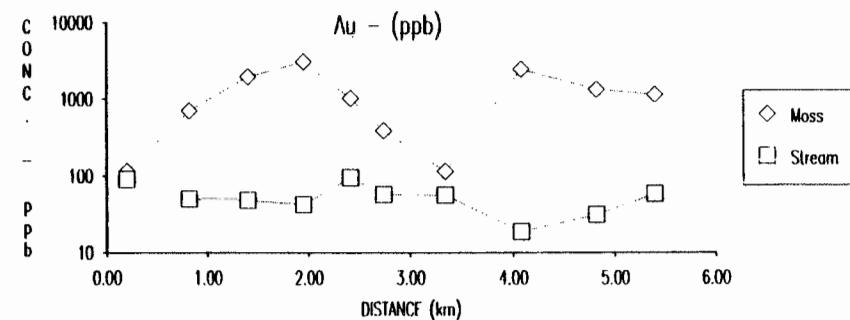
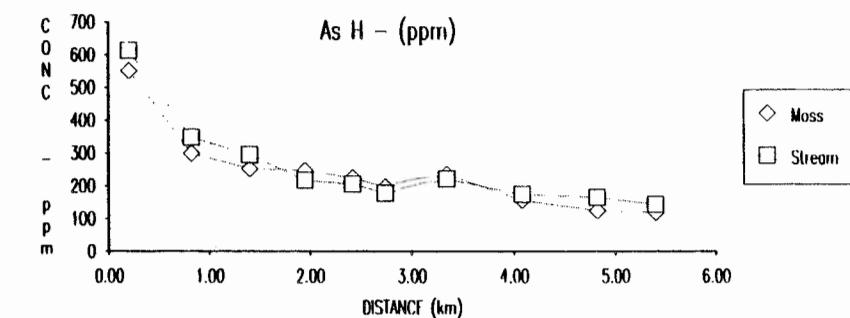
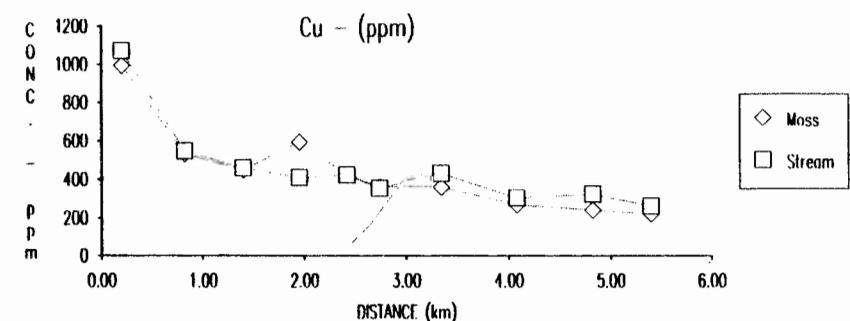


Figure 3 Down stream dispersion patterns for copper, arsenic and gold in the -80 mesh fraction of both moss-mat sediment and conventional stream sediment in McKay Creek, central Vancouver Island.

## Conclusions

In wet mountainous environments, the collection of moss-mat sediments offers several advantages over conventional stream sediments:

- Moss-mats are easily located and sampled.
- Moss-mats provide 4 - 5 times more -80 mesh sediment relative to similarly collected stream sediments.
- Elements transported hydromorphically exhibit concentrations and dispersion characteristics in moss-mat sediments similar to those observed for stream sediments.
- High density minerals are enriched in moss-mat sediments relative to stream sediments. The degree of enhancement may be related to the specific gravity of the mineral. This should be particularly beneficial for improving contrast in environments prone to a high degree of mechanical weathering.

## Check Sites

To provide a framework of reference for comparing geochemical results between moss-mat and stream sediments, both sample media were collected at 1 "check" site for every 17 routine sites. In total, 217 check sites were sampled during the 1989 and 1990 RGS programs comprising 185 sites on Vancouver Island and 32 sites on the mainland.

Scatter diagrams (Fig. 4) have been generated to compare relative elemental concentrations between moss-mat and stream sediment from check sites. Regression lines, calculated using reduced major axis regression analysis, are presented in each diagram and in Table 3. Regression slopes (measure of proportional bias), intercepts (measure of fixed bias) and the significance of the correlation coefficients  $r$  (measure of clustering of data points about the regression line) were calculated using 95% confidence limits.

Three patterns are evident, elements which exhibit minor proportional bias towards higher values within stream sediments (regression slopes  $> 1.0$ ), little or no proportional bias (regression slopes near 1.0) and proportional bias towards higher values within moss-mat sediment (regression slopes  $< 1.0$ ).

Elements enriched in stream sediment (cobalt, copper, manganese, nickel and zinc) are chemically related, they all have a  $2+$  aqueous species under oxidizing neutral to acidic conditions (Rose *et al.*, 1979) that can be hydromorphically transported and readily scavenged by Mn-oxides and organic compounds. Support for this hypothesis is seen in a corresponding proportional bias towards higher organic contents (as measured by loss on ignition) in stream sediments. To test this hypothesis scatter diagrams were generated for manganese versus LOI and copper versus manganese (all in stream sediments). Significant (95% confidence level) correlations were noted in each case.

Iron, lead, mercury, uranium and gold exhibit notable enrichment within moss-mat sediment. These elements commonly form detrital minerals having high specific gravities ( $> 5.0 \text{ g/cm}^3$ ). The degree of enrichment would appear to be a function of specific gravity, gold with the highest specific gravity (15.0 - 19.0  $\text{g/cm}^3$ ) shows the greatest enrichment (regression slope = 0.717). Since several mineral species with varying specific gravities may be present for elements such as iron (magnetite, hematite, pyrite, limonite, iron hydroxides and ferrosilicates) resulting in a scattering of data points, direct correlation between enrichment and specific gravity is not possible without in-depth mineral species determinations.

Elements such as chromium, arsenic and barium (1989 RGS data) are neither scavenged by organic matter nor form minerals with high specific gravities. These elements are likely occurring primarily within silicates (Cr, Ba) or have been scavenged by hydrous iron oxides (As).

## Mechanisms for Sediment Trapping in Moss-Mats

Speculatively, two processes are involved whereby both fine sediment and heavy minerals accumulate within moss mats. Moss mats growing on boulders and logs are perched above the mean annual water level of the stream. They receive sediment only during floods related to spring runoff or major storms. During these events, sediment charged water flows over, around and through the moss mat. Filter trapping of fine grained 'light' sediment likely occurs as water passes through the dense mat of fronds and leaves. Density trapping of heavy minerals may be related to a reduction of water turbulence over the mat similar to what occurs over gravels of a placer trap (Fletcher, 1990). Enrichment could be a cyclic process involving density trapping and flushing of the mat. At peak flood stages, water velocity over the mat may allow deposition of only the densest heavy minerals. As the flood wanes, decreasing flow velocity allows progressive trapping of less dense heavy minerals. During the waxing stage of the next flood, the 'lighter' heavy minerals are progressively plucked from the mat resulting in proportionally greater concentrations of high density heavy minerals such as gold.

**Table 5. Regression Equation Parameters for Various Elements in Moss-Mat Sediments Versus Stream Sediments**

Element	RMA Regression Equation Parameters						Corr. Coef. (r)	Notes
	Slope	95% limits		Inter.	95% limits			
	m	+	-	b	+	-		
<b>Manganese*</b>	<b>1.066</b>	1.108	1.025	<b>-0.155</b>	-0.041	-0.268	<b>0.8716</b>	Comparatively enriched in stream sediments (slope > 1.0), these elements have a 2+ aqueous species under neutral to acidic oxidizing conditions. They are transported hydromorphically and are readily scavenged by organic compounds and manganese hydroxides. All have correlation coefficients (r) near 1.0. LOI is also higher in stream sediments
<b>Nickel*</b>	<b>1.041</b>	1.067	1.016	<b>-0.019</b>	0.012	-0.051	<b>0.9438</b>	
<b>Cobalt</b>	<b>1.038</b>	1.066	1.009	<b>-0.386</b>	0.156	-0.927	<b>0.9305</b>	
<b>Zinc</b>	<b>1.031</b>	1.058	1.003	<b>1.128</b>	3.241	-0.985	<b>0.9308</b>	
<b>Copper*</b>	<b>1.030</b>	1.048	1.011	<b>-0.029</b>	0.002	-0.059	<b>0.9684</b>	
<b>Chromium</b>	<b>0.989</b>	1.011	0.968	<b>-7.127</b>	-4.038	-10.22	<b>0.9534</b>	Exhibiting little or no bias, these elements occur as trace constituents in silicate minerals or adsorbed onto Fe-oxides and hydroxides. They are transported mechanically.
<b>Barium<sup>+</sup></b>	<b>0.979</b>	1.037	0.922	<b>16.001</b>	34.591	-2.589	<b>0.7634</b>	
<b>Arsenic*</b>	<b>0.955</b>	0.985	0.925	<b>0.072</b>	0.097	0.047	<b>0.9128</b>	
<b>Mercury*</b>	<b>0.928</b>	0.998	0.859	<b>0.109</b>	0.240	-0.022	<b>0.7083</b>	The following elements exhibit notable enrichment in moss-mat sediments (slope < 1.0). Commonly found as heavy detrital minerals with specific gravities of 5 g/cm <sup>3</sup> or greater, they are transported mechanically. Enrichment is probably a function of density trapping with the degree of enrichment related to specific gravity.
<b>Iron</b>	<b>0.854</b>	0.991	0.716	<b>0.086</b>	0.853	-0.681	<b>0.5560</b>	
<b>Lead</b>	<b>0.841</b>	0.885	0.797	<b>0.434</b>	0.667	0.201	<b>0.7884</b>	
<b>Uranium</b>	<b>0.828</b>	0.886	0.769	<b>0.058</b>	0.181	-0.064	<b>0.7018</b>	
<b>Gold*</b>	<b>0.717</b>	0.873	0.560	<b>-0.007</b>	0.161	-0.175	<b>0.3078</b>	

\* Statistics calculated based on log-transformed data  
+ Based on 1989 RGS data

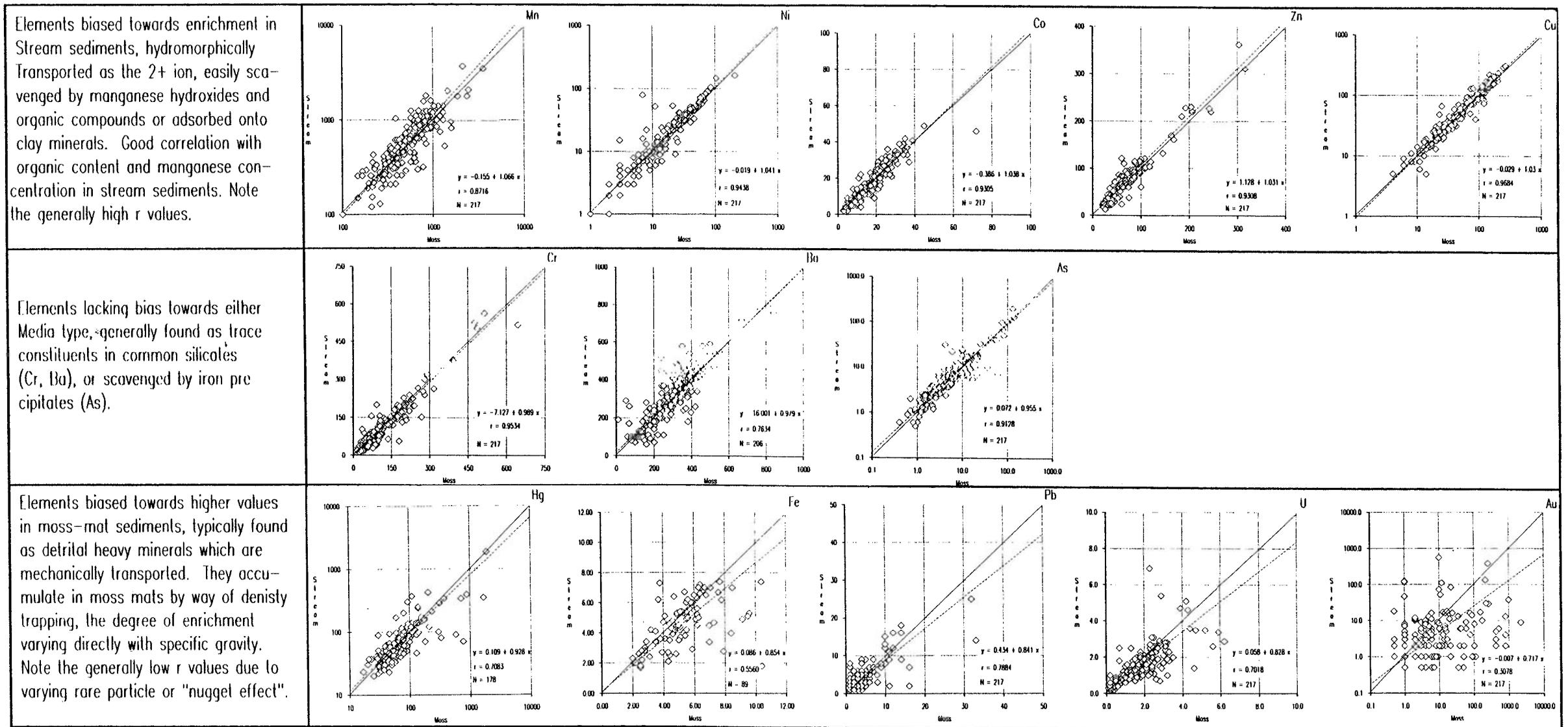


Figure 4. Comparison of element concentrations in Moss-Mat sediment (X-Axis) versus stream sediment samples (Y Axis).

## COMMENTS ON INTERPRETING GOLD DATA

The following discussion reviews the format used to present the gold geochemical data and outlines some important points to consider when doing an interpretation. Understanding gold geochemical data from regional stream and moss-mat sediments requires an appreciation of the unique chemical and physical characteristics of gold and its mobility in the surficial environment.

Gold occurs most commonly in the native form. It is chemically and physically resistant and is commonly dispersed in micron-sized particulate form. Gold's high specific gravity results in heterogeneous distributions, especially in stream sediments. Gold typically occurs at low concentrations (in the ppb range). Gold concentrations of a few ppm may represent economic deposits. Background levels encountered for stream sediments seldom exceed 10 ppb and commonly are near the detection limit of 1 ppb.

The foregoing factors can result in a particle sparsity or "Nugget Effect", wherein very low concentrations of gold are heterogeneously distributed in the surficial environment. Hence, a major problem facing exploration personnel is obtaining a representative sample. In general, the lower the concentration of gold or the larger the average grain size, the larger the sample size must be to reduce uncertainty as to whether sub-sample analytical values truly represent actual values. Conversely, as gold concentrations increase, the number of gold particles to be shared in random sub-samples increases and the variability of results decreases (Clifton *et al.*, 1969; Harris, 1982).

The limited amount of material collected during rapid, reconnaissance-style regional surveys and the need to analyze for a broad spectrum of elements, precludes the use of large sample weights (*i.e.* 30 grams) for gold analyses. The RGS programs uses 10 gram samples, consequently results tend to be highly variable and qualitative rather than quantitative. In addition to the usual blind analytical duplicates and control reference standard materials for evaluating and monitoring analytical variability, repeat analyses are performed on:

- samples exceeding the 95th percentile for gold (100 ppb) based on the complete 1990 RGS dataset;
- samples with low gold concentrations but anomalous concentrations in one or more pathfinder elements (As, Cu, Pb, Zn, Sb, Hg); and
- samples exhibiting large discrepancies between original and repeat analyses.

Presentation of gold data within the booklet and on the symbol and value map differ from other elements as follows:

### 1) Summary Statistics

- Only the initial gold value was used.
- Gold values less than the variable detection limit were set to 1 ppb.

### 2) Symbol and Value Gold Map

- Repeat analyses and blind duplicate pairs are listed in brackets following the initial determination.
- Both values for field duplicate pairs are listed separated by a slash "/".
- Symbol size represents the highest value in field duplicate, blind duplicate and repeat analysis pairs.
- Possible variations in map format presentation:
  - + .....Data < 50th percentile
  - + 77.....Single analysis > 90th percentile
  - + 103(42)...Initial and first repeat analysis
  - + 103/42....Field duplicate pair

In summary, geochemical follow-up investigations should be based on careful consideration of all geological and geochemical information and a particularly thorough appraisal of gold geochemical data and its variability. In some cases, prospective follow-up areas may be indirectly identified by pathfinder element associations in favorable geology, although an anomalous gold response due to natural variability may be lacking. 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. Subsequent repeat sub-sample analyses will increase the reliability of results and permit a better understanding of natural variability which can then be used to improve sampling methodology and interpretation.

## EVALUATION OF 1990 RGS ANALYTICAL DATA

### INTRODUCTION

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 reproducibility (precision) allows us to quantify the amount of variation due to sampling and analysis, and is an integral part of the evaluation of geochemical data. Quality control procedures using duplicate samples should be conducted prior to carrying out any detailed data interpretation. Utilization of paired duplicates (Analytical Blind Duplicates and Field Site Duplicates) provide information on precision and aid in assessing:

- Analytical precision over the range of values encountered (Thompson and Howarth method)
- Metal variability within and between sample sites (Analysis of Variance)

### THOMPSON AND HOWARTH METHOD

Application of analysis of variance techniques can only determine an average precision value for a range of concentrations. In actual fact, it has been shown (Thompson and Howarth, 1973) that where there is a wide range of concentrations in a set of samples both the absolute and relative errors in analytical determinations can vary across the range. To deal with this complexity, alternative ways of estimating precision using randomly selected analytical duplicates, have been considered in detail by Thompson and Howarth (1973,1976,1978).

Briefly, their method involves dividing 50 or more analytical duplicate pairs into groups with narrow concentration ranges, and employing the median of absolute differences between pairs of duplicate pairs ( $X_1, X_2$ ) as an estimator of the standard deviation ( $s$ ). The group mean value of all the mean average values  $(X_1 + X_2)/2$  is used as an estimator of the average concentration. If this procedure is repeated for a number of successive narrow concentration ranges a set of corresponding mean concentration and standard deviation estimates is obtained. The relationship between them can be found by simple linear regression from which precision can be calculated from the equation:

$$P_c = 2 (S_o/c + K)$$

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.

### 1990 RGS Precision Estimates

Precisions estimates for selected elements were calculated from 148 blind analytical duplicate pairs from the entire 1990 RGS database using the Thompson and Howarth method as follows:

- Step 1. Blind analytical pairs were initially subsetted on basis of sample type (84 moss-mat sediment and 64 stream sediment pairs, respectively, see Appendix B).
- Step 2. A list of duplicate means and corresponding absolute differences was calculated for each sample media.
- Step 3. The list was sorted in increasing order of concentration means.
- Step 4. The mean concentration and the median difference between pairs for the first group of 9 samples for moss mats, and the first group of 7 stream sediments were determined, respectively.
- Step 5. Step 4 was repeated for each successive group of 9 moss-mat analytical pairs and 7 stream sediment analytical pairs ignoring any remainder less than 9 and 7 respectively.
- Step 6. 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.

Precision estimates were determined for As, Co, Cr, Cu, Fe, Mn, V, U and Zn. This particular suite of metals was selected on the following basis:

- Their distributions approximated the Gaussian curve
- The majority of their concentrations were well above their detection limits.

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

- Metal abundances are dependent on rare grains (eg. Au, W, Sn, Hg)
- Concentration levels are near or at the detection limit (eg. Ag, Bi, Cd, Ni, Pb, Mo, Sb)
- Precision of the method of analysis is poor (eg. F)
- Data contains outliers

## Results

Precision estimates obtained from the Thompson and Howarth method are presented in Table 5 for both moss-mat and stream sediment duplicate data. Although, the regression on the median of absolute differences on the concentration means was only based on 9 singular points, the calculated correlation coefficient  $r$  proved to be significantly different than zero at the 95% confidence interval for all metals except for uranium in stream sediments. Regression plots (not shown) of the selected metals show that the simple linear regression more than adequately accounts for the relationship between the median of absolute differences and mean concentrations; thus it provides an excellent indicator of precision over the concentration range.

Precision estimates calculated by the Thompson and Howarth method for eight different metals at different concentration for moss-mat sediment samples levels averaged less than 8.9% at the 50th percentile concentration value, less than 8.4% at the 80th percentile and less than 8.1% at the 95th percentile.

In contrast, precision estimates for stream sediment samples averaged less than 11.2% at the 50th percentile concentration value, less than 9.8% at the 80th percentile and less than 9.1% at the 95th percentile.

## Conclusions

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

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

Precision estimates determined for selected elements from the 1990 RGS database are of similar magnitude to those observed from the above studies.

Table 5. Relative Precision estimates, Thompson and Howarth Method, BC RGS 24, 25, 26 Data

ELEMENT	MOSS-MAT SEDIMENT DATA										
	Analytical Blind Duplicate Parameters					Precision Estimates at Selected Percentiles					
	MIN	MAX	INTERCEPT	SLOPE	R-VALUE	50TH	PREC	80TH	PREC	95TH	PREC
COPPER	8	240	0.379	0.0279	0.883	55	7.00%	114	6.20%	173	6.00%
MANGANESE	100	1360	-5.941	0.0376	0.789	650	5.70%	1015	6.30%	1645	6.80%
CHROMIUM	12	314	1.284	0.0322	0.86	103	8.90%	171	7.90%	265	7.40%
COBALT	3	39	-0.168	0.0444	0.611	17	6.90%	25	7.50%	32	7.80%
ZINC	16	144	-0.513	0.0434	0.9	62	7.00%	86	7.50%	125	7.90%
ARSENIC	0.2	90	0.194	0.0386	0.817	3	20.70%	7.5	12.90%	24	9.30%
IRON	1.1	8.3	-0.069	0.0584	0.831	3.5	7.70%	5.3	9.10%	6.9	9.70%
VANADIUM	22	215	-1.135	0.0581	0.862	80	8.80%	129	9.90%	177	10.30%

ELEMENT	STREAM SEDIMENT DATA										
	Analytical Blind Duplicate Parameters					Precision Estimates at Selected Percentiles					
	MIN	MAX	INTERCEPT	SLOPE	R-VALUE	50TH	PREC	80TH	PREC	95TH	PREC
ZINC	10	250	0.56	0.0239	0.818	46	7.20%	76	6.30%	139	5.60%
MANGANESE	50	1150	1.542	0.0328	0.954	323	7.50%	560	7.10%	952	6.90%
ARSENIC	0.4	9.5	0.056	0.0346	0.68	2.6	11.20%	5.9	8.00%	21	7.50%
CHROMIUM	10	190	1.313	0.0312	0.714	41	12.60%	65	10.30%	113	8.60%
VANADIUM	10	115	0.633	0.0379	0.598	43	10.50%	61	9.70%	82	9.10%
COPPER	5	160	0.101	0.0462	0.927	25	10.00%	47	9.70%	91	9.50%
IRON	0.5	6	-0.034	0.0688	0.869	2	10.40%	2.6	11.10%	4.7	12.30%
URANIUM	0.3	11	0.085	0.0534	0.594	1.8	20.10%	3.5	11.50%	7.4	13.00%

## ANALYSIS OF VARIANCE

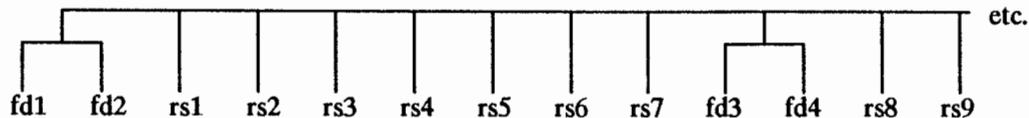
### Introduction

Invariably, users of geochemical data accept the resultant elemental trends and patterns on face-value, trusting that variations in concentrations are a product of lithology changes and mineralization interacting with the surficial environment (glacial history, climate, topography, etc.). What is rarely addressed and generally assumed, is that elemental variations introduced by sampling variability (site selection) and analytical variability (subsampling, digestion, instrumental calibration and drift) are negligible in comparison. Analysis of variance (ANOVA) tests have been performed on the 1990 RGS database to determine the variance component due to lithology and mineralization ( $VC_{\text{regional}}$ ) versus the variance component due to sampling and analysis ( $VC_{\text{site}}$ ) for each element. This will enable users to qualify anomalies they wish to follow-up.

### Method

In a properly structured survey, regional and site variance components can be calculated by incorporating field site duplicate samples (2 samples collected at 1 site) systematically in the sampling routine.

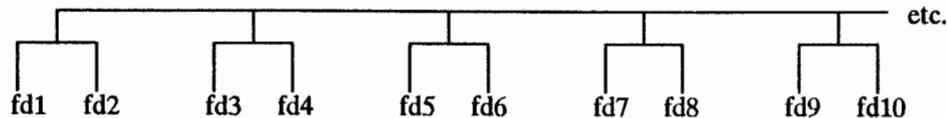
#### Systematic Sampling Routine



fd = field duplicate rs = routine sample

On a data subset comprising only field duplicate samples, simple ANOVA tests can be performed which measure  $VC_{\text{site}}$  as the total differences between samples (i.e. fd1 vs fd2, fd3 vs fd4) in each field duplicate pair and compares this against  $VC_{\text{regional}}$  measured as the total difference between field duplicate pairs (i.e. fd1:fd2 vs fd3:fd4 vs fd5:fd6 etc.).

#### Data subset comprising only field duplicates



Variance components are calculated in the following manner:

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

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

where  $x_i$  = 1st and 2nd samples of each field duplicate pairs

$\mu_i$  = mean for each duplicate pair

$n$  = number of duplicate pairs

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

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

where  $x_j$  = all samples in field duplicate pairs

$\mu_j$  = mean of all samples in field duplicate pairs

$N-1$  = number of samples in field duplicate pairs less 1

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

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

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

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

The above calculations can be made given certain conditions are met:

- a) The data subset comprising field duplicate pairs is representative of the much larger database comprising routine samples (similar concentration range and proportion of high and low values). This can be tested by taking the F ratio between of  $MSQ_{\text{field duplicates}}$  and  $MSQ_{\text{routine samples}}$ ;

$$(5) F \text{ Ratio}(v_1, v_2) = \frac{MSQ_{\text{field duplicates}}}{MSQ_{\text{routine samples}}}$$

where (6)  $MSQ_{\text{field duplicates}} = \Sigma(x_1 - \mu_1)^2 / n$   
 $x_1$  = 1st sample in each duplicate pair  
 $\mu_1$  = mean of 1st samples in duplicate pairs

$$(7) MSQ_{\text{routine samples}} = \Sigma(x_r - \mu_r)^2 / m$$

$x_r$  = routine samples  
 $\mu_r$  = mean of routine samples  
 $m$  = number of routine samples  
 $v_1 = n - 1$  = degrees of freedom for  $MSQ_{\text{field duplicates}}$   
 $v_2 = N - 1$  = degrees of freedom for  $MSQ_{\text{routine samples}}$

and comparing the ratio against critical F distribution values at the 95% ( $\alpha = 0.05$ ) or 99% ( $\alpha = 0.01$ ) confidence levels. For the field duplicate pairs population to be representative the F ratio must be less than the F distribution value for the given degrees of freedom (null hypothesis accepted). Tin (Sn) and tungsten (W) in moss-mat sediment and tin (Sn) in stream sediments are poorly represented by field duplicate samples. Variance components were not calculated for these elements.

b) The populations described by routine samples and field duplicate samples must approximate normal distributions. Since the RGS database includes samples derived from varying lithologies and mineral occurrences, it is necessary to log transform the data to approximate normal distributions.

### Conclusions

Figures 5a and 5c describe site and regional variation components for moss-mat sediments and stream sediments. General similarities are noted;

- Elements having good concentration ranges with relatively few detection limit values have low variance components due to sampling (<10% for moss-mat sediment and <7% for streams). These elements define geochemical trends related to true regional variations.
- Elements with low concentration ranges and numerous detection limit values (Ag, Bi, Cd, F, Mo) or suffer from extreme nugget effect problems (W, Au) have relatively high sampling variability. Geochemical trends relating to regional variations may be partially masked or obliterated by sampling and analytical variability.

To determine if geochemical trends are true (regional variation) versus generated (sampling and analysis), F ratios (figures 5b and 5d) can be calculated between  $MSQ_{\text{regional}}$  and  $MSQ_{\text{site}}$ ;

$$(8) F \text{ Ratio}(v_1, v_3) = \frac{MSQ_{\text{regional}}}{MSQ_{\text{site}}}$$

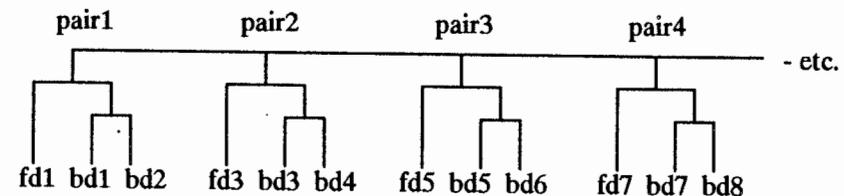
where (9)  $MSQ_{\text{regional}} = \Sigma \{ (x_i - \mu_i)^2 - (x_j - \mu_j)^2 \} / n - 1$

$v_1 = n - 1$  = degrees of freedom for  $MSQ_{\text{regional}}$   
 $v_3 = n$  = degrees of freedom for  $MSQ_{\text{site}}$

Higher F ratios mean better contrast between regional variation against variations in sampling and analysis. These F ratios can be tested against critical F distribution values at the 95% ( $\alpha = 0.05$ ) or 99% ( $\alpha = 0.01$ ) confidence levels. For regional variation to be considered different from (describing true geochemical trends) sampling and analytical variation, the calculated F ratio must exceed the critical F distribution value for the given degrees of freedom (null hypothesis rejected). Only tungsten (W) in stream sediments failed this criteria. Although gold (Au) in moss-mat sediments had the highest  $VC_{\text{site}}$  value (63.2% of variance attributed to sampling and analytical variability) its F ratio (2.2) exceeded the critical F distribution value (1.69) at the 99% confidence level therefore true geochemical trends are reflected in the data.

### Methods for Improvement

The above ANOVA tests can be improved upon by calculating variability due to analysis separately from variability due to sampling. This requires a properly nested sampling pattern in which one sample in each of the field duplicate pairs is split into two blind duplicate samples.



Due to the unbalanced design (only one of the field duplicates is split in each pair) a simple ANOVA can not be used for calculating variance components. Garrett and Goss (1979) give a detailed account on using an unbalanced ANOVA design on regional geochemical survey data for lakes in Newfoundland. Garrett and Goss (1980) have also published a FORTRAN computer program that accommodates an unbalanced design with up to nine nesting levels (the above example has three nesting levels; pairs, field duplicates and blind duplicates). With the unbalanced design, the user can incorporate routine samples into the ANOVA calculations which removes the need to evaluate if the field duplicate pairs are representative of the population as a whole.

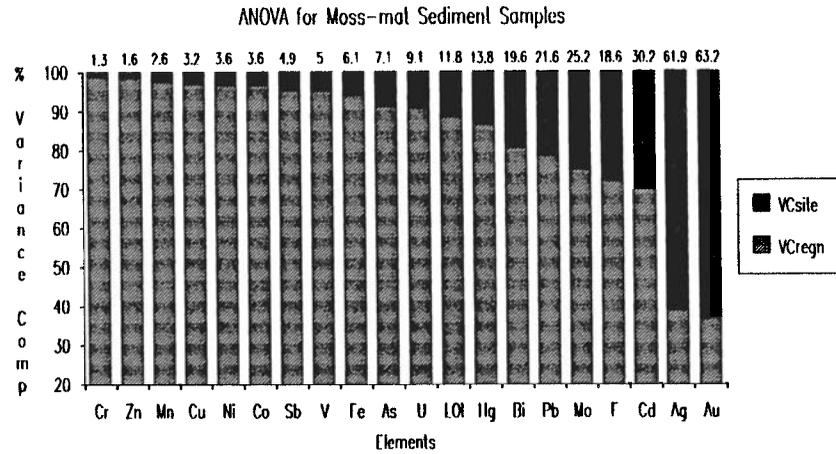


Figure 5a Simple ANOVA test performed on moss-mat sediment for field duplicate pairs. VCsite is the variance component attributed to sampling and analytical variability, VCreg is the variance component attributed to regional variability. In general, elements with VCsite <10% exhibit good concentration ranges with very few near or below detection limit values. Elements with VCsite >10% either exhibit nugget effect problems (Hg, Pb, Au), are highly site dependent (LOI) or have poor concentration ranges with numerous samples giving detection limit values (Bi, Mo, Cd, F, Ag). Tungsten (W) and tin (Sn) are poorly represented by the field duplicate pairs (null hypothesis rejected), their results can not be quantified or qualified.

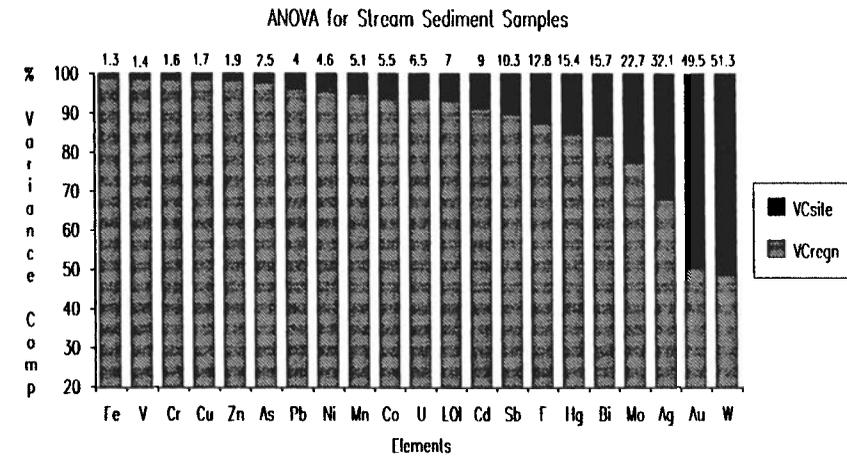


Figure 5c Simple ANOVA test performed on stream sediment for field duplicate pairs. VCsite is the variance component attributed to sampling and analytical variability, VCreg is the variance component due to regional variability. In general, elements with VCsite <7% exhibit good concentration ranges with very few near or below detection limit values. Elements with VCsite >7% either exhibit nugget effect problems (Au, W), are highly site dependent (LOI) or have low concentration ranges with numerous detection limit values (Cd, Sb, F, Bi, Mo, Ag). Tin (Sn) is poorly represented by the field duplicate pairs (null hypothesis rejected), it's results can not be quantified or qualified.

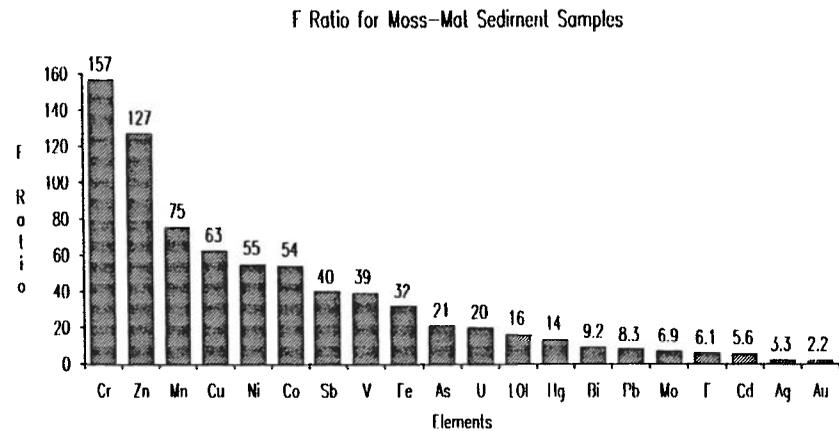


Figure 5d F Ratios comparing MSQregional versus MSQsite. F Ratios must exceed 2.96 for variability due to regional geochemical trends to be considered truly distinguishable from variability generated by sampling and analytical fluctuations (null hypothesis rejected) at the 99% confidence level. Only tungsten fails this criteria.

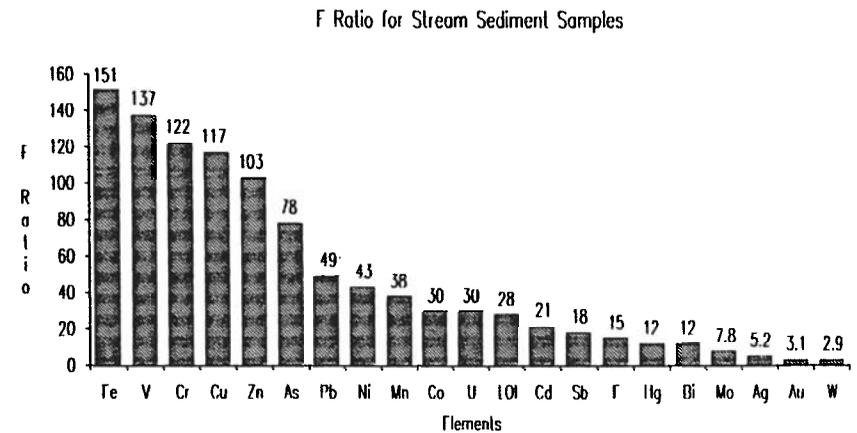


Figure 5d F Ratios comparing MSQregional versus MSQsite. F Ratios must exceed 2.96 for variability due to regional geochemical trends to be considered truly distinguishable from variability generated by sampling and analytical fluctuations (null hypothesis rejected) at the 99% confidence level. Only tungsten fails this criteria.

## SAMPLE EVALUATION CHARTS AND ANOMALY MAPS

### Introduction

Sample evaluation charts (Appendix D) and 1:500 000 scale anomaly maps (in map booklet) have been generated (see Flow Chart) to aid the user in identification of mineral targets worthy of follow-up.

### Sample Evaluation Charts

Sample evaluation charts highlight samples with enriched concentrations of various elements allowing rapid scanning of the data. Charts were generated in the following manner:

- Step 1 The complete 1990 RGS data set (BC Open File RGS 24, 25 and 26) is subdivided based on media (moss-mat vs. stream sediment) and underlying geology (Karmutsen Fm., Bonanza Gp., etc.).
- Step 2 The 90th, 95th and 98th percentile threshold levels are calculated for data subsets containing 10 or more samples and presented in a threshold table. Enrichment values are assigned to analytical results in the following manner:

- a value of 1 for concentrations  $\geq$  90th but  $<$  95th percentile,
- a value of 2 for concentrations  $\geq$  95th but  $<$  98th percentile, and
- a value of 3 for concentrations  $\geq$  98th percentile.

- Step 3 Sample ratings are calculated by summing enrichment values, only samples with a rating of 3 or more are listed in the evaluation charts.

Enrichment values were not calculated for the following;

- Uranium and Fluorine in water, pH and LOI; and
- Data subset thresholds below the following base levels.

Elements	Base level	Elements	Base level	Elements	Base level
Fe	0.10 %	Zn, Cu, Pb, Ni, Co	10 ppm	Ag, Cd, Sb, Bi	0.5 ppm
F	200 ppm	As, Mo, Sn, W	5 ppm	Hg	50 ppb
Mn, V, Cr	25 ppm	U	1 ppm	Au	5 ppb

### Anomaly Maps

Base metal and precious metal anomaly maps highlight the spatial relationships between anomalous samples which may not be apparent in the evaluation charts.

- Step 4 Site values are calculated from the evaluation charts by summing the enrichment values for the following associations:

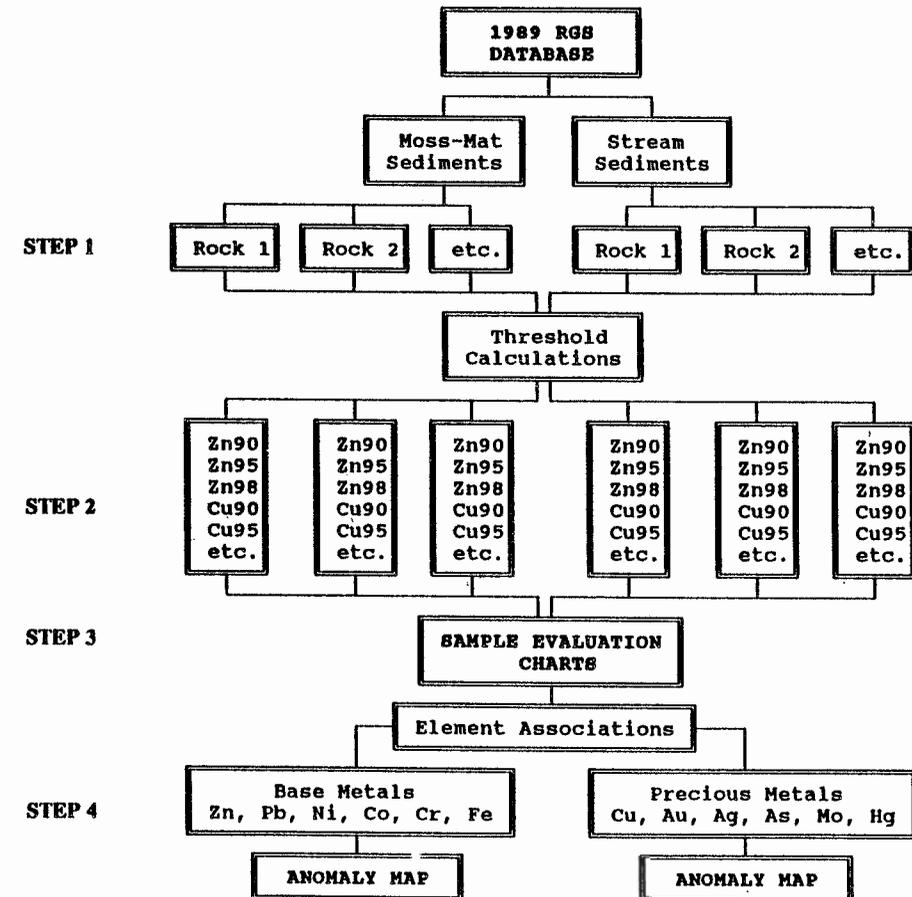
- Base metals - Zn, Pb, Ni, Co, Fe, Cr (massive sulphides and base-metal skarns)
- Precious Metals - Cu, Au, Mo, As, Hg, Sb (porphyry, hydrothermal and skarn deposits)

Note that only site values of 3 or more are plotted.

### Methods for Improvement

The techniques employed are a method of data presentation and interpretation. Computer literate users are encouraged to explore other avenues at their leisure. Specific recommendations are:

- 1) Evaluating samples based on predominant rock type found within the drainage basin may improve background and anomaly definition. At present, sample lithology is recorded as the lithology underlying the sample site.
- 2) Generating histograms or probability plots for each media/lithology data subset may better define elemental threshold levels for sample evaluation.
- 3) Using alternate element associations or element weighting may better define anomalous sample sites.



## CORRELATION MATRICES

### Introduction

Correlation matrices found in Appendix E have been provided to assist in resolving elemental relationships observed in the database. Matrices were generated in the following manner:

- 1) Data subsets are drawn from the complete 1990 RGS database, subdivisions are based on media type (i.e. moss-mat vs. stream sediment) and lithology (i.e. Karmutsen Fm.). Meaningful correlations can only be drawn on unimodal data, subdividing reduces the chance of polymodal populations. Only subsets containing 40 or more samples are used.
- 2) All data is log transformed to reduce the effect of large concentration range on statistical calculations.
- 3) Element correlations are calculated as  $r$  (linear correlation coefficient) values.
- 4) Symbols have been substituted for  $r$  values in the matrices to allow rapid evaluation:

   $r < 0.5$   
•  $0.5 < r < 0.7$   
••  $0.7 < r < 0.8$   
•••  $r > 0.8$

For those users unfamiliar with correlation matrices, a general overview follows, a more complete discussion is given by Sinclair (1986). The term correlation refers to a statistical relationship that can exist between paired variables. Every day examples may included;

- a strong positive correlation (sympathetic relationship) between alcohol consumption and traffic related deaths, and
- a strong negative correlation (antipathetic relationship) seen between interest rates and volume of major item purchases (houses, cars, etc.).

In such cases, the two variables being examined exhibit a direct (cause and effect) or indirect (both variables controlled by an outside factor) dependency, a change in one variable is accompanied by a change in the other. The degree of correlation can be measured using the linear regression correlation coefficient  $r$  which can vary from a perfect correlation value of 1 (positive correlation) or -1 (negative correlation) to a total lack of correlation value tending to 0. Where numerous variables (i.e. ICP suite of 30 elements) are to be paired and tested, the data is best presented as a matrix. An  $r$  value is calculated between each variable listed on the Y and X axes with the result recorded in the box representing the intersection of the two variables.

In geochemistry, correlation calculations can be used to determine element associations. We may want to measure anomalous (i.e. between Cu and Zn in soils over a massive sulphide target) or background (i.e. between high Ni and ultramafic rocks) associations. Due to the nature of the RGS program (reconnaissance scale), significant correlations will usually reflect background element associations in underlying lithologies. This information will aid in resolving subtle anomalies due to mineral occurrences.

The significance of the correlation coefficient (does the correlation reflect a true association) is strongly dependent upon the number of pairs used in the calculations. The significance can be tested using  $F$  tables which give critical  $r$  values for varying degrees of freedom (number of data pairs - 2) at various confidence levels (95%, 99% or 99.9%).

$F$  Table giving critical  $r$  values for the 95%, 99% and 99.9% confidence levels.

d.f.*	Critical $r$ Values			d.f.*	Critical $r$ Values		
	95%	99%	99.9%		95%	99%	99.9%
1	0.997	0.999	1.000	10	0.576	0.708	0.823
2	0.950	0.990	0.999	20	0.423	0.537	0.652
3	0.878	0.959	0.991	40	0.304	0.393	0.490
4	0.811	0.917	0.974	60	0.250	0.325	0.408
5	0.754	0.875	0.951	80	0.217	0.283	0.357
6	0.707	0.834	0.925	100	0.195	0.254	0.321
7	0.666	0.798	0.898	150	0.159	0.208	0.264
8	0.632	0.765	0.872	200	0.138	0.181	0.230
9	0.602	0.735	0.847	500	0.088	0.115	0.147

d.f.\* degrees of freedom = N (Number of pairs) - 2

### Methods of Improvement

Users of the RGS database may want to improve upon these methods. Specific recommendations are:

- 1) Generate scatter diagrams for each correlation to ensure  $r$  values have not been over or underestimated due to outlier data (inadvertent mixing of rock types or biasing due to anomalous data).
- 2) Determine elemental associations for anomalous samples by generating a matrix for each element using either the 95th percentile concentration or a threshold determined from a probability plot.

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# 1990 Regional Geochemical Survey

## RGS 24

### Victoria / Cape Flattery - NTS 92B / 92C

#### APPENDIX A

## Field Observations and Analytical Results

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

Table A-1 Geology of Victoria/Cape Flattery Map Sheets - 92B / 92C

FORMATION		DESCRIPTION	FORMATION		DESCRIPTION
1990	1989		1990	1989	
<b><u>STRATIFIED ROCKS</u></b>					
<b>MPs</b>	Ts	<b>CENOZOIC</b> Tertiary Miocene and Pliocene <u>Sooke</u> : sandstone, shale, conglomerate	<b>uTK</b>	uTKl uTKm uTK	<b>MESOZOIC</b> Triassic <u>Karmutsen</u> : basalt, pillow lava
<b>EOc</b>	lTE lTH	Eocene and Oligocene <u>Carmanah Group</u> : sandstone, shale	<b>PBL</b>		<b>PALEOZOIC</b> Permian <u>Buttle Lake</u> : limestone
<b>EM</b>		Eocene <u>Metchosin Group</u> : pillow basalt	<b>Cs</b>	CPs	Carboniferous (or younger) <u>Sicker Group</u> : meta-andesite, dacite
<b><u>INTRUSIVE ROCKS</u></b>					
<b>uKN</b>	uKg uKS	<b>MESOZOIC</b> Cretaceous <u>Nanaimo Group</u> : sandstone, shale, conglomerate	<b>ETb</b>		<b>CENOZOIC</b> Tertiary <u>Sooke</u> : augite gabbro
<b>JKLR</b>		Jurassic and Cretaceous <u>Leech River</u> : greywacke, phyllite, schist	<b>MJqm</b>	Jg	<b>MESOZOIC</b> Jurassic quartz monzonite, granite, monzonite
<b>JKPR</b>	JKP	<u>Pacific Rim</u> : greywacke, argillite	<b>MJgd</b>	Jg	granodiorite
<b>lJB</b>	lJB lJBV lJb	Jurassic <u>Bonanza</u> : andesite, dacite, rhyolite	<b>MJqd</b>	Jg	quartz diorite
<b>uTQ</b>	uTO uTPB	Triassic <u>Quatsino and Parson Bay</u> : limestone, argillite	<b>din</b>	PMdn PMSV	<b>ROCKS OF UNKNOWN AGE</b> Coast Plutonic Complex diorite foliated to gneiss diorite, amphibolite

**Table A-2 Reference Guide for Field Observations**

Column	Definition and Descriptions	Column	Definition and Descriptions	Column	Definition and Descriptions	
<b>MAP</b>	1:50 000 NTS map sheet number	<b>SED COL</b>	Sediment Colour: B = Black      R = Red G = Grey-Blue    T = Tan-Brown O = Olive-Green   W = White-Buffer P = Pink        Y = Yellow	<b>CHL PTN</b>	Channel Pattern: S=Shoots-Pools    M=Meandering B=Braided        D=Disturbed	
<b>SAMPLE ID</b>	Sample number			<b>ELEV</b>	Elevation: in metres	
<b>UTM ZONE</b>	UTM Zone Number			<b>SED PPT</b>	Sediment Precipitate: N = None (otherwise same as SED COL)	<b>PHY</b>
<b>UTM EAST</b>	UTM East Coordinate	<b>CON</b>	Contamination: N = None            D = Domestic P = Possible        F = Forestry A = Agricultural   M = Mining			
<b>UTM NORTH</b>	UTM North Coordinate	<b>SED COMP</b>	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)	<b>DRN</b>	Drainage Pattern: D=Dendritic        H=Herringbone G=Glacially        I=Interrupted deranged        R=Rectangular	
<b>STA</b>	Replicate Sample Status: 0 = Routine Sample 1 = 1st Field Duplicate 2 = 2nd Field Duplicate 8 = Blind Duplicate 9 = Control Reference			<b>STRM WPTH</b>	Stream Width: in metres	<b>TYP</b>
<b>MED</b>	Sample Media Collected: 1 = Stream Sediment only 6 = Stream Sediment & Water 7 = Moss-Mat Sediment only 8 = Moss-Mat Sediment & Water	<b>STRM DPTH</b>	Stream Depth: in centimetres	<b>ODR</b>	Stream Order: 1=Primary            3=Tertiary 2=Secondary        4=Quaternary	
<b>FORMATION ROCK TYPE AGE</b>	{ see Table A-1 }	<b>BNK</b>	Bank Composition: A = Alluvium      R = Rock C = Colluvium    S = Talus G = Outwash      T = Till O = Organic        U = Unknown	<b>SRC</b>	Stream Source: G=Groundwater    S=Spring runoff M=Melt water      U=Unknown	
<b>WAT COL</b>	Water Colour: 0 = Colourless    2 = White Cloudy 1 = Brown Clear   3 = Brown Cloudy	<b>BNK PPT</b>	Bank Precipitate: N = None (otherwise same as SED COL)	<b>M</b> <b>O</b> <b>S</b> <b>S</b>	<b>HGHT</b>	Height: above stream in metres
<b>FLW</b>	Water Flow Rate: 0 = Stagnant      3 = Fast 1 = Slow            4 = Torrent 2 = Moderate	<b>CHL BED</b>	Channel Bed: B = Boulders      S = Gravel-Sand F = Silt-Clay      O = Organics		<b>COLR</b>	Colour: L=light green D =Dark green    B =Brown-black
					<b>HLTH</b>	Health: A = Alive    D = Dead
				<b>HOST</b>	Host: 1=Rock    2=Friable Rock 3=Log        4=Decomposed Log	
				<b>THCK</b>	Thickness of Mat: centimetres	

**Table A-3 Methods and Specifications for Sample Analysis**

Element	Units	Detection Limits	Sample Weight	Digestion Technique	Determination Method	
Gold	ppb	1 ppb	10 gm	Fire Assay fusion	FA-AA	Atomic absorption spectrophotometry after digestion of dore bead by aqua regia
Silver	ppm	2 ppb 0.1 ppm	5 gm 10 gm			
Cadmium	ppm	0.2 ppm	1 gm	3 ml HNO <sub>3</sub> let sit overnight, add 1 ml HCl in 90°C water bath for 2 hrs cool add 2 ml H <sub>2</sub> O wait 2 hours	AAS	Atomic Absorption Spectrophotometer using air-acetylene burner and standard solutions for calibration, background corrections made for Pb, Ni, Co, Ag, Cd.
Cobalt	ppm	2 ppm				
Copper	ppm	2 ppm				
Iron	%	0.02 %				
Lead	ppm	2 ppm				
Manganese	ppm	5 ppm				
Nickel	ppm	2 ppm				
Zinc	ppm	2 ppm				
Molybdenum	ppm	1 ppm	0.5 gm	Al solution added to above		
Vanadium	ppm	5 ppm	1 gm	HNO <sub>3</sub> -HCl-HF taken to dryness, hot HCl added to leach residue		
Chromium	ppm	5 ppm				
Bismuth	ppm	0.2 ppm	2 gm	HCl - KClO <sub>2</sub> digestion, KI added to reduce Fe, MIBK and TOPO for extraction	AAS-H	Organic layer analyzed by Atomic Absorption Spectrophotometry with background correction
Antimony	ppm	0.2 ppm				
Tin	ppm	1 ppm	1 gm	sintered with NH <sub>4</sub> I, HCl & ascorbic acid leach	AAS	Atomic Absorption Spectrophotometry

**Table A-3 (Continued) Methods and Specifications for Sample Analysis**

Element	Units	Detection Limits	Sample Weight	Digestion	Determination Method	
Arsenic	ppm	1 ppm	0.5 gm	add 2 ml KI & dil. HCl to .8M HNO <sub>3</sub> - .2M HCl	<b>AAS-H</b>	2 ml borohydride solution is added to produce AsH <sub>3</sub> gas which is passed through heated quartz tube in the light path of Atomic Absorption Spectrophotometer (after Aslin, 1976)
Mercury	ppb	10 ppb	0.5 gm	20 ml HNO <sub>3</sub> & 1 ml HCl	<b>AAS-F</b>	10% stannous sulphate added to evolve mercury vapour Atomic Absorption Spectrometer determination (after Jonasson et al., 1973)
Tungsten	ppm	1 ppm	0.5 gm	K <sub>2</sub> SO <sub>4</sub> fusion HCl leach	<b>COLOR</b>	colorimetric: reduced tungsten complexed with toluene 3,4 dithiol
Fluorine	ppm	40 ppm	0.25 gm	NaCO <sub>3</sub> -KNO <sub>3</sub> fusion H <sub>2</sub> O H <sub>2</sub> O leach	<b>ION</b>	Citric acid added and diluted with water, Fluorine determined with specific ion electrode (after Ficklin, 1970)
Uranium	ppm	0.5 ppm	1 gm	nil	<b>NADNC</b>	Neutron Activation with delayed neutron counting (after Boulanger et al., 1975)
LOI	%	0.1 %	0.5 gm	nil	<b>GRAV</b>	Sample ashed (500°C), weight difference measured
pH - water	pH unit	0.1	25 ml	nil	<b>GCE</b>	Glass-calomel electrode system
U - water	ppb	0.05 ppb	5 ml	nil	<b>LIF</b>	add .5 ml Fluran place in Scintrex UA-3 analyzer
F - water	ppb	20 ppb	25 ml	nil	<b>ION</b>	Fluorine measured by ion specific electrode