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Enhanced interpretation of RGS data using catchment basin analysis and weighted sums modeling: examples from map sheets NTS 105M, 105O and part of 105P

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Heberlein Geoconsulting
Extracting value from geochemistry

Yukon Geological Survey

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Cover photo: Weighted sums model for Carlin-type deposits, NTS 105M.

PREFACE

Regional stream sediment geochemical data generated by the Geological Survey of Canada (GSC) have been successfully used as an exploration tool in Yukon for several decades. Between 2010 and 2012, Yukon Geological Survey re-analyzed stream sediment sample pulps from GSC's Archives in Ottawa, upgrading the dataset for all available material from Selwyn Basin to a 53 element suite using ICP-MS analysis. The project was led by Wayne Jackaman, and the data were released as nine YGS Open Files (2011-28-30; and 2012-6-10).

As a next step to improving the dataset, two of the areas covered by the recently-released Open Files were selected for further data processing to add value to the raw data. Catchment areas were delineated for each sample, and data were modeled to isolate the geochemical signatures that are characteristic of the known mineral deposit types in the area. Data processing and interpretation were undertaken by Dave Heberlein, and the maps were generated by Olwyn Bruce.

This report and the accompanying series of maps present the results of this "value-added" analysis of raw stream sediment geochemical data. The project was funded by the Canadian Northern Economic Development Agency (CanNor) through their Strategic Investments in Northern Economic Development program.

Carolyn Relf

Director,
Yukon Geological Survey

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Enhanced interpretation of RGS data using catchment basin analysis and weighted sums modeling: examples from map sheets NTS 105M, 105O and part of 105P

Heberlein, D.R., 2013. Catchment basin analysis and weighted sums modeling: enhanced interpretation of RGS data using examples from map sheets NTS 105M, 105O and part of 105P. Yukon Geological Survey, Open File 2013-16, report and 116 maps.

ABSTRACT

The ongoing program of reanalysis of RGS samples is producing a high quality regional dataset that when completed will be an invaluable resource to help explorers identify areas for prospecting and staking. As a pilot study, this project adds value to the raw data for two map sheets; NTS 105M and 105 O and part of 105P, by applying advanced interpretation techniques to enhance patterns that may be caused by mineralization. Catchment basin analysis is used to correct the raw data for background shifts caused by changes in local geology that could otherwise mask subtle mineralization signals. The effect of dilution due to increasing catchment basin size is also assessed. Modeling of the levelled RGS results for six mineral deposit types using Weighted Sums Modeling (WSM) is undertaken to highlight areas with potential for those specific mineral deposit types. Data is presented as a series of 1:250 000 scale thematic maps showing catchment basins colour coded by levelled element concentration and WSM scores.

INTRODUCTION

In 2010, Yukon Geological Survey (YGS) awarded a multi-year contract to Noble Exploration Services to re-analyze archived stream sediment samples originally collected by the Geological Survey of Canada under their National Geochemical Reconnaissance Program. By the end of 2012 a total of 9498 archived stream sediment samples had been re-analyzed for a suite of 53 elements by aqua regia digestion and ICP-MS or ICP-OES. Results for eight 1:250 000 map sheets (full and partial areas) have been released as open files as illustrated in Figure 1. This report presents the results of a case study on two of those map sheets, NTS 105M (OF 2012-08) and 105O and part of 105P (OF 2011-30), designed to add value to the new analyses.

Traditional interpretation of RGS data utilizes relatively simplistic 'dot plot' maps to visually present concentrations for single elements. While reasonably effective for highlighting potential areas of interest, this methodology is limited in a number of ways. First, it provides a misleading impression of the effective area of sampling coverage. Maps showing a relatively uniform distribution of sample locations give the impression of complete coverage of the area when in actual fact this is rarely the case. At a typical sample density of one sample per 10 km^2 a large number of drainages are un-sampled and as a result targets could be missed. Furthermore variations in catchment basin size and geology mean that dilution and background shifts due to changes in lithology could mask patterns of interest.

Second, single element plots do not allow for easy investigation of geological processes. For example in order to identify geochemical signatures related to a particular style of mineralization or to highlight areas of hydromorphic concentration that could be otherwise misinterpreted as a mineralization signal, combinations of elements describing those processes need to be used.

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This study investigates these issues through catchment basin analysis and the application of Weighted Sums Modeling (WSM) to the multi-element results.

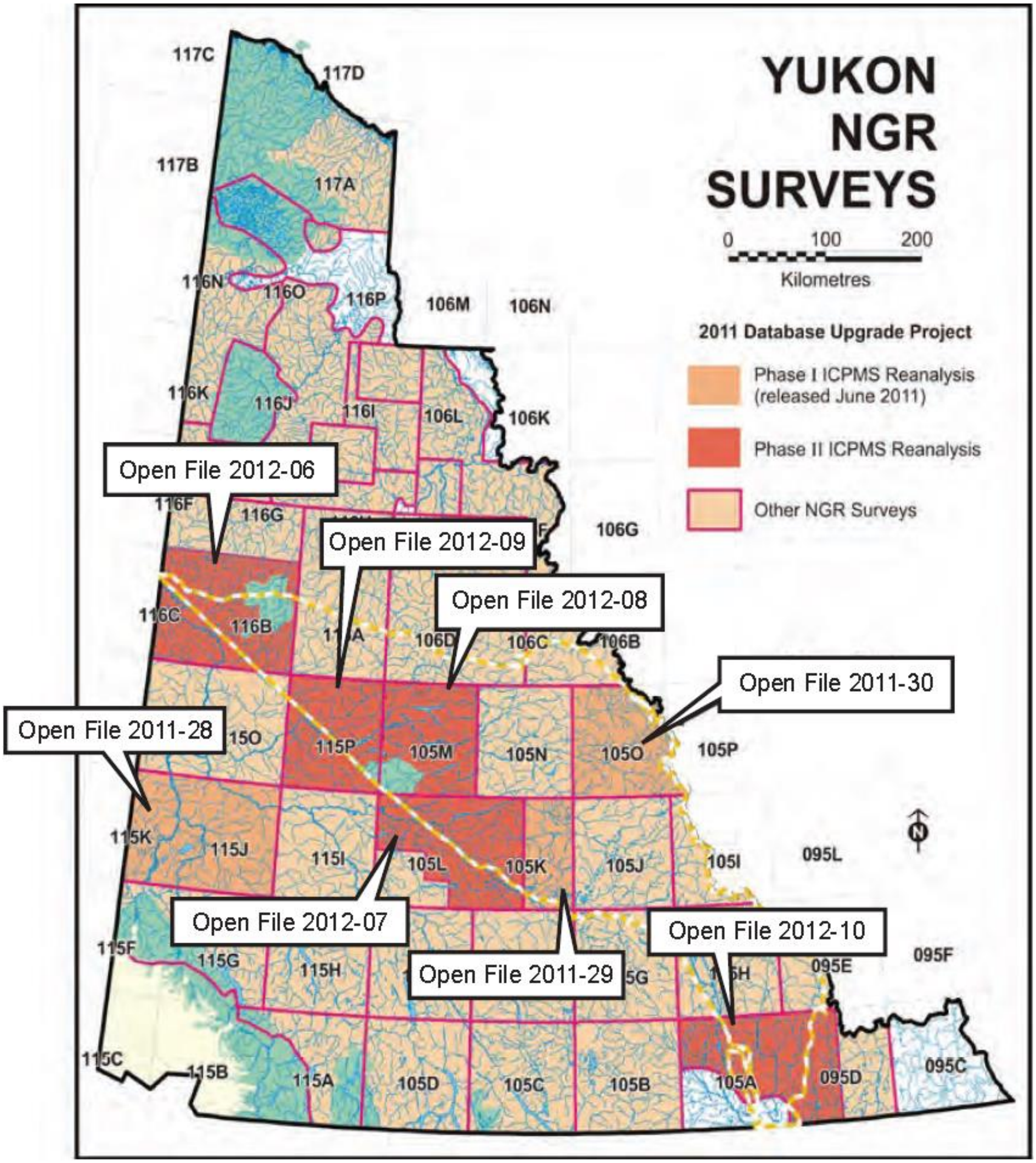

Figure 1. *Recent Open Files for RGS reanalyses. Map sheets included in this study are highlighted in green.*

CATCHMENT BASINS

Effect of Catchment Basin Geology

A stream sediment sample represents the average composition of sediment passing through that point in the drainage. It is a composite of material eroded from the entire surface area of the catchment basin (assuming equal erosion rates over the catchment area) upstream from the sample location. Consequently sediment composition is highly influenced by the bedrock and surficial geology of the catchment basin (Bonham-Carter and Goodfellow, 1986; Carranza, *et al.*, 1997; Ottensen and Theobald, 1994; Sibbick, 1994). Background shifts caused by variations in catchment basin geology may mask relatively subtle signals caused by mineralization.

A good example of this effect was reported by Sibbick (1994) from a 1993 moss-mat survey carried out by the British Columbia Geological Survey (BCGS) on northern Vancouver Island. Results of this study show that less than 10% of known copper occurrences are found in catchment basins with moss-mat Cu values above 100 ppm (80th percentile) even though 70% of the mineral occurrences in the map area contain Cu-bearing mineralization. Sibbick concluded that the poor response was either due to a lack of a response from these occurrences or that it had been suppressed by the high background concentration of the most widespread lithology in the area: the Karmutsen volcanics.

Arne and Bluemel (2011), in their interpretation of RGS results from the QUEST South area of southern British Columbia, show that effective background corrections for the dominant bedrock unit can be done using Log (10)-Z-Score levelling of raw data or on residuals produced from regression analysis. The former method preserves the overall data distribution including outliers that could be important indicators of mineralization. The same levelling approach is used for this study.

Effect of Catchment Area

Dilution is another factor determining whether an anomaly may be detected (Hawkes, 1976; Moon, 1999). Regional stream sediment surveys typically encompass a wide range of catchment basin sizes. It is common to observe the most elevated metal values in catchment basins with the smallest surface areas, where dilution of the signal is relatively minor. Larger catchment basins have a much higher total sediment yield, which causes dilution of the mineralization signal. Therefore the possibility exists that lower intensity anomalies in larger catchment basins could be ignored. The effect of catchment basin size on element concentration is investigated in this study.

Decoupling

Another possible complication in larger catchment basins is decoupling (Sleath and Fletcher, 1982; Fletcher, 1997). This occurs where the link between the catchment basin slopes and sediment supply to the stream become disconnected. Decoupling can happen in higher order drainages where the stream bed is separated from the eroding slopes by alluvial deposits (*i.e.*, flood plains or alluvial terraces). In this situation material eroded from the valley slopes (colluvium) is deposited and stored at the base of the slope along the edges of the flood plain instead of entering the stream. When this occurs the primary source of sediment entering the stream is its own alluvial deposits. Under these conditions stream sediment anomalies related to mineralization are unlikely to occur. Erosion of tills and glaciofluvial or glaciolacustrine deposits low on the valley slopes would have the same effect.

METHODOLOGY

Catchment Basin Definition

Basins can be defined either manually by digitizing polygons around topographic divides, or digitally using GIS hydrological modeling software and a digital elevation model (DEM). Manual digitizing was used for this study. For the majority of catchment basins where the sample location is located on or close to the stream, digitization was relatively straight forward. However, in a small number of cases the sample location was either displaced from the stream or located in areas without well-defined drainages. In the former case the sample location is assumed to be at the nearest point on the closest second order stream. In the latter case catchment basins could not be defined and the samples had to be excluded from the interpretation. Similarly samples located on third order streams are also excluded so as to avoid prohibitively large and uninterpretable catchment areas.

Surface areas for each catchment basin were automatically calculated in ArcGIS and appended to the attribute table. A GIS query was also used to attribute each catchment basin polygon with the percentage surface area of each geological unit present in the catchment. Defined catchment basins for NTS 105M and 105O and part of 105P are illustrated in Figures 2 and 3.

Weighted Sums Modeling

The application of Weighted Sums Modeling (WSM) to exploration geochemistry is described by Garrett and Grunsky (2001) as a means to model multi-element data using *a priori* knowledge of the mineralogy and element composition of the sought after mineral deposit (Kane, 1977; Garrett *et al.*, 1980). In this procedure weights or relative importance are assigned to each variable or a subset of variables according to some geochemical or mineralogical model of the target mineral deposit type or geological process. Weighted sums (WS) are new variables calculated from the multi-element geochemical results. Like Principal Components Analysis (PCA) or Factor Analysis scores, WS scores have the form of normal or standardized scores with a mean of zero and a standard deviation of one. The main difference between WSM and traditional multivariate statistical methods is that the user assigns the variable weightings rather than determining them with a covariance/correlation matrix for the dataset, as is done in PCA. Furthermore WSM is a robust statistical technique that is not influenced by the presence of outliers (Beckman and Cook, 1983).

The reader is referred to Garrett and Grunsky (2001) for a description of the WS calculation. In summary, relative importance is assigned for each variable. A weighting of 3, for example, means that that particular element is three times more important than an element with a weighting on one. Weighting can be positive or negative. Positive weightings mean that the target model is associated with elevated concentrations of an element. Negative weightings indicate that low concentrations or depletions of an element are important.

Individual relative importance is converted into weights that sum to one by dividing each importance by the sum of the absolute values of importance (*i.e.*, ignoring the negative signs). A requirement of the method is that the sums of the squares of the final weights also equal one. This is achieved by dividing each weight by the square root of the sum of the squares of the weights.

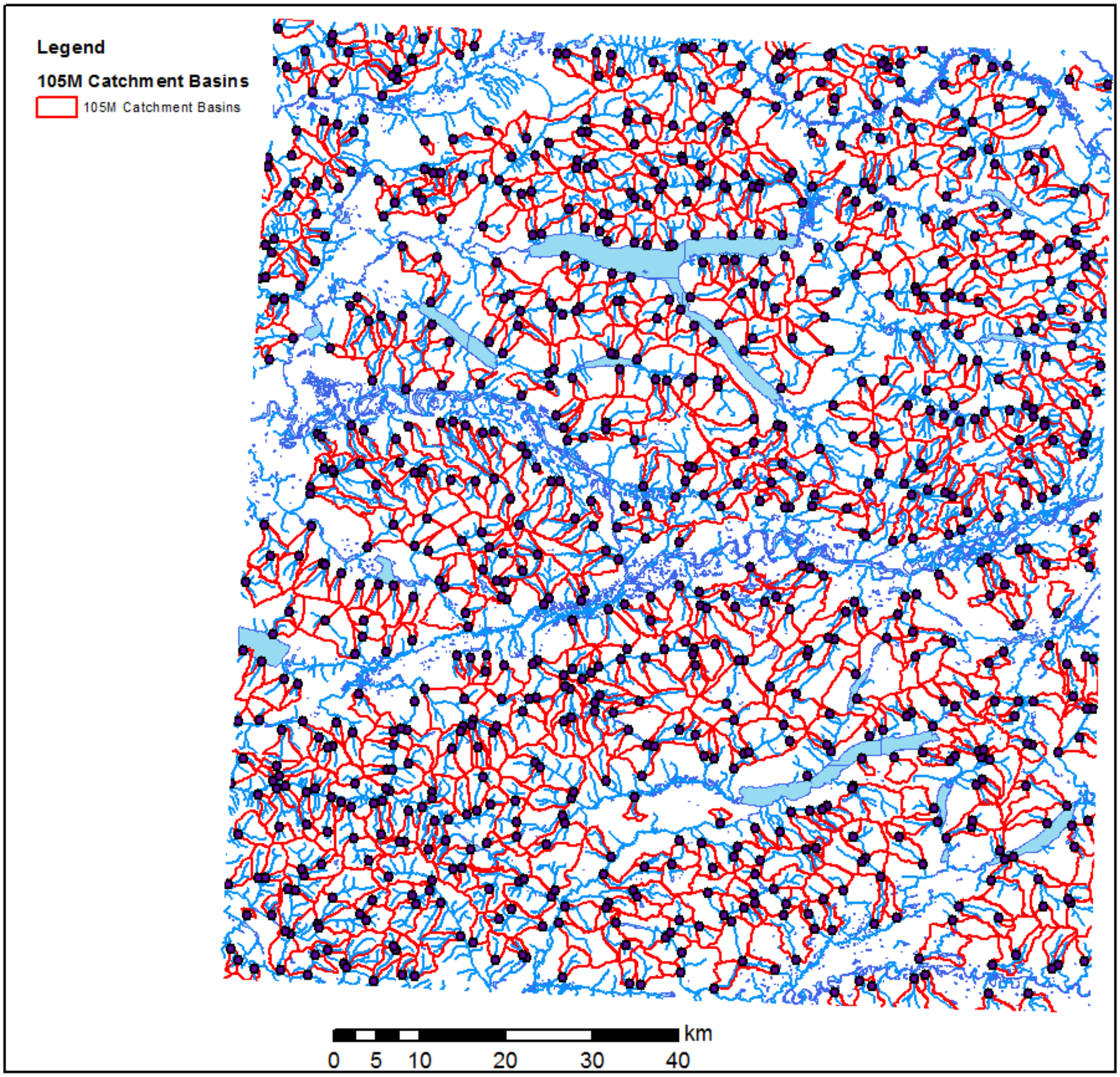

Figure 2. *Defined catchment basins for NTS 105M.*

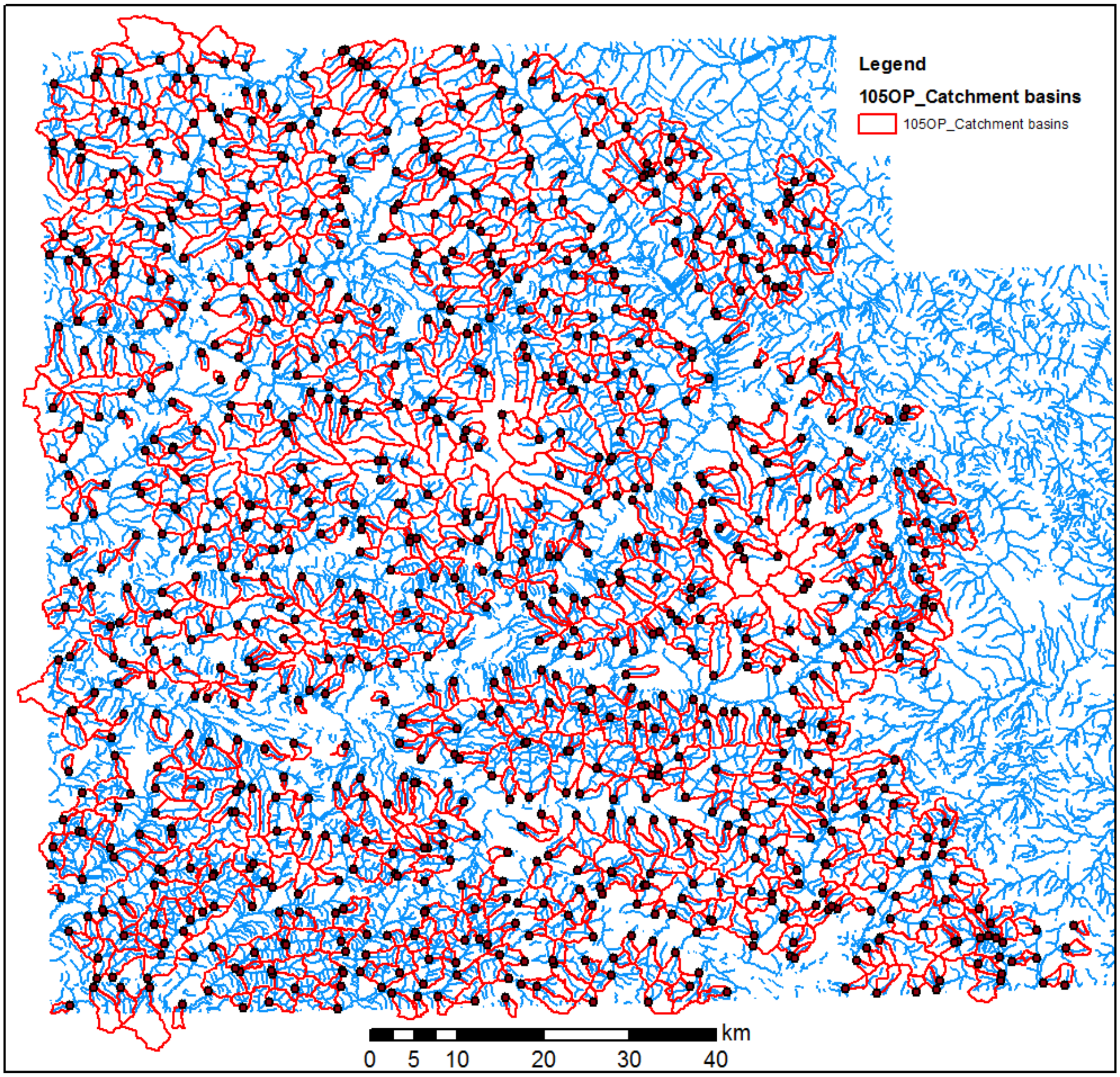

Figure 3. *Defined catchment basins for NTS 105O and parts of P.*

The next step involves calculation of the normal scores for the variables included in the model for each individual sample. To do this, robust estimates of the mean and standard deviation are used. The median (or 50th percentile) is used as a robust estimate of the mean, and the inter-quartile range (IQR) multiplied by 0.7413 is used as a robust estimate of the standard deviation. IQR is the difference between the 75th and 25th percentiles of the data distribution and therefore covers a band of data 25% wide (or 0.67449 standard deviation units) on either side of the mean. The constant 0.7413 is used to convert the IQR, which covers a range of 1.3490 standard deviation units to an equivalent standard deviation[1]. Weighted sums are then calculated by multiplying the normal scores for each element by the element's corresponding weight and summing for each sample. The high resistance of the median and IQR to outliers mean that it is not usually necessary to trim outlier and far outliers from the dataset before calculation.

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[1] For a normal distribution the standard deviation is equal to 0.7413*IQR, where 0.7413 is the reciprocal of 1.349.

Models and Weightings

Six mineral deposit types (SEDEX, Porphyry Cu, W-Skarn, IRCG, Polymetallic veins, and Carlin) that are either known or believed to occur in the map sheet areas and one geochemical process (hydromorphic dispersion) are modeled using the WS method. Included elements and their relative importance are presented in Table 1.

Table 1. *Deposit models and element relative importance used in the WSM calculations.*

Deposit Type	**Ag**	**Au**	**As**	**Ba**	**Bi**	**Cd**	**Co**	**Cu**	**Cs**	**Fe**	**Hg**	**K**	**Mn**	**Mo**	**Ni**	**Pb**	**S**	**Sb**	**Tl**	**W**	**Zn**
Polymetallic Veins	4	4	3			4	1	2		1	1		1	1	1	5		3			5
W-Skarn			3		3					1		3		3						5	1
Porphyry Cu	2	2			1			5	3					3			2				
Intrusive Related Cu-Au	1	2	5		5			2		1	5		1	2		1		1		2	
SEDEX				5		3									1	5		1	5		5
Carlin	2	1	5	2							4							5			
Hydromorphic Dispersion	2		1			4	5	2		5			5	2	4	2		1			3

Data Presentation

Results of each WS model were attached to the corresponding catchment basin polygons using a spatial join in ArcGIS. This process allows for the entire polygon to be assigned a colour based on its WS score. Colours are assigned on the basis of the following percentile breaks:

0-50%	Dark blue
50-75%	Pale blue
75-90%	Pale green
90-95%	Yellow
95-98%	Orange
98-100%	Red

With this scheme, catchment basins with the hotter colours represent samples with the geochemical characteristics consistent with the mineralization style being modeled.

Thematic maps showing the WSM model results for NTS 105M and 105O/P are presented in Appendices A and B.

Correction for Catchment Basin Dominant Lithology

Another component of this study addresses the effect of catchment basin geology on the RGS results. As mentioned earlier, background shifts caused by changes in catchment basin geology may result in subtle mineralization signals being overwhelmed by lithologically-induced geochemical variations for some key elements.

In order to remove these effects, the results for a subset of elements have been levelled using the method described by Arne and Bluemel (2011). Levelling was done in ioGAS® software using the Log (10)-Z-Score transformation with dominant lithology (REG_Lith) as the classification variable. For this method, the dataset is divided into sub-populations based on the dominant lithology of the catchment basins. Results for each population are first log (10) transformed and then the means and standard deviations are calculated for each one. Z-Scores are derived by subtracting the mean of the sub-population from each value and dividing the result by the standard deviation. Then, the Log (10)-Z-Scores for all of the sub-populations are recombined into a single dataset for plotting. Examples of unlevelled and levelled results for Cu from NTS 105M are shown in Figure 4. Summary statistics including percentile breaks used for thematic map colouring are shown in Tables 2 to 5.

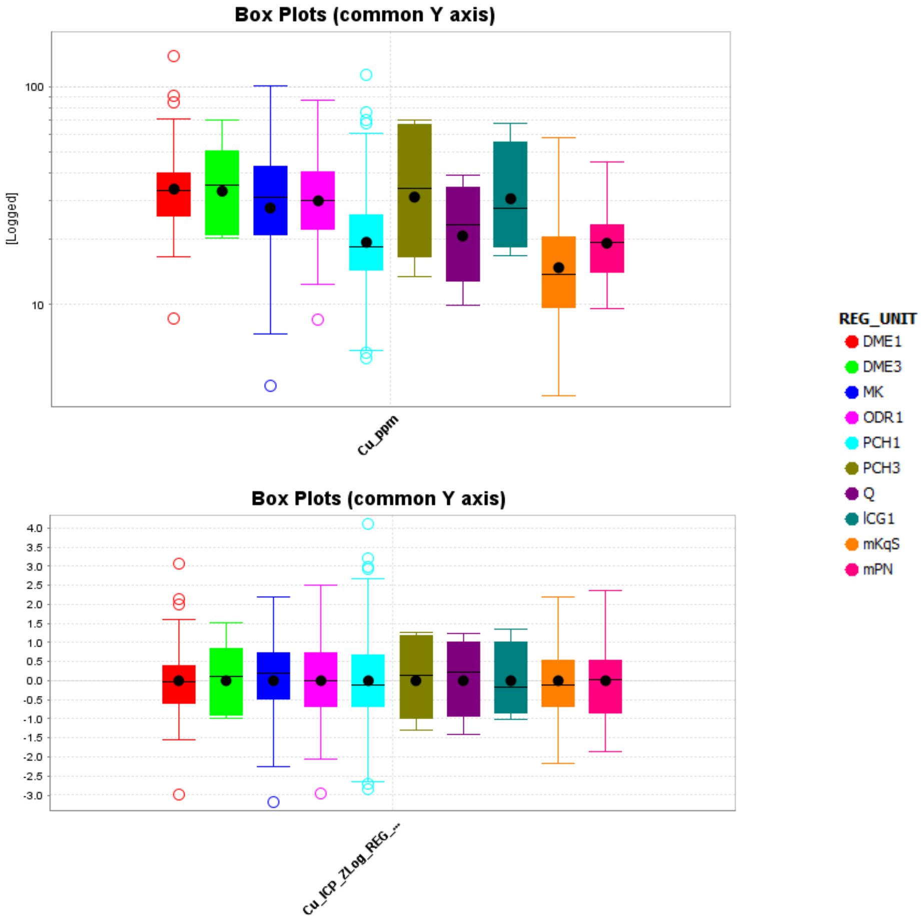


Figure 4. *An example of unlevelled (top) and levelled (bottom) results for Cu from NTS 105M.*

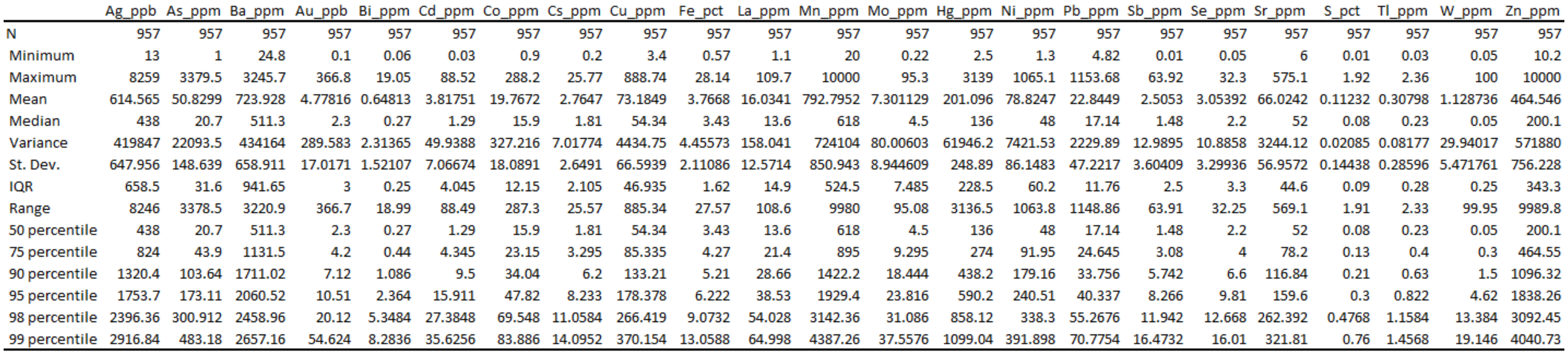
Table 2. *Summary statistics for selected elements from NTS 105M (unlevelled).*

	Ag_ppb	As_ppm	Ba_ppm	Au_ppb	Bi_ppm	Cd_ppm	Co_ppm	Cs_ppm	Cu_ppm	Fe_pct	La_ppm	Mn_ppm	Mo_ppm	Hg_ppm	Ni_ppm	Pb_ppm	Sb_ppm	Se_ppm	Sr_ppm	S_pct	Tl_ppm	W_ppm	Zn_ppm
N	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847
Minimum	19	0.7	33.7	0.1	0.04	0.04	3.1	0.16	3.83	0.66	0.25	79	0.09	2.5	6.7	2.57	0.07	0.05	7.3	0.01	0.01	0.05	25
Maximum	52952	6108	2156.2	210.5	23.17	61.01	89.2	26.3	138.42	7.22	61.9	10000	49.65	5803	311.5	430.79	27.68	9.8	601.1	2.23	0.95	100	4828
Mean	257.452	25.7207	299.222	3.37875	0.23094	0.74468	9.82054	1.05357	24.2517	2.11307	15.226	595.0779	1.092468	80.6806	24.0438	13.2566	0.86419	0.76824	39.6378	0.06579	0.092	0.743211	102.879
Median	110	8.7	196.9	1.7	0.16	0.32	8.5	0.61	20.51	2.01	14.1	374	0.57	46	20.8	10.35	0.41	0.4	29.9	0.03	0.07	0.05	74
Variance	3592097	45391.7	92629.2	116.319	0.66767	5.98762	37.2314	2.32362	190.127	0.51696	38.4714	1053875	5.731727	51624	243.715	658.253	3.5394	1.05887	1641.33	0.01999	0.0047	21.58253	34722.9
St. Dev.	1895.28	213.053	304.35	10.7851	0.81711	2.44696	6.10175	1.52434	13.7887	0.719	6.20253	1026.584	2.394103	227.209	15.6114	25.6564	1.88133	1.02901	40.5133	0.14138	0.0689	4.6457	186.341
IQR	126	8.6	175.4	1.6	0.1	0.49	3.9	0.58	15.07	0.79	6.9	282	0.77	51	10.8	5.79	0.62	0.7	23.7	0.04	0.06	0.15	48.9
Range	52933	6107.3	2122.5	210.4	23.13	60.97	86.1	26.14	134.59	6.56	61.65	9921	49.56	5800.5	304.8	428.22	27.61	9.75	593.8	2.22	0.94	99.95	4803
50 percentile	110	8.7	196.9	1.7	0.16	0.32	8.5	0.61	20.51	2.01	14.1	374	0.57	46	20.8	10.35	0.41	0.4	29.9	0.03	0.07	0.05	74
75 percentile	194	14.7	310.3	2.7	0.22	0.68	10.9	1.02	30.06	2.43	18	552	1.16	80	27.3	13.62	0.88	0.9	45.5	0.06	0.11	0.2	104.7
90 percentile	340.6	34.96	631.18	4.7	0.3	1.332	13.8	2.15	40.078	2.882	23.5	853.2	2.142	150.2	36.24	18.008	1.646	1.6	67.76	0.11	0.17	0.62	168.66
95 percentile	532.8	61.68	974.56	7.42	0.426	2.208	17.42	3.636	47.93	3.35	27.02	1326	2.996	217.4	44.92	21.586	2.398	2.3	87.52	0.2	0.23	2.66	227.56
98 percentile	862.24	131.212	1335.46	16.916	0.7404	4.4608	26.012	5.334	66.9564	4.3208	30.4	3653.04	4.9716	342.76	61.636	31.6332	4.3128	3.712	134.228	0.4308	0.29	7.448	356.004
99 percentile	1471.68	217.764	1539.78	44.82	1.1216	7.3296	40.008	6.6064	72.9452	4.8868	35.508	6983.32	6.9192	425.08	83.9	42.6708	6.8144	6.008	201.744	0.7288	0.3152	17.484	442.916

Table 3. *Summary statistics for selected elements from NTS 105M (levelled)*

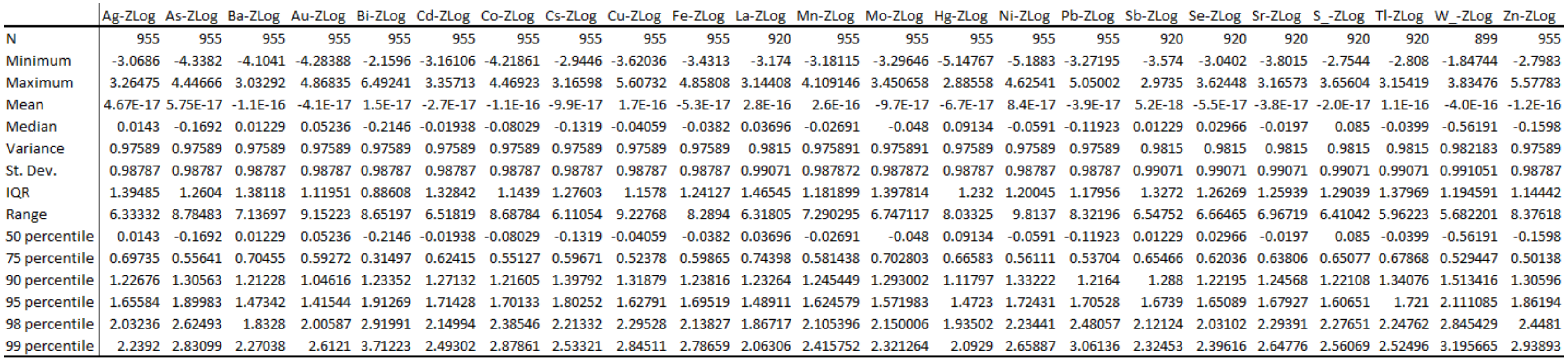
	Ag_ZLog	As_ZLog	Ba_ZLog	Au_ZLog	Bi_ZLog	Cd_ZLog	Co_ZLog	Cs_ZLog	Cu_ZLog	Fe_ZLog	La_ZLog	Mn_ZLog	Mo_ZLog	Hg_ZLog	Ni_ZLog	Pb_ZLog	Sb_ZLog	Se_ZLog	Sr_ZLog	S_ZLog	Tl_ZLog	W_ZLog	Zn_ZLog
N	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847	847
Minimum	-3.045	-3.213	-2.735	-5.134	-2.864	-3.004	-2.531	-2.101	-3.177	-3.622	-9.990	-3.554	-3.126	-3.589	-2.853	-3.439	-2.093	-3.437	-2.577	-2.025	-3.727	-1.736	-2.500
Maximum	4.802	8.004	3.643	4.747	9.735	4.132	6.108	5.142	4.112	4.171	3.597	4.629	6.535	4.648	7.019	4.443	4.766	3.764	5.092	3.737	5.427	5.645	4.397
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median	-0.088	-0.162	-0.068	-0.014	-0.097	-0.106	-0.083	-0.146	-0.058	0.001	0.002	-0.104	-0.077	0.008	-0.079	-0.044	-0.200	-0.033	-0.120	-0.134	-0.126	-0.613	-0.064
Variance	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989
St. Dev.	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995
IQR	1.257	1.088	1.279	0.955	1.097	1.187	1.134	1.149	1.329	1.218	1.132	1.064	1.097	1.200	1.150	1.270	1.220	1.286	1.247	1.290	1.211	1.145	1.197
Range	7.847	11.218	6.378	9.881	12.599	7.137	8.640	7.243	7.289	7.793	13.588	8.182	9.661	8.237	9.872	7.883	6.859	7.201	7.669	5.761	9.154	7.381	6.897
50 percentile	-0.088	-0.162	-0.068	-0.014	-0.097	-0.106	-0.083	-0.146	-0.058	0.001	0.002	-0.104	-0.077	0.008	-0.079	-0.044	-0.200	-0.033	-0.120	-0.134	-0.126	-0.613	-0.064
75 percentile	0.580	0.445	0.604	0.482	0.518	0.508	0.527	0.483	0.657	0.596	0.559	0.466	0.496	0.595	0.522	0.602	0.551	0.568	0.573	0.580	0.689	0.512	0.529
90 percentile	1.277	1.325	1.240	0.983	1.082	1.304	1.121	1.217	1.303	1.133	1.182	1.113	1.254	1.152	1.270	1.279	1.370	1.278	1.275	1.209	1.152	1.420	1.177
95 percentile	1.702	1.884	1.839	1.484	1.607	1.959	1.571	1.850	1.603	1.499	1.576	1.700	1.751	1.597	1.758	1.625	1.786	1.641	1.668	1.843	1.578	2.120	1.774
98 percentile	2.331	2.532	2.594	2.370	2.297	2.482	2.319	2.793	2.141	2.386	1.964	2.947	2.210	2.029	2.363	2.188	2.526	2.191	2.494	2.625	2.182	2.969	2.598
99 percentile	3.012	2.970	2.874	3.416	2.837	3.065	3.729	3.482	2.439	2.902	2.269	3.721	2.615	2.546	2.958	2.699	3.026	2.395	3.006	3.013	2.576	3.966	3.247

Table 4. *Summary statistics for selected elements from NTS 105O/P (unlevelled).*



	Ag_ppb	As_ppm	Ba_ppm	Au_ppb	Bi_ppm	Cd_ppm	Co_ppm	Cs_ppm	Cu_ppm	Fe_pct	La_ppm	Mn_ppm	Mo_ppm	Hg_ppm	Ni_ppm	Pb_ppm	Sb_ppm	Se_ppm	Sr_ppm	S_pct	Tl_ppm	W_ppm	Zn_ppm
N	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957	957
Minimum	13	1	24.8	0.1	0.06	0.03	0.9	0.2	3.4	0.57	1.1	20	0.22	2.5	1.3	4.82	0.01	0.05	6	0.01	0.03	0.05	10.2
Maximum	8259	3379.5	3245.7	366.8	19.05	88.52	288.2	25.77	888.74	28.14	109.7	10000	95.3	3139	1065.1	1153.68	63.92	32.3	575.1	1.92	2.36	100	10000
Mean	614.565	50.8299	723.928	4.77816	0.64813	3.81751	19.7672	2.7647	73.1849	3.7668	16.0341	792.7952	7.301129	201.096	78.8247	22.8449	2.5053	3.05392	66.0242	0.11232	0.30798	1.128736	464.546
Median	438	20.7	511.3	2.3	0.27	1.29	15.9	1.81	54.34	3.43	13.6	618	4.5	136	48	17.14	1.48	2.2	52	0.08	0.23	0.05	200.1
Variance	419847	22093.5	434164	289.583	2.31365	49.9388	327.216	7.01774	4434.75	4.45573	158.041	724104	80.00603	61946.2	7421.53	2229.89	12.9895	10.8858	3244.12	0.02085	0.08177	29.94017	571880
St. Dev.	647.956	148.639	658.911	17.0171	1.52107	7.06674	18.0891	2.6491	66.5939	2.11086	12.5714	850.943	8.944609	248.89	86.1483	47.2217	3.60409	3.29936	56.9572	0.14438	0.28596	5.471761	756.228
IQR	658.5	31.6	941.65	3	0.25	4.045	12.15	2.105	46.935	1.62	14.9	524.5	7.485	228.5	60.2	11.76	2.5	3.3	44.6	0.09	0.28	0.25	343.3
Range	8246	3378.5	3220.9	366.7	18.99	88.49	287.3	25.57	885.34	27.57	108.6	9980	95.08	3136.5	1063.8	1148.86	63.91	32.25	569.1	1.91	2.33	99.95	9989.8
50 percentile	438	20.7	511.3	2.3	0.27	1.29	15.9	1.81	54.34	3.43	13.6	618	4.5	136	48	17.14	1.48	2.2	52	0.08	0.23	0.05	200.1
75 percentile	824	43.9	1131.5	4.2	0.44	4.345	23.15	3.295	85.335	4.27	21.4	895	9.295	274	91.95	24.645	3.08	4	78.2	0.13	0.4	0.3	464.55
90 percentile	1320.4	103.64	1711.02	7.12	1.086	9.5	34.04	6.2	133.21	5.21	28.66	1422.2	18.444	438.2	179.16	33.756	5.742	6.6	116.84	0.21	0.63	1.5	1096.32
95 percentile	1753.7	173.11	2060.52	10.51	2.364	15.911	47.82	8.233	178.378	6.222	38.53	1929.4	23.816	590.2	240.51	40.337	8.266	9.81	159.6	0.3	0.822	4.62	1838.26
98 percentile	2396.36	300.912	2458.96	20.12	5.3484	27.3848	69.548	11.0584	266.419	9.0732	54.028	3142.36	31.086	858.12	338.3	55.2676	11.942	12.668	262.392	0.4768	1.1584	13.384	3092.45
99 percentile	2916.84	483.18	2657.16	54.624	8.2836	35.6256	83.886	14.0952	370.154	13.0588	64.998	4387.26	37.5576	1099.04	391.898	70.7754	16.4732	16.01	321.81	0.76	1.4568	19.146	4040.73

Table 5. *Summary statistics for selected elements from NTS 105O/P (levelled).*



	Ag-ZLog	As-ZLog	Ba-ZLog	Au-ZLog	Bi-ZLog	Cd-ZLog	Co-ZLog	Cs-ZLog	Cu-ZLog	Fe-ZLog	La-ZLog	Mn-ZLog	Mo-ZLog	Hg-ZLog	Ni-ZLog	Pb-ZLog	Sb-ZLog	Se-ZLog	Sr-ZLog	S_-ZLog	Tl-ZLog	W_-ZLog	Zn-ZLog
N	955	955	955	955	955	955	955	955	955	955	920	955	955	955	955	955	920	920	920	920	920	899	955
Minimum	-3.0686	-4.3382	-4.1041	-4.28388	-2.1596	-3.16106	-4.21861	-2.9446	-3.62036	-3.4313	-3.174	-3.18115	-3.29646	-5.14767	-5.1883	-3.27195	-3.574	-3.0402	-3.8015	-2.7544	-2.808	-1.84744	-2.7983
Maximum	3.26475	4.44666	3.03292	4.86835	6.49241	3.35713	4.46923	3.16598	5.60732	4.85808	3.14408	4.109146	3.450658	2.88558	4.62541	5.05002	2.9735	3.62448	3.16573	3.65604	3.15419	3.83476	5.57783
Mean	4.67E-17	5.75E-17	-1.1E-16	-4.1E-17	1.5E-17	-2.7E-17	-1.1E-16	-9.9E-17	1.7E-16	-5.3E-17	2.8E-16	2.6E-16	-9.7E-17	-6.7E-17	8.4E-17	-3.9E-17	5.2E-18	-5.5E-17	-3.8E-17	-2.0E-17	1.1E-16	-4.0E-16	-1.2E-16
Median	0.0143	-0.1692	0.01229	0.05236	-0.2146	-0.01938	-0.08029	-0.1319	-0.04059	-0.0382	0.03696	-0.02691	-0.048	0.09134	-0.0591	-0.11923	0.01229	0.02966	-0.0197	0.085	-0.0399	-0.56191	-0.1598
Variance	0.97589	0.97589	0.97589	0.97589	0.97589	0.97589	0.97589	0.97589	0.97589	0.97589	0.9815	0.975891	0.975891	0.97589	0.97589	0.97589	0.9815	0.9815	0.9815	0.9815	0.9815	0.982183	0.97589
St. Dev.	0.98787	0.98787	0.98787	0.98787	0.98787	0.98787	0.98787	0.98787	0.98787	0.98787	0.99071	0.987872	0.987872	0.98787	0.98787	0.98787	0.99071	0.99071	0.99071	0.99071	0.99071	0.991051	0.98787
IQR	1.39485	1.2604	1.38118	1.11951	0.88608	1.32842	1.1439	1.27603	1.1578	1.24127	1.46545	1.181899	1.397814	1.232	1.20045	1.17956	1.3272	1.26269	1.25939	1.29039	1.37969	1.194591	1.14442
Range	6.33332	8.78483	7.13697	9.15223	8.65197	6.51819	8.68784	6.11054	9.22768	8.2894	6.31805	7.290295	6.747117	8.03325	9.8137	8.32196	6.54752	6.66465	6.96719	6.41042	5.96223	5.682201	8.37618
50 percentile	0.0143	-0.1692	0.01229	0.05236	-0.2146	-0.01938	-0.08029	-0.1319	-0.04059	-0.0382	0.03696	-0.02691	-0.048	0.09134	-0.0591	-0.11923	0.01229	0.02966	-0.0197	0.085	-0.0399	-0.56191	-0.1598
75 percentile	0.69735	0.55641	0.70455	0.59272	0.31497	0.62415	0.55127	0.59671	0.52378	0.59865	0.74398	0.581438	0.702803	0.66583	0.56111	0.53704	0.65466	0.62036	0.63806	0.65077	0.67868	0.529447	0.50138
90 percentile	1.22676	1.30563	1.21228	1.04616	1.23352	1.27132	1.21605	1.39792	1.31879	1.23816	1.23264	1.245449	1.293002	1.11797	1.33222	1.2164	1.288	1.22195	1.24568	1.22108	1.34076	1.513416	1.30596
95 percentile	1.65584	1.89983	1.47342	1.41544	1.91269	1.71428	1.70133	1.80252	1.62791	1.69519	1.48911	1.624579	1.571983	1.4723	1.72431	1.70528	1.6739	1.65089	1.67927	1.60651	1.721	2.111085	1.86194
98 percentile	2.03236	2.62493	1.8328	2.00587	2.91991	2.14994	2.38546	2.21332	2.29528	2.13827	1.86717	2.105396	2.150006	1.93502	2.23441	2.48057	2.12124	2.03102	2.29391	2.27651	2.24762	2.845429	2.4481
99 percentile	2.2392	2.83099	2.27038	2.6121	3.71223	2.49302	2.87861	2.53321	2.84511	2.78659	2.06306	2.415752	2.321264	2.0929	2.65887	3.06136	2.32453	2.39616	2.64776	2.56069	2.52496	3.195665	2.93893

Levelled results for selected elements were attached to their corresponding catchment polygons using the same process described for the WSM results; colours were assigned using same percentile breaks. Thematic maps of levelled concentrations for map sheets NTS 105M and 105O/P are presented in Appendices C and D.

Effects of Catchment Basin Size

The relationship between element concentration and catchment basin size can be assessed graphically to identify regional background concentrations (after correction for dominant lithology), optimal catchments basin size for RGS sampling, and potentially under sampled areas. Variations in catchment basin area for both map sheets are shown in Figures 5 and 6 and summarized statistically in Table 6. On NTS 105M, catchment basins vary in area from 0.2 km^2 to 114.7 km^2 with a median value of 5.14 km^2. A similar variation is present on NTS 105 O/P where the minimum area is 0.18 km^2, the maximum is 44.5 km^2, and the median values is 4.27 km^2. Very small catchment areas of <1km^2 represent 2.95% (105 M) and 4.49% (105 O/P) of the total and possibly represent poorly or incorrectly located samples.

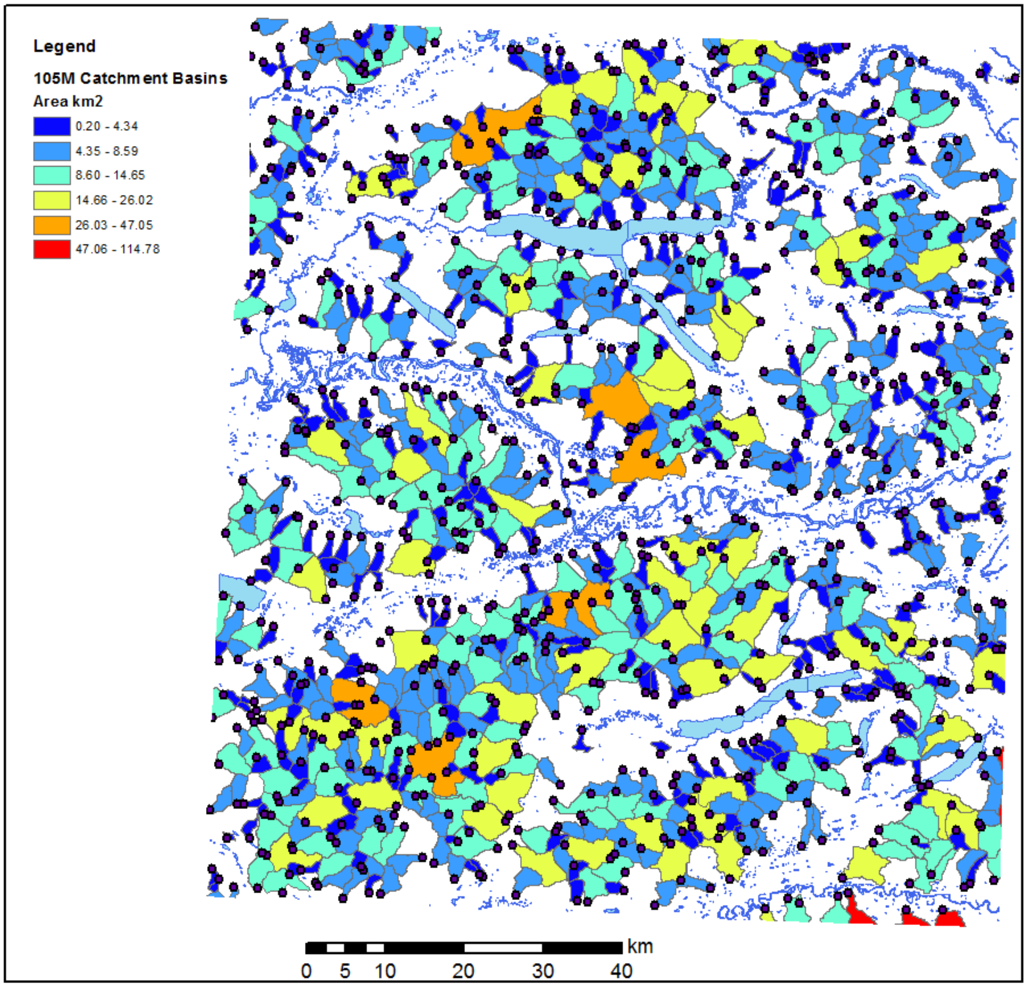


***Figure 5**. NTS 105M catchment basins; colour coded by surface area.*

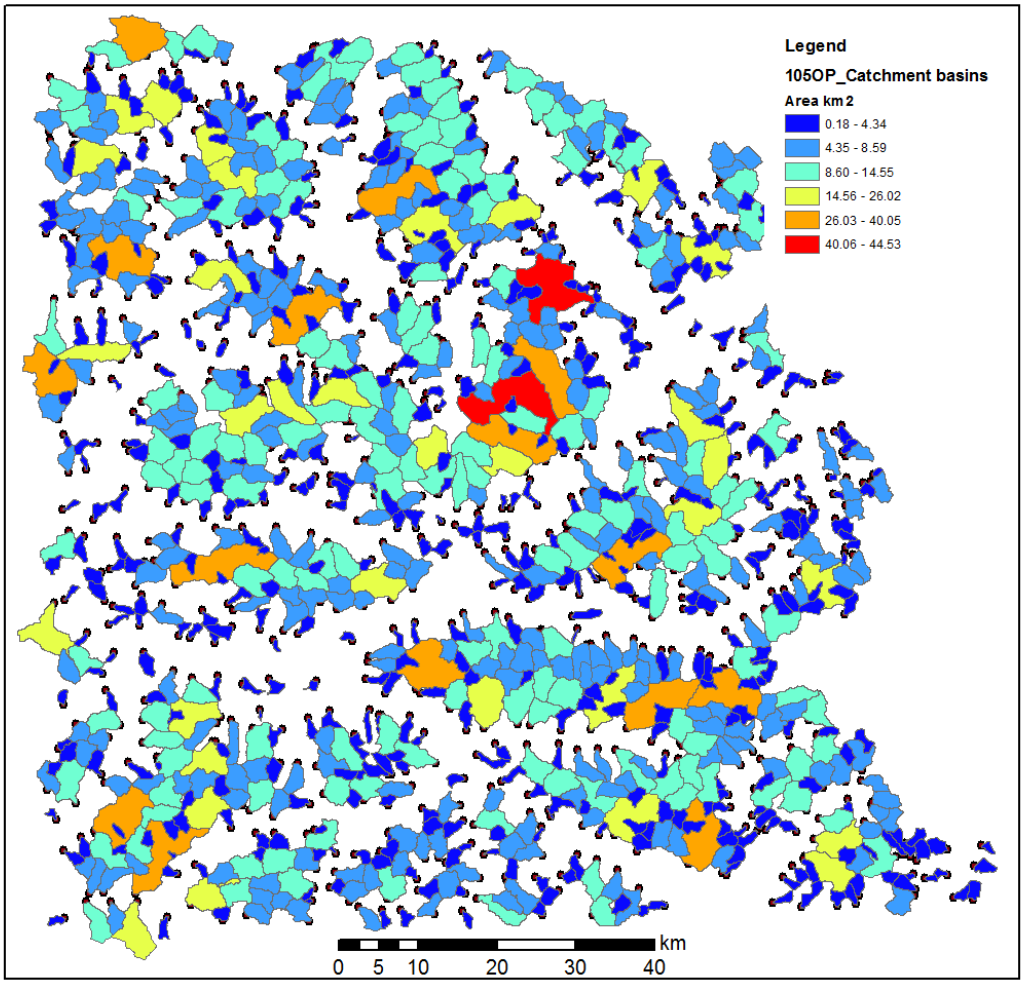


Figure 6. *NTS 105O/P catchment basins; colour coded by surface area.*

Table 6. *Summary statistics for catchment basin area.*

	105M	105O/P
N	847	957
Minimum	0.20	0.18
Maximum	114.78	44.53
Mean	6.97	5.89
Median	5.14	4.27
Variance	63.56	29.20
Standard Deviation	7.97	5.40
Coefficient of Variation	114.32	91.69
Robust Coefficent Of Variation	86.74	94.55
Interquartile Range	6.01	5.44
Range	114.58	44.35
50 percentile	5.14	4.27
75 percentile	8.79	7.78
90 percentile	13.63	11.60
95 percentile	17.68	15.05
98 percentile	23.25	23.76
99 percentile	31.95	30.77

Regional background concentrations and the effects of dilution in larger catchment basins can be assessed empirically using concentration versus catchment basin area scatter plots. An example for Cu (levelled for dominant lithology) for map sheet 105M is presented in Figure 7. The horizontal line marks median concentration of Cu. Data points below this line are regarded as background, while those above the line are considered to be potentially anomalous. The higher up the Y-axis a point is the more anomalous the catchment basin. The vertical line indicates the median catchment basin size (5.14 km^2). As catchment basin area increases the variation in Cu concentration about the median decreases. Therefore for larger catchment basins, anomalous values would have lower overall Cu concentrations than samples in smaller catchment basins. This is the result of dilution. Samples with Cu values higher than the median value in larger catchment basins could therefore be of importance and should be investigated further. Examples are highlighted by the red circles in Figure 7.

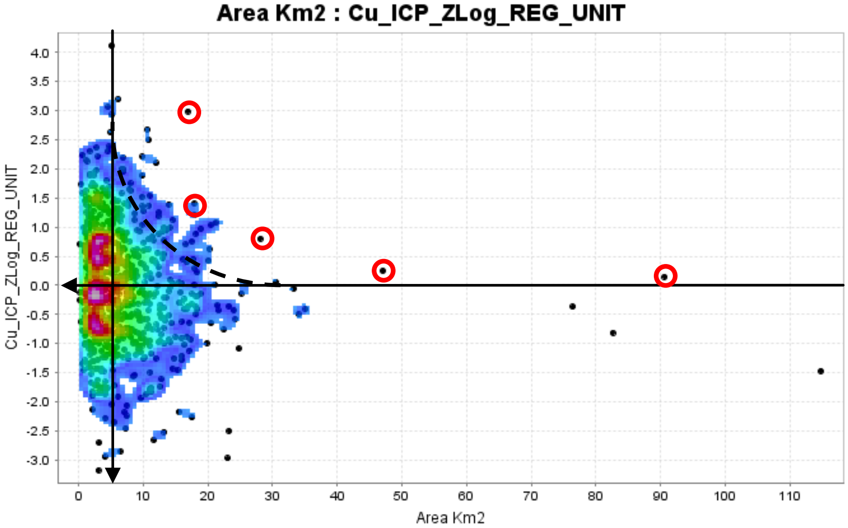


Figure 7. *Contoured scatter plot showing the relationship between Cu (levelled for dominant lithology) and catchment area for NTS 105M: the vertical line denotes the median catchment basin area and the horizontal line the median Cu concentration. Red circles highlight samples of potential interest for follow-up in larger catchment basins.*

Scatter plots for a number of ore and pathfinder elements for the map areas are presented in Figures 8 and 9. Many of these elements have potentially important concentrations in larger catchment basins. Of note are Ag, Pb, and Sb on NTS 105M, and most of the elements on NTS 105 O/P, which all have elevated values at larger catchment areas. These samples represent exploration opportunities in areas that conventional statistical treatment of the analytical results would not highlight as being of interest.

This analysis can be also be used to highlight areas with insufficient sampling coverage that could benefit from additional infill sampling. The red and orange polygons in Figures 5 and 6 have catchment areas of > 5 times the median value. They indicate samples that were inadvertently collected from higher order streams (*i.e.*, 3rd vs. 2nd) than the rest of the survey.

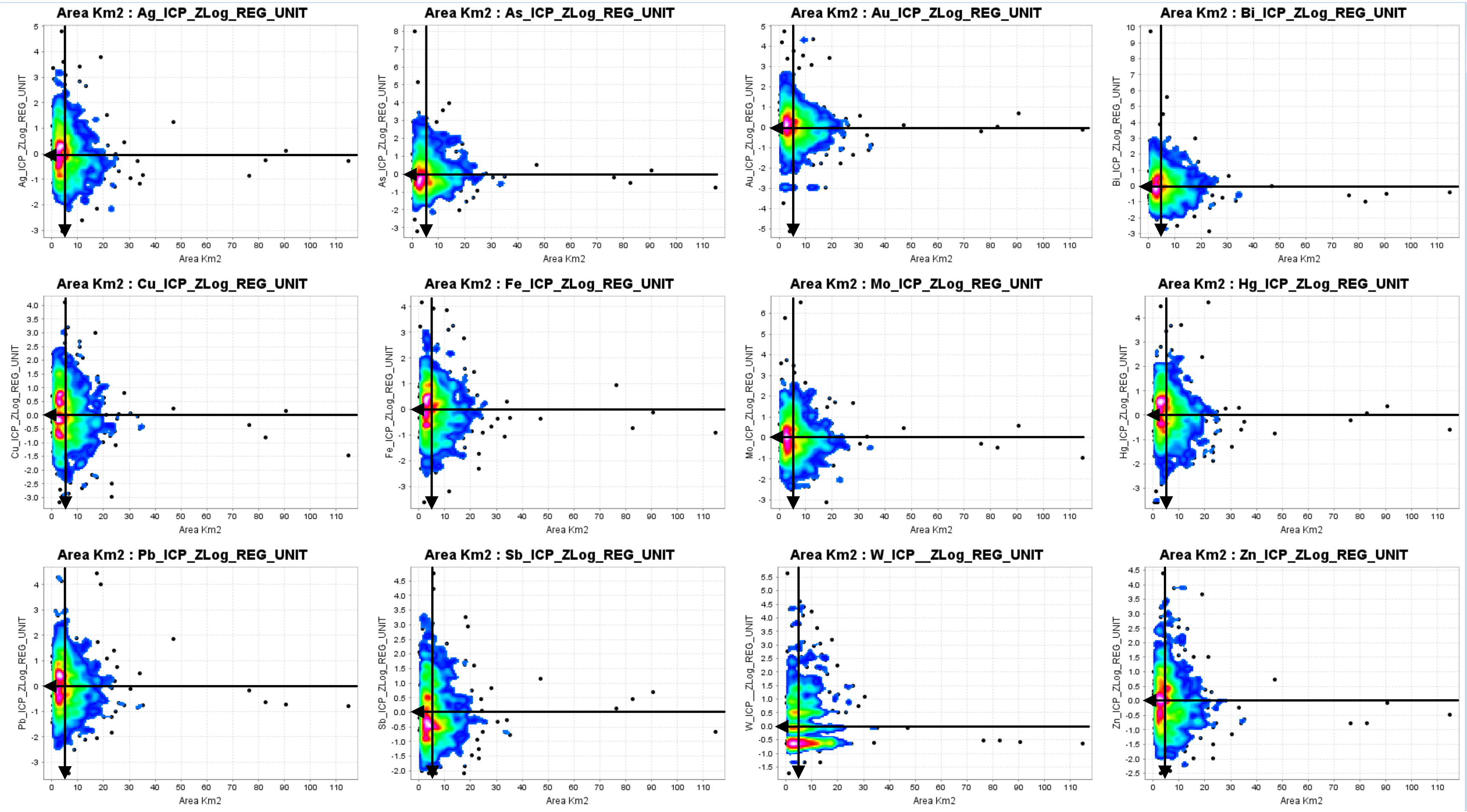
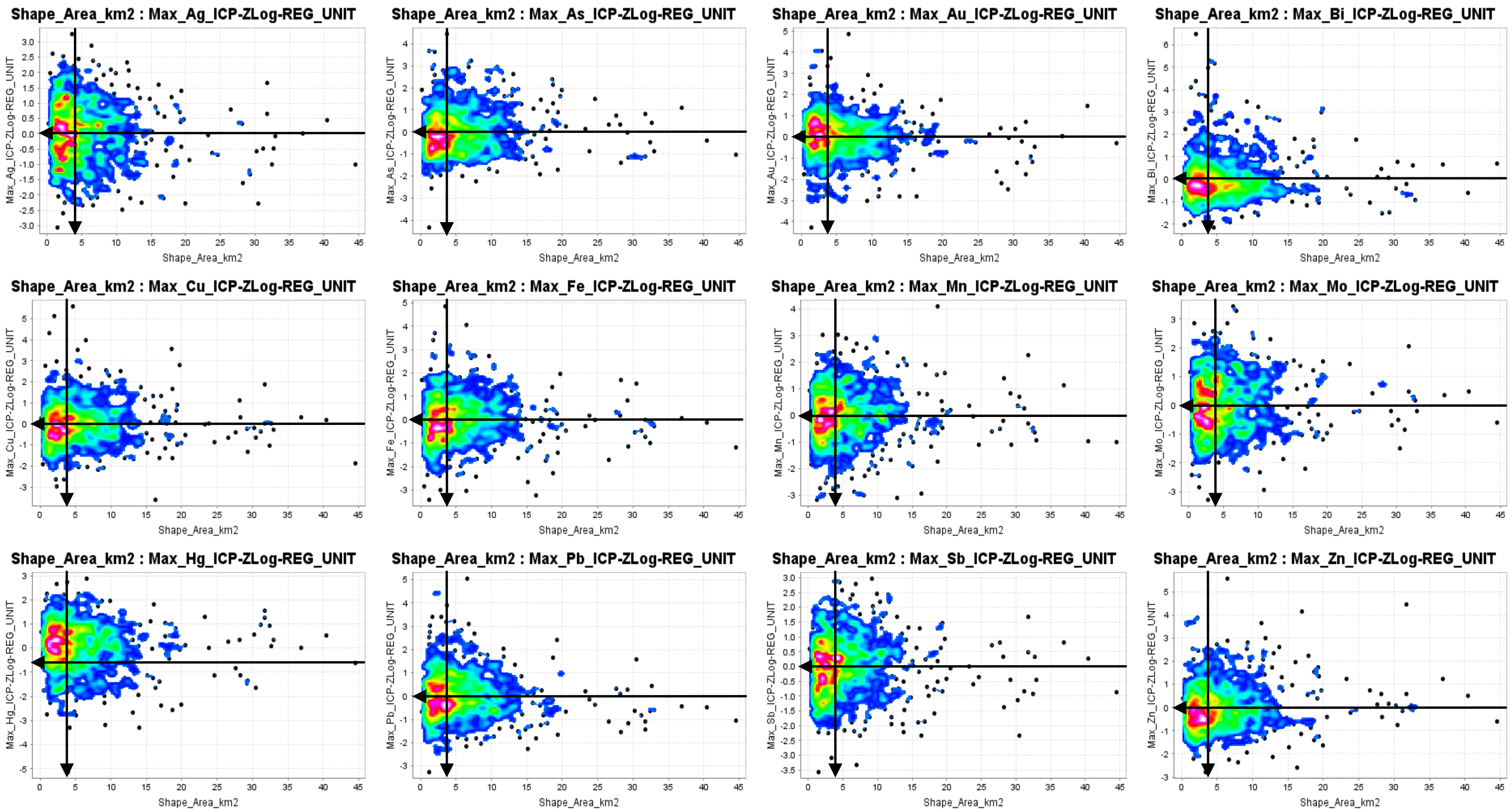


Figure 8. *Contoured concentration vs. catchment area scatter plots for selected ore and pathfinder elements for mapsheet NTS 105M. Horizontal and vertical lines show median concentration and catchment basin size. Samples falling above the median concentration at larger catchment areas should be considered for further investigation.*



Shape_Area_km2 : Max_Ag_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_As_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Au_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Bi_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Cu_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Fe_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Mn_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Mo_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Hg_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Pb_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Sb_ICP-ZLog-REG_UNIT

Shape_Area_km2 : Max_Zn_ICP-ZLog-REG_UNIT

Figure 9. *Contoured concentration vs. catchment area scatter plots for selected ore and pathfinder elements for mapsheet NTS 105O/P. Horizontal and vertical lines show median concentration and catchment basin size. Samples falling above the median concentration at larger catchment areas should be considered for further investigation.*

Stream pH Results

Where available, stream pH readings can greatly assist with the interpretation of stream sediment geochemistry results. Oxidizing sulphides in a catchment basin cause acidification of ground water and surface run-off and therefore, depending on the size of the sulphide source and catchment basin, may form detectable acidic (lower pH) anomalies at the stream sediment sample site. Furthermore stream pH also acts as a control on the precipitation of ferric hydroxide. At pH values below about 5.5 (the pH of hydrolysis of ferric hydroxide) base metals, Fe and Mn reside in solution in the stream water and will not form detectable metal anomalies in the sediment. When the pH rises as a result of dilution or neutralization by mixing with more alkaline water or reaction with a reactive substrate like limestone, ferric hydroxides precipitate in the stream bed. The formation of red and orange precipitates is accompanied by co-precipitation and/or adsorption of other metals onto the hydroxide surfaces to form a hydromorphic anomaly.

Hydromorphic anomalies may form at a considerable distance downstream from the metal source. Their typically highly elevated concentrations for elements such as Fe, Mn, Ni, Co, Cd, Cu, and Zn are often mistaken for more direct expressions of mineralization and on follow up the metal sources are quite often not identified. Therefore the mapping of stream pH can be useful for distinguishing between metal anomalies caused by detrital and hydromorphic processes.

Stream pH results for both map sheets are presented in Appendix E. Catchment basins coloured red indicate streams with pH values below the pH of hydrolysis of ferric Fe (<pH 5.6) where base metals are likely to have low values in the stream sediments. Orange colours (pH 5.6-6.7) highlight catchments with pH values immediately above the pH of hydrolysis of Fe where hydromorphic precipitation is likely to occur. This of course assumes that there is a source of metal in the catchment basin.

The hydromorphic WSM (Appendices A and B) shows catchment basins where elements typically associated with hydromorphic anomalies have elevated concentrations. The use of the hydromorphic WSM and the stream pH thematic maps together should allow for filtering out of non-detrital metal anomalies that could be otherwise be misinterpreted as mechanically derived bedrock source anomalies and followed up with no definitive results.

DISCUSSION

Extracting the maximum possible benefit from RGS geochemical results involves more than simply plotting raw numbers on a map. Recognition that each sample point represents the entire surface area of the catchment basin upstream from it is important. By mapping RGS samples as their corresponding catchment basins it is possible to more easily assess the effective survey coverage and to identify areas with missing or insufficient sampling. Furthermore, the use of catchment basins can also assist with evaluating the effects of geology on regional background concentrations and the amount of dilution caused by changes in catchment basin area. If not taken into account these variables could easily mask important patterns related to mineralization.

Additional value can be obtained by applying multivariate statistical methods to the data to extract patterns caused by different geological processes. In this report Weighted Sums Modeling has been used to highlight drainages with multi-element characteristics consistent with different styles of mineralization that are either known to occur or are likely to occur in the map areas. Thematic maps based on WS models should help to focus exploration into very specific areas. Many of the catchment basins highlighted by the different WS models contain known mineral occurrences of the same or a similar mineralization style. There are a number of catchment basins for each WSM with high scores that have no known mineral occurrences. These are considered to be exploration opportunities that require further investigation.

Finally, the hydromorphic WSM and stream pH can be used together to identify and filter out potential hydromorphic anomalies that could otherwise be erroneously interpreted as mechanically derived anomalies.

In conclusion, this study has hopefully enhanced the value of the recently reanalyzed RGS samples and highlighted not only a number of potential target areas for six different deposit types, but has also introduced an alternative and more effective way of analyzing stream sediment results.

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