

Preliminary results from water sampling in the Pelly-Cassiar Platform volcanic belt, southeastern Yukon

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ABSTRACT

Water and sediment samples were collected from 13 creeks/springs which drain the Devono-Mississippian Pelly Mountains volcanic belt that hosts the Wolf and MM volcanogenic massive sulphide (VMS) deposits. Preliminary results indicate that water and sediment sampling may be a viable method of exploration for VMS mineralization in this area. A creek draining the Wolf zinc-lead-silver deposit has elevated levels of lead and zinc in water and sediment samples. A sediment sample from the MM zinc-lead-copper deposit drainage is elevated in silver, copper and lead, but not zinc. A creek draining the Fire (Chzerpnough) prospect has elevated levels of barium, lead and zinc in sediment and cadmium, nickel and zinc in water.

Each creek sampled has a distinctive white precipitate, coating the rocks, sediment and vegetation in the creek bed, that is likely composed of aluminium hydroxide or aluminium and calcium sulphate.

RÉSUMÉ

Des échantillons d'eau et de sédiments ont été recueillis dans 13 ruisseaux et sources drainant la bande volcanique dévono-mississippienne des monts Pelly qui abrite les gisements de sulfures massifs volcanogènes (SMV) Wolf et MM. Les résultats préliminaires indiquent que l'échantillonnage de l'eau et des sédiments peut s'avérer une méthode viable d'exploration des minéralisations de SMV dans cette région. Les échantillons d'eau et de sédiments d'un ruisseau drainant le gisement Wolf de zinc-plomb-argent présentent des concentrations élevées de Pb et de Zn. Un échantillon de sédiments du bassin versant du gisement MM de zinc-plomb-cuivre présente des concentrations élevées d'Ag, de Cu et de Pb, mais non de Zn. À l'emplacement d'un ruisseau drainant la zone d'intérêt Fire (Chzerpnough), les sédiments présentent des concentrations élevées de Ba, Pb et Zn et l'eau des concentrations élevées de Cd, de Ni et de Zn.

Chaque ruisseau échantillonné est caractérisé par un précipité blanc qui enrobe les roches, les sédiments et la végétation du lit des ruisseaux et qui est vraisemblablement composé d'hydroxyde d'aluminium ou d'aluminium et de sulfate de calcium.

INTRODUCTION

Volcanogenic massive sulphide (VMS) mineralization in the Pelly-Cassiar Platform is hosted by the Devono-Mississippian Pelly Mountains volcanic belt which is about 80 km long and up to 25 km wide (Fig. 1). The beds of creeks and springs draining the volcanic rocks are locally coated by a distinctive white precipitate several metres below the water source. This paper presents preliminary geochemical data from an orientation survey in which water and sediment samples were collected in 13 of these creeks (Fig. 2).

Previous studies have shown that groundwater and sediment chemistry can be a valuable guide to the discovery of concealed metal sulphides. For example, Lett and Jackaman (1995) and Lett et al. (1997) identified geochemical pathfinders in stream sediments and waters for base metal sulphide mineralization in the Kechika Trough of northeastern B.C. Earle (1975) showed that in some locations in the MacMillan Pass area of eastern Yukon, stream waters are a better guide to mineralization than stream sediment samples. This is especially true in acidic waters where the absorption of trace metals by secondary iron oxides in stream sediments is suppressed. Cameron (1977) reported

that waters are the most convenient medium for more detailed levels of exploration in areas around massive sulphide mineralization hosted by Archean metavolcanic rocks in the Agricola Lake area, NWT. Using geochemical data for drill hole and spring water samples collected around the Eustice massive sulphide deposit in Quebec, Hoag and Webber (1976) determined that sulphate levels below 160 ppm were principally due to non-bacterial oxidation, whereas higher sulphate levels reflected extensive bacterial surface oxidation of sulphides. Sibbick (1995) analyzed sulphate and pH values from regional geochemical survey (RGS) data to identify areas with acidic high-sulphate streams. This analysis was carried out in an attempt to predict the location of areas with potential acid rock drainage (ARD) problems in the Mount Waddington area (NTS 92N) of British Columbia. In this area acid sulphate streams are associated with known mineralization.

In the present study, samples were collected to investigate the relationship between spring-water chemistry, type of precipitate, sediment chemistry and proximity to known mineralization. These data provide information on the use of water and sediment sampling in the search for VMS mineralization in the Pelly Mountains volcanic belt.

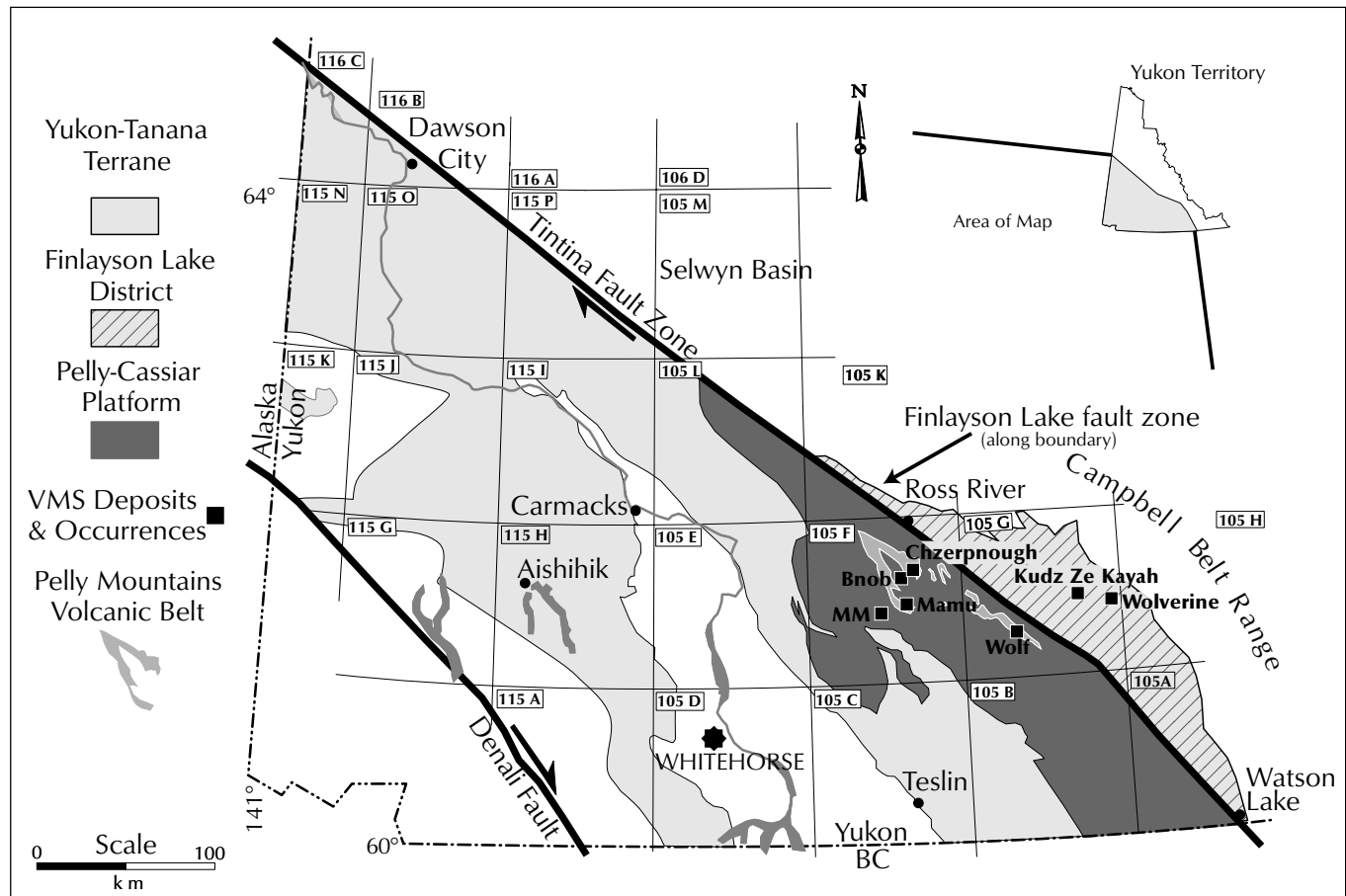


Figure 1. Location map of Pelly-Cassiar Platform and the Pelly Mountains volcanic belt (Modified after Wheeler and McFeely, 1991).

DESCRIPTION OF STUDY AREA

LOCATION AND TOPOGRAPHY

The region sampled lies within the Pelly-Cassiar Platform and forms part of the Pelly Mountains, which are characterized by northwest-southeast trending ridges from approximately 1,200 to 2,000 m in elevation. Evidence of glacial erosion and alpine glaciation occurs throughout the area. The tree line reaches up to roughly 1,600 m; above this elevation, ridge crests and steep slopes are covered by rocks, talus and felsenmeer.

The streams that were sampled have narrow stream beds, typically less than 1 m wide, with moderate gradients. Flow rates are seasonably variable but generally moderate.

GEOLOGICAL SETTING

Geology, mineralization and structure of the Pelly Mountains volcanic belt have been described by previous workers, including Wheeler et al. (1960a, b), Tempelman-Kluit et al. (1975 and 1976), Tempelman-Kluit (1977a, b), Morin (1977), Gordey (1977, 1981) and Mortensen (1979 and 1982); current geological mapping of the area can be found in Hunt (this volume). Principal geological elements of the volcanic belt can be summarized as follows:

- The belt trends roughly northwest-southeast and is made up of Devono-Mississippian intermediate to felsic volcanic rocks that conformably to unconformably overlie Silurian-Devonian carbonate and argillite;
- Similar Silurian-Devonian carbonate and argillite locally overlie the volcanic rocks along thrust faults;

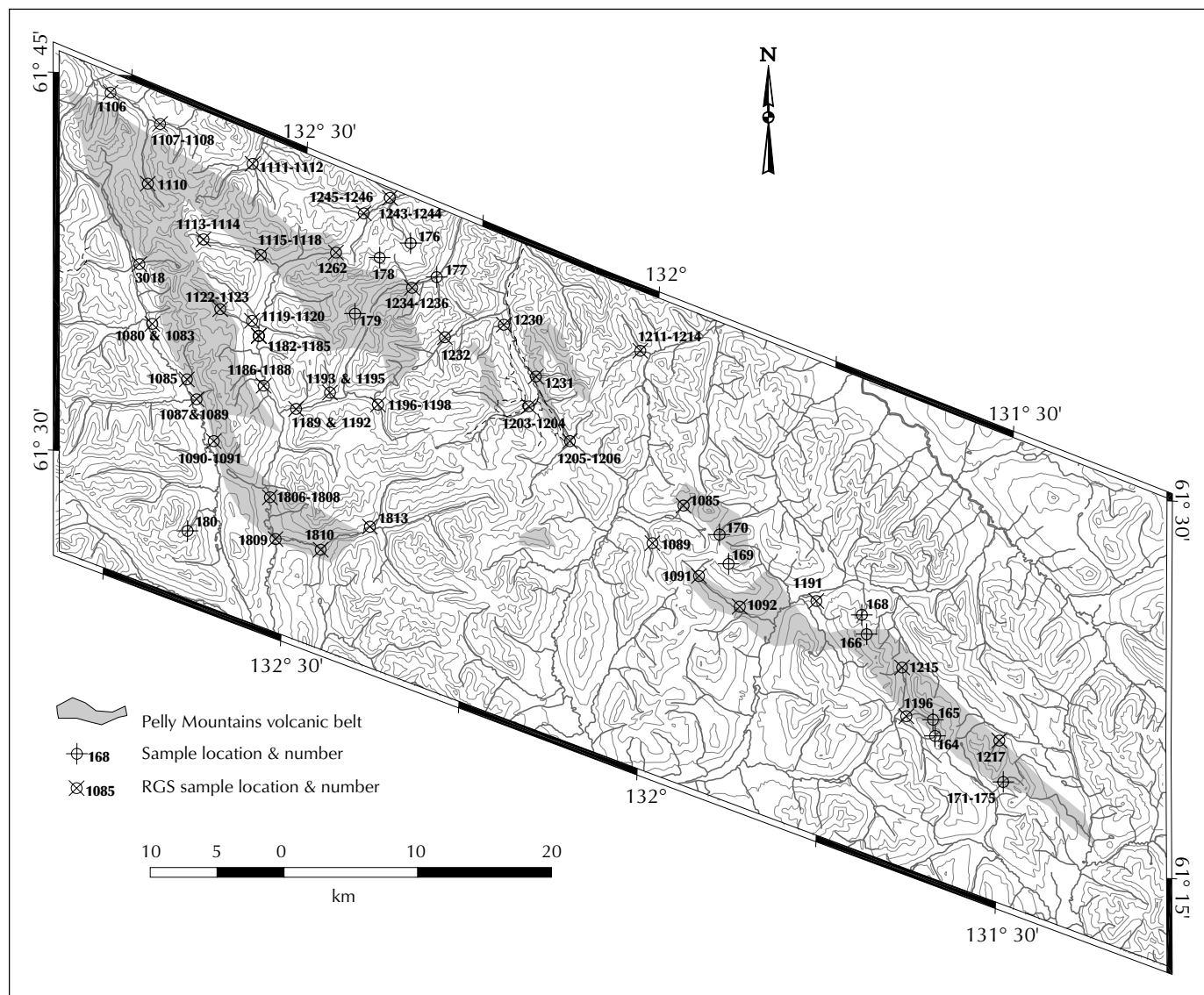


Figure 2. Location map of the Pelly Mountains volcanic belt with sample locations. RGS locations are from Hornbrook & Friske, 1985, 1988.

- The volcanic rocks are dominantly greenschist facies metamorphic grade and have undergone two, and locally three, phases of deformation;
- VMS mineralization including the Wolf (pyrite ± sphalerite ± galena ± barite) and MM (barite ± pyrite ± sphalerite ± galena ± chalcopyrite) deposits is hosted by felsic rocks within the volcanic succession (Yukon Minfile, 1997; Gibson et al., this volume).

SAMPLING AND FIELD METHODS

A total of 15 sites in the volcanic belt were sampled over a two-day period in late July, 1998. At each site, white precipitate coats the clastic sediment and vegetation in the creek bed. This precipitate is not generally found where the water surfaces, but is evident in the channel several metres downstream from the discharge point.

Sample sites are described in Appendix A and their location is shown in Figure 2 and Table 1. One water and one sediment sample were collected from each site with the exception of the spring draining the Wolf deposit (informally named Pearl creek) which was sampled in four locations, each an increased distance from the source as shown in Figure 3, and sites 167 and 174, where only sediment samples were collected.

The following samples and data were collected at each of the study sites:

- Water pH and conductivity (dissolved solids) were measured with Cole-Parmer hand-held metres.
- The temperature was measured using a scientific thermometer.
- Two one-litre bottles of water were taken from springs, surface streams or seepages. One of the bottles of water was acidified with ultrapure nitric acid to pH 2. Both bottles were filtered (flow through) using a 0.45 µm filter to give samples of 250 ml. The water samples that were acidified were done so before being filtered which may have altered the concentration of some elements in solution. Samples 170 (acidified) and 170a (non-acidified) show an example of the effects of acidification: the concentration of most elements, with the exception of As, B, Fe and K were increased. Therefore, the absolute values of elements in these samples should not be compared with those from other studies. However, since all samples were treated equally in this study they can be compared to one another.
- A one- to two-kg sample of sediment (including precipitate) in/beside the creek bed.

Four duplicate water samples were collected and one blank was added to give a total of 20 water samples. Two duplicates were collected for a total of 19 sediment samples.

LABORATORY ANALYSIS

Filtered, acidified water samples were analyzed for a suite of 33 elements (Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Te, Ti, Tl, V, W & Zn) by inductively coupled plasma (ICP) emission spectroscopy at ACME Analytical, Vancouver, British Columbia. Four of the samples were also analyzed by inductively coupled plasma mass spectrometry (ICP-MS) at Activation Laboratories Ltd., Ancaster, Ontario, for a suite of 66 elements (Li, Na, Mg, Al, Si, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Pt, Au, Hg, Tl, Pb, Bi, Th, U, Y, Zr, Nb, Mo, Ru, Pd, Ag, Cd, In, Sn, Sb, Te, I, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd & Tb) in order to compare analytical methods. Quality of the water geochemical data and possible sample contamination were monitored by analysis of filtered, distilled/deionized water blanks and blind sample replicates.

Non-acidified water samples were measured for sulphate content by ion chromatography at B.C. Research Ltd., Vancouver, British Columbia.

Stream sediment samples were analyzed by Chemex Labs Ltd. in North Vancouver, British Columbia. There the samples were dried and sieved to -80 mesh before being analyzed for 32 elements (Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Sc, Sr, Ti, Tl, U, V, W & Zn) by ICP-AES following aqua regia digestion.

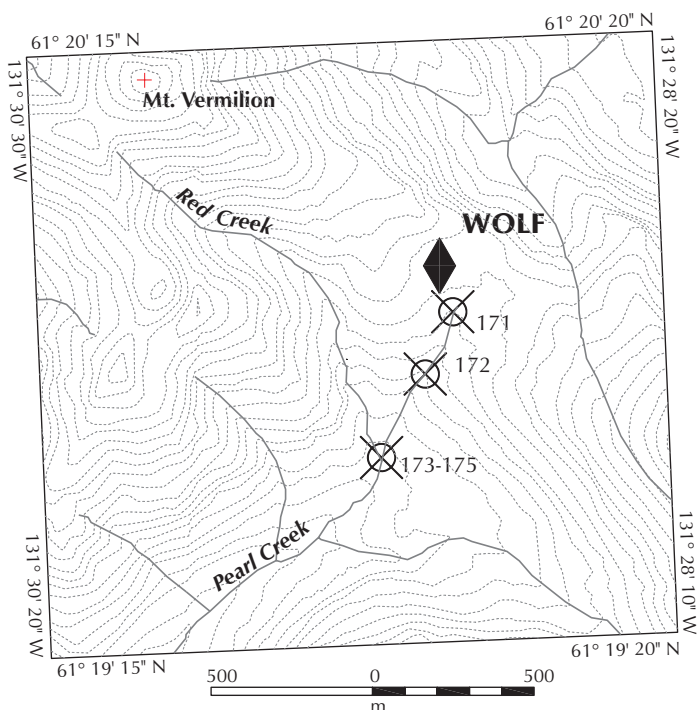


Figure 3. Location of samples collected from Pearl Creek (Wolf deposit).

RESULTS AND DISCUSSION

Results are shown in Table 1 for water samples analyzed by ICP. Several of the elements were excluded from the following interpretation because of probable significant loss during the interval between sampling and analysis (Hg) and absence of any detectable concentration in the samples (Ag, As, B, Be, Bi, Cr, Li, Sb, Se, Te, Tl, V & W). Table 2 contains the results for water samples analyzed by ICP-MS. Again several of the elements were excluded from the interpretation because of probable significant loss during the interval between sampling and analysis (Hg) and absence of any detectable concentration in the samples (Ta, W, Os, Pt, Au, Ru, Pd, Ag & Te).

The results for stream sediment samples are also shown in Table 1. The samples did not contain detectable concentrations of Bi, Ga, Hg, Na, Sb, Ti, Tl, U and W, and these elements were excluded from the interpretation.

CREEK PRECIPITATE

The composition of the distinct white precipitate which coats rocks, sediment and vegetation in some creeks draining the Pelly Mountains volcanic belt is unknown (samples of the precipitate have been sent for analysis but results are not yet available). However, it likely consists of aluminium hydroxide, or aluminium and calcium sulphates (K. Fletcher, pers. comm., 1998), or possibly barite. Changes in the water and sediment chemistry in Pearl Creek appear to support this interpretation as described below.

Table 1 and Figure 4 show that in Pearl Creek between the source (sample 171) and the beginning of the white precipitate (sample 172), the pH and temperature of the water increase while conductivity and the concentration of most elements in water decrease and those in the sediment increase; an exception to this is Pb which decreases in both sample mediums. The white precipitate probably occurs in response to the changes in pH and is likely composed primarily of Al, Ca and SO₄ minerals since the concentration of Al, Ca and SO₄ contained in the water decreases significantly and that of the sediment increases at the onset of precipitation (sample 172). Analysis of sample 172 using MINTEQ software predicted the following possible saturated minerals in Pearl Creek: AlOHSO₄, Al₄(OH)₁₀SO₄, alunite, boehmite, diaspore, ferrihydrite, gibbsite, goethite, hematite, K-jarosite, maghemite, cuprousferite and leidrocrocite (Sibbick, 1998, written communication) suggesting that the white precipitate likely contains one or more of the above minerals.

A similar situation was described by Earle (1975) in the Nahanni map area (NTS 105 I) where a white aluminium hydroxide precipitate begins to form as the pH increases. Such precipitates may occur in any acidic environment and are likely the result of the weathering of sulphides. However, they are not necessarily an indication of mineralization as the acidity may be caused by finely disseminated sulphides throughout a rock unit and not by massive sulphide mineralization. For example, in the MacMillan Pass area, creeks with white precipitate are associated with the Howard's Pass deposit but also with barren areas underlain by black shale which contains fine grained disseminated pyrite (Earle, 1975; Goodfellow, 1989).

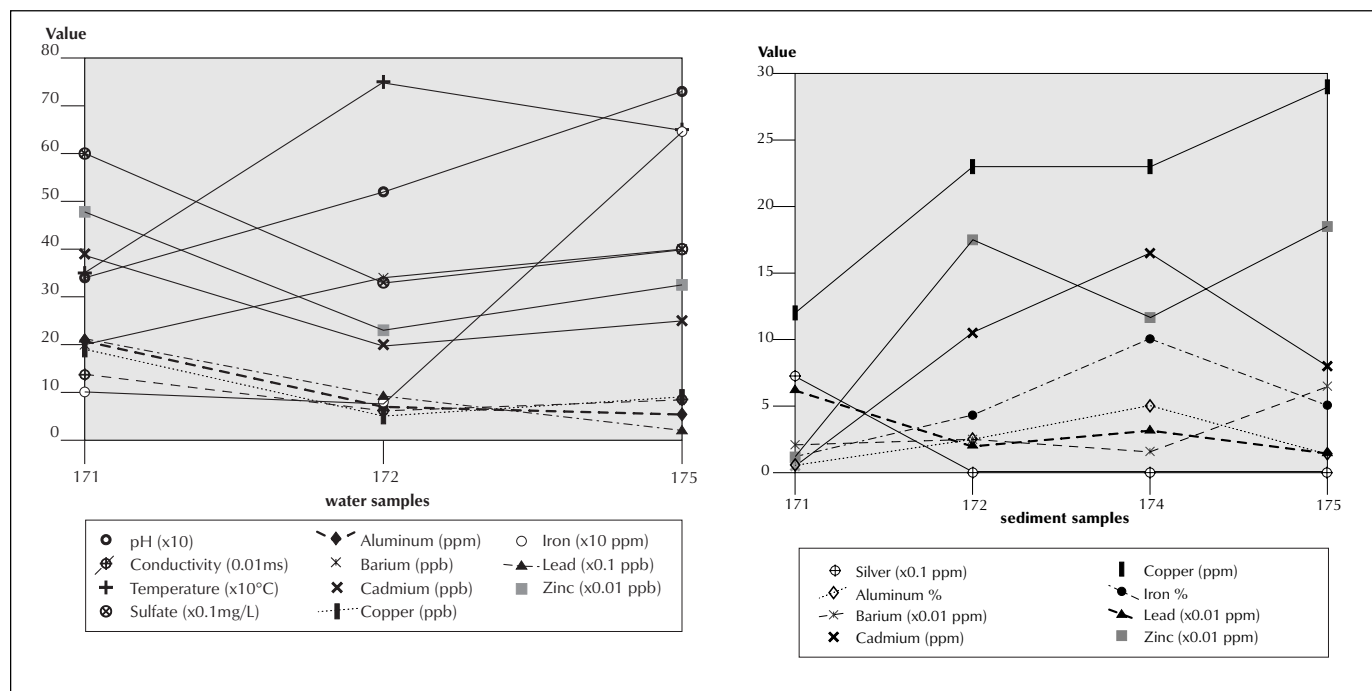


Figure 4. Graphs of results for Pearl Creek water and sediment samples showing the changes in element concentration with changes in pH.

GEOLOGICAL FIELDWORK

Table 1. Results of water and sediment analysis divided into acidic, moderately acidic and alkaline suites.

SAMPLE	Detection Limit	Acidic (pH < 4.5)			Moderately acidic (pH 4.5-6.9)						Alkaline (pH > 6.9)				
		171	170	170a (non-acidified)	164	168	172	179	dup of 179 (SO ₄)	177	178	176	169	dup of 169 (sed)	173
Latitude		61° 28'51"			61° 21'05"	61° 26'12"	61° 19.748	61° 36'46"		61° 38'22"	61° 38'28"	61° 39'40"	61° 27'38"		61° 19.591
Longitude		131° 53'57"			131° 35'42"	131° 41'32"	131° 29.074	132° 25'16"		132° 18'49"	132° 23'28"	132° 21'03"	131° 53'29"		131° 29'23"
Location		105G/6 Pearl Creek	105G/5		105G/5	105G/5	105G/6 Pearl Creek	105F/	105F/	105F/ RAT	105F/	105F/	105G/5 @ Cry 138		105G/6 Rusty Creek
pH		3.4	4.4		4.9	5.0	5.2	6.2		6.6	6.6	6.7	7.0	7.0	7.0
Conductivity (ms)		1370	2000		630	1220	620	1630		690	420	670	690		890
Temperature (°C)		3.5	6.0		7.0	5.5	7.5						5.5		6.0
Ag(sed) (ppm)	0.2	72.6	0.8		1	< 0.2	0.4	0.6		0.4	0.6	0.8	< 0.2	< 0.2	1.4
Ag(H ₂ O) (ppb)	< 5	< 5	< 5		< 5	< 5	< 5	< 5		64	40	< 5	< 5		< 5
Al(sed) (%)	0.01	0.58	1.16		3.42	1.54	2.53	1.37		1.14	1.22	2.21	4.53	3.47	2.34
Al(H ₂ O) (ppm)	0.1	20.9	87.0	2.9	64.4	35.6	7.0	3.1		8.4	4.0	0.9	10.6		4.4
As(sed) (ppm)	2	4	8		20	18	12	26		22	16	26	14	20	16
As(H ₂ O) (ppb)	30	< 30	34	45	< 30	< 30	< 30	39		< 30	< 30	< 30	< 30		30
B(H ₂ O) (ppb)	20	20	20		34	20	20	20		20	20	20	20		20
Ba(sed) (ppm)	10	210	260		100	310	250	950		190	180	190	180	190	350
Ba(H ₂ O) (ppb)	20	< 20	< 20	< 20	49	78	34	< 20		34	39	< 20	69		34
Be(sed) (ppm)	0.5	< 0.5	0.5		1.5	0.5	2.0	2.0		0.5	0.5	1.0	3.0	3.0	0.5
Be(H ₂ O) (ppb)	2	4	15	< 2	4	5	< 2	< 2		< 2	< 2	< 2	< 2		< 2
Ca(sed) (%)	0.01	0.09	0.07		0.2	0.21	0.26	0.07		0.19	0.14	0.6	0.33	0.37	7.76
Ca(H ₂ O) (ppm)	0.1	82.5	237.2	187	90.6	103.6	57.7	185.1		88.0	54.7	312.0	99.0		101.8
Cd(sed) (ppm)	0.5	0.5	2.5		1.5	0.5	10.5	7.0		0.5	0.5	2.0	46.5	58.5	62.5
Cd(H ₂ O) (ppb)	2	39	253	148	6	46	20	146		< 2	< 2	< 2	15		31
Ce(H ₂ O) (ppb)	30	229	3004	73	377	2052	79	67		119	< 30	< 30	98		< 30
Co(sed) (ppm)	1	1	6		6	14	12	3		25	24	9	47	58	17
Co(H ₂ O) (ppb)	5	50	217	< 5	5	58	14	< 5		9	14	< 5	6		< 5
Cr(sed) (ppm)	1	22	12		10	81	35	2		7	2	12	11	8	17
Cu(sed) (ppm)	1	12	52		23	32	23	38		43	17	61	39	33	58
Cu(H ₂ O) (ppb)	2	19	223	3	17	16	5	6		8	3	2	6		11
Fe(sed) (%)	0.01	1.20	2.42		3.01	6.55	4.32	5.18		7.21	10.30	13.15	5.34	5.30	6.63
Fe(H ₂ O) (ppm)	0.01	1.01	0.02	0.17	2.08	0.66	0.08	0.21		27.86	6.17	0.07	3.38		9.84
K(sed) (%)	0.01	0.12	0.06		0.09	0.23	0.15	0.09		0.06	0.1	0.09	0.03	0.04	0.08
K(H ₂ O) (ppm)	0.1	1.2	0.3	1.4	1.6	0.7	0.9	1.4		1.1	1.2	0.6	0.5		0.6
La(sed) (ppm)	10	40	50		50	70	80	240		20	30	40	140	160	30
Mg(sed) (%)	0.01	0.24	0.16		0.22	0.58	0.82	0.05		0.10	0.05	0.07	0.34	0.25	4.09
Mg(H ₂ O) (ppm)	0.1	50.0	163.7	138.1	7.0	46.9	24.7	106.7		20.6	12.4	60.4	18.6		45.9
Mn(sed) (ppm)	5	85	145		705	280	1750	615		450	620	340	4810	6110	3150
Mn(H ₂ O) (ppm)	0.01	12.52	6.56	3.71	2.26	6.29	4.08	3.62		0.12	0.49	0.01	0.8		0.3
Mo(sed) (ppm)	1	1	4		6	7	11	13		5	2	8	7	9	5
Mo(H ₂ O) (ppb)	5	< 5	8	< 5	5	5	< 5	5		5	< 5	5	8		< 5
Na(sed) (%)	0.01	< 0.01	0.01		< 0.01	< 0.01	< 0.01	< 0.01		< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
Na(H ₂ O) (ppm)	0.1	0.3	2.9	0.5	0.3	0.6	0.3	0.5		0.4	0.3	0.5	0.3		0.4
Ni(sed) (ppm)	1	8	57		27	54	27	13		44	14	63	169	229	17
Ni(H ₂ O) (ppb)	20	63	1335	247	73	354	21	243		20	23	54	63		< 20
P(sed) (ppm)	10	690	790		760	790	630	410		960	1520	1930	700	850	340
P(H ₂ O) (ppm)	0.02	0.07	0.1	0.03	1.92	0.06	0.03	0.03		0.11	0.05	0.07	0.06		0.06
Pb(sed) (ppm)	2	630	16		38	32	214	142		38	76	52	14	20	140
Pb(H ₂ O) (ppb)	10	214	< 10	< 10	< 10	< 10	94	< 10		< 10	< 10	< 10	< 10		< 10
Sc(sed) (ppm)	1	13	3		1	4	2	< 1		3	3	6	1	1	1
Si(H ₂ O) (ppm)	0.02	13.60	21.62	10.4	12.27	14.94	4.27	10.19		6.55	6.26	5.01	9.73		8.09
Sr(sed) (ppm)	1	7	17		50	51	20	15		45	17	79	32	36	102
Ti(sed) (%)	0.01	< 0.01	< 0.01		< 0.01	0.08	< 0.01	< 0.01		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ti(H ₂ O) (ppb)	10	< 10	33	< 10	< 10	20	< 10	< 10		< 10	< 10	< 10	< 10		< 10
V(sed) (ppm)	1	6	18		12	27	13	2		22	7	21	10	10	6
Zn(sed) (ppm)	2	118	532		246	176	1750	1200		178	190	428	1420	1880	6390
Zn(H ₂ O) (ppb)	5	4780	15717	11312	419	4385	2300	11150		29	49	72	739		4098
S(H ₂ O) (ppm)	0.03	196.05	471.3	271	105.36	206.1	92.28	267.72		80.91	58.23	251.91	95.73		134.01
SO ₄ (H ₂ O) (ppm)	0.1	600	1380		360	630	330	690	740	210	150	680	248		430

Table 1. ...continued

SAMPLE	Alkaline (pH > 6.9)										Blanks				
	175	166	dup of 166 (H ₂ O)	167 (sed)	dup of 167 (sed)	180	dup of 180 (SO ₄)	180a (non- acidified)	Rerun of 180a	174 (sed)	165	Water blank #1	Water blank #2	Water blank #3(SO ₄)	Water blank #4(SO ₄)
Latitude		61° 25'18"				61° 27'34"				61° 19.591	61° 21'48"				
Longitude		131° 41'02"				132° 38'48"				131° 29'23"	131° 35'56"				
Location		105G/5				105F/MM				105G/6 junction	105G/5				
pH	7.3	7.4		7.4	7.4					7.6	8.3				
Conductivity (ms)		920				710				850	520				
Temperature (°C)		4.0								6.5	10				
Ag(sed) (ppm)	0.8	< 0.2		< 0.2	< 0.2	1.6				1.2	< 0.2				
Ag(H ₂ O) (ppb)	< 5	< 5	< 5			< 5		< 5	< 5		5	< 5	< 5		108
Al(sed) (%)	1.42	4.136		9.15	10.75	0.78				5.02	0.6				
Al(H ₂ O) (ppm)	5.4	< 0.1	< 0.1			0.5		0.6	0.5		1.2	< 0.1	< 0.1		0.5
As(sed) (ppm)	14	32		26	32	102				8	8				
As(H ₂ O) (ppb)	< 30	< 30	< 30			< 30		< 30	< 30		30	< 30	< 30		150
B(H ₂ O) (ppb)	20	20				20					20				
Ba(sed) (ppm)	650	250		340	310	320				160	90				
Ba(H ₂ O) (ppb)	40	37	39			< 20		< 20	< 20		27	< 20	< 20		483
Be(sed) (ppm)	1.0	4.0		11.0	13.0	< 0.50				2.0	2.0				
Be(H ₂ O) (ppb)	< 2	< 2	< 2			< 2		< 2			< 2	< 2	< 2		131
Ca(sed) (%)	0.48	0.52		1.05	1.17	0.06				0.09	0.18				
Ca(H ₂ O) (ppm)	93.2	174.9	176.0			96.3		94.6	95.2		64.3	< 0.1	< 0.1		< 0.1
Cd(sed) (ppm)	8.0	4.0		12.0	8.5.0	0.5				16.5	< 0.5				
Cd(H ₂ O) (ppb)	25	< 2	< 2			< 2		2	2		4	< 2	< 2		100
Ce(H ₂ O) (ppb)	< 30	< 30	< 30			< 30		< 30	< 30		116	< 30	< 30		< 30
Co(sed) (ppm)	6	15		24	13	< 1				8	3				
Co(H ₂ O) (ppb)	< 5	< 5	< 5			< 5		< 5	< 5		< 5	< 5	< 5		115
Cr(sed) (ppm)	20	30		39	35	< 1				25	4				
Cu(sed) (ppm)	29	91		112	127	92				23	12				
Cu(H ₂ O) (ppb)	9	2	12			3		2	2		7	< 2	< 2		111
Fe (%)	5.07	6.44		5.33	4.93	9.65				10.05	3.53				
Fe(H ₂ O) (ppm)	6.46	0.04	0.06			0.13		0.08	0.08		0.33	0.01	0.01		0.61
K(sed) (%)	0.07	0.14		0.15	0.13	0.46				0.08	0.12				
K(H ₂ O) (ppm)	0.6	0.5	0.5			0.9		0.9	0.9		0.3	< 0.1	< 0.1		< 0.1
La(sed) (ppm)	40	480		780	870	40				20	220				
Mg(sed) (%)	0.38	0.47		0.68	0.56	0.30				0.33	0.11				
Mg(H ₂ O) (ppm)	40.1	20.9	21.0			26.3		26.0	26.2		20.9	< 0.1	< 0.1		< 0.1
Mn(sed) (ppm)	725	1140		2770	1040	555				940	1250				
Mn(H ₂ O) (ppm)	0.79	< 0.01	< 0.01			< 0.01		< 0.01	< 0.01		0.05	< 0.01	< 0.01		0.52
Mo(sed) (ppm)	4	15		11	5	11				9	8				
Mo(H ₂ O) (ppb)	< 5	5	5			< 5		< 5	< 5		< 5	< 5	< 5		477
Na(sed) (%)	< 0.01	0.01		0.01	0.01	0.01				< 0.01	< 0.01				
Na(H ₂ O) (ppm)	0.5	0.5	0.5			0.3		0.3	0.3		0.3	< 0.1	< 0.1		< 0.1
Ni(sed) (ppm)	23	40		39	33	1				16	5				
Ni(H ₂ O) (ppb)	< 20	< 20	< 20			< 20		< 20	< 20		39	< 20	< 20		434
P(sed) (ppm)	730	810		1290	1350	330				420	390				
P(H ₂ O) (ppm)	0.03	0.03	0.06			0.03		0.04	0.04		0.04	< .02	< .02		0.02
Pb(sed) (ppm)	156	76		54	58	422				326	18				
Pb(H ₂ O) (ppb)	22	< 10	< 10			< 10		< 10	< 10		< 10	< 10	< 10		112
Sc(sed) (ppm)	2	4		7	6	< 1				1	< 1				
Si(H ₂ O) (ppm)	5.64	3.62	3.62			4.36		4.39	4.27		2.77	0.06	0.05		0.16
Sr(sed) (ppm)	29	55		100	112	10				12	13				
Ti(sed) (%)	< 0.01	0.06		0.08	0.06	0.04				< 0.01	< 0.01				
Ti(H ₂ O) (ppb)	< 10	< 10	< 10			< 10		< 10	< 10		< 10	< 10	< 10		< 10
V(sed) (ppm)	14	35		25	20	3				9	3				
Zn(sed) (ppm)	1850	672		1855	1500	284				1165	78				
Zn(H ₂ O) (ppb)	3250	< 5	< 5			97		96	95		11	< 5	< 5		610
S(H ₂ O) (ppm)		125.79	125.97			95.82		95.67	93.90		120.93	< 0.03	0.03		0.06
SO ₄ (H ₂ O) (ppm)		410	390			227	239			400	123			< 1	< 1

STREAM SEDIMENT AND WATER SAMPLES

If the results of stream sediment analyses are to be used in conjunction with those for water analyses variations in the secondary environment must be taken into consideration; for example differences in pH which may cause changes in the trace element content of stream sediments and water (Fletcher and Doyle, 1974). These variations can lead to the suppression of some true anomalies and the generation of false anomalies. For example, Cu and Zn are soluble at low pH, therefore Cu and Zn concentrations in sediments are likely to be low in an acidic environment (Hansuld, 1966; Earle, 1975). This can be seen in Pearl Creek: at the source (sample 171) where the pH is 3.4 the Cu and Zn contents of the water are 19 and 4780 ppb, respectively, and those of the sediment are 12 and 118 ppm respectively; about 250 m downstream (sample 172) where the pH has increased to 5.2 the Cu and Zn content of the water have decreased to 5 and 96 ppb, respectively, and that of the

sediment has increased significantly to 23 and 1,750 ppm, respectively. In the MacMillan Pass area, Fletcher and Doyle (1974) and Earle (1975) showed that the threshold value for Zn in stream sediments is four times greater under neutral or slightly alkaline conditions than in strongly acidic (pH < 4.5) streams. This indicates that data for mobile elements should not be interpreted without reference to the pH of the stream and should only be compared with data for streams of similar acidity.

Other elements that are mobile under acidic conditions include Ni, Mn, Cd and Co (Fletcher and Doyle, 1974; Earle, 1975; Cameron, 1977; Goodfellow, 1989). Therefore, under acidic conditions concentrations of these elements are likely to be low in sediment and elevated in water samples.

Less mobile elements such as Pb and Ag are not as significantly influenced by stream pH and are often a useful indicator of proximity to mineralization (e.g., Fletcher and Doyle, 1974; Earle, 1975; Goodfellow, 1989). Results reported by Cameron

Table 2. Results of water analysis by ICP-MS.

Trace element values are in parts per billion. Negative values equal not detected at that lower limit.				
Sample ID	165	175	179	180
Li	-1	2	3	7
Na	463	720	757	486
Mg	16,700	37,500	103,000	22,900
Al	1,630	5,820	3,070	668
Si	2,240	4,260	7,770	3,430
K	465	962	2,080	1,350
Ca	62,500	86,600	149,000	90,900
Sc	-1	2	3	1
Ti	0.9	1.2	1.8	1.1
V	0.19	0.27	0.09	0.10
Cr	-0.5	0.5	-0.5	-0.5
Mn	55	577	2,800	10
Fe	437	4,910	658	373
Co	0.162	2.449	0.360	0.144
Ni	0.90	6.02	198	1.59
Cu	10	12	5.5	4.3
Zn	65	2,530	8,730	106
Ga	1.18	0.62	2.20	0.25
Ge	0.20	0.09	0.90	0.09
As	1.06	1.19	2.09	1.54
Se	1.1	1.7	2.8	1.2
Br	5	6	6	-3
Rb	0.528	1.884	3.340	3.186
Sr	149	331	304	124
Y	9.412	9.502	70.98	8.468
Zr	0.170	0.131	0.433	0.499
Nb	0.01	0.02	0.01	0.02
Mo	0.5	0.5	0.1	0.5
Ru	-0.02	-0.02	-0.02	-0.02
Pd	-0.02	-0.02	-0.02	-0.02
Ag	-0.2	-0.2	-0.2	-0.2
Cd	0.43	25.7	155	2.34
In	-0.001	0.152	0.002	-0.001
Sample ID	165	175	179	180
Sn	0.1	0.3	-0.1	0.2
Sb	0.06	0.18	0.08	0.18
Te	-0.2	-0.2	-0.2	-0.2
I	1.0	1.1	1.1	0.9
Cs	0.116	0.046	0.007	0.258
Ba	28	38	9.8	19
La	81.18	15.09	513.7	17.01
Ce	95.9	22.9	57.5	10.6
Pr	14.64	4.174	70.07	4.787
Nd	48.33	16.71	234.4	17.45
Sm	7.727	4.622	36.99	4.081
Eu	0.938	1.165	4.232	0.511
Gd	9.790	5.146	48.21	4.062
Tb	0.796	0.573	4.163	0.516
Dy	2.319	2.406	14.26	2.426
Ho	0.257	0.307	1.781	0.330
Er	0.630	0.722	4.154	0.802
Tm	0.045	0.076	0.299	0.080
Yb	0.293	0.495	1.690	0.428
Lu	0.040	0.070	0.237	0.047
Hf	0.020	0.023	0.123	0.027
Ta	-0.01	-0.01	0.01	-0.01
W	-0.02	0.24	-0.02	-0.02
Re	0.002	0.002	0.001	0.005
Os	-0.002	-0.002	-0.002	-0.002
Pt	-0.02	-0.02	-0.02	-0.02
Au	-0.002	-0.002	-0.002	-0.002
Hg	-0.2	-0.2	-0.2	-0.2
Tl	0.015	0.381	0.016	0.011
Pb	2.3	35	4.2	2.6
Bi	0.034	0.042	0.021	0.015
Th	0.040	0.321	0.081	0.208
U	0.181	1.646	0.052	0.942

(1977) for samples of water and sediment collected near massive sulphide mineralization in the Agricola Lake area, NWT, show that Pb, Ag and Hg are immobile in the surface environment and are largely retained in soils near the mineralization. However, Zn, Cd and Cu are mobile and are dispersed far along the lake-stream system draining the mineralization.

In order to compare streams throughout the Pelly Mountains volcanic belt, variations in pH were taken into account and the samples were divided into highly acidic (pH < 4.5), moderately acidic (pH 4.5 to 6.9) and alkaline (pH > 6.9) suites as suggested by Fletcher and Doyle (1974) and shown in Table 1.

Samples 171, 172, 174 and 175 are from Pearl Creek which drains the Wolf Zn-Pb-Ag deposit. These samples all have elevated Pb and Zn values. Water sample 171 also has an elevated sulphate content. Sample 179, which was collected near the Fire (Chzernpough) prospect, has elevated Pb and Zn levels plus Ni, Cd and sulphate. Sample 180 was collected from a creek draining the MM barite-pyrite ± sphalerite ± galena ± chalcopyrite deposit. It has elevated Pb, Ag and Cu levels but low levels of Zn in sediment and water samples. This sample was the only one collected that had an elevated level of As.

The remaining samples were not collected near any known mineralization. For samples 168 and 170, shale may be the source of zinc as the samples also have elevated levels of As, Co, Ni and sulphate, and were collected close to the contact between the volcanic rocks and the underlying carbonate/shale sequence. Similar shales are known to produce anomalous zinc values in the Driftpile Creek (Lett et al., 1997) and MacMillan Pass areas (Earle, 1975). Of the remaining samples with elevated values (all in sediment: **164**: Ag; **166**: Cu; **167**: Cu, Zn; **169**: Cd, Co, Ni, Zn; **176**: Cu, Fe, SO₄), samples 167, 169 and 176 are the most interesting as they have multiple element anomalies.

The data in Table 1 also shows that there is a close correlation between the concentration of Mn in water and the increase in pH; the Mn content of water decreases as the pH increases. This relationship is similar to that documented by Fletcher and Doyle (1974) for the MacMillan Pass area.

The results of sulphate analysis for the water samples show that overall, the sulphate content of the water decreases as the pH increases; the S content also decreases overall. Sulphate is most soluble in acidic waters and the decrease in sulphate content is likely due to the precipitation of aluminium and/or barium sulphates as the waters become increasingly alkaline.

COMPARISON TO EXISTING RGS DATA

Regional geochemical stream sediment samples (RGS) were collected at an average density of one sample per 13 square km throughout the Pelly Mountains volcanic belt (Fig. 2; Hornbrook and Friske, 1985, 1988). The RGS samples located proximal to the volcanic belt have pH values ranging from 7.0 to 8.4 and

should therefore only be compared to sediment samples from creeks of similar alkalinity. This comparison reveals that at the southeast end of the belt only one RGS sample is anomalous (1085 on NTS 105G) with elevated values of Zn, Cu and Cd. The remainder of the belt (NTS 105F) has several anomalous RGS samples (**1090** - Zn, Pb, Ag, Cd; **1110** and **1203** - Cu; **1122**, **1123** and **1188** - Pb; **1206** - Pb, Ag).

All of the RGS samples have barium contents significantly greater than samples from the present study. This, plus the high pH values, may be an indication that the RGS samples were collected in creeks that drain older platformal strata and do not directly drain the volcanic belt.

CONCLUSIONS

Preliminary results of spring/creek water sample analysis reveal:

- The creek draining the Wolf deposit varies in pH from 3.4 to 7.6 and has elevated levels of Pb and Zn in water and sediment samples. Changes in the element content of water and sediment samples occur over short distances as the pH changes indicating that the location of a given sample is important if samples from various creeks are to be compared.
- Creeks draining areas of known mineralization have elevated base metal content in water and/or sediment samples indicating that this may be a viable exploration method for locating VMS mineralization in the Pelly Mountains volcanic belt.
- A creek draining the MM deposit (sample 180) has a pH of 7.5 and elevated levels of Ag, Cu and Pb in sediment but not in water, and Zn is not elevated.
- A creek draining the Fire pyrite-barite occurrence (sample 179) has a pH of 6.2 and elevated levels of Ba, Pb and Zn in sediment and Cd, Ni and Zn in water.
- Several samples from creeks not located near any known mineralization (samples 164, 166, 167, 169, 176) returned elevated values of Cu and Zn suggesting the presence of pyritic shale, or possibly, undiscovered mineralization.
- The white precipitate in the creeks is likely composed of aluminium hydroxide or aluminium and calcium sulphate, and indicates an acidic environment, at least locally. The precipitate likely occurs where there are rapid pH changes and can be indicative of base metal mineralization.

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Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

APPENDIX A

SAMPLE SITE DESCRIPTIONS

Sample 164 – Water and silt samples were collected from a creek with white precipitate, 1 m upstream from the junction with a rusty creek.

Sample 165 – Water and silt samples were collected from a creek with white precipitate, about 20 m below a lake outlet.

Sample 166 – Water and silt samples were collected from a creek with white precipitate, below the area of white precipitate.

Sample 167 – Silt sample collected from the same site as 166, but upstream in the area of white precipitate.

Sample 168 – Water and silt samples were collected from a creek with white precipitate, near the source at the point where there was a change from white to rusty precipitate downstream.

Sample 169 – Water and silt samples were collected from a creek with white precipitate, near the source at the point where there was a change from white to rusty precipitate downstream.

Sample 170 – Water and silt samples were collected from a seep flowing over argillite, at the first appearance of a white precipitate.

Sample 171 – Water and silt samples were collected from the source of Pearl Creek, which drains the Wolf deposit. There is no white precipitate at the source.

Sample 172 – Water and silt samples were collected from a site about 100 m downstream of 171, where white precipitate first appears.

Sample 173 – Water and silt samples were collected from Red Creek, which joins Pearl Creek, about 400 m downstream from its source.

Sample 174 – A silt sample was collected from Pearl Creek, at the junction with Red Creek.

Sample 175 – Water and silt samples were collected from immediately below the confluence of Pearl and Red creeks.

Sample 176 – Water and silt samples were collected from the rusty part of the creek, upstream from a white precipitate, north of Chzerpnough prospect.

Sample 177 – Water and silt samples were collected from a small creek near a seep, Chzerpnough prospect.

Sample 178 – Water and silt samples were collected from the Rat claims, close to a seep with white precipitate in the creek. The creek was rusty above the white precipitate.

Sample 179 – Water and silt samples were collected from the head of a creek, just above where white precipitate occurred. The head of the creek is swampy.

Sample 180 – Water and silt samples were collected from a creek on the MM property, at the contact between rusty and white precipitate.

