Geochemical Exploration Techniques for Plutonic-related Gold Deposits in Southern B.C. (NTS 82M/4, M/5, M/6 and 82F/7)

By Ray Lett and Wayne Jackaman

KEYWORDS: Plutonic-related gold deposits, moss mat sediment, stream sediment, Regional Geochemical Surveys.

INTRODUCTION

Discovery of the Liese Zone on the Pogo property in Alaska (containing an estimated 9.98 million tons of ore grading 0.52 oz gold/ton) where gold-arsenic-copper-bismuth mineralization occurs in gneiss-related quartz bodies close the margin of a Cretaceous batholith (Smith et al., 1999) has stimulated exploration for similar plutonic-related gold deposits in British Columbia. The Pogo property was discovered by follow-up of a subdued (35 ppb) stream sediment geochemical gold anomaly (Robertson, 1998). Similarly, only 15 ppb gold was detected by a regional stream survey in a sediment sample collected from a creek draining the Cam-Gloria mineral occurrence (MINFILE 82M 266), a gold-bismuth-lead mineralized, granite-hosted quartz vein, in southern B.C. (Matysek et al., 1991). This occurrence was found in 1997 by prospecting after anomalous gold values were identified in a regional till sample close to the mineralized vein (Bobrowsky et al., 1997).

There is presently limited published information about the geology or the application of geochemistry for plutonic-related gold deposits in British Columbia. These deposits may be difficult to find by traditional stream sediment surveys because the gold and associated pathfinder elements such as tin, bismuth and tungsten are relatively immobile and tend to be erratically distributed in the sediment. Drainage sediments in British Columbia are also prone to dilution by barren glacial material (unlike the non-glaciated area in Alaska where the Pogo property is located) and therefore gold anomaly contrast may be more subdued. In general, gold anomaly contrast can be improved using more appropriate sample media such as moss mat sediment or a heavy mineral fraction (Matysek and Day, 1987).

A study was carried out in August 1999 by the authors to compare the geochemical response of intrusive-related gold mineralization in different reconnaissance scale sample media such as stream sediment, moss mat sediment and heavy mineral concentrates. The study is part of a Geological Survey Branch initiative to examine the potential for intrusive-related gold deposits in the Province. Results of the geological component are described by Logan, 2000, Geological Fieldwork 1999, Paper 2000-1, this volumes). Geochemical samples were collected in two areas of southern British Columbia, one near Adams Lake and the other east of Kootenay Lake.

Objectives of this study were to 1) develop a better understanding of the stream geochemical response of plutonic-related mineralization; 2) compare the merits (cost effectiveness) of different stream sampling, sample preparation and analytical methods to improve the ability of stream sediment geochemistry to detect plutonic-related gold mineralization; 3) add value to the current RGS database to stimulate future mineral exploration and; 4) evaluate other factors such as element backgrounds in different sample media and bedrock types for improving methods of geochemical data interpretation.

This paper describes the survey areas, sampling technique, the sample preparation and analytical methods used and discusses preliminary geochemical results.

ADAMS LAKE SURVEY AREA DESCRIPTION
(NTS 82M/4, M/5, M/6 and 92P/8)

Location

Detailed stream geochemical studies in parts of NTS map sheet 82M/4, M/5 and M/6 focused on the area around the Cam-Gloria Gold occurrence (MINFILE 82M 266) located west of Honeymoon Bay on Adams Lake. Regional stream sampling covered a larger 350 square kilometre area to the west and north-west. Three sites were also sampled within the Newhykulston Creek watershed in NTS 92P/8 (Figure 1).

Physiography and Climate

The survey area is within the Shuswap Highlands, a region of broad forested mountains of moderate to high relief (Holland, 1976). The region bounded by Gollen Creek, Adams Lake, Fennel Creek and the East Barriere River is a dissected plateau with an undulating surface averaging 1700 metres above sea level and with hill tops reaching 1800 metres. Principal drainage is by the west
flowing Fennel Creek, East Barriere River and Bendelin Creek and to the east by Spapilem, Fisher, Stratton and Gollen Creeks. The creeks draining into Adams Lake typically have steep gradients (10-15 degrees), are fast flowing and follow steep-sided, deep valleys. The two tributaries of Newhykulston Creek, where samples were collected, join to flow west into the North Thompson River from a rolling plateau that has an average elevation of 1700 metres above sea level.

The climate of the area is moist and temperate. Winter temperatures typically range from -10 to -15°C, summer temperatures can reach 30°C. Annual precipitation averages 417 mm (measured at Vavenby) falling as snow in the winter months and as rain mainly between June and July. The spring freshet occurs between mid May and late June.

Bedrock Geology

The survey area is partly underlain by Cambrian to Mississippian rocks of the Eagle Bay Assemblage and Fennell Formation and by the mid-Cretaceous Baldy Batholith. The Eagle Bay Assemblage, part of the Kootenay Terrane, was originally deposited along the ancestral margin of North America. Older Eagle Bay rocks range from quartzites, quartz-rich schists and limestone. These are overlain by grit, phyllite and quartz mica schist and coarse grained elasic metasediments interbedded with felsic volcanic rocks. Above the metasedimentary rocks are limestone and calcareous phyllite, calcisilicate schist and skarn, pillowed greenstone and chlorite-sericite-quartz schist of felsic origin. At the top of the sequence are slates and siltstone. The Fennell Formation is a Devonian to Permian sequence of oceanic bedded cherts, gabbro, diabase, pillow basalt, sandstone, quartz-porphyry rhyolite and conglomerate that forms part of the Slide Mountain Terrane and has a thrust contact with Eagle Bay Assemblage. The mid-Cretaceous Baldy Batholith is predominantly massive light-grey, coarse-grained quartz monzonite. Xenoliths of country rock are common close to the contact of the Batholith with the Eagle Bay Assemblage. The eastern and northern margins of the Batholith are marked by medium-grey biotite and muscovite Devonian orthogneiss. In addition to the Baldy Batholith there are several smaller satellite intrusive granitic bodies and one of these has been mapped close to the headwaters of Newhykulston Creek (Schiarriza and Preto, 1987).

Surficial Geology

The uplands are mainly covered by till, colluvium, and glaciofluvial deposits, whereas fluviatile, glaciofluvial and glaciolacustrine sediments have accumulated in the valleys. These sediments were deposited initially by a predominately northwest to southeast ice advance followed by deglaciation processes during the late Wisconsin. There are two types of basal till deposited in the area, each reflecting a different bedrock source. South of the survey area where geology is dominated by metavolcanic and metasedimentary rocks basal till is massive to poorly stratified with a sandy silt to silty clay texture. In most of the stream survey area, however, the basal till is sandier and light to medium grey in colour reflecting a granitic bedrock source. Boulder fields and massive clast-supported ablation till covers bedrock and basal till on the plateau. The ablation till is generally less compact, dense and cohesive and the sandy matrix is poorly consolidated. Clast content is higher than basal till (up to 45 per cent) and clast size ranges from granule to boulder. Clast lithologies are almost entirely of Baldy Batholith rocks (Dixon-Warren et al., 1997).

Mineral Occurrences

The principal mineral occurrence in the survey area is the Cam-Gloria Gold property (MINFILE 82M 266) discovered in 1997 by follow-up of a regional till geochemical anomaly (Bobrowsky et al., 1997). The “discovery” occurrence is a large, rusty auriferous quartz vein located on the north fork of the Grizzly Creek Forest Service road, approximately 3 kilometres west of the Honeymoon Bay campsite on Adams Lake. The vein strikes at 50 degrees, dips steeply northwest and is up to 10 metres wide and roughly 200 metres in length. Pyrite, galena and minor chalcopyrite occur in the quartz and samples of the sulphide-rich vein material contain 1.38 ppm gold, 7.8 ppm silver, 55 ppm bismuth, 430 ppm lead, 118 ppm copper and 21 ppm molybdenum (Lett et al., 1998). Within one kilometre of the auriferous quartz vein there are several narrow monzonite-hosted quartz-fluorite veins and a 30 centimetre wide quartz-pyrite-pyrrhotite vein.

Two other documented mineral occurrences within or close to the Baldy Batholith are the NSP (MINFILE 82M 127) near the headwaters of Spapilem Creek where chalcopyrite occurs as disseminations and in thin quartz stringers in quartz-biotite gneiss and the SAN (MINFILE 82M 135) between North Barriere and Saskum Lakes.
where pyrite, galena, sphalerite and chalcopyrite occur in a granite hosted, sheared quartz vein.

**KOOTENAY LAKE SURVEY AREA DESCRIPTION (82F/07)**

**Location**

The geochemical survey covered roughly 150 square kilometre southeast of Boswell on Kootenay Lake within the watersheds of Akokli, Sanca and Skelly Creeks (Figure 1). Stream sampling included creeks draining known mineral occurrences on Mount Sherman and Mount Dickson.

**Physiography and Climate**

The survey area is located in the southern Purcell Mountains. Elevations range from 550 metres on the shore of Kootenay Lake to 2700 metres on the peak of Haystack Mountain. Principal watersheds are of those Akokli and Sanca Creeks and east flowing Skelly Creek. The height of land between Akokli and Sanca Creeks is very rugged and the highest elevation (2700 metres) on this ridge is Mount Sherman. South of Sanca Creek the topographic relief is more subdued and above 1700 metres the land surface is a rolling, forested plateau.

Climate of the area is moist and temperate. Winter temperatures average - 6°C and in summer reach 30°C. Annual precipitation averages 580 mm (measured at Bonners Ferry) falling mainly as snow at higher elevations in the winter months. The spring freshet occurs between mid-May and late June.

**Bedrock Geology**

Most of the survey area is underlain by rocks of the Creataceous Bayonne Batholith. This Batholith comprises white to light-grey, medium to coarse-grained biotite granite and quartz monzonite. These rocks intruded siltstones and quartzites of the Creston Formation which forms the lower part of the Proterozoic Purcell Supergroup. The contact between the Creston Formation and Bayonne Batholith is located just south of Akokli Creek and trends northwest to southeast (Borovic, 1987).

**Surficial Geology**

Glacial and recent surficial deposits range from talus and colluvium above timber line and on steep slopes to basal till at lower elevations. Thick glaciofluvial, glaciolacustrine and fluvial deposits fill the major valleys and the Kootenay Lake basin. The till, deposited by a predominately north to south ice advance parallel to Kootenay Lake during the Fraser Glaciaion is sandy textured reflecting a predominantly granite source rock (Fulton and Smith, 1978). Glacial and inter-glacial deposits from earlier Wisconsinan glaciations including Okanagan Centre till, paleosol and Bessette sediments have been recognised at the north end of Kootenay Lake (Alley et al., 1986).

**Mineral Occurrences**

Mineral occurrence in the survey area are typically polymetallic gold-silver-lead-zinc-tungsten veins and mineralized quartz vein stockworks hosted by the granite and quartz monzonite. The Valparaiso occurrence (MINFILE 82FSE 038), located north of Ginol Creek and south of Akokli Creeks is a quartz-filled fissure containing pyrite, arsenopyrite, wolframite, galena, sphalerite and chalcopyrite in granite and granodiorite locally altered to chlorite and sericite. Gold and silver are disseminated in the quartz. The German (Gold) Basin showing (MINFILE 82FSE 039) is also a gold mineralized quartz vein in granodiorite at an elevation of 2133 metres located on the western slope of Mount Sherman. The vein contains scattered irregular bands and patches or pyrite, galena, chalcopyrite and scheelite. Typical metal concentrations of the vein material are 39.7 percent lead, 366 grams per tonne silver and 3.4 grams per tonne gold. The Elmo showing (MINFILE 82FSE 137), located in a cirque west of Mount Dickson, is a stockwork of quartz-muscovite veinlets in medium grained, equigranular and coarse-grained to porphyritic quartz monzonite phases of the Bayonne Batholith. Within the stockwork are scattered molybdenite, scheelite, fluorite, magnetite, pyrite and chalcopyrite grains.

**SAMPLING TECHNIQUES**

An objective of the study was to compare the geochemical response from plutonic-related gold mineralization in different sample media at an average density of 1 sample per 12 kilometres typical of a routine regional stream geochemical survey. Samples were taken from larger, first and second order creeks draining catchments covering 10 - 15 square kilometres and especially creeks where previous regional stream sediment and till surveys had detected anomalous gold levels. More detailed stream sampling at a higher density was attempted around known gold occurrences. Samples were collected in August, 1999 following the spring freshet. The number and type of samples collected in each are summarized in Table 1.

A total of 68 stream water, 74 stream sediment and 74 moss mat samples (including field duplicates) were collected from 40 sites in 82M/4, 82M/5 and 82M/6 (Adams Lake area), 3 sites in 92P/8 (Newhykulston Creek) and 25 sites in 82F/7 (Kootenay Lake area). In addition 25 bulk screened sediment samples were taken from selected sites for analysis of gold and other elements in a -150 (<100 micron) mesh heavy mineral fraction. The bulk samples were collected from the higher energy environment corresponding to a coarse gravel deposit in the stream channel by wet-sieving sufficient material through an 18 mesh (<1 millimetre) nylon screen to recover 10 kilograms of <1 millimetre sized sediment. Wet
Fine textured sediment, typical of material routinely collected during a regional survey was also taken, generally from the sandy part of a bar in the stream channel, and stored in a high wet strength Kraft paper bag. Live moss containing trapped sediment, collected from the surface of boulders or logs in the active stream above the water level, was also stored in Kraft bags. Abundant moss occurred at almost all of the stream sites and was only sparse in areas disturbed by logging. Water samples were collected by filling a 125 millilitre high-density polyethylene bottle after previously rinsing the bottle with the stream water. A two litre bulk water sample was collected at selected sites (generally where a bulk sediment was taken) and later filtered through a 0.45 micron filter to recover the suspended sediment.

Considerable effort was made to choose sample sites upstream of known anthropogenic disturbances such as bridges or culverts or logged areas. This was often difficult in practice because of extensive logging in both survey areas. In fact, detailed stream sediment sampling around the Cam-Gloria occurrence was limited because of poorly developed primary drainages and considerable surface disturbance of stream channels by logging. During regional sampling where a stream flowed through an obviously disturbed area every effort was made to locate the sample site in a undisturbed riparian zone or where secondary timber growth had stabilized the terrain. Field observations about sample media, sample site, local terrain and float geology were recorded and an aluminum tag inscribed with the sample identification number was fixed to a permanent object at each sample site.

**SAMPLE PREPARATION**

Sediment and moss mat samples were prepared by Eco-Tech Laboratories Ltd. (Kamloops, B.C.). The samples were air dried and the - 80 ASTM mesh (<177 micron) fraction recovered by disaggregating the sediment or pounding the moss and then dry sieving through a stainless steel screen. Control reference material and analytical duplicate samples were inserted into each analytical block of twenty sediment samples at the Geological Survey Branch Laboratory in Victoria. Any remaining - 80 mesh sediment was archived for future analyses.

The <1 millimetre fraction of bulk stream sediments were processed by C.F.Minerals Research Ltd. (Kelowna, B.C.) to recover heavy minerals. Samples were wet sieved into the following size fractions: - 20 +35, - 35 +60 and -60 mesh and after drying, the - 60 mesh fraction was slowly fed into the middle of a column of tetrabromomethane (TBE), with a specific gravity of 2.96. The resultant heavy minerals that settled to the bottom of the TBE column were then further separated by methylene iodide (MI), with an effective specific gravity of 3.27. The minerals with a specific gravity above 3.27 are called the heavy (H) fraction. The - 60 mesh heavy fraction was then further sieved into - 60 +150 and - 150 (<100 micron) mesh fractions. A Frantz electromagnetic separator was used to generate distinct -150 mesh, heavy fractions based on variations in magnetic susceptibility, as follows: magnetic (M), paramagnetic (P) and nonmagnetic (N). The - 150 mesh, heavy, nonmagnetic fractions (-150HN) were placed in vials for neutron activation analysis.

**SAMPLE ANALYSIS**

The prepared stream sediment, moss mat sediment and quality control samples were analysed for bismuth by aqua regia digestion - hydride generation atomic absorption spectroscopy (AAS-H) and for cadmium, cobalt, copper, iron, lead, manganese, nickel, silver and zinc by aqua regia digestion - flame atomic absorption spectroscopy (AAS). Background corrections were made for lead, nickel, cobalt and silver. The analytical methods are described in more detail by Matysek et al., 1991. Fluorine content of samples was determined by the sodium carbonate-bicarbonate acid digestion-fluoride ion electrode method (FION) described by Ficklin (1970). The samples were also analysed for molybdenum and vanadium by an aqua regia digestion and atomic absorption spectroscopy using a nitrous oxide acetylene flame. Aluminium chloride solution was added to the digested sample solution as a releasing agent before the determination of molybdenum and vanadium by atomic absorption. Mercury was determined by aqua regia digestion - flameless atomic absorption (AAS-F) using the method described by Jonasson et al. (1973). Samples were analysed for tin by ammonium iodide fusion, triethylphosphine oxide - methyl iodobutyl ketone extraction and flame atomic absorption spectrometry (NIAA) as described by Moldan et al. (1970). Loss on ignition of sediment and moss mat samples (GRAV) was determined by ashing the material at 500°C for three hours and then weighing the residue. All of the atomic absorption, fluorine and tin analyses were carried out by CanTech Laboratories (Calgary, Alberta). Reported detection limits for the elements determined by atomic absorption, fluorine and loss on ignition are given in Table 2.

A representative split of each sediment, rock and heavy mineral sample was analysed for antimony, arsenic, barium, bromine, cerium, cesium, chromium, cobalt, gold, hafnium, iron, lanthanum, lutetium, nickel, rubidium, samarium, scandium, sodium, tantalum, terbium,
thorium, tungsten, uranium, ytterbium and zinc using thermal, instrumental neutron activation analysis (INAA) by Activation Laboratories (Ancaster, Ontario). Instrumental neutron activation analysis involves irradiating the sediment samples, which range from 1 to 46 grams for 30 minutes with neutrons (flux density of $7 \times 10^{11}$ neutrons/cm$^2$/second). After approximately 1 week, the gamma-ray emissions for the elements are measured using a gamma-ray spectrometer with a high resolution, coaxial germanium detector. Counting time was approximately 15 minutes per sample. Table 2 lists the detection limits reported for elements determined by this method.

Water samples were analysed for pH, sulphate, fluoride and uranium by CanTech Laboratories (Calgary, Alberta). Detection limits for each element are listed in Table 2. The pH of water samples was measured using a combination glass-reference electrode (GCE). Sulphate was determined by a barium sulphate suspension turbidimetric method (TURB). Water samples were analysed for fluoride by mixing an aliquot of the sample with an equal volume of total ionic strength adjustment buffer (TISAB II solution) and measuring fluoride ion content using a Corning 101 meter with an Orion fluoride electrode (ION). Uranium in waters was determined by laser-induced fluorescence analysis (LIF) with a Scintrex UA-3 uranium analyzer.

### Table 2: Reported Detection Limits

<table>
<thead>
<tr>
<th>Element</th>
<th>Mthd</th>
<th>D.L.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>Sb</td>
<td>INA</td>
<td>0.1  ppm</td>
</tr>
<tr>
<td>Arsenic</td>
<td>As</td>
<td>INA</td>
<td>0.5  ppm</td>
</tr>
<tr>
<td>Barium</td>
<td>Ba</td>
<td>INA</td>
<td>50   ppm</td>
</tr>
<tr>
<td>Bromine</td>
<td>Br</td>
<td>INA</td>
<td>0.5  ppm</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>INA</td>
<td>1 %</td>
</tr>
<tr>
<td>Cerium</td>
<td>Ce</td>
<td>INA</td>
<td>3   ppm</td>
</tr>
<tr>
<td>Cesium</td>
<td>Cs</td>
<td>INA</td>
<td>1   ppm</td>
</tr>
<tr>
<td>Chromium</td>
<td>Cr</td>
<td>INA</td>
<td>5   ppm</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Co</td>
<td>INA</td>
<td>1   ppm</td>
</tr>
<tr>
<td>Europium</td>
<td>Eu</td>
<td>INA</td>
<td>2   ppm</td>
</tr>
<tr>
<td>Gold</td>
<td>Au</td>
<td>INA</td>
<td>2   ppb</td>
</tr>
<tr>
<td>Hafnium</td>
<td>Hf</td>
<td>INA</td>
<td>1   ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>INA</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Lanthanum</td>
<td>La</td>
<td>INA</td>
<td>0.5 ppm</td>
</tr>
<tr>
<td>Lutetium</td>
<td>Lu</td>
<td>INA</td>
<td>0.05 ppm</td>
</tr>
<tr>
<td>Neodymium</td>
<td>Nd</td>
<td>INA</td>
<td>5   ppm</td>
</tr>
<tr>
<td>Rubidium</td>
<td>Rb</td>
<td>INA</td>
<td>15  ppm</td>
</tr>
<tr>
<td>Samarium</td>
<td>Sm</td>
<td>INA</td>
<td>0.5  ppm</td>
</tr>
<tr>
<td>Scandium</td>
<td>Sc</td>
<td>INA</td>
<td>0.1  ppm</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>INA</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Tantalum</td>
<td>Ta</td>
<td>INA</td>
<td>0.5  ppm</td>
</tr>
<tr>
<td>Terbium</td>
<td>Tb</td>
<td>INA</td>
<td>0.5  ppm</td>
</tr>
<tr>
<td>Thorium</td>
<td>Th</td>
<td>INA</td>
<td>0.2  ppm</td>
</tr>
<tr>
<td>Tungsten</td>
<td>W</td>
<td>INA</td>
<td>1   ppm</td>
</tr>
<tr>
<td>Uranium</td>
<td>U</td>
<td>INA</td>
<td>0.5  ppm</td>
</tr>
<tr>
<td>Ytterbium</td>
<td>Yb</td>
<td>INA</td>
<td>0.2  ppm</td>
</tr>
<tr>
<td>Bismuth</td>
<td>Bi</td>
<td>AAS-H</td>
<td>0.2 ppm</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Cd</td>
<td>AAS</td>
<td>0.2  ppm</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Co</td>
<td>AAS</td>
<td>2   ppm</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
<td>AAS</td>
<td>2   ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>AAS</td>
<td>0.02 %</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb</td>
<td>AAS</td>
<td>2   ppm</td>
</tr>
<tr>
<td>Loss on Ignition</td>
<td>LOI GRAV</td>
<td>0.1 %</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
<td>AAS-F</td>
<td>10 ppb</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn</td>
<td>AAS</td>
<td>5   ppm</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Mo</td>
<td>AAS</td>
<td>1   ppm</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni</td>
<td>AAS</td>
<td>2   ppm</td>
</tr>
<tr>
<td>Silver</td>
<td>Ag</td>
<td>AAS</td>
<td>0.2 ppm</td>
</tr>
<tr>
<td>Tin</td>
<td>Sn</td>
<td>NAIAA</td>
<td>1 ppm</td>
</tr>
<tr>
<td>Vanadium</td>
<td>V</td>
<td>AAS</td>
<td>5   ppm</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
<td>AAS</td>
<td>2   ppm</td>
</tr>
<tr>
<td>Fluoride (waters)</td>
<td>FW ION</td>
<td>20 ppb</td>
<td></td>
</tr>
<tr>
<td>pH (waters)</td>
<td>pH</td>
<td>GCE</td>
<td></td>
</tr>
<tr>
<td>Sulphate (waters)</td>
<td>SO4 TURB</td>
<td>1 ppm</td>
<td></td>
</tr>
<tr>
<td>Uranium (waters)</td>
<td>UW AAS</td>
<td>0.05 ppb</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Arithmetic Correlation Coefficients for Analytical and Field Duplicate Samples

<table>
<thead>
<tr>
<th>Element</th>
<th>Analytical Duplicates</th>
<th>Field Duplicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>$R^2 = 0.998$</td>
<td>$R^2 = 0.227$</td>
</tr>
<tr>
<td>Arsenic</td>
<td>$R^2 = 0.983$</td>
<td>$R^2 = 0.987$</td>
</tr>
<tr>
<td>Chromium</td>
<td>$R^2 = 0.984$</td>
<td>$R^2 = 0.968$</td>
</tr>
<tr>
<td>Tungsten</td>
<td>$R^2 = 0.955$</td>
<td>$R^2 = 0.973$</td>
</tr>
</tbody>
</table>

PRELIMINARY RESULTS

Neutron activation data for stream sediment and moss mat sediment samples are discussed in this paper. Because of the small number of drainage samples collected only six field duplicate moss mat sediment and eight analytical duplicate samples were analysed. The $R^2$ correlation coefficients are greater than +0.9 for most elements in the field duplicate sample pairs and in the analytical duplicate sample pairs. This demonstrates good sampling and analytical reliability. An exception is the poor correlation ($R^2$ coefficient + 0.227) between gold values for moss sediment field duplicate samples (Table 3). This large variation between duplicate samples has been observed by Matysek, Gravel and Jackaman, (1988) and is believed to reflect local differences affecting the entrapment and sorting of sediment by the moss.

Statistics (mean, median, standard deviation, maximum value, minimum value) for gold, loss on ignition and 39 other elements in stream sediment and moss mat sediment samples are listed in Tables 4 and 5. Data from both survey areas was combined to calculate the statistics. The majority of elements demonstrate higher mean, median and maximum concentrations in moss mat sediments compared to stream sediments. Most notable is gold that exceeds 1000 ppb in moss mat sediment from two sites, but only reaches 59 ppb in stream sediments.
Tungsten, iron and tantalum are also enhanced in moss samples relative to the stream sediments suggesting that the moss preferentially captures heavier minerals (Matysek, Gravel and Jackaman, 1988). Other elements such as antimony, arsenic and cobalt have almost identical mean, median and maximum concentrations in both sample types or in the case of rubidium and sodium are lower in the moss mat sediments. This difference could be explained by the different hydraulic behaviour of individual minerals (e.g. gold, scheelite) as opposed to rock grains (containing varying sodium and rubidium) when these are transported by stream water. The relationship between gold, arsenic and tungsten in moss sediment and stream sediment is also demonstrated by the scatter plots shown in Figure 2 where element concentration in moss sediment is plotted as a function of element concentration in stream sediment for samples collected at the same site.

The distribution of gold in moss mat sediment samples from the Adams Lake and Newhykulston Creek survey areas is in moss mat sediment. Sediment from the Spapilem Creek headwaters stream only has 7 ppb gold by comparison to the high values in Spapilem Creek, 35 ppb gold occurs in the moss sediment. Sediment from the Spapilem Creek headwaters just north of Cam-Gloria has 25 ppb gold, but the sediment only contains 5 ppb gold (Figure 4). A previous regional stream sediment surveys (RGS) reported by Matysek et al., (1991) found a similar, low level of gold (15 ppb) in the stream sediment from Grizzly Creek.
A moss mat sediment sample from a branch of Newhykulston Creek has 223 ppb gold, and values to 45 ppb could be detected 5 kilometres downstream. Only 5 ppb gold occurs in the stream sediment. However, moss sediment and stream sediment have almost identical arsenic levels reaching 15.3 ppm. The headwaters of Newhykulston Creek are underlain by a small granite intrusive and up to 51 ppb gold has been found in till down-ice of the granite (Bobrowsky et al., 1998).

A moss mat sediment sample from a stream flowing north into Gollen Creek (82M/5) has 92 ppb gold in the moss sediment. Fisher and Stratton Creeks located to the south have over 20 ppb gold in the moss sediment, but only just detectable gold in the stream sediment (Figure 4). Stratton Creek water also contains 41 ppm sulphate and 550 ppb fluoride. The combination of enhanced gold in the moss sediment and anomalous water chemistry suggest a sulphide-fluorite mineralized source in the watershed of Stratton Creek. The distribution of tungsten in moss sediment is shown in Figure 7 and the highest value (40 ppm) found in the area occurs in a north branch of Bendelin Creek. There is only a weak spatial correlation between moss sediment gold and moss sediment tungsten anomalies.

Gold content in moss sediment samples from the Kootenay Survey area is lower than in the Adams lake.
Gold (ppb) in Moss Mat Sediments

Figure 3. Gold in moss mat sediments, Adams Lake area.

Gold (ppb) in Stream Sediments

Figure 4. Gold in stream sediments. Adams Lake area.
Figure 5. Gold in moss mat sediments, Kootenay Lake area.

Figure 6. Gold in stream sediments, Kootenay Lake area.
Figure 7. Tungsten in moss mat sediments, Adams Lake area.

Figure 8. Tungsten in moss mat sediments, Kootenay Lake area.
area and the highest value (34 ppb) occurs in stream flow-into Akokli Creek from the German (Au) Basin showing on the north west side of Mount Sherman (Figure 5). No gold was detected in sediment from this stream although 59 ppb occurs the sediment from a creek draining the south side of Mount Sherman into Sanca Creek (Figure 6). Tungsten levels (Figures 7 and 8) are typically higher in the Kootenay area moss mat sediment samples and the highest value (402 ppm) occurs in moss sediment from a creek flowing from the watershed containing the Elmo occurrence. Almost no (less than 10 ppm) tungsten is present in moss sediment and stream sediment from creeks draining the German (Gold) Basin showing on south side of Akokli Creek (including “Tungsten” Creek).

CONCLUSIONS

Preliminary results for the Adams Lake area reveal that the gold content of moss mat sediment is much higher than stream sediment collected at the same sample site. However, gold is highly variable in duplicate moss sediment samples. This pattern of gold enhancement and high variability is consistent with the results of previous geochemical studies where both sample media were compared (Matysek and Day, 1987). Other elements such as tungsten and chromium are also enriched in the moss sediment relative to stream sediment, but element variability between field duplicate samples is smaller. In the Kootenay Lake area the highest gold value occurs in stream sediment rather than moss mat sediment. However, the gold anomalous stream sediment and moss mat sediment samples are from different streams. Tungsten values are much higher in moss mat sediment from the Kootenay area and levels, to some extent, reflect known tungsten mineral occurrences.

Further work to complete this study will involve: 1) comparison of gold and other element values in heavy mineral concentrates, stream sediments, suspended sediments and moss mat sediments. The heavy mineral samples are intended to assess the ability of streams to concentrate gold and other high density minerals in stream-bed sediment; 2) evaluation of stream and moss sediment data for other pathfinders (e.g. tin, bismuth, fluorine) for intrusive related gold mineralization; 3) comparison of aqua regia digestion - atomic absorption spectrometry and aqua regia digestion - inductively coupled plasma mass spectrometry analysis of selected samples for gold and pathfinder elements and; 4) field follow-up to establish if the gold anomalies do indeed reflect intrusive related or other styles of gold mineralization.

ACKNOWLEDGEMENTS

The authors appreciate help from M. Cathro with the interpretation of the geochemical data and reviews of this paper by G. McArthur and S. Cook. Richard Mann is thanked for assistance with sample preparation and with compilation of the field data.

W. Gilmour and K. Daughtry, Discovery Consultants, are especially thanked for their advice on sample collection for heavy mineral preparation.

REFERENCES


