



BRITISH COLUMBIA GEOLOGICAL SURVEY GEOFILE 2007-6

WORKSHOP NOTES: DRAINAGE GEOCHEMICAL SURVEYS – STREAM SEDIMENTS, LAKE SEDIMENTS, MOSS MATS, HEAVY MINERALS

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Introduction

Government agencies and mining companies commonly use drainage sediment geochemistry for evaluating the mineral resources over a large area based on the premise that the sediment chemistry and mineralogy reflect the bedrock and surficial geology of the drainage catchment area upstream from the sample site. Fluvial sediment forms by the physical and chemical weathering of bedrock within the catchment basin. In the absence of mineralization the sediment geochemistry reflects normal or background element concentrations typical of the source bedrock. Mineralized bedrock, if present, will be revealed by the presence of elevated metal and/or indicator mineral contents in sediment. Ideally, the metal content of sediment collected at intervals along a stream channel will display both a peak value close to the entry point of the metal into the drainage basin and a down stream asymptotic decay curve that reflects dilution of mineralized material. This dilution is caused by barren bedrock, surficial material or fluvial material. At some point

along the dilution curve the anomalous geochemical signal of the mineralization will merge with the geochemical background. While this simple model describes element dispersion in the sediment weathered from a small catchment basin, it is less reliable for predicting dispersion from a larger catchment basin where the stream becomes decoupled from the surrounding valley slopes and the sediment is less representative of bedrock geochemistry (Fletcher, 1997). Drainage anomaly length is also constrained by the point where anomalous values can be reliably distinguished from the geochemical background. Anomaly strength (contrast) is the ratio of the peak value to background.

The mountainous terrain and well-developed drainages typical of British Columbia make it a region especially suited for using stream sediment geochemistry to find new mineral resources. As a result the British Columbia Geological Survey started a regional stream sediment and stream water geochemical survey (RGS) in 1976 as part of the Geological Survey of Canada National Geochemical Reconnaissance (NGR) Program. This survey now covers about 70 percent of the province with field and analytical data from the collection and analysis of over 50 000 stream sediment, lake sediment and surface water samples.

The main objective of the RGS is to identify regions of high mineral potential based on elevated element concentration in drainage sediment. The survey has also created a high quality, seamless geochemical database that can be used for mineral exploration, environmental monitoring and land use evaluation. Much of the applied research by government and non-government agencies and universities has focused on understanding how fluvial processes, surface geochemistry, catchment basin morphology and geology contribute to the formation of a stream sediment anomaly. The object of the research is to

improve drainage survey design. For example, the basic strategy of the British Columbian RGS is to collect stream sediment samples at an average density of 1 sample per 13 km² from active first or second order streams approximately 60 m upstream from a confluence, a possible source of contamination (forestry, mining, domestic) or a tidal influence if the stream flows into the ocean. Since the survey aims to detect elements with a range of physical and chemical properties (e.g. density, solubility), the collected sample is ideally of fine textured sand and silt collected from a relatively low energy fluvial environment. While this survey strategy can generally outline regions of higher mineral potential it is less effective for detecting individual mineral deposits or where the sediment is less representative of the source area, such as in low relief terrain or in larger catchment basins. Modifications to survey design have been made in different areas of British Columbia to improve the ability of stream geochemistry for detecting mineralization, the simplest of which is increasing sample density. This approach has helped identify primary geochemical zones surrounding massive sulphide deposits south of Terrace, British Columbia (Alldrick and Jackaman, 2002).


Sampling moss-captured sediment solved the problem of finding insufficient fine-grained sediment sample in torrential streams typical of Vancouver Island where annual rainfall exceeds 100 cm. High-density minerals, such as Au, are also preferentially captured by moss, thereby improving anomaly contrast. However, the mechanism of sediment transport and accumulation by moss is still uncertain and warrants more research (Matysek and Day, 1988). In northwestern and central British Columbia analyzing a heavy mineral concentrate (HMC) prepared from a bulk sediment sample collected at a high energy stream site improves the ability of geochemical surveys to

detect mineralization at a lower sample density. Concentrate mineralogy and mineral grain shape can also aid in estimating the proximity of an anomaly to the source (Lett and Friske, 2006). Drainage systems are poorly developed, but lakes are common in low relief areas, typical of central British Columbia, and therefore lake sediments are collected as an alternative to stream sediment (Cook and McConnel, 2001). Stream and lake water samples collected routinely at the same time as sediment are used to measure such parameters as water pH and, in some areas, the dissolved metal content of the water. A recent lake sediment survey over part of the British Columbia interior demonstrated how lake sediment and water sampling could complement existing stream sediment sampling in an area where drainages were poorly developed (Jackaman, 2007).

The systematic recording of information about the sample site is important for data interpretation. Field forms are designed for helicopter-supported stream and lake surveys where careful collection and accurate recording of field information must be balanced against maintaining survey efficiency. Quality control is vital in order to maintain a high quality database. The RGS quality control scheme monitors sampling and analytical variability by randomly inserting field and analytical duplicate samples and control reference samples into each batch of 20 samples collected. The analytical duplicate and control reference samples are inserted after sample preparation. Field duplicates are two separate samples collected at the same site, generally several metres apart from sediment that has similar characteristics. The minus 80 mesh fraction of sediment samples is routinely analysed for a range of elements by a combination of instrumental neutron activation (INAA) and aqua regia digestion followed by inductively coupled plasma mass spectrometry (ICP-MS) as well as loss on ignition (LOI) at 500°C and for fluoride by a


fusion and specific ion electrode. Samples with anomalous Au are routinely checked by a second Au analysis.

Lett and Jackaman (2004) previously describe many of the techniques used in reconnaissance scale drainage surveys carried out by the British Columbia Geological Survey. Geofile 2007_6 comprises the slides and notes presented as part of a workshop “Exploration Geochemistry – Basic Principles and Concepts” given as part of the Exploration 07 the 5th Decennial International Conference on Mineral Exploration, Toronto, Canada (Lett, 2007). The aim of the presentation was to describe more fully using illustrated examples and case histories the survey techniques such as survey design, sampling methods for stream sediment, water, lake sediment moss sediment and heavy minerals in addition to quality control procedures, sample preparation and sample analysis.

 **BRITISH COLUMBIA**
The Best Place on Earth

Drainage Geochemical Surveys
Stream Sediments, Lake Sediments,
Moss Mats, Heavy Minerals

Ray Lett
Geological Survey
BC Ministry of Energy, Mines &
Petroleum Resources



Good morning. In this part of the short course I'll be focusing on stream and lake sediment surveys with emphasis on sampling techniques.

Outline

- Drainage Geochemistry – Basics
- BC Drainage Sampling strategies
- BC Regional Geochemical Survey
- Sample Media Comparison
- Training – Encouraging a new generation of Geochemists

First, I'm going to talk briefly about the principals of using drainage sediment to find mineral deposits, then I'll describe some of the sampling strategies used in British Columbia. I'll briefly summarise a regional drainage survey covering much of BC and then show some survey results using different sample media. I'll finish the talk by showing how we are trying to train a younger generation of geochemists.

Acknowledgements

- **Wayne Jackaman** – Noble Exploration Services
- **Peter Friske** – Geological Survey of Canada
- **Zoe Sandwith** – University of Victoria, British Columbia

I'd like to acknowledge some of the people who contributed to this talk.

Wayne Jackaman, Noble Exploration Services, Sooke, BC. He provided the slides showing the helicopter supported lake sediment surveys.

Dr. Peter Friske, Head of the Applied Geochemistry Unit, GSC. He contributed results of the heavy mineral sampling in Northwestern British Columbia.

Zoe Sandwith helped me with sampling during 2007 & acted as camera person.

Why Drainage Geochemistry?

- Sediment geochemistry reflects drainage basin geology
- Physical & chemical processes disperse elements forming drainage anomalies
- Dispersion trains typically show metal contents decreasing from source
- Dispersion train length & profile reflects dilution of mineralized sediment by background material

So Why Use Drainage Geochemistry as tool to find mineral deposit?

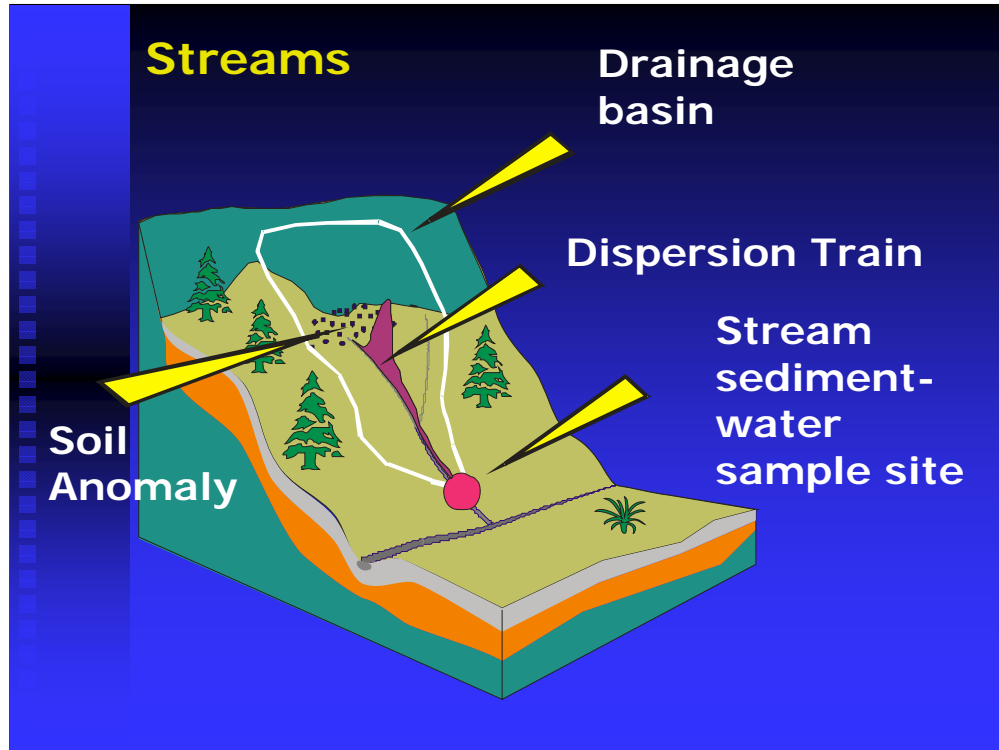
Drainage sampling has a long tradition & was described in 1548 by Georgius Agricola who distinguished between clastic and hydromorphic dispersion.

Drainage surveys are based on the concept that fluvial and chemical processes carry metals and minerals from within a drainage catchment (watershed) to a site of mineral (& metal) accumulation – commonly termed an anomaly

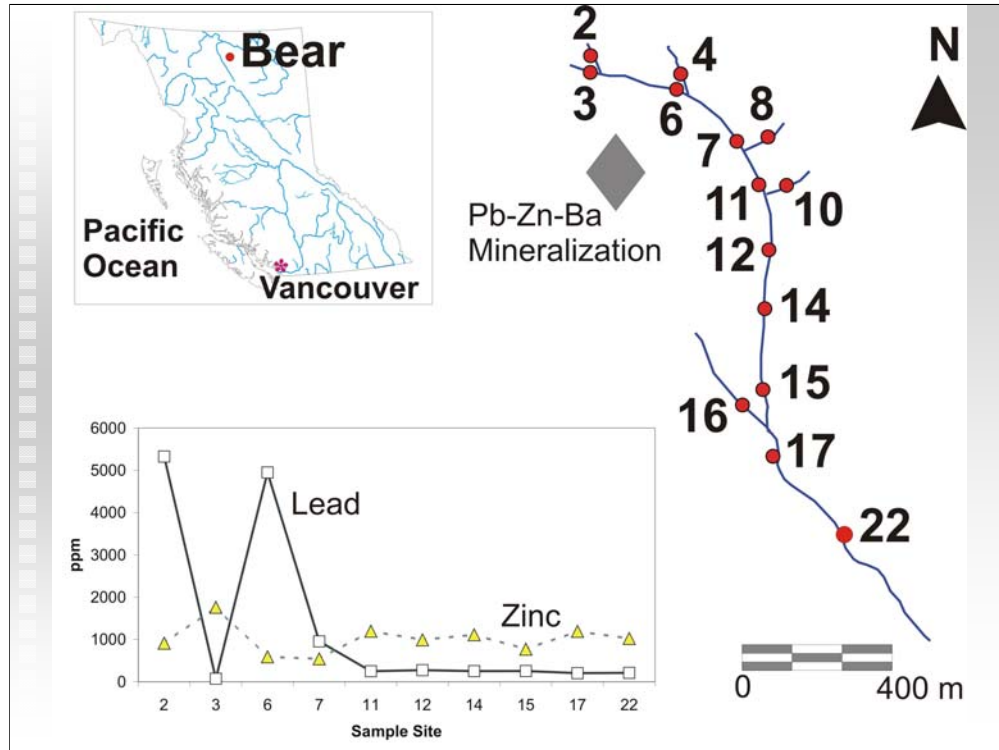
The source for the minerals can be weathered bedrock, glacially transported sediment (e.g. till) or previous fluvial deposits. Also, the source area is well defined by the limits of the drainage basin.

Elements will be transported by a combination of physical and chemical fluvial processes, the dominant depending on climate & the characteristics of the stream catchment basin (e.g. size, topographic relief). The content of anomalous metal (or mineral) decreases down stream through dilution from non-mineralized material forming a dispersion train. Catching the dispersion train that is correctly identifying just what is anomalous is a key to detecting a mineralized source.

Determining just what constitutes an anomaly for different elements is critical and relies on estimating geochemical background. This will depend on bedrock and surficial chemistry and the characteristics of the near surface environment. For example, a shale can have a high Zn background. Organic-rich lake sediments can also have a high background of more mobile metals such as Cu & Mo.



This cartoon shows the relationship between a source (a geochemical soil anomaly), the catchments basin, anomaly decay curve and a feasible sediment sample point where it is hoped that evidence of the soil anomaly can be detected in the stream sediment geochemistry. In reality the catchment basin size will be larger than shown in the cartoon and will be defined by the topographic limits of the watershed. The dispersion train can be quite short for chemically less mobile elements (e.g. Pb, W), but longer for more mobile elements such as Zn. An anomaly can reflect a change in water chemistry such as an increase in water pH due to solution of a limestone unit crossing the creek. At that point there could be a sharp increase in the content of metal (e.g. Cu) in sediment. Other factors responsible for metal (and mineral) accumulation giving rise to an anomaly are a change in stream gradient (physical process), bank collapse (landslides), decoupling of the channel from the valley side (increased exotic sediment in the stream) and the presence of manganese oxide coatings on boulders (chemical – adsorption of metals).

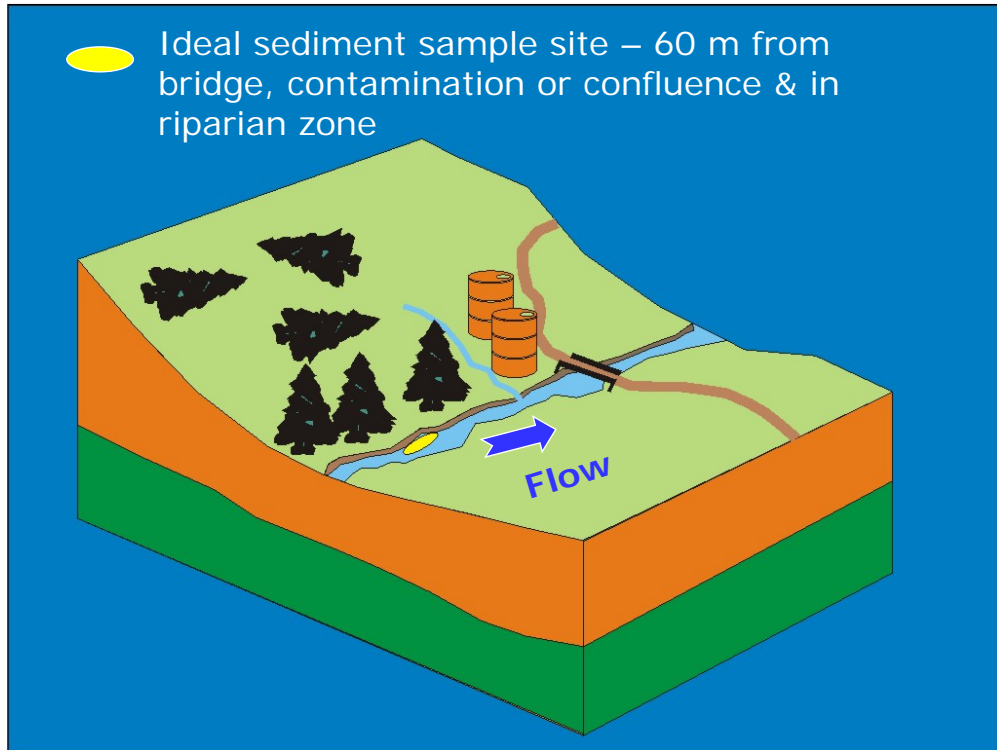


This slide shows the variation of Zn and Pb in sediment downstream from a Pb-Zn-Ag sedex sulphide – barite deposit hosted by Paleozoic shales. The downstream Pb profile is erratic and has a steep dispersion train curve reflecting the presence of detritus galena in the sediment. The downstream Zn profile is smoother because the geochemically more mobile Zn has dissolved in the stream water. The long Zn dispersion train reflects both absorption of Zn to sediment in the stream plus the abundance of shale that had a high Zn background (typically 770 ppm based on rock sample analysis). The high Zn background suggests that Pb would be a more reliable indicator of Pb-Zn mineralization in this area. Sediment Zn geochemical anomalies could also form in parts of the stream where the metal is absorbed to manganese oxide coatings on boulders or where secondary Zn minerals precipitate at higher pH. A marked stream water pH increase can occur when the channel erodes a limestone horizon.

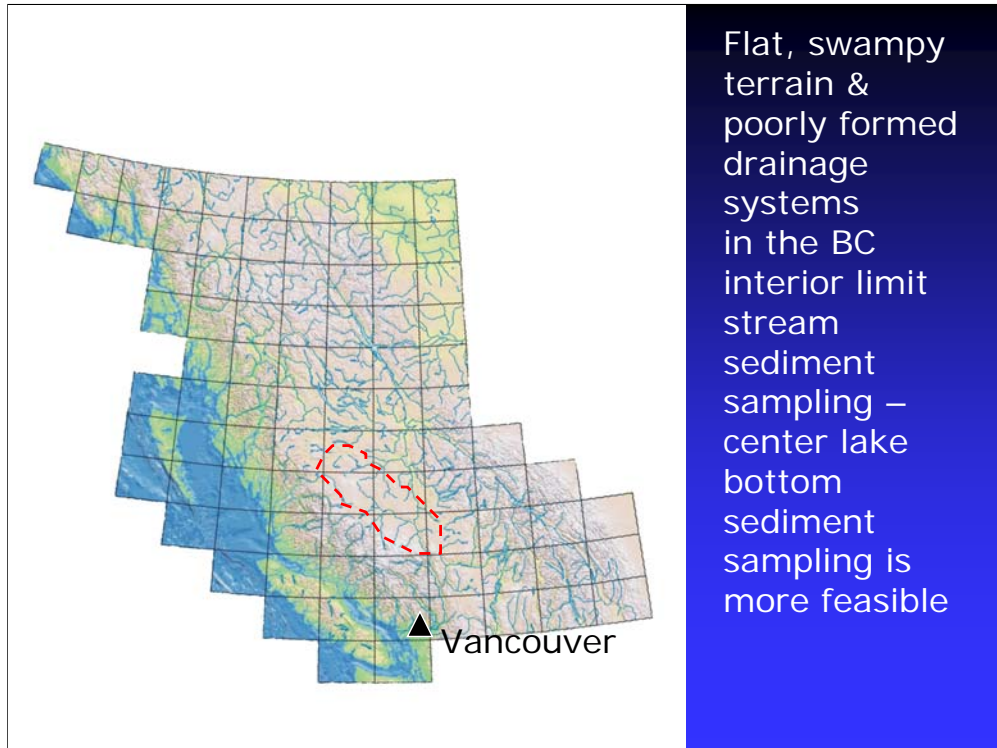
Stream Sediment & Water
sampling - Avoid wearing
Au, Ag, Pt rings



This shows a typical reconnaissance scale stream sediment-water survey in progress. The sediment is being collected from the finer textured material on the point bar. This fluvial sediment is most suitable for detecting more geochemically mobile elements such as Mo, Cu, As, Ni and Zn, but is less ideal for detecting more physically transported elements such as Ba, Au, Sn, W & Pb because of larger sampling variability associated with more dense, detrital minerals (i.e. “nugget” effect). However, for large regional surveys a compromise is needed between speed and ease of collection against the ability of the survey to detect anomalous levels of all of the elements that may be present in the source catchment area. During this reconnaissance scale stream sediment-water survey in the Bowser basin area on North-western British Columbia both sediment and stream water samples were taken at an average density of 1 sample/ 13km². About 0.5 to 1 Kg of sediment is collected in a Kraft high wet strength bag. The water is collected in a 250 ml Nalgene bottle. An important precaution is that samplers must not wear jewelry (e.g. gold rings) to avoid sample contamination during collection. Credit to Wayne Jackaman for this photograph.



Any survey has to be designed so that sample locations will avoid obvious contamination from industrial, human and forestry sources. In this cartoon a sediment sample site is ideally located on a lateral bar and more than 60 metres upstream from a bridge, a collection of rotting oil drums, a tributary drainage and in a riparian zone of trees along the drainage channel. Final site selection is made by the sampler based on the feasibility of collecting suitable, uncontaminated material.



Much of British Columbia is mountainous and has well-developed drainage systems. This is ideal topography for stream sediment surveys and hence much of the province has been covered.

However, a large part of the British Columbia interior is flat and is covered by glacial deposits and recent plateau basalts so that there are few well defined drainages, but numerous lakes. The obvious strategy for regional geochemical surveys would be to use lakes rather than streams.

Typical low relief in BC interior

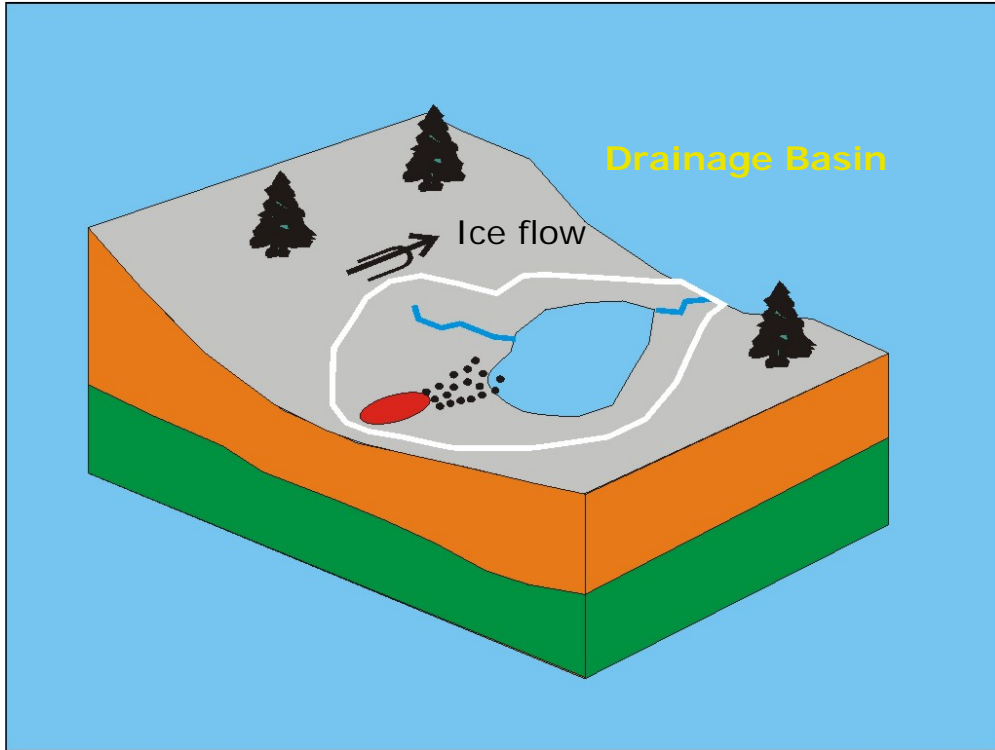


This is typical low, swampy terrain in central British Columbia. Credit to Brian Grant for this photograph.

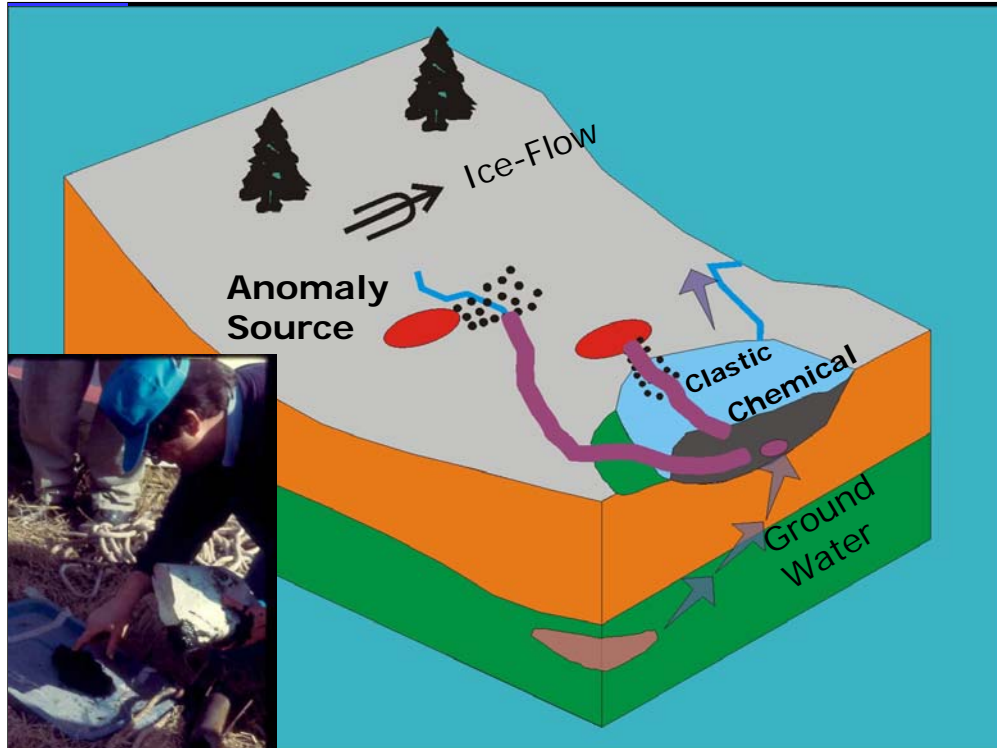
Flat & Featureless



This flat and featureless area is west of Williams Lake, British Columbia. This is typical low, swampy terrain in central British Columbia. Credit to Brian Grant for this photograph.



This cartoon shows a typical mineral source from which mineralized rock material has been glacially transported into the lake. In reality, the lake catchment area would be much larger than that actually shown in the cartoon.



This cartoon shows the various pathways along which metals can be dispersed into a lake basin.

A stream dispersion train is one obvious source and ground water another source. In both cases metals will be captured by the organic-rich, gelatinous center lake sediment. An example of this type of sediment is shown in the insert.

Clastic dispersion gives rise to a near shore lake sediment anomaly.



This shows collecting centre lake bottom sediments with a helicopter. Actual collection will be carried out from the deck mounted on the float when the helicopter land on the lake. The survey was carried out recently in central British Columbia by Wayne Jackaman and was funded by a non-government organization, Geoscience BC. Credit to Wayne Jackaman for this photograph.

2006 Geoscience BC Helicopter
Lake sediment-water survey

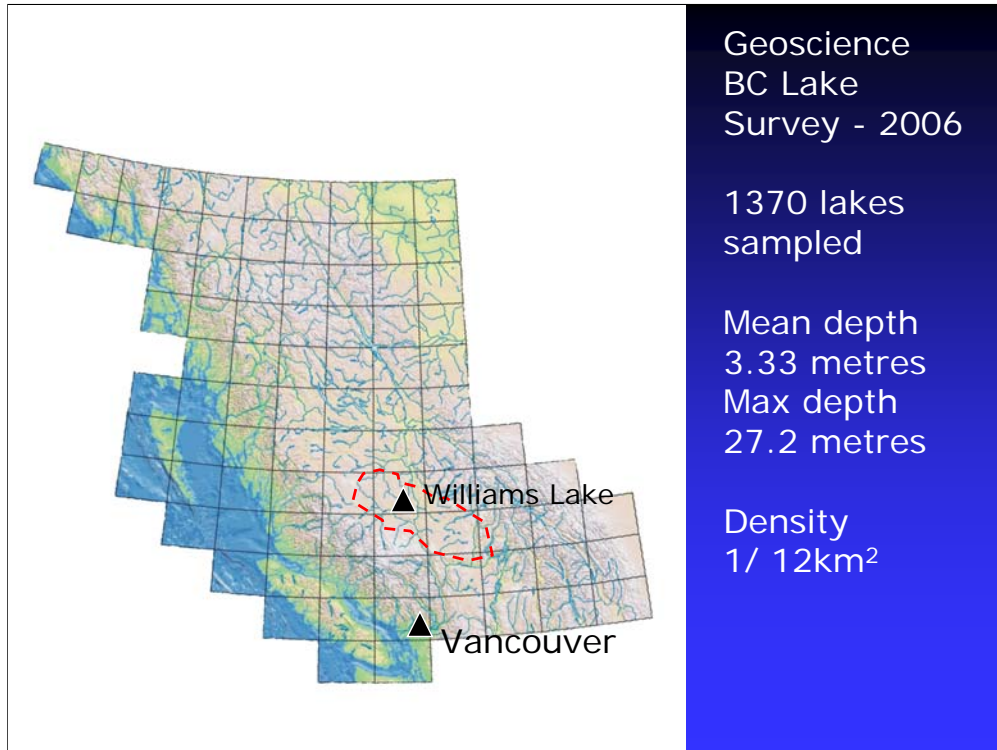


Here's a view of emptying a "Hornbrook" type lake sediment sampler during routine survey operation. The sampler is about 40 cm long & 3 cm diameter and is weighted close to the lower end to increase penetration into the sediment. It has a one-way flap valve in the tube to retain the sediment. The sampler is attached to a nylon rope (marked at meter and 0.5 metre units) and simply dropped from the deck when the helicopter is stationary on the lake. Generally there is sufficient momentum for the sampler to penetrate 20 to 30 cm into the sediment. The sampler is pulled up by hand and the material transferred to a sample bag with a scoop. This slide shows transferring material from the sampler to a bag. Credit to Wayne Jackaman for this photograph.



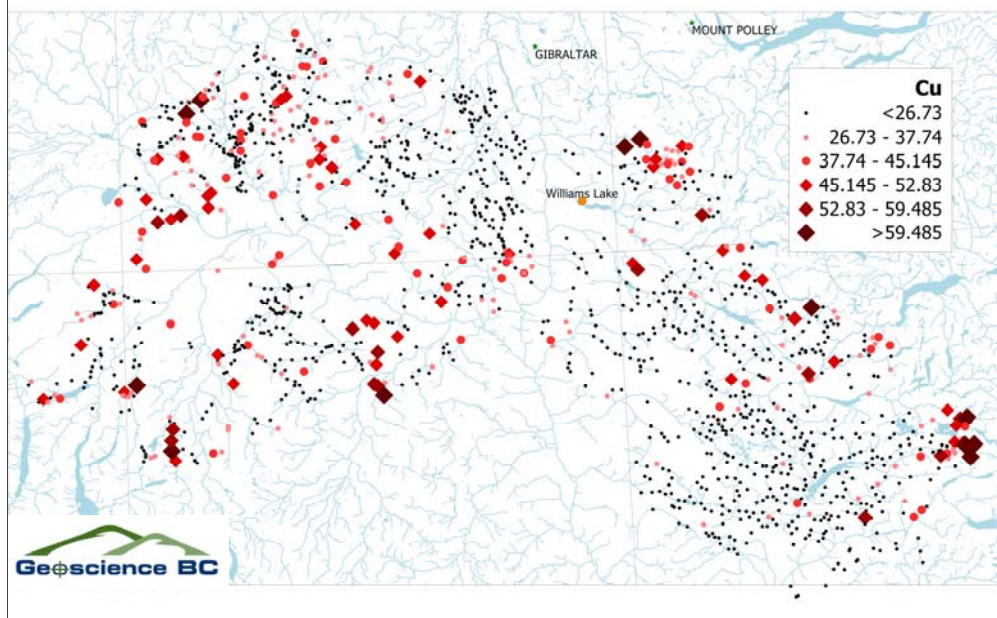
More detailed lake sediment sampling can be carried out in summer and winter

More detailed lake sediment sampling can be carried out in winter. The sampler can be kept free of ice in a drum of hot water (heated with a propane torch) mounted on the sledge. Cutting through the ice generally takes 1 to 2 minutes depending on thickness.



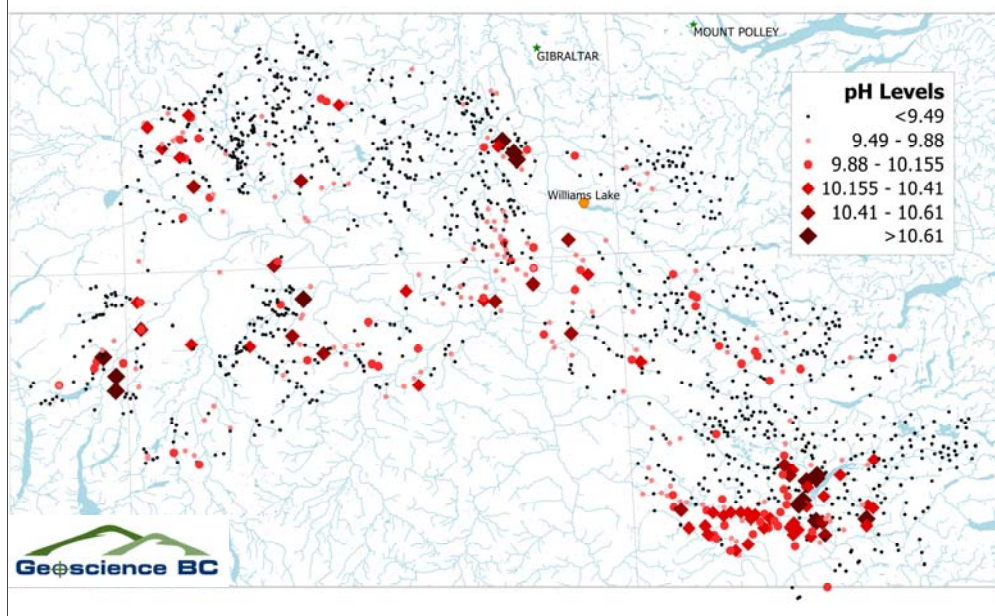
Here's an example of a recent (2006) lake sediment survey managed by Wayne Jackaman and funded by Geoscience BC. This survey was carried out to complement routine RGS sampling in an area of few streams with lake sediments. During this survey 1370 lakes were sampled (center lake sediment and water) at a density of 1 sample /12 km².

2006 Geoscience BC lake sediment survey - Copper



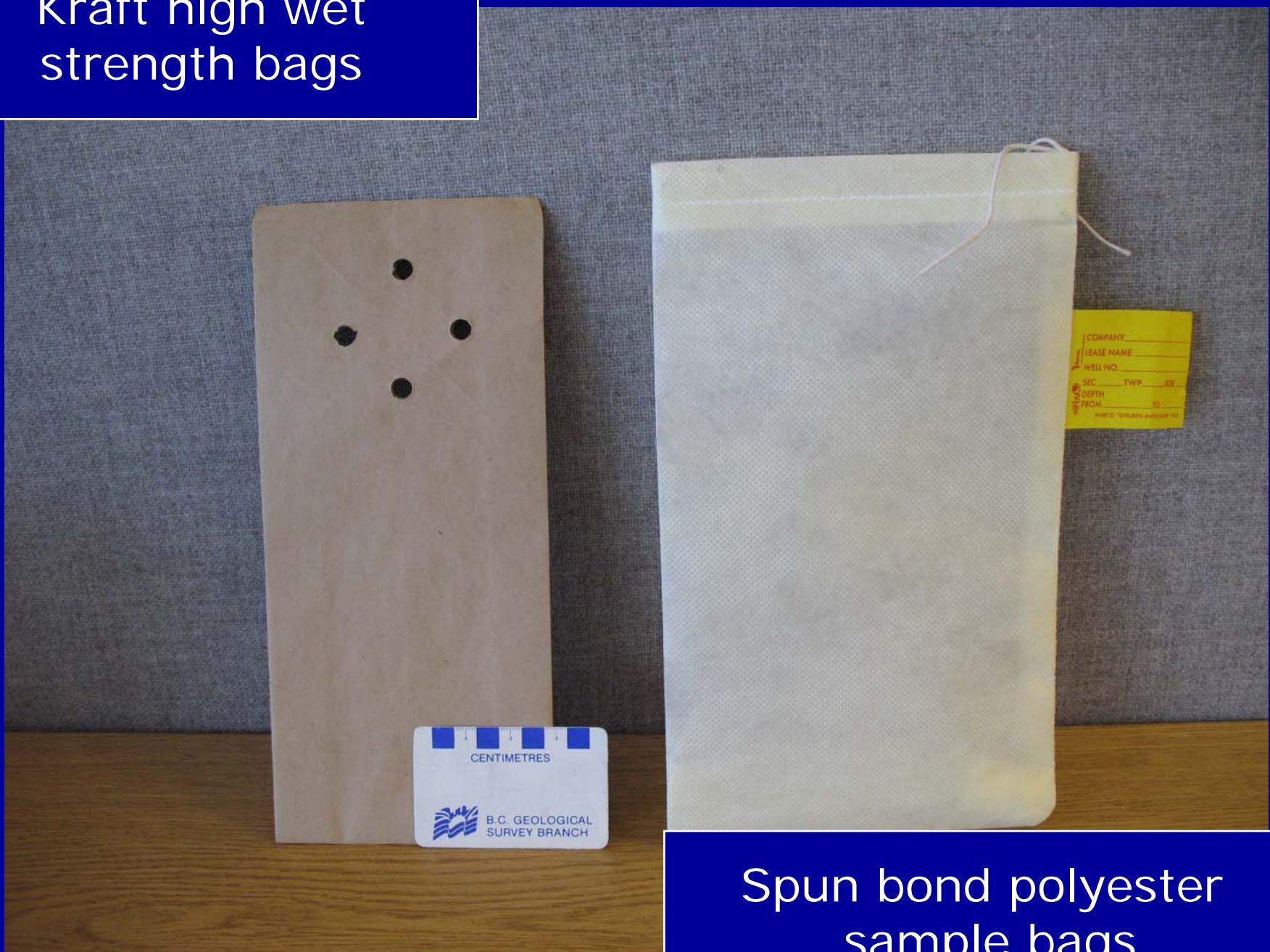
This slide shows the distribution of copper in center lake sediment. The eastern part of the survey area is underlain by predominantly Mesozoic volcanic island arc rocks that host porphyry Cu-Mo (e.g. Gibraltar) and porphyry Cu-Au (e.g. Mount Polley) deposits. West of Williams Lake area predominantly Eocene plateau volcanic and Mesozoic sedimentary (Cache Creek Group) rocks covered by extensive glacial sediments. Note that there is a strong cluster of anomalies (> 59 ppm) in the SE part of the survey area.

2006 Geoscience BC Lake Sediment Survey – Water pH



This slide shows the variation of lake water pH. Note that some of the lakes are extremely alkaline and at this pH it might be expected that there would be enhancement of Cu due to precipitation. However, there seems no relationship between high Cu and high pH suggesting that organic matter content is a more important factor for accumulation of metal.

Kraft high wet strength bags



Spun bond polyester sample bags

Recording site information & Quality Control are key to a high quality database

NTS SHEET	YEAR	SAMPLE NUMBER	COLLECTORS	SAMPLE TYPE	WIDTH	DEPTH	REP. STAT.	QTY	MO
CONTAMINATION <input type="checkbox"/> None <input type="checkbox"/> Possible <input type="checkbox"/> Probable <input type="checkbox"/> Definite <input type="checkbox"/> Mining <input type="checkbox"/> Industry <input type="checkbox"/> Agricult <input type="checkbox"/> Domestic <input type="checkbox"/> Forestry <input type="checkbox"/> Burn <input type="checkbox"/> Other	BANK TYPE <input type="checkbox"/> Alluv <input type="checkbox"/> Colluv <input type="checkbox"/> Till <input type="checkbox"/> Outwash <input type="checkbox"/> BareRock <input type="checkbox"/> TalScr <input type="checkbox"/> Organic <input type="checkbox"/> Other	WATER COLOUR <input type="checkbox"/> Clear <input type="checkbox"/> BnTrans <input type="checkbox"/> WhClky <input type="checkbox"/> BnClky <input type="checkbox"/> Other STREAM FLOW <input type="checkbox"/> Stagn <input type="checkbox"/> Slow <input type="checkbox"/> Modert <input type="checkbox"/> Fast <input type="checkbox"/> Torrt	SAMPLE COLOUR <input type="checkbox"/> Rd-Bn <input type="checkbox"/> Wh-Bf <input type="checkbox"/> Black <input type="checkbox"/> Yellow <input type="checkbox"/> Green <input type="checkbox"/> Gy-Blu <input type="checkbox"/> Pink <input type="checkbox"/> Bf-Bn <input type="checkbox"/> Brown <input type="checkbox"/> DkBrown <input type="checkbox"/> Other BOTTOM PCPT <input type="checkbox"/> None <input type="checkbox"/> Rd-Bn <input type="checkbox"/> Wh-Bf <input type="checkbox"/> Black <input type="checkbox"/> Yellow <input type="checkbox"/> Green <input type="checkbox"/> Grey <input type="checkbox"/> Pink <input type="checkbox"/> Bf-Bn <input type="checkbox"/> Other BANK PCPT <input type="checkbox"/> None <input type="checkbox"/> Rd-Bn <input type="checkbox"/> Wh-Bf <input type="checkbox"/> Black <input type="checkbox"/> Yellow <input type="checkbox"/> Green <input type="checkbox"/> Blue <input type="checkbox"/> Pink <input type="checkbox"/> Other	<input type="checkbox"/> SedOnly <input type="checkbox"/> SedWat <input type="checkbox"/> SedWatAcid	STRM PHYSIOG <input type="checkbox"/> Plain <input type="checkbox"/> Swamp <input type="checkbox"/> Penpin <input type="checkbox"/> Hilly <input type="checkbox"/> Moun/M <input type="checkbox"/> Moun/Y DRNGE PATTRN <input type="checkbox"/> Poor <input type="checkbox"/> Dendrc <input type="checkbox"/> Herbn <input type="checkbox"/> Rectin <input type="checkbox"/> Trellis <input type="checkbox"/> Discnt <input type="checkbox"/> Closed STRM SOURCE <input type="checkbox"/> Unknown <input type="checkbox"/> Ground <input type="checkbox"/> Sp'gMelt <input type="checkbox"/> RecRain <input type="checkbox"/> Glacier	STRM TYPE <input type="checkbox"/> Undfnd <input type="checkbox"/> Permnt <input type="checkbox"/> Interm <input type="checkbox"/> Re-emerg <input type="checkbox"/> Trellis <input type="checkbox"/> Discnt <input type="checkbox"/> Closed STRM CLASS <input type="checkbox"/> Undefined <input type="checkbox"/> Primary <input type="checkbox"/> Secondary <input type="checkbox"/> Tertiary <input type="checkbox"/> Quaternary			
COMMENTS					POSITION				

Routine Quality Control is Based on field duplicate, analytical duplicate and standards in every block of 20 sample collected

The Geological Survey of Canada field information forms have options for collecting field information listed in the different categories so that the sampler just “ticks the box” for the variable in each category. One of the categories is to identify field duplicate samples recognising that a good quality control program starts in the field. The quality control relies on inserting. In the field duplicate samples, generally taken 2-3 metres separation from the same sediment types will be inserted randomly whereas replicate analytical samples & standards are inserted in blocks of 20 samples collected after sample preparation, but before analysis. In each batch of 20 samples there is a reserved position for insertion of analytical replicates (generally a split on the first field duplicate sample) and for a standard reference material.

Pre-shipping sediment sample drying – limits damage to wet samples during shipping



Sample drying is important not only to make the wet samples less susceptible to damage during shipping but also to allow a check of samples with insufficient material. Here is the dry at Bell 2 in NW British Columbia set up during the Bowser Lake survey.

Pre-shipping sample drying also allows a check on missing samples and monitors sample size



Here's an interior view of the dry at Bell 2. Note that the bags are identified by National Topographic System (NTS) map sheet number and a 4 digit sample number. All bags and bottles (including those for the "reserved sites" in the blocks of 20) are numbered before the survey starts. If several crews are sampling at the same time pre-numbered sets grouped between 1001 to 1500, 3001 – 3500 and 7001 – 7500.



Stream or lake water pH and conductivity are measured in the field (in earlier surveys only pH was measured by the lab and usually several months after collection). An unfiltered, un-acidified sample is taken for anion analysis. In some surveys a second sample is taken for determination of trace metals. Shown here are 250ml, 125 ml, 60 ml Nalgene sample bottles. The raw water for anion analysis is collected in the 250 ml bottle. A second sample of the raw water for trace metal analysis is collected in the 125 ml bottle and filtered as soon as possible after collection (typically the same day in a field preparation laboratory). A 60 ml syringe is used for filtration attached either a sealed unit on-line filter (more simple to use but more expensive) or an on-line filter with a replicable 0.45 micron filter paper. Filtered water samples are acidified with ultra-pure nitric acid. Batches sent for analysis include filtered water samples, filtered blank water samples, unfiltered blank water samples, travel blank water samples and water standards.

Sample Analysis

The < 0.177 mm (- 80 mesh) sediment fraction is analysed for:

- 33 elements (including Au) by instrumental neutron activation (INAA)
- 32 elements (including Cu, Pb, Zn, S) by aqua regia digestion-ICPMS
- Loss on ignition, fluorine, tin

Water sampled are analysed for pH, F, U & trace elements

Stream sediment, moss sediment and lake sediment samples are dried at 35 to 40 °C before preparation. Stream sediments and moss sediments are disaggregated and sieved to the < 0.177 mm (- 80 mesh) fraction through a nylon or stainless steel screen in the laboratory before inserting quality control standards and duplicate splits of the sieved samples into each batch of 20 samples. Lake sediments are milled in a ceramic mill to – 150 mesh before analysis. Routine sediment analysis comprises

Determination of 33 elements (including Au, U) by instrumental neutron activation (INAA)

Determination of up to 37 elements (including Cu, Pb, Zn, S) by aqua regia digestion-inductively coupled mass spectrometry

Determination of Loss on ignition (LOI), fluorine and for some surveys, tin.

Water sampled are analysed for pH, F, U & for some surveys, trace elements by ICPMS



Here are 2 models of pH and conductivity meter. They are calibrated each day with 2 buffers.

The BC Regional Geochemical Survey

- Part of the National Geochemical Reconnaissance (NGR) program
- Reconnaissance-scale (1/13km²) drainage sediment and water surveys since 1976
- Stream sediment-water, lake sediment-water, till & heavy mineral sampling

Lets move to the BC Regional Geochemical Survey The RGS is:

Part of the National Geochemical Reconnaissance (NGR) program.

Reconnaissance-scale drainage sediment and water surveys since 1976.

It includes lake sediment-water, till & heavy mineral sampling.

Objectives

- Identify high mineral potential areas
- Produce baseline geochemical data (e.g for environmental monitoring)
- Test new geochemical methods
- Train new geochemists
- Help industry find new exploration targets

Its Aims are:

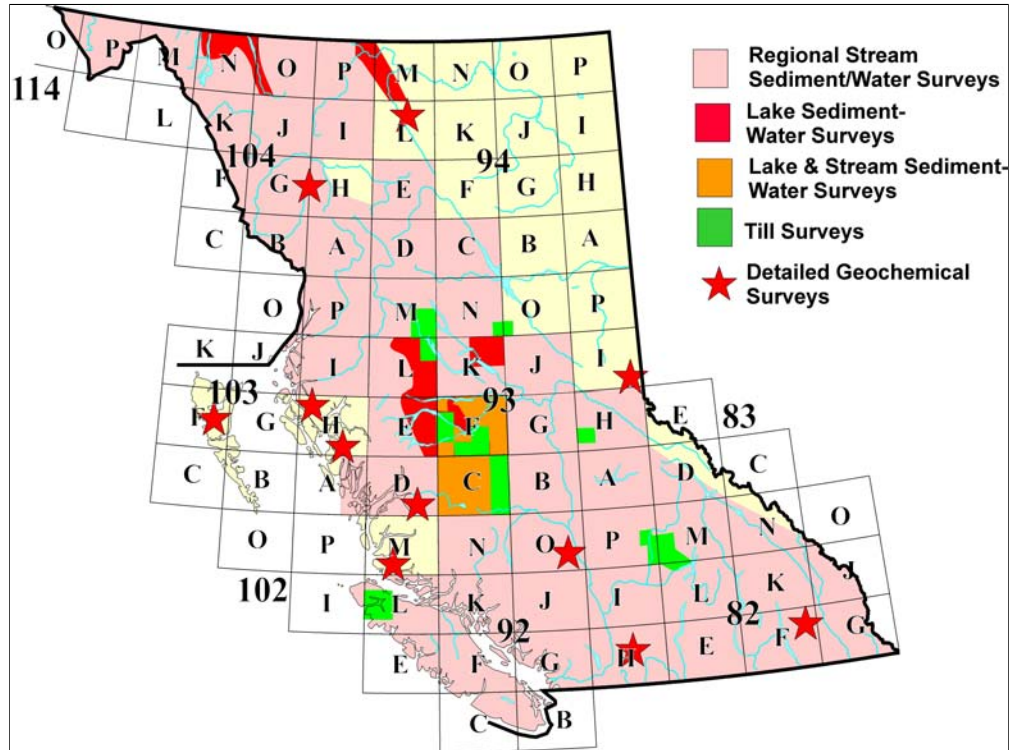
Primarily to Identify areas of high mineral potential.

Also to Produce baseline geochemical data (e.g. for environmental monitoring).

Test how effective are new geochemical methods for finding new mineral deposits.

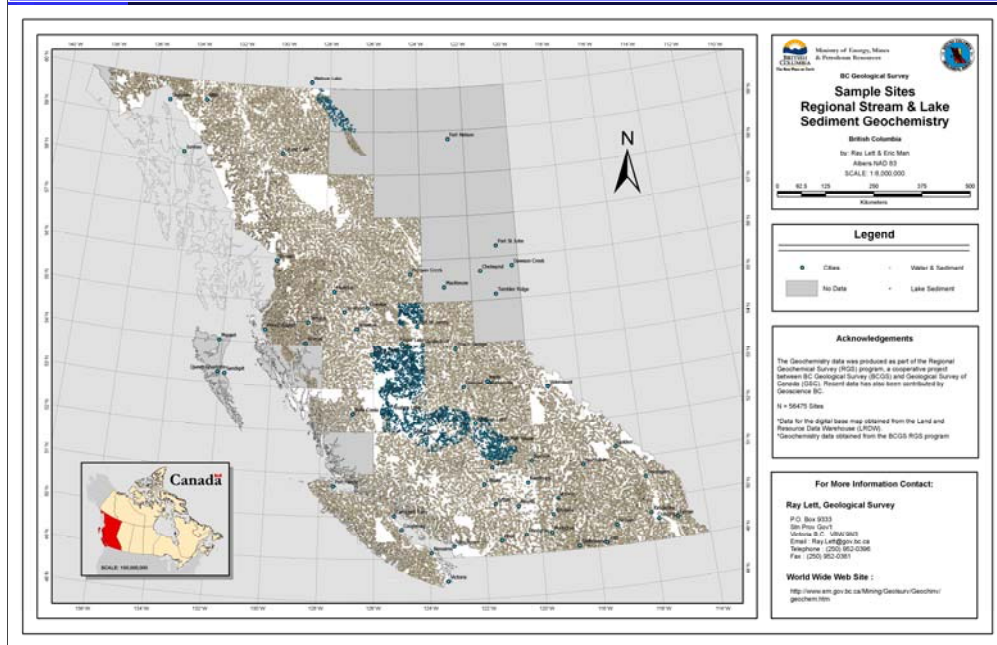
Training a new generation of applied geochemists.

Helping industry find new exploration targets (although the reconnaissance scale sample density may be too low to always be successful).



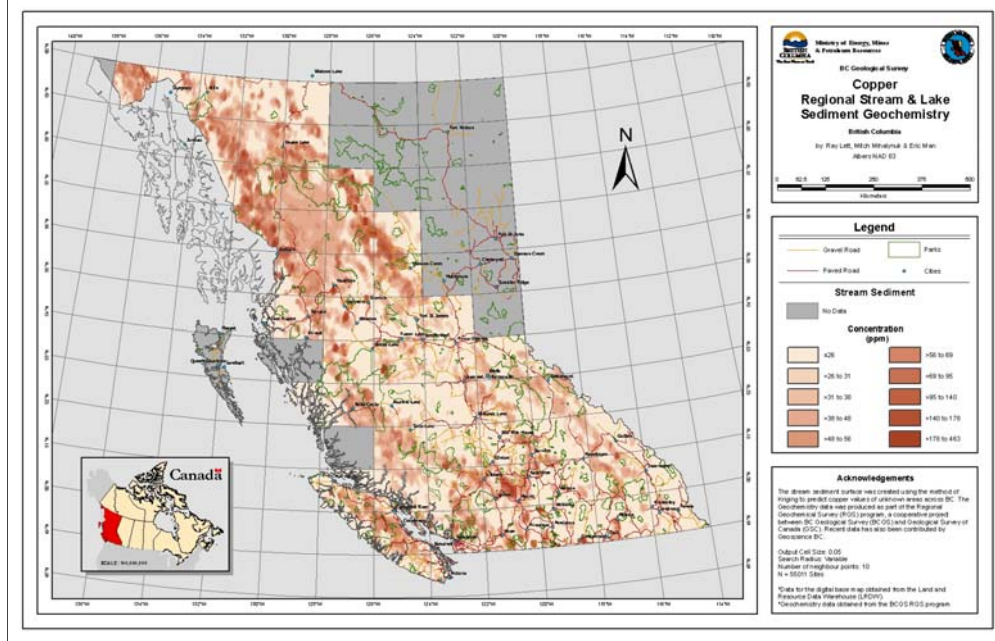
This map shows the coverage of the different types of geochemical survey carried out by government and non-government (e.g. Geoscience BC) agencies in British Columbia. The slide identifies more detailed i.e. higher density surveys undertaken to study specific problems or evaluate specific areas.

Sediment sample coverage

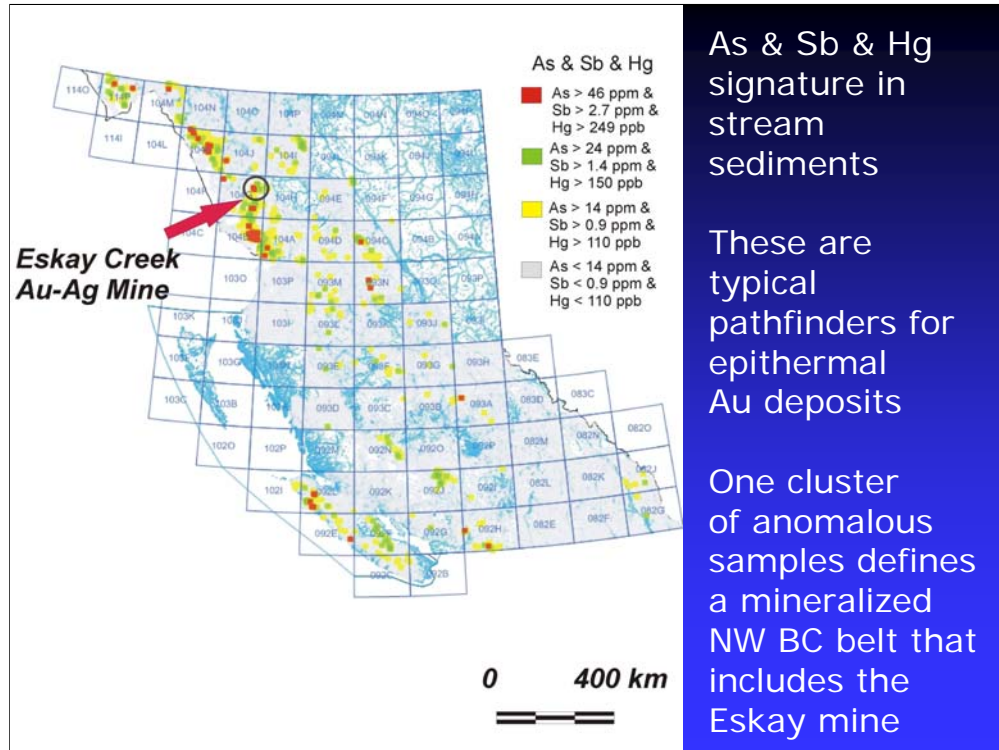


This map shows the location of stream and moss sediment samples sites (brown) and lake sediment (blue) in British Columbia.

Contoured Cu



This map shows contoured copper from stream sediment, lake sediment and moss sediment data. The map is a preliminary version of one that will be part of a geochemical atlas of British Columbia to be released by the British Columbia Geological Survey later in 2007. Producing copper mines are identified on the map and several belts of elevated Cu corresponding to Cu-mineralized island arc volcanic rocks are outlined. The data has been levelled before contouring to compensate for differences between Cu background in moss sediment, stream sediment and lake sediment.



As & Sb & Hg signature in stream sediments

These are typical pathfinders for epithermal Au deposits

One cluster of anomalous samples defines a mineralized NW BC belt that includes the Eskay mine

This map shows sediment samples with and elevated As and Sb and Hg. These elements were selected because they are typical pathfinder signature for epithermal gold deposits. Anomalous values clearly outline a belt in north western British Columbia that follows the "Golden Triangle" and includes the world class Eskay Creek Au-Ag mine.

Improving drainage surveys

- Higher density Sampling
- Using other sample types
 - Moss Mat sediment
 - Heavy Minerals
- Training samplers

The regional survey where samples are collected between 1 /10 km² and 1 /15 km² will outline belts where the geology has elevated content of certain elements. However, the sample density is often too low to detect individual deposits. There have been recent examples where the routine RGS has been successful as the primary exploration tool.

The routine survey can be improved by adjusting sample density so that the survey will better detect mineralization or by using a different sample type. Lake sediments are an obvious example to deal with areas where there are few streams, but many lakes.

Moss mat sediment was introduced in the early 1990's to solve the problem of sampling fast flowing mountain streams on Vancouver Island where there was depletion in fine grained sediment relative to the gravel and boulders.

Using Moss Mat Samples – An Alternative sediment in fast-flowing mountain streams



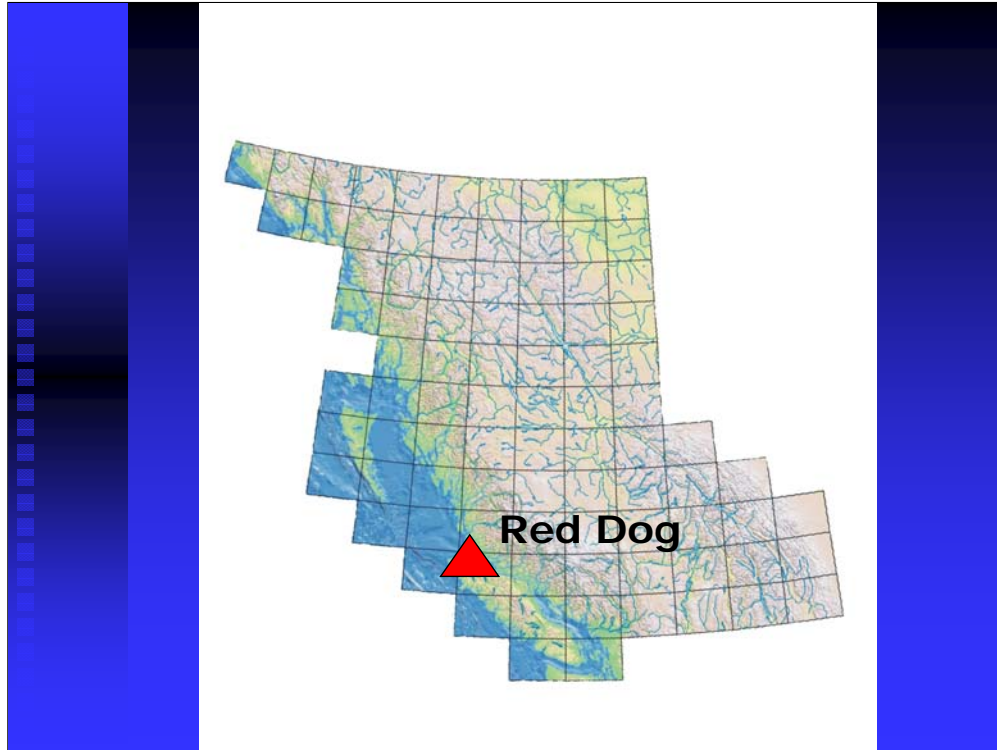
This slide shows moss sediment sampling in the Lillooet area – Thanks to Garret Larcroux of the Ts'kw'aylaxw First Nation for assistance with sampling.



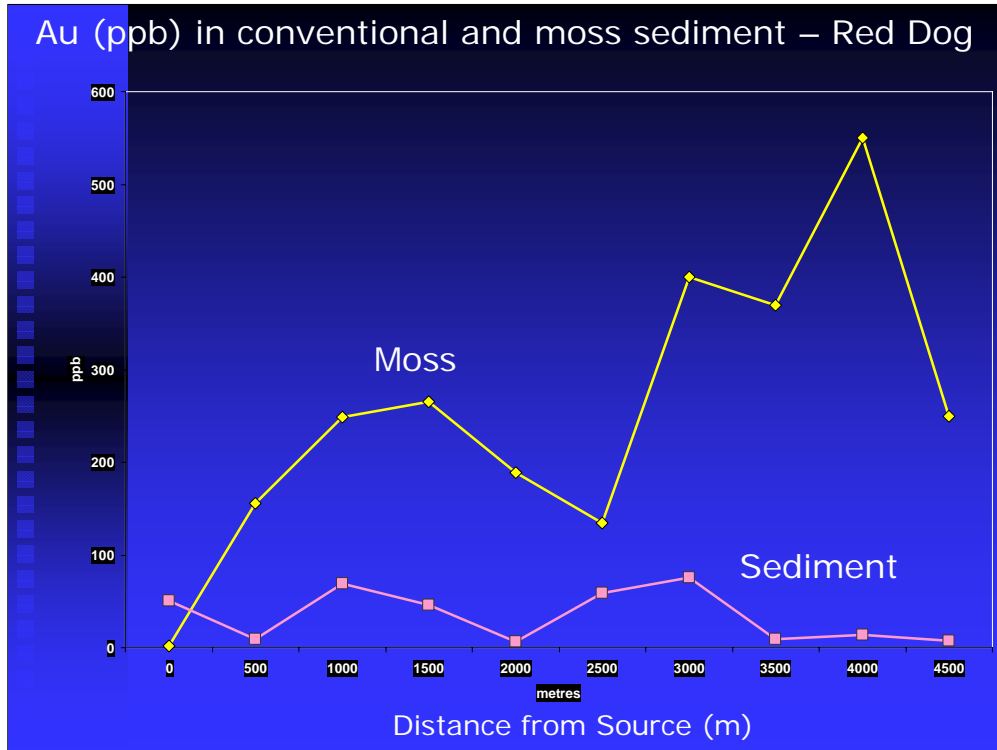
Ideally, moss should be:

- Just above the water level
- Alive
- With abundant captured sediment

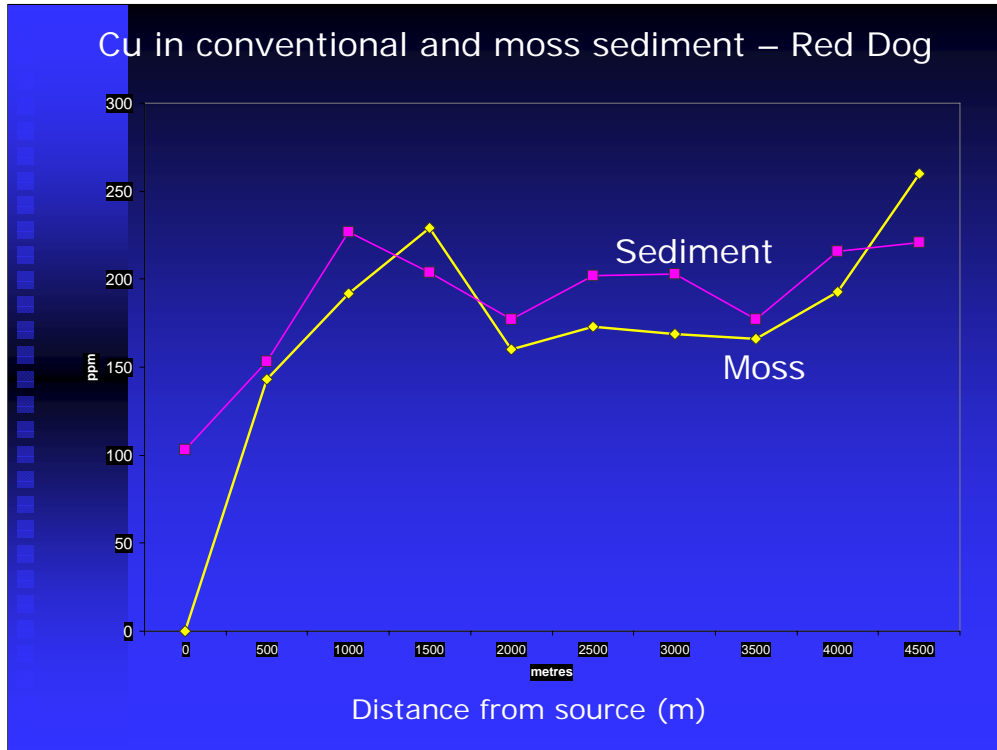
Here is second example of moss sampling. The ideal sample material will be live moss, growing on boulders or pebbles just above the water level and containing abundant sediment with the moss is handled (gritty to feel).



The Red Dog porphyry Cu-Mo-Au-Ag sub economic deposit at the north end of Vancouver Island illustrates the marked difference between the behavior of Au and Cu in stream and moss sediments. The copper and iron sulphides are hosted in Jurassic Bonanza volcanics. The creek has a 150 m vertical drop over the 3.7 km interval sampled.



The profile of Au shows a subdued pattern along the stream reach in sediment, but significant increase at about 3 km down stream from the mineralization.



By contrast, the Cu sediment profile is similar to the moss. Clearly the Au is being dispersed by a clastic mechanism whereas the Cu may be transported by more hydromorphic processes.

Heavy Minerals – A solution to more challenging sample sites



Concentrating minerals from a bulk sample of stream sediment is another way of dealing with challenging, high energy fluvial sites – here is an example of a high energy stream & a transverse bar in north west British Columbia. Thanks to Brian Wardrop and Keith Fraser of McElhanney Consulting for demonstrating sampling under hazardous conditions.

Ideal HM Sample Site

- Clast supported, tightly packed, poorly sorted gravel in well formed bedrock depression, pothole or crevice
- Clasts = **boulders**, cobbles, pebbles,
- Matrix = sand and silt
- Good Site = Excavation to bedrock and/or presence of abundant well-rounded boulder sized clasts

Here are some of the main criteria for an ideal heavy mineral site.

Clast supported, tightly packed, poorly sorted gravel in well formed bedrock depression, pothole or crevice

Clasts = **boulders**, cobbles, pebbles,

Matrix = sand and silt

Good Site = Excavation to bedrock and/or presence of abundant well-rounded boulder sized clasts




Heavy Mineral Sampling

Heavy mineral sampling in at high energy NW British Columbia stream with Dr. Peter Friske, Geological Survey of Canada. About 10 to 12 kg of -12 mesh gravel are recovered by wet screening into a 12 l pail. The pail is lined with 2 heavy duty PVC bags the are sealed after the sediment has been screened. Moss and conventional sediment are also taken at each site. Thanks to Brian Grant, British Columbia Geological Survey, for recording this event and for the next slide.

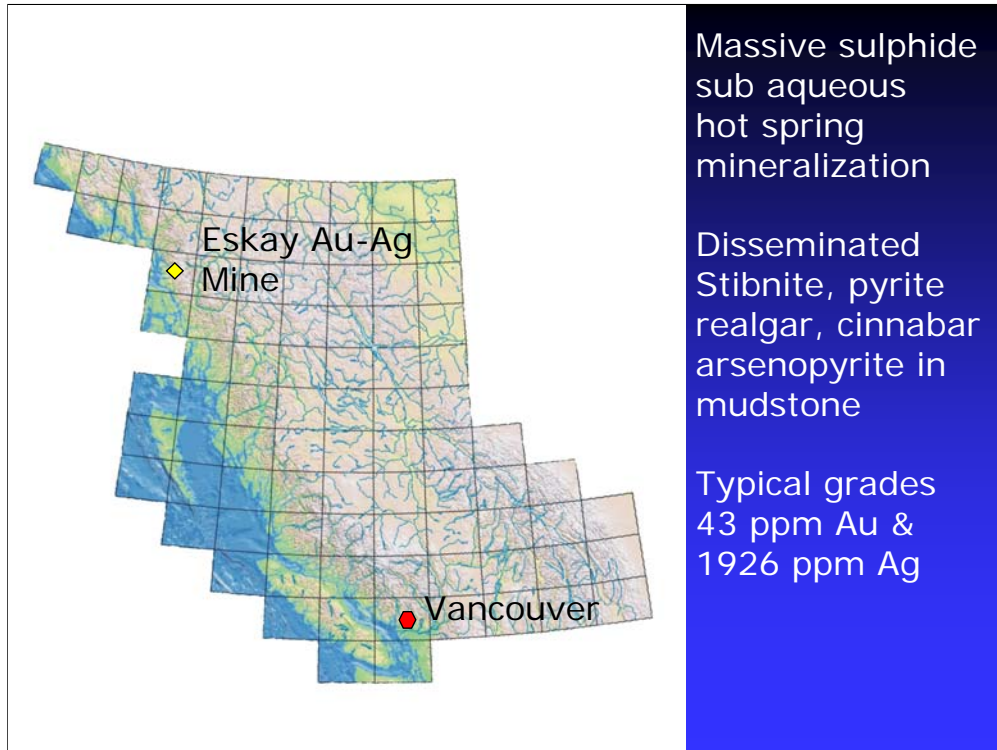


Another view of sampling. Gloves are necessary for washing the sample in view of the cold water.


NATIONAL GEOCHEMICAL RECONNAISSANCE
(SITE, HMC, Routine Water, Cation Water Field Card - 9 June 2003)

NTS SHEET	YEAR	SAMPLE NUMBER	REP. STA.	WIDTH	DEPTH	DATE	TIME	COLLECTORS
GENERAL PHYSIOGRAPHY <input type="checkbox"/> Mountainous <input type="checkbox"/> Youthful <input type="checkbox"/> Mountainous <input type="checkbox"/> Mature <input type="checkbox"/> Hilly <input type="checkbox"/> Plain <input type="checkbox"/> Peneplain <input type="checkbox"/> Swamp SURFACE EXPRESSION <input type="checkbox"/> Hummocky <input type="checkbox"/> Inclined <input type="checkbox"/> Level DRAINAGE PATTERN <input type="checkbox"/> Dendritic <input type="checkbox"/> Herringbone <input type="checkbox"/> Rectilinear <input type="checkbox"/> Trellis <input type="checkbox"/> Poor <input type="checkbox"/> Discontinuous <input type="checkbox"/> Closed SITE DRAINAGE <input type="checkbox"/> Well <input type="checkbox"/> Moderate <input type="checkbox"/> Poor	STREAM SOURCE(S) <input type="checkbox"/> Ground <input type="checkbox"/> Spring/Melt <input type="checkbox"/> Glacier <input type="checkbox"/> Recent Rain <input type="checkbox"/> Unknown STREAM CLASS <input type="checkbox"/> Primary <input type="checkbox"/> Secondary <input type="checkbox"/> Tertiary <input type="checkbox"/> Quaternary <input type="checkbox"/> Undefined STREAM TYPE <input type="checkbox"/> Permanent <input type="checkbox"/> Intermittent <input type="checkbox"/> Re-emergent <input type="checkbox"/> Undefined STREAM FLOW <input type="checkbox"/> Stagnant <input type="checkbox"/> Slow <input type="checkbox"/> Moderate <input type="checkbox"/> Fast <input type="checkbox"/> Torrential	WATER COLOUR WATER CLARITY <input type="checkbox"/> Transparent <input type="checkbox"/> Partially Cloudy <input type="checkbox"/> Cloudy VEGETATION <input type="checkbox"/> Coniferous <input type="checkbox"/> Deciduous <input type="checkbox"/> Mixed <input type="checkbox"/> Grass <input type="checkbox"/> Bog <input type="checkbox"/> Other BANK TYPE(S) <input type="checkbox"/> Alluvium <input type="checkbox"/> Colluvium <input type="checkbox"/> Till <input type="checkbox"/> Outwash <input type="checkbox"/> Bare Rock <input type="checkbox"/> Talus/Scree <input type="checkbox"/> Organic <input type="checkbox"/> Other	CONTAMINATION(S) <input type="checkbox"/> None <input type="checkbox"/> Possible <input type="checkbox"/> Probable <input type="checkbox"/> Definite <input type="checkbox"/> Mining <input type="checkbox"/> Industry <input type="checkbox"/> Agriculture <input type="checkbox"/> Domestic <input type="checkbox"/> Forestry <input type="checkbox"/> Burn <input type="checkbox"/> Other BANK PRECIPITATE <input type="checkbox"/> No <input type="checkbox"/> Yes Colour(s) _____ BOTTOM PRECIPITATE <input type="checkbox"/> No <input type="checkbox"/> Yes Colour(s) _____	STREAM SEDIMENT SAMPLE COLOUR(S) STREAM SEDIMENT COMPOSITION Sand _____ % Silt & Clay _____ % Organics _____ % SAMPLE TYPE(S) <input type="checkbox"/> NGR Silt <input type="checkbox"/> HMC Bulk <input type="checkbox"/> Clast/Pebble <input type="checkbox"/> Routine Water <input type="checkbox"/> Cation Water <input type="checkbox"/> Other IN-SITU WATER PH _____ COND _____	HMC SITE <input type="checkbox"/> Longitudinal Bar <input type="checkbox"/> Transverse Bar <input type="checkbox"/> Point Bar <input type="checkbox"/> Diagonal Bar <input type="checkbox"/> Boulder Trap <input type="checkbox"/> Log Trap <input type="checkbox"/> Vegetation Trap <input type="checkbox"/> Bedrock Step <input type="checkbox"/> Pool <input type="checkbox"/> Gravel Veneer <input type="checkbox"/> Stream Bed <input type="checkbox"/> Beaver Dam SITE RATING <input type="checkbox"/> Good <input type="checkbox"/> Good to Moderate <input type="checkbox"/> Moderate <input type="checkbox"/> Moderate to Poor <input type="checkbox"/> Poor CLAST SHAPE Rounded _____ % Sub-Angular _____ % Angular _____ % Platy/Flat _____ %	HMC SITE COMPOSITION Cobbles _____ % Pebbles _____ % Sand _____ % Silt _____ % Clay _____ % Organics _____ % CLAST LITHOLOGY(IES) _____ % _____ % _____ % _____ % BEDROCK EXPOSED <input type="checkbox"/> No <input type="checkbox"/> Yes Type(s) _____ BOULDERS PRESENT <input type="checkbox"/> No <input type="checkbox"/> Yes Type(s) _____		
N A D ZN UTM EASTING UTM NORTHING								
COMMENTS:								

A modified Geological Survey of Canada sediment form captures information about the site. This form includes the provision to record information about the HMC site, composition and clast shape in addition to stream sediment information.

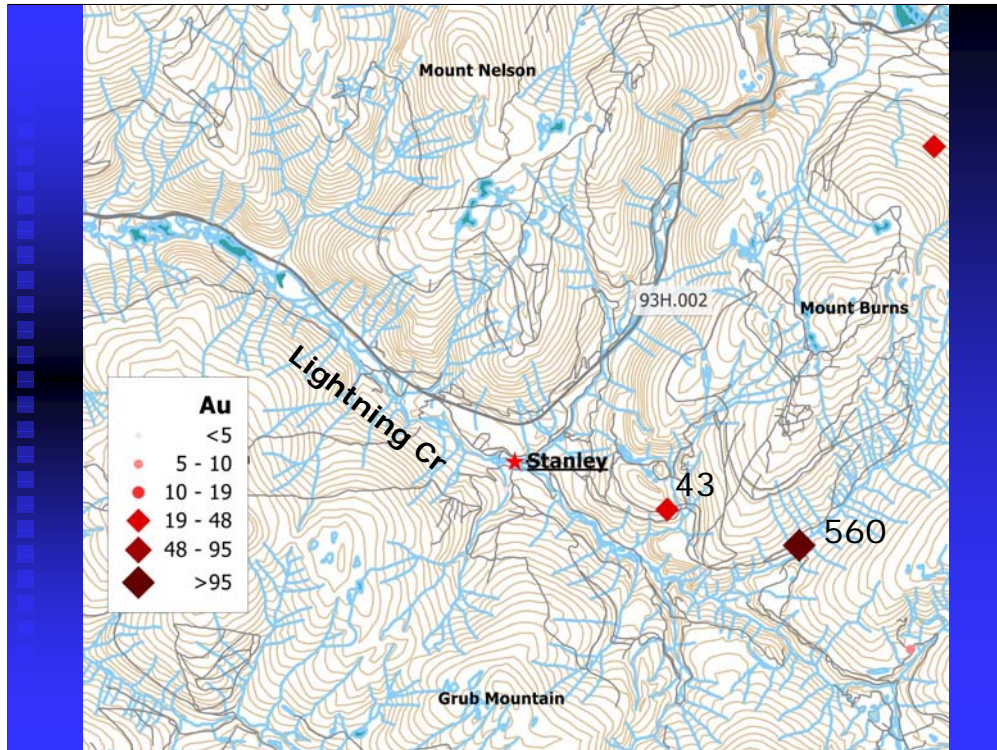


Here is an example of a heavy mineral survey for Au near the Eskay Au-Ag mine in northwestern British Columbia.

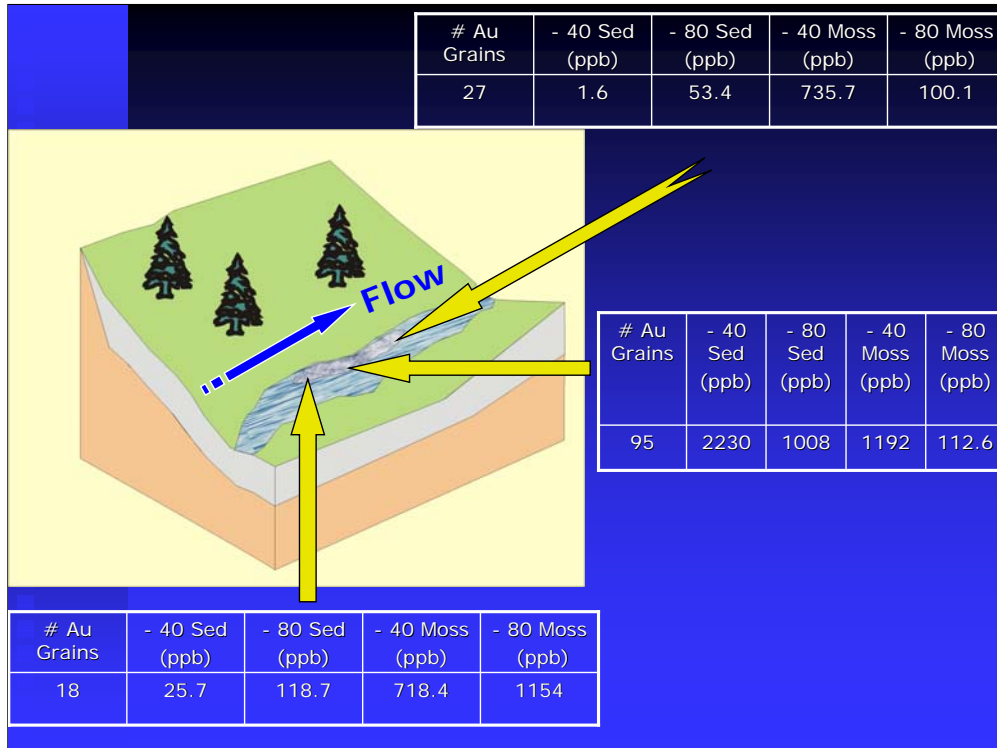
Eskay Mine – NW BC



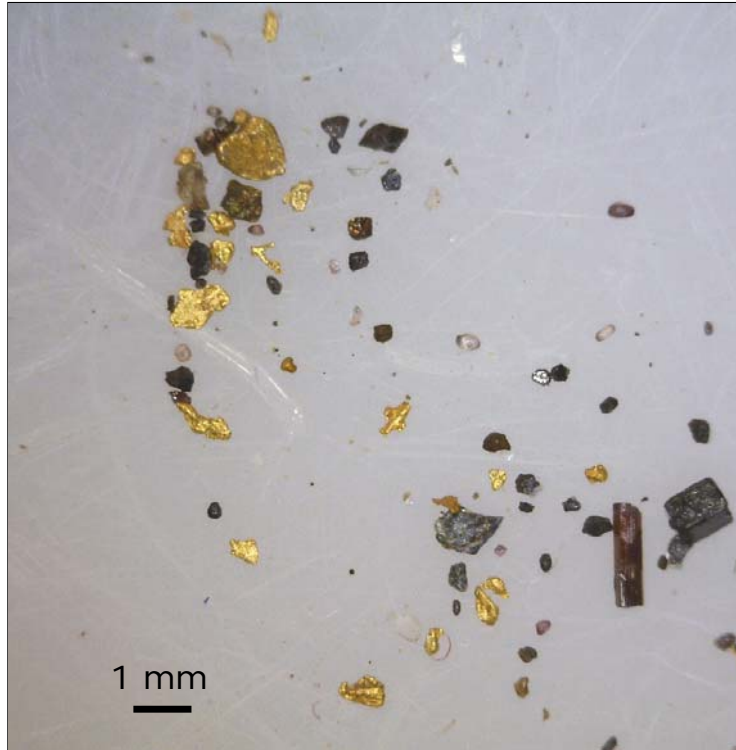
This slide shows the Eskay Mine illustrating the mountainous topography of the area



This slide shows a recent study to compare the amount of Au in conventional sediment, moss sediment and HMC along a bar in Lightning Creek near Barkerville, British Columbia. Here's a map of the site plus the conventional RGS values in sediment. Several of the tributary creeks are anomalous.



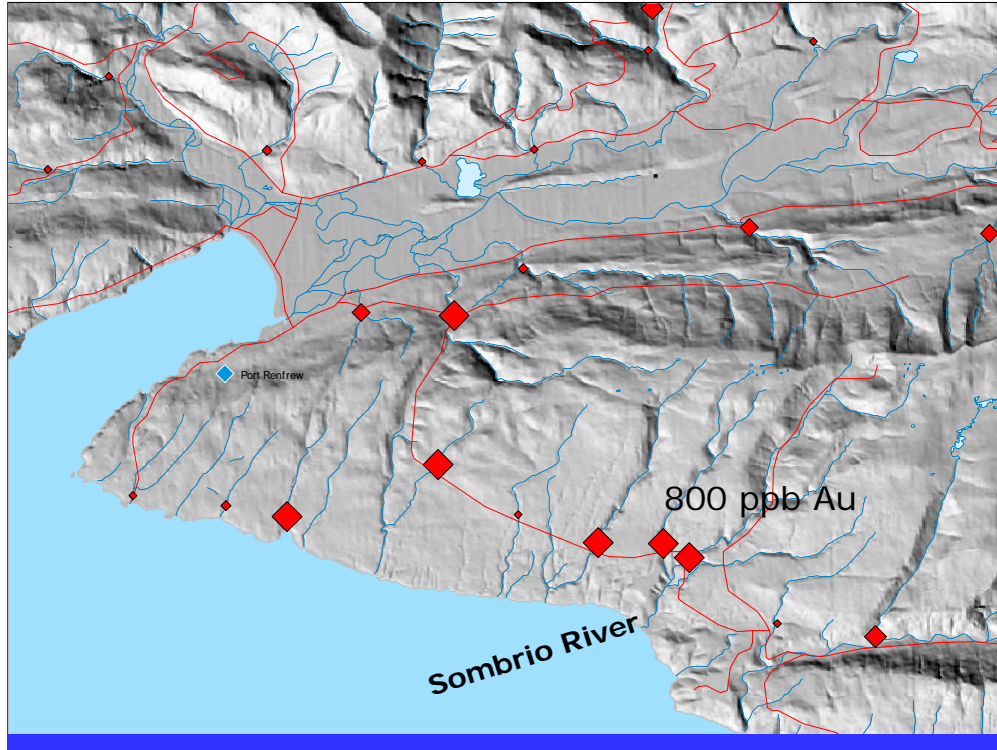
Here are the number of Au grains and the Au content of the – 40 and -80 mesh size fraction of the sediment samples collected at 10 metre intervals from a bar along Lightning Creek. The sample from the upstream site on the bar shows an expected increase of Au from the coarser sediment size fraction (25.7 ppb) to the -80 moss sediment (1154 ppb Au). This pattern reversed in the next downstream sample are could be evidence of paler mining in the area. The study illustrates the degree of variation that can occur in sediment samples collected for Au.



Gold &
mineral
grains in
HMS of
2007-
93H-1004

The HMS
Contains
80-90
Au grains

This slide shows Au and other mineral (pyrite, tourmaline) grains from HM sample containing 95 Au grains. The shape of the Au grains ranges from rounded to modified (shows some angularity).

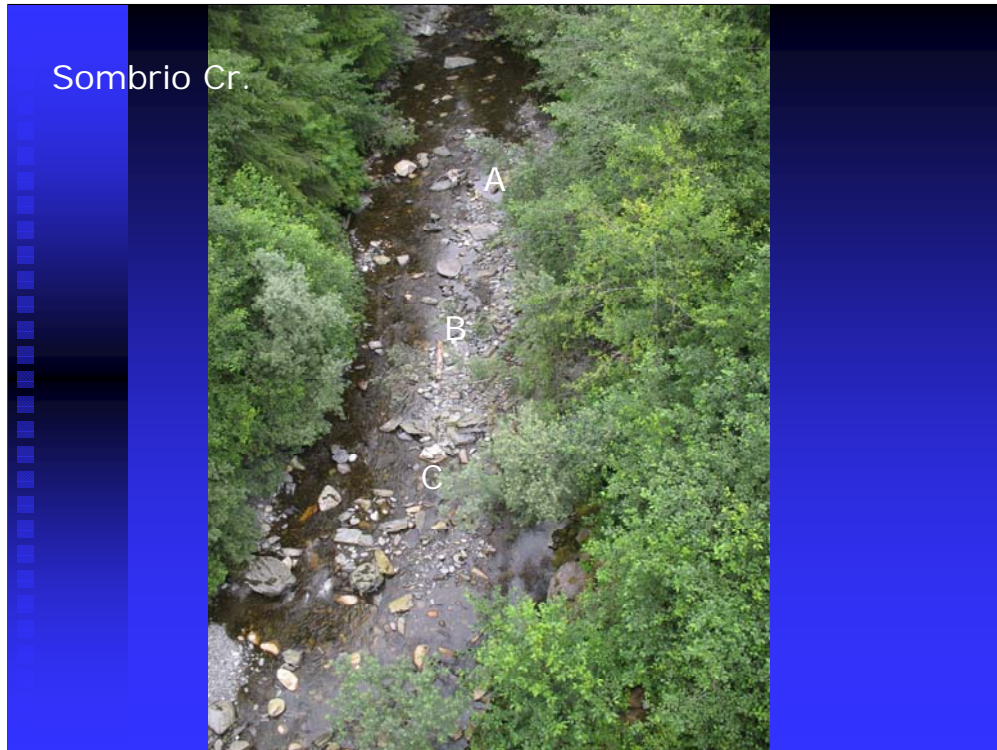


This slide shows another example comparing the amount of Au in conventional sediment, moss sediment and heavy mineral concentrates along a bar in Sombrio River west of Victoria on Vancouver Island, British Columbia. The map identifies the site and the Au value in sediment collected during a previous regional survey.

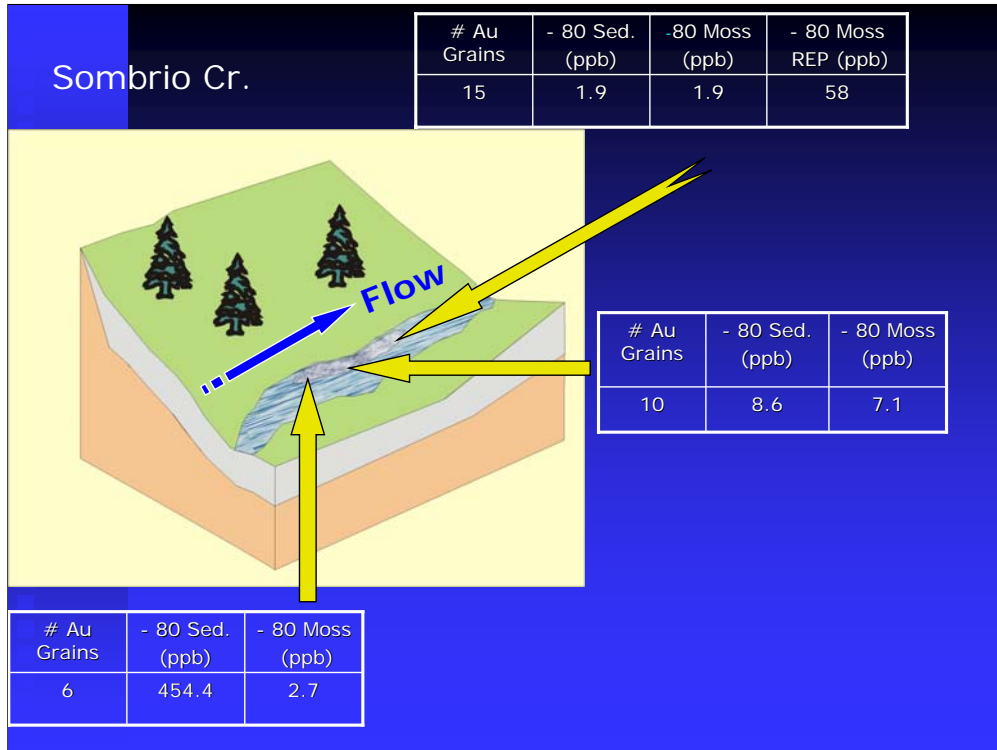
Bar in Sombrio Cr,
Vancouver Island



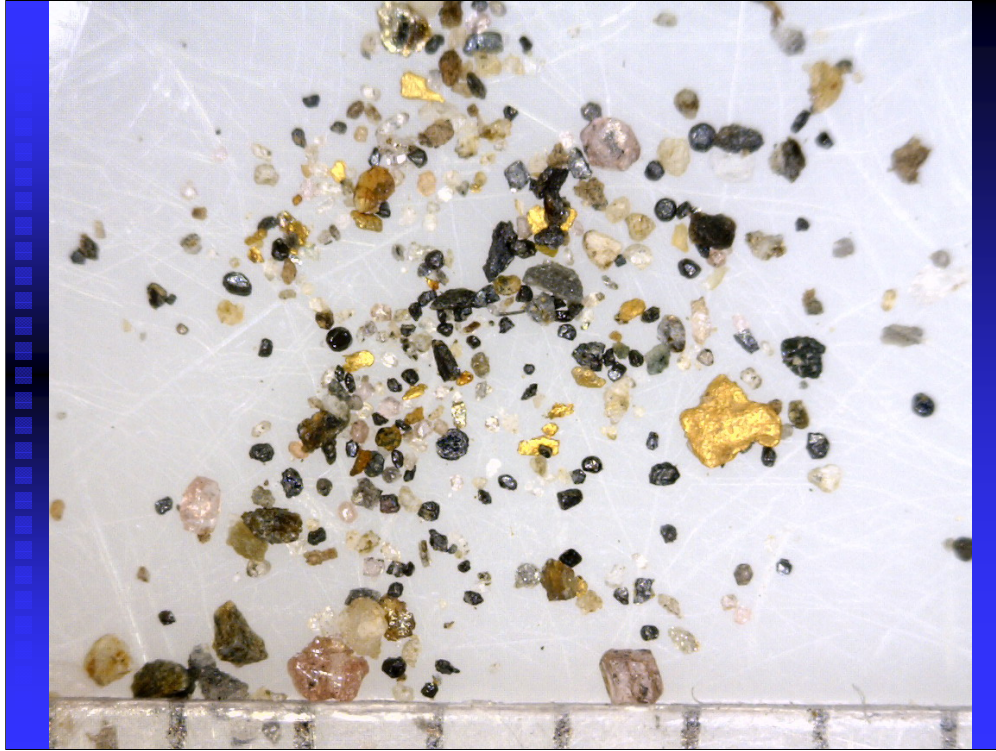
This slide shows the upstream end of the bar. Note that the water flow is slow in the creek when sampling was carried out in August, 2007.



This slide shows all of the bar where samples were collected in Sombrio Creek upstream. A sampler (RL) can be seen sitting on a boulder towards the upstream end of the bar. The three sites where heavy mineral bulk sediment and conventional stream sediment are about 10 to 15 m intervals marked A, B and C. The moss sediment was collected close to the creek bank on the right of the slide. Credit to Zoe Sandwith for taking this photograph.



Rather surprisingly, the highest Au value from the Sombrio Creek bar is in the -80 mesh fraction of the stream sediment rather than the moss sediment. This may reflect that the moss collected from close to the creek bank was not inundated with creek water and therefore had less chance to capture Au from the suspended sediment. The Au grains show a progressive increase from the upstream to down stream end of the bar. Again, the study illustrates that a single sediment sample from a creek may fail to detect Au.



This slide shows the Au and other mineral grains in the mid point sample. Note that most of the grains are rounded and show a range of sizes.



Ideally, at this point in the presentation there would be a short video on training BC Geological Survey students in sampling techniques.

Just testing for reactions ---



Finally, just testing for your reactions – Any questions about the talk?

Key References

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