GEOCHEMICAL SURVEYS – PITFALLS AND PUZZLES

Ray Lett

Geofile
This talk will illustrate some geochemical survey pitfalls, a few puzzles (at least to the author) and a brief review of the current GSB Geochemical program.
There are always the pitfalls of poor sampling technique, absence of any field data describing the sample collected, contamination during sampling and sample preparation and an unsuitable analytical method chosen for a survey that will make interpreting geochemical survey data difficult. There are also the obvious pitfalls during fieldwork that should be avoided.
A regional survey with a sampling density between 1 /10 km$^2$ to 1 /15 km$^2$ will outline bedrock geology that has an elevated trace element geochemical background. This sample density is generally too low to detect all of the exposed mineral occurrences that would be revealed by the stream geochemistry as an obvious anomaly. However, there have been recent BC examples where the routine RGS has been successful as the primary exploration tool. A routine geochemical survey can be improves by adjusting sample density so that the sampling will better detect mineralization or by using a different sample types. 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 fine grained sediment was depleted from the stream bed load. Moss mat sediment can improve gold anomaly contrast because the moss captures fine-grained sediment and heavy mineral from the suspended sediment at periods of high water flow (e.g. Spring runoff). It is important that live moss mats are collected from boulders and logs close to the stream water level.
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.
This side shows the locations of the geochemical orientation surveys on Vancouver Island, including the Red Dog property documented in BC Geological Survey Geofile 2008-08. Drainage from the Red Dog Cu-Mo-Au-Ag sub-economic porphyry deposit at the north end of Vancouver Island illustrates the difference between the behavior of Au in stream versus moss sediments. The creek has a 150 m vertical drop over the 3.7 km reach of the channel where moss and sediment samples were taken.
The profile shows that Au values are below 100 ppb in stream sediment from the channel for 4.5 km, but significantly increase to almost 600 ppb in the moss sediment with a peak at about 3 km downstream from the an area where this most likely Cu-Au sulphide mineralization.
Slide 7 illustrates another example to compare the distribution of Au in conventional stream sediment to Au in moss sediment and Au in heavy mineral concentrates along a bar in Sombrio River west of Victoria on Vancouver Island, British Columbia. Stream flow is south to the sea from rocks forming the Pacific Rim Leach River complex. The map identifies the site and shows the Au value detected in sediment collected during a previous BC Geological Survey regional survey.
Slide 8 shows the Sombrio Creek gravel bar where samples were collected. There are three sites where a heavy mineral bulk sediment and conventional stream sediment where collected from the upstream end, midpoint and tail of the bar at about 10 to 15 m intervals marked by A, B and C on the slide. Bulk samples were from shallow (10-15 cm depth) pits in the bar. The moss sediment was collected close to the creek bank (but about 5-10 cm about the present water level) on the right of the slide (hidden by the trees). Credit to Zoe Sandwith for this photograph showing the bar upstream from the BC Highway 14 road bridge.
Slide 9 shows that the highest Au value from the Sombrio Creek bar is in the - 80 mesh fraction of the stream sediment and not in the - 80 mesh fraction of the moss sediment as might be expected from the Red Dog example. This difference may reflect that the moss collected from close to the creek bank was infrequently submerged in the creek water floe and therefore had less chance to capture Au from the suspended sediment. The Au grains show a progressive increase in number from the upstream end of the bar to the bar tail. The study illustrates that a single sediment sample from a large gravel bar may not be sufficient to detect anomalous Au because the erratic distribution of Au in the sediment. Also, moss sediment must be carefully collected to make sure it has sufficient contact with the water.
This slide shows Au and other mineral grains in the heavy mineral concentrate made from the bar point B bulk sediment sample (~2mm fraction). Most of the grains are rounded and have a range of sizes.
Slide 11 shows a hazard of the poor preparation of till samples collected from a regional survey in the Babine Lake area, central BC. An instrumental neutron activation (INAA) analysis of the – 63 micron till samples from Babine Lake till survey produced some spectacular Au results (over 10 ppm) that, if published, had the potential of stimulating a staking rush to the area. The INAA Au levels were confirmed by an aqua regia-ICP (inductively coupled plasma emission spectroscopy) analysis (1 ppm detection limit) of a split of the prepared till sample so the quality of the analysis appeared acceptable. Also, only Au appeared to reach such high levels compared to other elements. Contamination of the sieve with Au bearing rock during preparation at a commercial laboratory was most likely the reason for the high values because two independent methods reported a similar Au content. Also, the Au values decreased sharply from a peak along an exponential decay curve through the sequence of samples sieved for analysis. Having suspected contamination a second sample of the archived raw bulk till was prepared by the BC Geological Survey, analysed by INAA and found to contain less than 20 ppb in the – 63 micron fraction. The risk of a sample preparation problem can be reduced by keeping a “witness” split of the sample separate from that sent for analysis and carefully examining quality control and the reported data for inconsistencies.
Slide 12 shows the distribution of Au values in the till if they had been released to the public. The “Gold in till – Re-Analysis” in the legend shows the range of values after preparation of a second samples from the bulk till and analysis for Au by INAA. All of the high Au values shown on the map would have disappeared because the maximum value shown in the legend is now 13 ppb.
Using an unsuitable analytical method can lead to problems in a geochemical survey. Slide 13 illustrates a difference between instrumental neutron activation analysis (INAA) and aqua regia digestion followed by inductively coupled plasma mass spectroscopy (aqua regia-ICPMS). INAA is non-destructive and reports near-total element abundances in all minerals forming the sample whereas aqua regia will only measure a varying fraction of the total amount of an element in a sample depending on a mineral solubility in the nitric-hydrochloric acid leach. For many elements (e.g. W, Cr, Zr) commonly found in refractory minerals (e.g. chromite) aqua regia-ICPMS is a partial analysis. For other elements present in sulphide the method is near-total. Hence, an appreciation of sample mineralogy and the aim of the survey are important when selecting the analytical method.
Slide 14 compares the results of an INAA and aqua regia-ICP analysis of soil samples collected over a lead-zinc sulphide lens containing barite. The difference between the aqua regia-ICP (partial) Ba and the INAA Ba (near total) indicates that barite is abundant in the soil. The low Ba values in the soil by aqua regia-ICP may also reflect a suppression effect from the high sulphate liberated by the sulphide dissolution that would enhance BaSO₄ precipitation from the digestion solution.
Slide 15 illustrates two common methods used for trace element analysis of sediment samples collected during regional geochemical surveys (RGS) typical of those carried out by the BC Geological Survey, Geological Survey of Canada and Geoscience BC. An earlier analytical method used to detect element in RGS samples was an aqua regia digestion of the sediment followed by atomic absorption spectrophotometry (AAS). This method is robust, but can only determine one element at a time. A more recent method is an aqua regia digestion followed by inductively coupled plasma mass spectroscopy (ICP-MS). This is multi-element and therefore more efficient and can measure elements to a lower detection limit. Both methods will only measure part of the total amount of an element in a sample depending on a mineral solubility in the nitric-hydrochloric acid leach. Results of the two methods should be very similar, but there will be differences in the amount of metal liberated depending on the conditions of the digestion.
While a difference in the results produced by the two methods (i.e. Aqua regia-AAS versus aqua regia-ICPMS) may have little effect on exploration geochemistry where the object is to identify anomalous values, it can be more obvious when regional survey data is contoured. This shows the contoured RGS copper in BC – note the edge effect along a map sheet boundary.
Slide 17 shows the distribution of copper in the archived stream sediment samples from the McLeod Lake map sheet that were analysed by an aqua regia digestion – ICPMS. The samples were originally analysed for Cu in 1985 by aqua regia digestion – AAS.
Slide 18 summarises the results of a statistical t test applied to mean values for elements determined first by aqua regia–atomic absorption and later by aqua regia-ICPMS. All values except for Fe log transformed before the t test was applied and also tested to determine if the distributions had equal or unequal variance. Red to blue indicates difference (red higher than blue) and green indicates no difference at the 0.05 probability level. Note that although some of the means are apparently identical the t test shows that statistically the means are different. The same differences could influence merged survey data if the RGS samples from one map sheet were analysed by aqua regia-ICPMS and samples from an adjacent sheet analysed by aqua regia-AAS.
Moving on to some questions asked by geochemists trying to interpret soil geochemical data. Selecting the optimum soil horizon for sampling to give maximum anomaly contrast for ore indicator and pathfinder elements is often a puzzle and can be illustrated by an orientation survey carried out over the Shiko Lake Cu-Au porphyry property. This orientation is among several studies undertaken in 2007 by the BC Geological Survey to try and better understand the soil and till geochemical expression of drift covered porphyry Cu-Au mineralization using conventional (e.g. Aqua regia-ICPMS) and a less conventional, partial extraction method (e.g. Mobile metal ion (MMI from X-ray labs, Toronto), Enzyme leach, Bioleach, SGH from Actlabs, Ancaster, Ontario).
Slide 20 summarises the geology of the Shiko Lake property near Quesnel Lake, BC. A complex syenite-monzonite-diorite intrusive into Nicola basalt and volcaniclastic rocks is been mineralized with Cu and Fe sulphides and with Au. There are also alternation envelopes around the intrusive. The Mount Polley Cu-Au mine is about 8 km to the north of the property. Previous exploration by several mining companies most recently has involved overburden drilling and IP surveys. Results of detailed GSB soil sampling along a north to south traverse will be shown in the next slides.
Side 21 is of a till exposure (ice transported minerals and rock fragment forming a compact, unsorted glacial deposit) and of more a detailed profile with the A, B and C soil horizons identified. Material was taken from the F-H, “upper” B, and “lower” B and C horizon each down soil profiles to establish the geochemical changes and element variations with depth and to try and replicate routine sampling carried out by exploration companies.
Sample analysed for a range of elements by aqua regia digestion followed by inductively coupled plasma mass spectroscopy and by INAA. Several partial extraction techniques such as MMI, Bioleach and Enzyme Leach were also used to try and improve anomaly contrast. B soil samples were also analysed for loss on ignition, for pH and for soil gas hydrocarbons (SGH).
Slide 23

Slide 23 is a view north towards Quesnel lake close to the North Cu-Au mineralized to give a better appreciation of the terrain and ice-flow features (ice flow is from the south east to North West). The view shows the detailed soil profile locations.
Slide 24 shows the variation of Cu by aqua regia-ICPMS in samples from different soil horizons along the profile crossing part of the North mineralized zone. The C Survey values have been merged with those for a previous overburden drilling program to better define the variation of metal along the traverse. Copper anomaly contrast is greatest in the C soil horizon compared to the B and F- H horizons and this may partly reflect analysis of the – 63 micron fraction compared to the – 0.177 mm fraction used for the B horizon samples. The asymmetric profile shape suggests a glacial transport of material from south to north. There is a contact between basalt and volcaniclastic rock under about 4 m of till between P67 and P68 close to where diamond drilling intersected about 5% disseminated pyrite plus anomalous Cu and Au values.
Slide 25 shows mobile metal ion (MMI), Bioleach & Enzyme Leach Cu in the lower B soil horizon across the NW zone. The peak is centered over Profile 67. Analyses are from lower B soil horizon samples. The profile is similar to that for aqua regia-ICPMS copper, but contrast is improved using the partial extractions.
Slide 26 shows the variation of Cu by MMI & Bioleach in the upper B horizon compared to the lower B. Note there is a similarity between results for each method and the difference between the response at the two depths. Contrast is clearly improved by using samples from the lower B soil horizon.
Slide 27 shows the variation of Au by aqua regia-ICPMS in different soil horizons and the number of Au grains isolated from the heavy mineral fraction of the C soil horizon. The variation of Au along the traverse is more erratic than that of Cu and the Au anomaly peak with the greatest number of pristine Au grains (local source) is displaced north from the Profile 67 Cu peak.
Slide 28 shows the distribution of Au by Mobile Metal ion (MMI), Bioleach and Enzyme Leach. Clearly MMI enhances Au anomaly contrast compared to other leaches with a sharp peak over profile P66.
Slide 29 shows the variation of Au by MMI in “upper” B and “lower” B soil samples. The MMI gold peaks in the two horizon are at the same point along the traverse, but contrast is improved by analysis of the “lower” B. Samples. A t test applied to MMI determined Au in the “upper” B compared to the “lower” B horizon shows that there is no statistical difference between the means of the two populations. This slide illustrates that care with soil sampling is needed to avoid variations in anomaly contrast from horizon to horizon.
Slide 30 shows pH in the “upper” B horizon along the same traverse as Cu and Au. There is a sharp decrease in soil pH at P68.
Slide 31 shows loss on ignition at 500°C (LOI) along the traverse. There is a low LOI value at P68 that appears similar to the variation in pH and Cu and Au determined by MMI and Bioleach. Organic matter or clay mineral content could influence soil pH and the geochemistry of the metals.
Slide 32 attempts to summarise the variation of Cu and Au in the soil with a simple model. The model shows the relationship between the bedrock source of the metal, the vertical projection of the mineralization to surface to the surface and displaced (due to ice transported material containing mineralized bedrock) till-soil geochemical patterns in the different horizons. The model speculates that soil pH has influenced geochemical anomaly contrast.
Slide 33 Summarizes the BC Geological Survey Geochemical program including:

- Field research to improve geochemical exploration techniques used by industry.
- Training of students in field sampling and advising on student project research.
- Providing geochemical analytical services (sample preparation & QC) in support of GSB bedrock mapping, mineral deposit and till survey projects.
- Delivering the BC Certified Assayers Program i.e. examination & certification of assayers in BC as required by the MEMPR Act.
- Partnerships include sample analysis funded by the GSC and support to Geoscience BC and GSC regional geochemical surveys by supplying standard reference materials.
- Database upgrades include updates to the BC regional geochemical survey database with Geoscience BC data.
- Client services – trying to answer your many questions.
And, finally, the release of new geochemical information.
The Wingdam Conglomerate: Geological Setting, Detrital Zircon Geochronology and Regional Significance

Filippo Ferri
Resource Development and Geoscience Branch,

Jim Logan
Geological Survey Branch,
Slide Mountain Terrane is a Late Paleozoic back-arc basin between the Ancestral North American margin and a mid to Late Paleozoic arc system.
Early to Middle Triassic clastic succession

Montney

Halfway/Doig

- Siltstone/sandstone
- Siltstone/shale
- Sandstone
- Sandstone/siltstone

Pardonet Fm
Baldonnel Fm
Charlie Lk Fm
Halfway Fm
Doig Fm
Montney Fm

(Edwards et al, 1994)
Wingdam conglomerate

- First described by Struik (1988)
- McMullin et al., (1990) first detailed its significance
- Similar quartz-rich clastics described from the base of the Black Phyllite along the length of its exposure
- Erosional nature of basal Triassic Black Phyllite contact noted by Struik, Campbell and others
- These and other arguments have been used to support pre-Jurassic deformation
**Wingdam Conglomerate**

- **L. Trias. - E. Jur. Nicola Volcanics**
- **M. To L. Trias. Black Phyllite**
- **M. Triassic Wingdam Cong**
- **L. Prot. - Paleozoic Snowshoe Group**

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**Middle Triassic conodont assemblages from lower Black Phyllite**
Gneiss clasts
Detrital Zircon Geochronology for the Wingdam Conglomerate

No detrital zircons younger than earliest Triassic

Preferred Age

Relative probability

255 Ma

0 500 1000 1500 2000 2500 3000 3500 4000

360 Ma

0 500 1000 1500 2000 2500 3000 3500 4000
Wingdam detrital zircon geochronology (continued)

Combined data for samples 07JL02-06 and FF07-12b
Geochronology of gneiss clast in Wingdam conglomerate

Data-point error ellipses are $2\sigma$.

Concordant grain at ca. 355 Ma records the primary magmatic age of the clast protolith.
Lemieux et al., 2007

Detrital zircon spectra; Southern Canadian Cordillera
Ross and Gehrels, 1998
Detrital zircon spectra of Mount Roberts Formation, southern Quesnel Terrane

Lemieux et al., 2007
Mesozoic arc volcanics
Quesnel Terrane
Triassic sediments
Mesozoic arc volcanics
Quesnel Terrane
Triassic sediments
L. Paleozoic volcanics, sediments
Slide Mountain Terrane
L. Proterozoic to Paleozoic
Crooked Amphibolite (mafic - ultramafic)
Kootenay Terrane
L. Proterozoic-Paleozoic
Middle Cretaceous intrusions
Cariboo Terrane
Cambrian-Devonian
L. Proterozoic-Lower Cambrian
Amount of obduction

Crooked Amphibolite

Island Mountain amphibolite

Antler Fm – Sliding Mountain

Kootenay (distal miogeocline)

Miogeocline

Latest Permian to Middle Triassic

25 km
Conclusions

- Detrital zircon geochronology of the Wingdam conglomerate is compatible with it being sourced from Kootenay and Harper Ranch rocks
- Clast composition also suggests the Slide Mountain as a source

Also:
- The Crooked amphibolite is an erosional remnant of the Slide Mountain Terrane below the Triassic black phyllite
- The black phyllite sits unconformably on Kootenay and Crooked amphibolite rocks
- Wingdam conglomerate is a product of this unconformity
- Obduction of the Slide Mountain Terrane onto Kootenay rocks in Late Permian to Early Triassic times (Sonoman Orogeny) was the ultimate cause of these relationships
- Kootenay rocks most likely underlie much of the Quesnel Terrane
MINEovation and Efficiencies with MapPlace.ca

BCGS Open House
November 13, 2009
Outline

- MapPlace as a World Leader
  - Geoscience Databases
- MINEovative Application Examples
  1. Data Integration & Efficiencies
     - ARIS & MapBuilders
     - MINFILE & Property File
     - RGS, MTO
  2. Visualization & Interactive Tools
     - Google Earth Display
     - Publication Application
     - Exploration Assistant Tools
     - MapPlace2Go
  3. Where to Next
Geological Survey Branch

- Established in 1895
- Responsible for producing and housing geoscience information about mineral resources and mineral potential.
- Systematic inventory, assessment and archiving of the complex geology of BC.
Some GSB Database Milestones

1895  Establishment of Bureau of Mines
1947  Assessment Reports filing MTA Regs
1982-84  Open House (Roundup), new MINFILE
1985-95  Mineral Development Agreements
          1989  90 Staff, MDO Van., Surficial etc, National Accords
1995  Ward’s Paperless Office / MapPlace
2000  Geofiles, Web development, GIS
          MapPlace: BCYCM Award; Public Service Award 2001
2005  MTO, GeoscienceBC
2007  25K Assessment Reports scanned
Key Activities

Mapping and Deposit Models

Confidential Expertise
- Industry Clients
- General Public

Advise Government
- Land-use planning
- First Nations consultation

Data Custodian
- MapPlace, BCGeoMap, ARIS, MINFILE

Monitor Industry Activity
- Regional geologist reports

Clients

Mining Industry
Governments

Resource Assessment
Aboriginal Relations
Gold Commissioner
Land-use Branch
Permitting

First Nations
Communities
Public
Universities
Investors
Consultants
Students
Business
Insurance Companies
Search and Rescue
Legal
Real Estate
Environmental Groups
Geology of BC
Quality of geological database

2006/2007 Mining Survey
96% Encourages Investment
Not a Deterrent to investment

Fraser Institute Annual
Survey of Mining Companies
2007/2008
372 companies
in 70 countries

Figure 15: Geological Database
(includes quality and scale of maps, ease of access to information, etc.)

Annual Survey of Mining Companies
2005/2006
64 jurisdictions

Deterrent to investment
Would not pursue exploration

60% 70% 80% 90% 100%
“BC really has its act together when it comes to putting information in the public domain.

Many jurisdictions go only part way, but BC does a lot more than asked to.”

*Fraser Institute Survey 2008*
Collaboration with www.GeoBC.gov.bc.ca

GeoBC
BC's GEOGRAPHIC GATEWAY

Archaeology & Culture
Base Maps
Fish, Wildlife & Plants
Forest, Grasslands & Wetlands
Fresh Water & Marine
Land Ownership & Status
Land Use Plans
Mining & Petroleum
Parks, Recreation & Tourism

Welcome to the GeoBC Gateway Application

SEARCH GeoBC
Digital Access Efficiencies

Reduce environmental footprint
Save exploration dollars

Less travel and use of resources
e.g. Victoria-Vancouver:
CO2 Equivalent Emissions: 90 kg

Historical exploration reports
e.g. $90K drill hole

Mineral Titles Online staking since 2005

Interactive linkages with other databases
BC Geoscience Databases

- **MINFILE**
  - 12,441 mineral occurrences
  - 28,438 polygons
  - 930 tracts
  - 55K+ RGS; 10K rock; till
  - 35 published surveys

- **Digital Geology Map**
  - 28,438 polygons
  - 930 tracts
  - 35 published surveys

- **Mineral Potential**
  - 12,441 mineral occurrences
  - 930 tracts
  - 55K+ RGS; 10K rock; till
  - 35 published surveys

- **Geochemical Data**
  - 55K+ RGS; 10K rock; till
  - 35 published surveys

- **Geophysical Data**
  - 30,000+ ARIS 99% scanned
  - 860 reports; 10K boreholes

- **Exploration Reports**
  - 30,000+ ARIS 99% scanned
  - 860 reports; 10K boreholes

- **COALFILE Library**
  - 43,000+ maps and reports
  - 105 deposit descriptions

- **Property Files**
  - 43,000+ maps and reports
  - 105 deposit descriptions

- **Deposit Profiles**
  - 43,000+ maps and reports
  - 105 deposit descriptions

- **BC Age database**
  - 7760+ records
  - 3700 geoscience maps & reports

- **Publications from 1887**
  - 7760+ records
  - 3700 geoscience maps & reports

- **Topo, Admin, Landuse, Imagery, geophysics**

...on top of Base Data
Submit Digital Reports

1947-2009 Reported Expenditures $1.5B

30,291 Assessment Reports
99% Scanned PDFs
Clients are able to get more interest in their BC properties as a result of the ARIS database.

Projects become more efficient by not repeating previous exploration work.

ARIS with Orthophoto & Link to PDF Report
ARIS MapBuilder Help

Step 1: The Data Entry Form

- Enter the name of your property.
- Enter all Tenure ID Numbers for your property. Separate the ID numbers by commas.
- Press the Create Map button.

Property Name:

Tenure ID Numbers:

511709,507614,501290,515549,515550
Step 2: The Location Map

- The map opens and displays your property's location.
- Clicking Claim Map will zoom in to your property.
- Clicking Print will print your Location Map. PDF Sample
Step 3: The Claim Map

- The map zooms in to show your property.
- Clicking Claim Map will zoom out to the Location Map.
- Clicking Print will print your Claim Map. PDF Sample
Step 4: The Tenure Report

- Clicking "Tenure Report" will open a new window with a report of all tenures in your property.
- The Tenure Report provides links to MTO.

Mineral Titles Online Report

Click on Tenure Number for more information

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LIBC Metadata

Mineral Title Online
BC Geological Survey
British Columbia Ministry of Energy, Mines and Petroleum Resources
Step 5: View your claims in Google Earth

- Clicking Google Earth will download a Google Earth KML file.
- You must have Google Earth installed on your computer to view KML files.
Average update Jan 1996

12,441 MINFILE Occurrence Records
$6M

4000 occurrences added or updated in last 10 years
MINFILE Summary Report

Summary Report

- Reports available

- Hot Link to MapPlace.ca

- Hot Link to ARIS Reports
# New Report Design

## Regional Geochemical Survey Report

### SUMMARY

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### Metadata Note: value of -1 indicates no data.
Upstream Query
Demo on Google Earth

Upstream Watersheds

Catchment Basin

Upstream Edges

(MINEovation)
Mineral Titles OnLine Report

Summary Report for the selected claims

Links to multiple claims.

Access to all aspects of the MTO website information

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Total Area: 3917.812 ha
# Mineral Titles Detail Report

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**Map Numbers:**

082F

**Owners:**

201067 Peter Lawrence Wells 100.0%

**Tenure Events:**

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<td>SOW Exploration and Development Work /</td>
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Investigate Mineral Tenures with the Exploration Assistant

Tenure due in next 30 days
Some GSC & GBC Surveys still to post

Airborne Geophysical Surveys $$$M
Footprints of reports by criteria. Select and view report for details.
Property File

The Reference Library Supporting MINFILE

- Documents to be scanned and posted as PDF files
- Indexed and Catalogued
- Search Utility
- Internet Access
- Linked to MINFILE Bibliography and MapPlace

comprises:

- Published and unpublished documents
- Maps and photos
- Press clippings and investor newsletters
- Corporate library donations
- Other ...

43K Documents
9585 online

$300K to index & scan

Donations:
Chevron, Placer Dome, Rimfire...

Mine Plans

Map original: 1948
MINFILE links to Property File

Bibliography

US 183; East 05-24; Starr A.M. (1956); others; Starr Ham A.M. (1956-80); development work; Starr (1956-11-24) regarding mine Western Exp. (1956-12-15); letter regarding mine development work and core samples with reply; Starr, C.C. (1956-12-31); letter regarding rippled rock core case; Starr, C.C. (1956-12-31); letter regarding mine report; Ham, A.M. (1957-01-09); letter regarding mine zinc grades; Starr, C.C. (1957-01-30); letter regarding CPR strike; Starr, C.C. (1957-06-25); report to shareholders; with financial statements and supporting documents; Ham, A.M. (1956-05-15); letter regarding mine development and reply; Starr, C.C. (1958-05-25); letter regarding mine development and reply; Xines, H.P.
Image Analysis Tool

Exploration Assistant

Image Analysis Toolbox

To select an image click on it with the arrow cursor so it is highlighted

- Bring to Top
- Original Order
- Analyze Image
- Clear Selection
- Focus Image

Toggle Image Group Layers (on/off)
- ASTER
- LANDSAT
- AVIRIS
- HYPERION

Enhanced Landsat Download
- Double click in red image outline

ASTER, Landsat, Aviris, Hyperion, Hyperspectral
False Colour Composite Analysis

Steps:
- Select a numerator and denominator band for each image colour. If the numerator and denominator are the same that rationing will not be performed but the designated band will be used.
- Adjust the "Analysis Area Pixel Width" value.
- Click on the "Digitize Centre of Interest" button and then select the desired point on the mouse screen.

A color scaled image of the selected dimension will be produced and centered on the digitized location.

Use the toggle button below to turn the analysis result image off and on.
Turn on or off any of the other data layers.

Digitize Center of Interest

Band 3 = 63.63 Red Numerator
Band 1 = 45.52 Red Denominator

Band 5 = 1.55-1.75 Green Numerator
Band 4 = 75-90 Green Denominator

Band 7 = 2.08-2.35 Blue Numerator
Band 6 = 2.08-2.35 Blue Denominator

500 = Analysis Area Pixel Width

Focus Images | Print Image

Back to Image Analysis Tools

Landsat Image: L10
Collection Date & Time: 2001-10-05 18:48:53 GMT

Image Source: GeoGratis
Relative abundance of iron oxides from the Highland Valley mine area.
MapPlace2Go designed for simple use

Fast Zoom
Easy to Use & Print
Limited Functionality
Mines & Major Projects
Project Record Summary

Wolverine - Perry Creek

Operator: Western Canadian Coal Corp
Sector: Coal
Status: Operating Mine
Commodity: Coking Coal
Latitude: 55.129
Longitude: -121.392
MINFILE: 093P 015
MMS: 1640013
EOA: 162
Address: 900-580 Hornby St.
Vancouver
BC V6C 3B6
Phone: 604-608-2692
Fax: 604-629-0075
Website: http://www.westerncoal.com/

MapPlace2Go Database Linkages

MapPlace & Google Earth
MINFILE Reports
Notices of Work
Environmental Assessments

MMS Notice of Work List - Mine #1640013

Click Notice of Work to See a Detailed Report

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Company

Project Information Centre (e-PIC)

Wolverine Coal Mine

Type: Typical EA Process (Active and Complete)
Category: Mining
Pre-application Start Date: 2001/12/31
Comments: Proponent receives provincial approval to construct a new coal mine near Tumbler Ridge. Amendment to Environmental Assessment Certificate MO-01, and Mine Permit No. C-233 received June 3 2005
Location: N.W. of Tumbler Ridge

List of Contacts

Documents

Under Review

Completed / Certified

Application and Supporting Studies
Aboriginal Comments/Submissions
EAO Generated Documents
Federal Comments/Submissions
Notice - News Releases

News Releases & Updates

2007 Annual Report

Western Canadian Coal Corp is a publicly traded company listed on the Toronto Stock Exchange (Symbol "WMC") and the Alternative Investment Market of the London Stock Exchange (AIM) (Symbol "WMC"). Western's corporate and administrative offices are located in Vancouver, British Columbia.

The Company was founded in October 1987 in the course of acquiring exploration and development stage mining properties for the international metallurgical market. The major assets of the Company are in bringing into production a high-quality, low-sulfur product of coal from the Northeast BC coalfields, including Elk, port, Iron and other facilities.

NEWS RELEASES & UPDATES

May 3, Western Canadian Coal Closes Stock 2006

term Financing and Reflected Debt

Apr 25, Western Canadian Coal Completes Share 2005

term Financing to Assist the Development of the Wolfe Creek Mine

Apr 10, Western Canadian Coal Receives 2006

Fiscal 2006 Operations Update

Notice - News Releases
Mines & Exploration:


2. Thematic Maps: Mining Economy interactive maps; select projects and report button.
Communities Benefit from Exploration Spending
- over 300 large projects
- $29M in 2001
- $130M in 2004
- $265M in 2006
- $416M in 2007
- $367M in 2008

Exploration Spending
- $130M in 2004
- $265M in 2006
- $416M in 2007
- $367M in 2008
## Mining Company Information

**Click Headings to Sort Table. Click on Report Number link for complete report.**

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Database Management

**Challenges**

- Format incompatibility
- Application/visualization tools
- Interpreting geosciences data
- Ageing & New data
- Storage costs
- Upgrades - servers, website, OS

**Solutions**

- Improvements/maintenance
- Development
- Analyzing geosciences data (Live Meeting)
- Focused updates
- Reclamation (disk space discipline)
- Deal with it

---

**Students**

Messaging

Collaboration
What’s Next...

data capture
GPS
gapology
topography
KML/KMZ
display

Geomatic Magic

MINenovation
Open Source
WMS
Collaboration
Integration
Partnerships

Strategy for
timely updates

BC Geology
on MapPlace.ca
Web-enabled Google Earth API Application

An enhanced scale-based density display of RGS KML files with link to detailed reports.

Regionated KML files for MINFILE.

1:2M Geology is also displayed.
1:2M Geology and ability to add KML/KMZ
RGS Follow-up in Yukon led to ‘White Gold Rush’

- “First significant hard rock gold discovery in the Klondike in over 100 years” Mike Burke.
- YMIP $20K covering 50% to 100% of exploration work; 2008 $700K budget increased to $1.8M in 2009; 106 applications.
- 1.84 GT over 102.5 m, with 8.81 GT over 24m.
- $10M spending in 2010. Company moved from New Zealand.
- Exploration stimulated by reinterpretation of the Casino copper-gold porphyry project.
- NATMAP geological compilation 2005.
Data Mining with MapPlace.ca

Thank You
Mining and Mineral Exploration Update - 2009

David Lefebure and Jay Fredericks
BC Ministry of Energy Mines & Petroleum Resources

BCGS Open House
Nov. 13, 2009
Your Regional Geologists

Dave Grieve
Bruce Madu
Bruce Northcote
John DeGrace (retired)
Paul Wojdak
Highlights

• Mines rebounding and starting again to invest in their future
• Numerous mine development projects; some stalled
• Reduced exploration activity; generally smaller and fewer
• Asian investments
Operating Metal and Coal Mines 2009

Commodity Codes

Ag - Silver
Au - Gold
Cu - Copper
Mo - Molybdenum
Pb - Lead
Zn - Zinc

Metal Mine

Coal Mine

Kemess South (Cu-Au)
Endako (Mo)
Huckleberry (Cu-Mo-Au-Ag)
Gibraltar (Cu-Mo)
Mount Polley (Au-Cu)
Max (Mo)
Quinsam
Myra Falls (Zn-Cu-Au-Ag)
Highland Valley Copper (Cu-Mo-Au-Ag)
Fording River
Greenhills
Line Creek
Elkview
Coal Mountain
Perry Creek
Trend
# Coal

## Established Mines
- Fording River
- Elkview
- Greenhills
- Line Creek
- Coal Mountain
- Quinsam

## New Mines
- Brule
- Trend Wolverine
- Wolverine

## Proposed
- Gething
- Horizon
- Lodgepole
- Herman
- Roman Mtn
- Goodrich
Goodrich Central South
First Coal Corp

- Project would apply AddCar remote u/g mining method
- 41 million tonnes measured and inferred metallurgical coal resource, Bickford & Gething Fms.
- 50,000 tonne bulk sample proposed for 2010

“Spine Road” access to project, site “C3” in the distance
Raven Project
Compliance Energy, Itochu & LG

metallurgical or thermal coal markets

42 drill holes (9,899 m) in 2009

Project description filed with Environmental Assessment Office
New Afton

• $590 million Underground mine, 11,000 t/day
• Working to develop underground, including new 4525 m conveyor access decline
• Production planned for late 2012
• 44.4 Mt @0.98% Cu, 0.72 g/t Au, 2.27 g/t Ag
Copper Mountain
Copper Mountain Mining Corp

- New resource 186 mT @ 0.411% Cu
- Plan mining revival - $402 million, 35,000 T/ day
- Financing partnership with Mitsubishi
- Mill construction started
- Planned start of production by mid 2011
Designing Mines for Reclamation

Mt. Milligan
Terrane Metals Corp.

- Smaller footprint
- Pit design to reduce highwall
- Tailings impoundment planned for wetlands
Designing Mines for Reclamation

Mt. Milligan
Terrane Metals Corp.

2007

- Returned to wilderness site with logging potential
- Pits become lakes
- Tailings impoundment becomes wetlands

Proposed Reclamation
Copper-Gold Projects in Environmental Assessment

Schaft Ck Reserves - 812 mT
@ 0.30% Cu, 0.21 g/ t Au, 0.020% Mo

Prosperity Reserves - 487 mT
@ 0.22% Cu, 0.43 g/ t Au
Copper-Gold Porphyry

KSM (Kerr-Sulphurets-Mitchell) Seabridge Gold

- 1.4 Billion tonnes, 0.66 g/ t gold  0.17% copper
- Shifted to geotechnical, engineering, environmental
- Entered Environmental Assessment Process
Ajax-Afton
• Preliminary economic assessment

Woodjam
• Goldfields signed agreement to explore Woodjam North

Kwanika
• Drilling on South Zone increases potential

Zymo
• Drilling expanded mineralized zone

Big Bulk
• Optioned by Anglo-Ashanti with drilling
Porphyry Molybdenum

Chu

TTM Resources Inc.

- Resource - 63,000,000 T @ 0.104% Mo (Meas + Ind.)
- 80 km south of Vanderhoof; entered environmental assessment process
Porphyry Molybdenum

Kitsault
Avanti Mining Inc

- Resource 158 m tonnes @ 0.10% Mo (Ind.) + 133 m T inf.
- Past mining - 13 m tonnes at 0.11% Mo (1967-1972, 1981-82)
- Work focused on assessment of a new tailings impoundment

Pit developed

Town site preserved (separately owned)
Capstone Mining (formerly Sherwood Copper)

- Limited fieldwork; engineering studies
Volcanic “Massive” Sulphide

Harper Creek
Yellowhead Mining Inc.

- Entered Environmental Assessment Process
- Modelling the deposit and collating data
- 538.4 Mt of 0.32% Cu at a 0.2% cut-off
Sedex Zinc-Lead Exploration

Ruddock Creek
Selkirk Metals Corp. merged with Imperial Metals Corp.

- Submitted project to Environmental Assessment Process
Orogenic Gold Vein

Yellow Jacket
Prize Mining Corporation and Eagle Plain Resources

- Atlin placer camp
- Volcanic and ultramafic-hosted gold-quartz stockworks
- Plan to mine 32,000 t in 2009
Snowfield
Silver Standard Resources

- New Snowfield North = East extension of Mitchell zone
- Seven drills and 80 member team
- New intersection of 0.70 g/t gold over 483m
Carbonatite: Tantalum-Niobium Exploration

Blue River
Commerce Resources Corp.

- Preliminary economic evaluation
BC Mineral Exploration Expenditure
$367 million in 2008

2009?
Recent Commodity Prices (in US $)

- Met Coal: $125-$150/t
- Copper: $2.60-3.00/lb
- Gold: $900-1120/oz
- Molybdenum: $10-15/lb

VS

?
Elk Valley Coal Corporation

Fording River, Elkview, Greenhills, Line Creek, Coal Mountain
Perry Creek (Wolverine)
Western Canadian Coal
Brule Mine
Western Canadian Coal Corp.
Trend
Peace River Coal Limited Partnership
New Mines and Mine Developments

Since 2005

January 2009
Copper Mines

Copper-Moly Mines
Highland Valley - Teck & Highmont
Gibraltar – Taseko Mines
Huckleberry – Imperial Metals (50%)

Copper-Gold Mines
Kemess – Northgate
Mount Polley - Imperial Metals
• Discovered new high grade South Flank zone (averted shutdown)
• 5,835,000 T @ 5.4% Zinc, 1.0% Copper, 1.3 g/ t Gold, 45 g/ t Silver
2008 Value of Mineral Production: $6.7 Billion

- Coal: 45%
- Copper: 25%
- Aggregates: 5%
- Others: 9%
- Gold: 4%
- Silver: 1%
- Zinc: 1%
- Ind. Min: 10%
Applied Geochemistry in Mineral Exploration - Pitfalls & Puzzles

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

- Sampling
- Sample preparation
- Sample analysis
A pitfall of moss mat sampling

- Moss mat sediment can improve gold anomaly contrast.
- Moss mats are an alternative where fine-grained sediment is limited in fast flowing streams.
- Moss should be collected from above & close to the water level.
Using Moss Mat Samples – An Alternative sediment in fast-flowing mountain streams
Geofile 2008-08. Survey Sites
<table>
<thead>
<tr>
<th># Au Grains</th>
<th>- 80 Sed. (ppb)</th>
<th>- 80 Moss (ppb)</th>
<th>- 80 Moss REP (ppb)</th>
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<tbody>
<tr>
<td>15</td>
<td>1.9</td>
<td>1.9</td>
<td>58</td>
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</tbody>
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**Sombrio Cr.**

<table>
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<th># Au Grains</th>
<th>- 80 Sed. (ppb)</th>
<th>- 80 Moss (ppb)</th>
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<tbody>
<tr>
<td>6</td>
<td>454.4</td>
<td>2.7</td>
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<table>
<thead>
<tr>
<th># Au Grains</th>
<th>- 80 Sed. (ppb)</th>
<th>- 80 Moss (ppb)</th>
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</thead>
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<tr>
<td>10</td>
<td>8.6</td>
<td>7.1</td>
</tr>
</tbody>
</table>
A sample preparation pitfall

INAA Au in the original sample

ICP Au in the original sample

INAA Au in a second split of the raw till
A pitfall of sample analysis

Neutron activation

Sample

ICP Mass Spectrometry

Irradiate in nuclear reactor & count isotopes

Leach in aqua regia & analyze by spectrometer

33 elements – near total

50+ elements - partial
Barium and lead in soil over sedex mineralization

- Ba-INA
- Ba-ICP
- Pb-ICP

Barsite-Pb-Zn Sulphides
A pitfall of RGS sample analysis

Atomic absorption

Sample

ICP Mass Spectroscopy

Aqua regia digestion - Spectrometer - analysis

single element - robust

Aqua regia digestion - Spectrometer - analysis

Multi – element - versatile
Copper in stream sediment samples

GEFILE 2006-09
McLEOD LAKE
BRITISH COLUMBIA
NTS 93J

Cu by ICPMS
Stream Sediment

Sample Sites with Highest Copper Concentration, 1149 Values

<table>
<thead>
<tr>
<th>Concentration (ppm)</th>
<th>Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;76.12</td>
<td>&gt;99</td>
</tr>
<tr>
<td>67.86 - 76.12</td>
<td>98 to 99</td>
</tr>
<tr>
<td>52.53 - 67.86</td>
<td>95 to 98</td>
</tr>
<tr>
<td>42.54 - 52.53</td>
<td>90 to 95</td>
</tr>
<tr>
<td>&lt;42.52</td>
<td>&lt;90</td>
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</table>

1088 Sample Sites
## AAS mean vs ICPMS mean T test (1149 RGS values - NTS 93J)

<table>
<thead>
<tr>
<th>Element</th>
<th>Aqua Regia-AAS</th>
<th>Aqua Regia-ICPMS</th>
<th>AR-AA-Mean</th>
<th>AR_ICPMS-Mean</th>
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</thead>
<tbody>
<tr>
<td>As</td>
<td></td>
<td></td>
<td>4.5</td>
<td>4.7</td>
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<tr>
<td>Cd</td>
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<td>0.46</td>
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<tr>
<td>Co</td>
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<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td></td>
<td>24</td>
<td>24.61</td>
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<tr>
<td>Fe</td>
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<td>2.14</td>
<td>2.22</td>
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<td>Hg</td>
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<td>141</td>
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<td>Mn</td>
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<td>Pb</td>
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<td></td>
<td>5</td>
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<td>Sb</td>
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<tr>
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<td>37</td>
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<tr>
<td>Zn</td>
<td></td>
<td></td>
<td>72</td>
<td>74.5</td>
</tr>
<tr>
<td>Different</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some Puzzles e.g. Shiko Lake
Soil Geochemistry
Shiko Lake – view N across the Quarry Zone
A Typical soil profile

Till – parent material

F-H Horizon
Ae Horizon
“Upper B” Horizon
“Lower B” Horizon
C Horizon

10 cm
ICP Mass Spectroscopy

Sample

ICP Mass Spectroscopy

Mobile metal ion (MMI) Bioleach, Enzyme Leach-ICPMS analysis

Improves contrast

Aqua regia digestion - Spectrometer -analysis

Multi – element - versatile
Upper B soil horizon pH
MMI Au Lower B soil horizon

Loss on ignition (LOI) at 500°C

Upper B soil horizon

Lower B soil horizon
Vegetation-drainage

Upper B horizon expression

Lower B horizon expression

Till expression

Bedrock - sulphide mineralization

Sulphide mineralization
Vertical projection of mineralization to surface
Ice-flow direction
Soil pH (High to Low)
Detrital dispersal train
Geochemical pattern
GSB Geochemistry

- Field – Improve geochemical methods.
- Training – Support student research.
- Laboratory – GSB Analytical Services.
- Assayers Program – Certification.
- Partnerships – GSC, GSBC, Industry.
- Database upgrades (e.g. RGS)
- Client services
New Geochemical Information

Key Geological Concepts on the Distribution of Jurassic Porphyry Au-Cu (Mo) and Epithermal (Au-Ag) Deposits in the Toodoggone District, North-Central B.C.

Stephen M. Rowins*, Paul Duuring, Bradley McKinley, & Jenni M. Dickinson
Dept. of Earth & Ocean Sciences, University of British Columbia

Larry J. Diakow
British Columbia Geological Survey

Robert A. Creaser
Dept. of Earth & Atmospheric Sciences, University of Alberta

* Now at the British Columbia Geological Survey (Stephen.Rowins@gov.bc.ca)

Sponsors: UBC, NSERC CRSNG, Northgate Minerals, Stealth Minerals
The Toodoggone Team - Acknowledgements

UBC
Dr. Stephen Rowins – Principal Investigator
Dr. Paul Duuring – Post-Doctoral Research Fellow
Bradley McKinley – M.Sc. Student
Jenni Dickinson – M.Sc. Student
Dr. Richard Friedman (Pine Geochronology)

BCGS
Dr. Larry Diakow

U Alberta
Dr. Robert A. Creaser

Northgate Minerals
Carl Edmunds, Chris Rockingham, Brian O’Connor, Ron Konst, Brian Kay

Stealth Minerals
Bill McWilliam, Dave Kuran, Dave Blann

Sable Resources
Mel Rahal

GSC
Rob Shives
Two papers just out this summer


- Dickinson et al. on the **Pine Porphyry Au-Cu** and McKinley et al. on **Kemess North** submitted shortly.
Toodoggone geology

100 km long by 30 km wide, NNW-trending belt of volcano-sedimentary rocks that hosts porphyry and epithermal deposits

Project aims:

- Construct detailed deposit models for porphyry and epithermal systems and investigate possible linkages
- Use the factual deposit models to develop a predictive Au-Cu exploration model for the entire district
Close temporal overlap between porphyry intrusion ages (ca. 205-191 Ma) and porphyry-style mineralization (ca. 203-194 Ma).

HS ages (ca. 201-182 Ma) overlap proximal porphyry intrusions and the youngest porphyry-style mineralization in the district at Pine (194 Ma).

LS ages (ca. 192-162 Ma) only overlap poorest quality HS ages and none of the porphyry intrusion ages. (several dykes at Griz-Sickle & Brenda do overlap).
The Kemess South Mine - structure

- E-striking fault
- Cut by later NW- and NE-striking faults
- Contact between MLG & Takla is intrusive
- Contact between MLG & Asitka is tectonic (fault)
- Contact between MLG & Hazelton Gr. is nonconformable
E-striking fault

Asitka Group siltstone

monzonite

Fault

North Block Fault

Surface
NW- and NE-striking faults

- Hazelton Grp
- volcaniclastic
- Mafic dike
- Asitka Group siltstone
Au-Cu-Mo distribution

Cu values at 1200 mRL

Monzonite Andesite

Potassic
Phyllic
Propylitic
Tectono-magmatic Evolution of Kemess South

i: Emplacement of MLG
ii: NBF
iii: Erosion, uplift, deposition of TD Fm. Rocks
iv: Reactivation of NBF
v: Horst-and-graben faults
vi: Present-day
Kemess South Fluid Inclusion Petrography

i & ii: Early Stage (Stage 1) Qtz-Py-Bt vein

iii & iv: Early Stage (Stage 2) Qtz-Py-Cpy-Mo-Mag-Bis vein

v & vi: Main-stage (Stage 3) Py-Qtz-Cpy-Ser-Cal-Mo vein
Kemess South Microthermometry: Early-stage veins (Stage 1)

P-T diagram of the H2O-NaCl system with halite liquidii and isochores for fluid inclusions from Kemess South.

Pressures of 0.6 to 1.8 kb correspond to depths of vein formation from 2.0 km to 5.9 km assuming lithostatic conditions and 1 kb = 3.3 km.

(Bodnar and Vityk, 1994)
Kemess South: Early-stage veins (Stage 2)

P-T diagram of the H2O-NaCl system with halite liquidii and isochores for fluid inclusions from Kemess South.

Pressures of 1.2 to 2.6 kb correspond to depths of vein formation from 4.0 km to 8.6 km assuming lithostatic conditions and 1 kb = 3.3 km.

The deeper estimates may be unreliable, although Butte has roots to 9 km.

(Bodnar and Vityk, 1994)
Kemess South: Main-stage veins (Stage 3)

P-T diagram of the H2O-NaCl system with halite liquidii and isochores for fluid inclusions from Kemess South.

Pressures of 1.0 to 3.0 kb correspond to depths of vein formation from 3.3 km to 9.9 km assuming lithostatic conditions and 1 kb = 3.3 km.

The deeper estimates are unreliable.

Greater pressure variation may be expected in Main-stage veins (longer event and more widely distributed).
The Kemess North Deposit

- Proven & probable reserve of 424 Mt containing 0.30 g/t Au and 0.16% Cu (Gray, 2005).
- Hosted in ca. 202 Ma diorite and overlying Takla Gr. basalt.
- Toodoggone Fm. Volcaniclastic rocks are ca. 199 Ma and crop out as prominent N-trending ridges.
Kemess North: Gridded Au concentrations from 216 ddh’s.

A. Two discrete near-surface ore bodies in Takla Gr. basalt separated by unmineralized TD Fm.
B. 150 m below the 1640 m RL, Au values are continuous across Takla Gr.
C. Block model demonstrating the disruption of a laterally continuous orebody by horst-and-graben normal faulting. Unmineralized TD Fm rocks down-dropped in the graben thereby lying adjacent to mineralized Takla Gr.
A. Sovereign diorite intrudes the Takla Group basalt at 202.7 ± 1.9 Ma (Diakow 2001)

Kemess North diorite intrudes at ca. 202 Ma (Diakow 2006b).

Au-Cu-Mo mineralization associated with the Kemess North diorite occurs at 201.8 ± 1.2 Ma (Re-Os on molybdenite)

B. Erosion and uplift occurs at an estimate rate of 1.7 km/My

This results in the exposure of the Sovereign diorite

C. Toodoggone Formation rocks (Duncan Member) are deposited at 199.1 ± 0.3 Ma (Diakow 2001)

The Duncan diorite pluton intrudes the Toodoggone Formation volcaniclastic rocks and Takla Group basalt at 197.3 ± 1.1/0.9 Ma (Diakow 2001)

D. North-south directed extension results in a steeply dipping, E-W striking normal fault that truncates the diorite and Takla Group basalt, and Toodoggone Formation rocks.

E. North-south directed shortening results in the formation of shallow, S-dipping reverse faults that truncate the Kemess North diorite. Younger Toodoggone Formation rocks are displaced beneath the Kemess North diorite

F. NW directed extension results in horst-and-graben style block shuffling of the stratigraphy

G. Finally, uplift and erosion results in the present-day exposure at Kemess North.
A. Sovereign diorite intrudes the Takla Group basalt at 202.7 ± 1.9 Ma (Diakow 2001).

Kemess North diorite intrudes at ca. 202 Ma (Diakow 2006b).

Au-Cu-Mo mineralization associated with the Kemess North diorite occurs at 201.8 ± 1.2 Ma (Re-Os on molybdenite).

B. Erosion and uplift occurs at an estimate rate of 1.7 km/Ma

This results in the exposure of the Sovereign diorite.

C. Toodoggone Formation (Duncan Member) rocks are deposited at 199.1 ± 0.3 Ma (Diakow 2001) via a fissure-style eruption, with the volcanic vent truncating the Kemess North pluton.

Toodoggone Formation rocks contain clasts of Takla Group basalt and Sovereign diorite.

D. Duncan diorite intrudes the Toodoggone Formation volcaniclastic rocks and Takla Group basalt at 197.3 ± 1.1/0.9 Ma (Diakow 2001).

E. Period of extension producing a large deep seated normal fault

North side of the EW-trending normal fault is down.

F. NW directed extension results in horst-and-graben style block shuffling of the stratigraphy.

G. Finally, uplift and erosion results in the present-day exposure at Kemess North.

“Fissure-style Eruption”
Kemess North: Fluid Inclusion Petrography

A: Early-stage vein
B: Main-stage vein
C: Early-stage vein
D: Main-stage vein
E: Early-stage vein
F: Main-stage vein
**Kemess North Microthermometry**

**Early-stage veins (biotite)**

1.5 – 2.0 kb corresponding to depths of vein formation at 5.0 to 6.6 km (using 1 kb = 3.3 km at lithostatic conditions). Corresponding temperatures range from 250° to 400 °C.

**Main-stage veins (sericite)**

1.2 – 2.5 kb corresponding to depths of vein formation at 4.0 to 8.2 km (using 1 kb = 3.3 km at lithostatic conditions). Corresponding temperatures range from 225° to 400 °C.

KN depths of 4 to 5 km just slightly deeper than KS depths of 2 to 4 km.
Salinity-Th (total) diagram for primary fluid inclusions from LS epithermal veins.

Excluding Baker, all inclusions are primary 2-phase, liquid-rich, aqueous inclusions. Baker is anomalous with primary inclusions including high-temperature, brine-rich and vapour-rich varieties.
The Baker “B” vein - Fluid Inclusions

Halite-homogenizers

2.0 to 5.6 km depth assuming lithostatic load. Same depths as KS and KN! These are porphyry related LS-IS veins.
Conclusions 1: Porphyry-Epithermal Linkages

- Porphyry-style ore fluids are directly involved in the formation of LS (IS) Au (Ag) epithermal veins at the Baker mine. Baker is deep, consistent with its formation in the favourable Takla Gr. basalt, which hosts KS and KN.

- A genetic link between porphyry systems and LS Ag (Au) deposits at Shasta, Lawyers, and Griz-Sickle is not established.

- Two varieties of LS (IS) epithermal deposits in the Toodoggone. (1) “Basin & Range” types localized along the NNW-trending basin-bounding faults with no direct link to Cu-Au porphyries; and (2) Peripheral halo around porphyry systems.
Porphyry systems are “simple” (thus relatively small) and relatively deep (3-5 km). Slow-boiling “pressure cooker” release.

Limited hypogene “upgrading” of Cu-Au ores = low grades.

KS & KN are porphyry “cousins”. Same far-field stress fields affected both deposits after formation. Similar structural controls (horst-and-graben).

Similar vein-types and alteration styles (common magmatic systems). Local variations due to host-rock compositions.
Conclusions 3: Exploration Targeting

- Normal faulting has structurally offset orebodies. They are not the result of deposits having multiple porphyry “centres”. Step across inferred faults and drill deep.
- “Point source” porphyry model with concentric zonation of alteration-mineralization is not likely very effective in the faulted & lithologically diverse Toodoggone.
- Host-rock important control over whether biotite (chl) or Kspar (ser) is dominant potassic alteration mineral. Not caused by different magma types (diorite vs. monzonite)
- No “favourable” intrusions recognized.
- Porphyries are relatively deep systems and unlikely to produce large LS epithermal systems (Baker?).
- Uplift and erosion is greatest in the south and any epithermal systems likely removed. Better epithermal preservation potential in the north, especially in “windows” of exposed Takla Group (Baker).
- The discovery of porphyry-style mineralization in 194 Ma felsic dykes at Pine confirms temporal overlap with LS epithermal mineralization in the Toodoggone.
Stratigraphic and plutonic framework for copper, gold and molybdenum, Thuya Creek – Woodjam Creek, south-central BC

Paul Schiarizza
Focus on Quesnel terrane


Preliminary products include 6 1:50 000-scale Open File bedrock geology maps

Final report, maps, databases in preparation
## Contributions

### Mapping

Steve Israel, Scott Heffernan, Amy Boulton, John Bligh, Kim Bell, Sandra Bayliss, Jenny Macauley, Britt Bluemel, Josh Zuber, Fern Wager, Arthur Paul, Devin Tait, Patrick Young, Kelly Schiarizza

### Geochronology

Richard Friedman, Thomas Ullrich

### Fossil Identifications

Mike Orchard, Terry Poulton, Paul Smith, Howard Tipper
General Geology

Focus on Quesnel Terrane-Nicola Group plus several plutonic suites
Complex, but generally synclinal – part of west verging fold system that roots in pericratonic rocks to the east

Steep east limb cut by Eocene dextral strike-slip faults

Most mappable faults probably Eocene

Low to sub-greenschist metamorphic grade; penetrative deformation only along east edge of Nicola belt (black phyllite unit)
Polylithic breccia unit
Basalt – breccia unit
Volcaniclastic unit
Lemieux Creek unit (Black phyllite unit)

Nicola Group
Middle and Upper Triassic
Four main subdivisions
Unconformably overlain by Lower Jurassic sandstone and conglomerate
Nicola Group: Lemieux Creek unit

Basal unit along eastern margin of group
Deposited on Slide Mountain terrane
Mainly black phyllite, slate, siltstone, quartzite, limestone
Quartz-rich units probably derived from pericratonic rocks to east
Middle andLateTriassic conodonts
Nicola Group: Volcaniclastic unit

Widespread, heterogeneous unit, dominated by volcanic sandstone, conglomerate and breccia. Also includes pyroxene-feldspar-phyric basalt, volcanic breccia, limestone, siltstone, chert. Scattered Late Triassic (mainly Carnian) macrofossils and conodonts. Interfingers? with upper part of Lemieux Creek unit.
Nicola Group: Basalt – Breccia unit

Pyroxene-phyric basalt, pillowowed basalt and basalt breccia
Locally includes feldspar-pyroxene sandstone, and limestone
Nicola Group: Polylithic breccia unit

Uppermost unit, exposed mainly on west side of Takomkane Batholith

Mainly polylithic breccia, conglomerate and feldspathic sandstone; breccias contain feldspathic plutonic and volcanic fragments

Locally includes pyroxene-phyric basalt

Commonly red

Late Triassic age constrained by underlying successions and cross-cutting Late Triassic plutons
Subdivisions of the Nicola Group have regional significance – eg. can be traced northward through the entire 93A map sheet.

(Source: BCGS 2009 Quest compilation map)
Plutonic suites

Quesnel Terrane: 5 suites, Late Triassic to Early Jurassic
+ Early Cretaceous granodiorite and granite
Quesnel Terrane
plutonic rocks

Early Jurassic granodiorite

Late Triassic monzodiorite

Early Jurassic pyroxenite and diorite
Mineral Occurrences

Most associated with plutonic rocks

All plutonic suites mineralized (but to varying degrees)
Mineral occurrences associated with Late Triassic monzodiorite suite

- Alkalic Cu-Au porphyry
- Cu-Au skarn
- Disseminated, fracture-controlled Cu (Au)
- Late Triassic monzodiorite, diorite, monzonite
Mineral occurrences associated with Early Jurassic granodiorite of Takomkane and Thuya batholiths.
Mineral occurrences associated with Early Jurassic ultramafic-mafic, diorite and quartz monzonite suites
Mineral occurrences associated with Early Cretaceous granitic rocks.
Summary of mineralization associated with different plutonic suites

<table>
<thead>
<tr>
<th>Time (Ma)</th>
<th>Event</th>
<th>Minerals/Mineralization</th>
</tr>
</thead>
<tbody>
<tr>
<td>245</td>
<td>T</td>
<td>quartz monzonite</td>
</tr>
<tr>
<td>200</td>
<td>J</td>
<td>monzodiorite, monzonite, diorite</td>
</tr>
<tr>
<td>145</td>
<td>EK</td>
<td>granodiorite</td>
</tr>
<tr>
<td>98</td>
<td></td>
<td>Porphry, Skarn</td>
</tr>
</tbody>
</table>

*Dissemination, stockwork; (may be part of porphyry system)*
Magmatic patterns in southern Quesnel Terrane

Plutonic suites and spatial patterns of Takomkane-Thuya area continue to south

Important mineral camps associated with Late Triassic monzodiorite suite

Newly discovered Woodjam SE zone suggests that Early Jurassic suite also has significant potential
Mid-Cretaceous Bayonne magmatic belt intersects Quensel Triassic-Jurassic magmatic belts in Thuya-Woodjam map area – adds potential for Mo-W porphyry and skarn occurrences.