Final Report

SOUTHERN BRITISH COLUMBIA – CANADA

Metallogenic and Geodynamic Cordilleran Field Trip

July 5-18, 2010

Organized by the SEG Student Chapters:
University of British Columbia (UBC) & University of Western Australia (UWA)

Chalcopyrite vein with potassic-altered(biotite-K-feldspar) selvages, Copper Mountain.

Thank you to our generous supporters and field guides:

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Dr. Lee Groat, UBC
Dr. Kelly Russell, UBC
Dr. Margot McMechan, GSC-Calgary
Dr. Barry Richards, GSC-Calgary
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Copper Mountain Mining, Peter Holbek, Mark Rein

Barrick Gold, Dwight Herbison

Teck, John Thompson, Suzanne Belanger, Samual McGeorge, David Endicott, Gerald Grubisa

Bralorne Gold Mines, Bret Armstrong

The Snaza'ist Centre, Brenda Gould
The Burgess Shale Foundation, Paul McNeil

Disclaimer: This report is a shared effort of the UBC and UWA SEG Student Chapters. Each student participant on the field trip wrote a section of this report, which was then compiled and edited by K. Rasmussen. Accuracy of the information reported cannot be guaranteed.

Executive Summary

Seven undergraduate and graduate students from the University of Western Australia (UWA), and 4 graduate students from the University of British Columbia (UBC) took part in a 2-week metallogenic and geodynamic field trip across the southern British Columbia (BC), from Vancouver to Calgary, and back. The trip started off with 2 presentations at UBC, followed by a group dinner. Dr. Jim Mortensen introduced all the participants to the tectonic and metallogenic evolution of the Canadian Cordillera, and Dr. Thomas Bissig explained the current state of knowledge on alkalic Cu-Au porphyry systems in BC. The next morning we left for the first tour: Copper Mountain, a historic alkalic Cu-Au porphyry mine, near the town of Princeton, that is currently undergoing advanced exploration in anticipation re-opening in the near future. Peter Holbek, VP Exploration for Copper Mountain Mining, provided the group with lunch and an excellent overview on the geology and exploration history of the Copper Mountain deposit. Assisted by Mark Rein, Minor Geologist, Peter led the group on a tour of several pit walls supplemented with mineralized core from nearby drill holes. That evening in Penticton, we were joined by Dr. Lee Groat from the University of British Columbia, who gave a post-dinner presentation on the geology and regional setting of gold skarn mineralization in the Hedley mining district, with a focus on the historic Nickel Plate and Mascot Au-skarn mines. The following morning, after driving up Apex Mountain, the group (now including Peter Holbek and Mark Rein) was treated to an overview of the Nickel Plate open pit and water remediation plant (formerly the mill) by Dwight Herbison, Site Manager for Barrick Gold, and a tour of the restored Mascot Mine historical mine site and underground mine by Brenda Gould, Archaeology Manager for the Snaza'ist Centre. After thanking our hosts for the previous day and half, the students continued on to Kelowna where the day was concluded with a wine tasting and some big purchases at the Cedar Creek Winery. The next tour on the trip was the Trail Metallurgical Plant and Applied Research & Tecknology Centre (ARTC), where we received two excellent presentations: by Suzanne Belanger on the zinc smelting operations, and by Nicki McKay on the ARTC. A thorough tour of the sweltering Zn processing and ARTC facilities was aided by Rachel Moore, Art Pithayachariyakul, Greg Richards, Mike Heximer, and Maura Malone of Teck. After the first of several nights as the only guests of a cozy hostel in the small mountain town of Rossland, we departed for a day-trip to Metaline Falls, Washingston State, where Samual McGeorge (Chief Geologist), Warren Dunbar (Chief Mine Geologist), and Heather Vanstrydonk and Dave Eggerton (Mine Geologists) for Teck welcomed us to the Pend Oreille MVT Pb-Zn mine site. After an overview of district and mine geology by Dave, we were split into 2 groups and driven underground to see Pb-Zn mineralized, optically continuous calcite-cemented breccias. Back on the surface, we were treated to a display of polished hand specimens and core labelled with Pb-Zn grades, and a pile of exceptional take-home samples from which everyone collected a piece or two. Our return to Canada in the evening was celebrated with a “meat-fest” BBQ on the back patio of the hostel in anticipation of a restful weekend. Saturday consisted of a leisurely morning tour of the historic Le Roi Au mine site and the adjoining Rossland Tourist Centre, lunch in the unique former Ag-mining town of Nelson, and a soak at the Ainsworth Hot Springs pools. On Sunday we departed Rossland for Cranbrook, where we split into 2 groups, one to stay and watch the World Cup Final match and the other to drive to the natural Lussier Hotsprings in

White Swan Provincial Park for some soaking in the pools and dunking in an icy cold river, before continuing on via backcountry logging roads to rendezvous in Fernie, Alberta (AB). The start of our second week on the road began with a visit the Elkview metallurgical coal mine on a particularly windy day just outside of Sparwood. David Endicott, Senior Geologist for Teck, met our group at the gates and spent a couple hours explaining the depositional and structural setting of several stacked coal beds while looking at outcrops of the stratigraphic sequence, and overlooking the open pit. A quick visit to the ore piles where several grades of coal are stacked proved to be a very dirty, but interesting, last-minute stop. After our tour of Elkview, we had lunch at the Frank Slide, where the town of Frank was buried in 1903 after a massive spring rockslide and avalanche off Turtle Mountain. From the interpretative centre, we were fully able to marvel at the 'side' of the mountain that came down on the town and spread across the valley, and the sheer size of some of the larger rocks adjacent to the highway. That evening, the group arrived in Banff, AB, for another multi-night stay. Early the next morning, we assembled and drove an hour to the village of Field, BC, in Yoho National Park, to meet our guide, Dr. Paul McNeil of the Burgess Shale Foundation, for the day's hike up to the Burgess Shale - Walcott Quarry, a UNESCO World Heritage Site. Although the weather proved to be somewhat difficult, and the views were limited by freezing rain-sleet-snow and fog, exploring the shale quarry and seeing real examples of many of the different life forms that have been found there since its discovery in 1910 was well worth the 10-km climb through the trees to the alpine. The following morning, we met Dr. Margot McMechan and Dr. Barry Richards of the Geological Survey of Canada, and started a full day-tour of the Foreland Belt. Margot and Barry led the group from the start of the foothills, in Cochrane, into the Rocky Mountains, along the way explaining the sedimentological and deformation history with a focus on MVT mineralization with several road-side stops. The tour concluded at Mount Field with a scramble up a scree slope to the base of massive carbonate cliffs into which several historic adits have been driven on both sides of the valley, and where a hunt for the biggest, best piece of massive sphalerite continued until practicality forced us to reluctantly return to Banff for the night. After our tour with Margot and Barry, we had a basic understanding of Foreland Fold and Thrust Belt geology and were able to carry on the next day alone, visiting the Foreland Belt road-side stops detailed in the Geological Association of Canada's " A Transect of the Southern Cordillera" guidebook. We met Bruce Madu, British Columbia Geological Survey, in Revelstoke and finished the day with an introduction by Bruce on the geology of the Omineca Belt and a series of road-side stops until we reached our destination for the night: several train cabooses converted into bunkhouses on Okanagan Lake in Squilax. Here, 2 additional students from UBC joined us for the remainder of the trip, for a total of 13 students. After a big pancake breakfast, we proceeded down the road to Highland Valley open pit Cu-porphyry mine where Gerald Grubisa, Senior Mine Geologist, orientated us to mine site safety and geology, and then drove us around in a tour bus to visit several stops in the blinding-white phyllic-altered Valley pit, and to a point overlooking the Lornex pit. Continuing on our drive for the remainder of the day we visited several more road-side stops with Bruce in the Intermontane Belt and arrived in Bralorne after a very long Friday on the road: tired, hungry, and ready to teach Bruce how to dominate at the local pool table. The following morning, a very short drive down to the Bralorne Au-vein mine site, which is currently undergoing active exploration drilling, led us to the door of Bret Armstrong, Mine Geologist for Bralorne Gold

Mines. Bret gave us the details of the orebody size and shape, discussed the historic underground mines that comprise the Bralorne deposit. A quick tour of the mill, followed by an extended visit to the mill stockpile (where several sharp eyes found VG!) concluded our visit. After a quick lunch at the local greasy spoon, we were on the road again. Bruce left us in Lillooet and from there we continued on our own through the spectacular Coast Belt, with a stop at Duffy Lake to admire the scenery, and over the Cayoosh Pass into the Pemberton Valley. The final day of our field trip began at the gas station in Pemberton, where we met Dr. Kelly Russell and post-doctoral fellow Marion Carpentier (UBC). After a quick overview of Coast Belt geology, the Cascade Arc, and recent geo-hazards in the Pemberton Valley by Dr. Russell, we were on our way down the busy Sea-to-Sky Highway, stopping at several key locations along the way and marvelling at the beautiful columnar-jointed basalt flows and incredible west coast scenery. Upon reaching Vancouver, the tour was concluded with dinner and drinks at the same brewery where we had started the trip, and plans for future collaborative efforts between the UBC and UWA SEG Student Chapters were made before reluctantly saying good-bye and dispersing.

The Tantalus Mountain Range, Coast Mountains. Left to right, **back:** M. Waugh, S. Terwindt, B. Dingli, P. MacDonald, J. Smith, E. Bordet, S. Vaca; **front:** Dr. K. Russell, K. Rasmussen, A. Razique, B. Hames, M. Trivanovic, D. Mole, S. Martin , M. Carpentier

The UBC and UWA SEG Student Chapters would like to gratefully thank the trip sponsors whose donations made this field trip feasible for the students, the presenters and tour guides that contributed so much to our understanding of Cordilleran geology, and the mining and exploration companies and their staff that generously allowed us access to their properties and acted as very receptive and informative hosts.

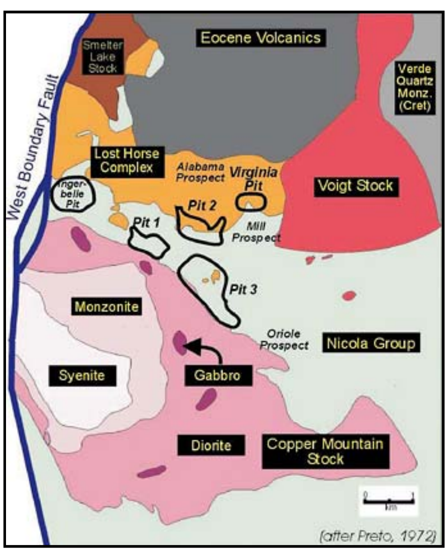
Monday, July 5

On the afternoon of Monday, July 5, members from the two SEG Student Chapters met for the first time at the University of British Columbia (UBC) for two, pre-fieldtrip presentations. Dr. Jim Mortensen gave a very detailed overview on Cordilleran geology, covering the geodynamic evolution of the Canadian Cordillera with a focus on the timing and setting of major metallogenic events. Dr. Thomas Bissig followed with an excellent presentation on alkalic Cu-Au porphyry systems in British Columbia. The group re-convened at a local, downtown Vancouver brewery and restaurant to celebrate the start of the 2-week field trip and to get to know each other better.

Tuesday, July 6: Copper Mountain Alkalic Porphyry Cu-Au Deposit

by Abdul Razique

The first tour of the trip was at the Copper Mountain open pits and advanced exploration project just outside of Princeton, ~4 hours drive from Vancouver. Copper Mountain is a silica-undersaturated, alkalic, Cu-Au porphyry deposit located in the northerly trending Quesnel terrane (Quesnellia) of the Canadian Cordillera. Quesnellia is an island-arc terrane, possibly underlain by rifted radiogenic North American basement, that is largely defined by the cohesive distribution of extensive andesitic volcanic rocks (and related plutons; e.g., the Copper Mountain Stock) and sedimentary rocks of Late Triassic Nicola Group, not present on North American rocks of the Cordillera. Along the length of Quesnellia, the Nicola Group has been intruded by early Jurassic mafic alkalic and calc-alkalic plutons and batholiths, which at Copper Mountain includes the alkalic Lost Horse Complex of diorite-monzodiorite and syenite. The Copper Mountain deposit is hosted in Nicola Group volcanic rocks (mafic-intermediate volcanic flows, flow breccia, and felsic-intermediate tuff and fragmental breccia) and centered on cluster of porphyry intrusions of the Lost Horse Complex.



Generalized geology map of Copper Mountain area.

Presentation on Copper Mountain geology, and exploration and mining history by Peter Holbek.

Porphyry Cu-Au mineralization is associated within bornite ± chalcopyrite ± pyrite ± magnetite bearing veins and veinlets. Cu-sulfide mineralization in these veins is genetically linked to the early high temperature sodic-calcic (albite-diopside-epidote-calcite) and potassic (K-feldspar-biotite-magnetite-epidote) alteration, and mineralization is mainly structural controlled with two main NE-SW and NW-SE trends defined by Au-rich massive sulfide veins. The veins are typically 1-5 cm thick and increase in intensity at the intersection of structures. Au-rich massive sulphide veins tend to dominate in structurally controlled zones of early stage potassic alteration. The geology, resource modeling combined with new geophysical signatures of induced polarization (IP) chargeability indicate the extent of mineralization to depths of at least 1000 m, and possibly deeper.

Historically, from 1923-1957, the Copper Mountain deposit was mined underground, and a total of 31.5 Mt of ore @ 1.08% Cu was extracted from the Pit 1 and Pit 3 areas. Based on an up-to-date resource calculation by Copper Mountain Mining Corporation (CMMC) in 2009, the Copper Mountain deposit contains proven and probable reserves of 211.1 Mt @ 0.36% Cu (or, 1.7 Blbs Cu). A more recent resource calculation based on 4,400 historical drill holes (400,000m) and 370 drill holes (107,000m drilling) by CMMC estimated 5 Blbs Cu @ 0.15% Cu cut off grade. The CMMC, in a joint venture with Mitsubishi, is planning to merge the existing pits to create an "super open pit", and to construct a new 35,000 t/day Cu concentrator. The reopening of mine will produce around 100 Mlbs/year Cu concentrate, with Au and Ag credits. The project is projected to produce 1.47 Blbs Cu, 452 000 oz Au, and 4.5 Moz Ag over a mine life of 17 years, and future mine development includes the a new mill with power supplied by the existing 138 kV power line.


Peter Holbek explaining the calc-sodic altered south wall and drill core from Pit 3.


Looking north over Pit 3.

The day concluded with a drive to Penticton, where the group and Peter met Dr. Lee Groat from the University of British Columbia for dinner, followed by cold drinks (courtesy of Peter) and a presentation by Lee projected on an outdoor patio wall introducing the Nickel Plate-Mascot mine geology in preparation for the next day's tours.

Wednesday, July 7: Nickel Plate Au-Sb Skarn & Mascot Au-skarn Historic Mines
by Ben Dingli

The group drove up Apex Mountain on a warm and clear morning to visit the Nickel Plate Au-Sb-skarn historic mine and Mascot Au-skarn historic mine. Apex Mountain lies in the Hedley mining district, Quesnellia, which straddles the eastern tectonic edge of the Late Triassic Nicola back-arc basin where basement rifting controlled the geometry of the basin margin, easterly derived sedimentation, and deposition of several economically important sedimentary facies. The Hedley mining district has two main skarn deposits types, one of which comprises economically important Au-skarns such as Nickel Plate. The Nickel Plate deposit is a typical reduced type Au-skarn system, as demonstrated by high pyrrhotite/pyrite in the mineralization and low Fe_2O_3/FeO ratios of the associated intrusions.

The Nickel Plate and Mascot Au-skarns are genetically and spatially related to Late Triassic diorite-gabbro stocks and dike-sill swarms of the Hedley suite of intrusions. Economic Au-skarns appear to be hosted only in the Nicola Group island-arc volcanic and sedimentary rocks, and on both a district and mine scale are structurally, stratigraphically, and lithologically controlled. Mineralization favours areas where the Hedley intrusions cut the calcareous, shallower marine sedimentary facies of the Hedley Formation, and are absent in the deeper water sedimentary rocks of the Stemwinder Formation. The underlying Paleozoic to Triassic Apex Mountain Complex (an obducted ophiolite?) underwent two deformational episodes resulting in tight minor folding and sub-vertical open folds, which at Nickel Plate are believed to have partly controlled the Au-skarn mineralization. Economic Au mineralization is has been found to be almost wholly confined to exoskarn. The overall grade of all the Au-skarn deposits in the district is approximately 7.4 g/t Au, and it was suggested that the mine may still have economic ore left in it, which may be appealing to junior exploration companies in the near future if the price of Au continues to climb.

Nickel Plate derives its name by the colour and lustre of the ore mineralization, with Au dispersed primarily within arsenopyrite. The mine reopened in 1978 after a boom in the Au price and continued production until 1996, when mining and milling operations ceased and the mill was converted into a water treatment plant. In 2002, Barrick Gold took control of the operation and continued the environmental remediation process, which will be continued for the next several years. Upon meeting Dwight Herbison, Site Manager for Barrick Gold, we took a ride in the back of some pickup trucks and enjoyed the scenic and precarious drive up to the Nickel Plate open pit. Dwight explained the mining and processing procedures of the mine, both in production and in remediation. The Nickel Plate deposit was mined in 20 ft benches, and an average of 15 000 t/day was mined with a 9:1 ore to waste ratio. The ore was processed through a 4000 t/day mill with feed grade averages of 0.08 oz Au/t, yielding 85 000 fine oz of Au/year.

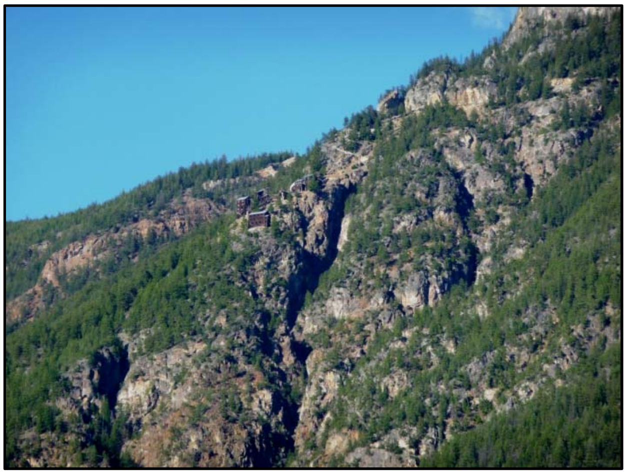
After viewing the open pit (and it's resident mountain goat family), we visited the mill (now a water treatment plant) and were able to get some great samples of mineralization from the adjacent waste rock dump, where plentiful pyrrhotite revealed how the mine got its name. Dwight further explained the new technology used in the water treatment plant, including the use of biological processes for tailings purification. This ‘biological water treatment process’ uses microorganisms, including bacteria protozoans and rotifers, to withdraw nutrients from the water (oxidising thicyanate, cyanide, and ammonia) and producing cell mass, which then is collected and allows for the treated water to exit the system.

Looking west into the Nickel Plate Au open pit.

Dwight Herbison (far right) describing the pit geology.

The former mill and current water treatment plant.

Once everyone had as many skarn samples as we could carry, we drove down a winding dirt road perched on the side of the mountain to Historic Mascot Au Mine which overlooks the magnificent Similkameen Valley. We were able to explore the original mine buildings built 1 km above the valley floor on a razor-back ridge! Our guide from the Snaza'ist Centre, Brenda Gould, talked us through the mine’s history and production, starting with staking of the “Mascot Wedge”, a sliver of ground that had been missed in a staking rush and reputed to be one of the richest claims in the district, by prospector Duncan Woods. The mine operated from 1936 to 1949, had up to 130 men working there at a time, and extracted 7.1 t Au. Our group was also shown the 1433 meters of tram line used by the site to transport married men from the valley floor (single men had to live in the bunkhouse on site) to the mine, and got to walk through a brief section of the underground workings. After appreciating the spectacular views and beautifully restored buildings, we began the slow and difficult climb back up the 589 stairs, motivated by the anticipation of cold chardonnay awaiting us at the Cedar Creek Winery in Kelowna.



The historic Mascot Au Mine, perched 5000 ft above the Similkameen Valley.

Looking from the blacksmith shop (foreground), to the cookhouse, the smaller miner's dry, and the white tramline wheelhouse.

Thursday, July 8: Trail Metallurgical Plant and Applied Research & Tecknology Centre
by Ben Hames

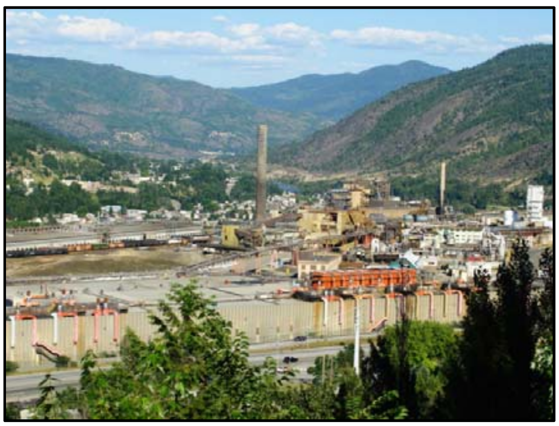
A sweltering day was the setting for our visit to Teck's Trail smeltering plant. The Trail operations are one of the largest integrated Pb-Zn metallurgical plants in the world, and at 295,000 t/yr of Zn produced, it is not hard to believe! While 2% of the western world Pb production is produced at the Trail Smelter, the focus is on Zn, and so was our tour. Suzanne Belanger met us at the entrance to the facility and guided us to a presentation room where we received a detailed overview on the Zn smelting process. Following the presentation, the group was divided into 2, and Rachel Moore and Art Pithayachariyakul took us around to visit several of the processes described in the presentation.

The Zn extraction process is known as the Roast-Leach-Electrowin (RLE) process. The process begins by oxidation of crushed ore – Zn sulphides (sphalerite) – to produce a Zn oxide referred to as Zn calcine. This oxidation is done in a 'roaster' at close to 1000°C, the size and temperature of which we were able to appreciate during Greg Richards' great, but stifling tour of the roasting processes. The reaction releases sulphur according to:
$2\ ZnS + 3\ O_2 \rightarrow 3\ ZnO + 2\ SO_2$

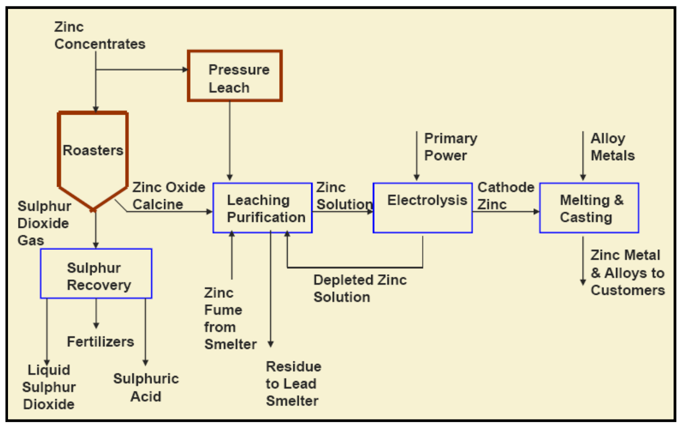
Conveniently, Trail Operations has an attached fertilizer production plant, thus excess sulphur is not wasted, and is also sold. The Zn calcine is highly impure, and contains significant iron as well as other impurities. Thus further purification is required. This involves several stages of sulphuric acid leaching at various strengths of acidity, as well as processing with Zn dust and steam. These processes, explained to us at the calcine plant by Mike Heximer, remove almost all impurities and produce Zn sulphate solution according to:
$ZnO + SO_3 \rightarrow ZnSO_4$

The highly pure Zn sulphate solution is then separated by electrolysis. This process (indeed the entire extraction process) is very demanding on electricity, and hydroelectric dams built on the property in the 1940's and 50's are a source of cheap power. We were also able to visit the (air-conditioned!) electrolysis plant where Maura Malone explained to us that as electricity is passed through the solution, Zn is deposited on the cathode, which is regularly 'scraped off'. Sulphuric acid produced in the process is used in the leaching process. The Zn is melted and cast into ingots and bars of various masses according to market demand. Approximately 75% of this demand is in North America.

Also on the property is Teck's Applied Research & Tecknology Centre (ARTC), where Nicki McKay filled us up with cold pop and cookies and gave a presentation, followed by an excellent tour of the facilities. Many aspects of research are conducted here, including miniature versions of crushers/millers to predict rock breakage, froth characterisation and optimisation, and applied mineralogy. The ART Centre at Trail has two specially equipped SEMs, with Mineral Liberation Analyser (MLA) software allowing for an automated mineralogical analysis of polished sections and pucks.



Looking east over the Trail Smelter.



Flow chart of Zn extraction process.

Friday, July 9: Pend Oreille Pb-Zn MVT Mine

by David Mole

On day 5 of the field trip, our group nipped over the border to northeastern Washington State, USA, to visit the Pend Oreille underground Pb-Zn MVT mine. There we met Samual McGeorge (Chief Geologist), Warren Dunbar (Chief Mine Geologist), and Heather Vanstrydonk and Dave Eggerton (Mine Geologists) of Teck, who were to show us around for the morning.

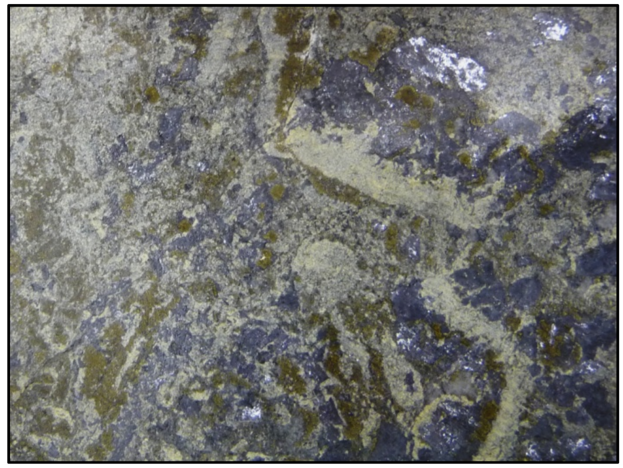
The Pend Oreille mine is a low temperature, stratabound, epigenetic carbonate-replacement deposit hosted by the Upper Cambro-Ordovician Metaline Formation, a carbonate shelf limestone. The Metaline Formation is at least 1800 m thick, it conformably overlies shales of the Maitlen Formation, and is in turn overlain by black carbonaceous siltstones of the Ledbetter Formation. A series of MVT deposits and occurrences form part of the Kootenay structural belt, from northeastern Washington into BC where it is found west of the Purcell anticlinorium. The host rocks have undergone several deformation events and are metamorphosed to lower greenschist facies. As per the MVT model, this deposit is inferred to have formed from low-temperature, saline brines at the edge of the rifted continental margin to ancestral North America. Saline brines followed permeable layers, leading to brecciation and alteration of the host rocks that are then mineralized with ongoing fluid activity. Multiple phases of faulting, brecciation, and precipitation have led to further fluid flow and ore formation and remobilization.

The Metaline Formation was originally divided into lower, middle, and upper members, although late diagenetic processes have modified the lithofacies. Two main mineralization horizons occur in the Metaline Formation: the Fe-poor Josephine horizon, which is hosted by the upper member; and the higher grade, Fe-rich Yellowhead horizon, which is hosted by the middle member several hundred metres below the Josephine horizon. The Josephine ore is hosted largely in the fragmental bioturbated limestone Josephine lithofacies, and the Yellowhead ore mainly a bedded sub-peritidal dolostone lithofacies. However, despite strong associations with certain lithofacies, both ore-types cut diagenetic lithofacies boundaries and are clearly younger. The Josephine horizon comprises primarily breccias containing angular fragments of Josephine and other lithofacies in a matrix of optically continuous calcite, with local concentrations of coarse-grained red-brown sphalerite and very little galena. The Josephine orebodies are up to 1000 m long, 40 m thick and 100 m wide. Pyrite, galena and sphalerite occur in a 1 : 10 : 70 volume ratio. The Yellowhead horizon was named for its high pyrite content and honey-yellow sphalerite, and typically has high galena contents. Yellowhead mineralization is relatively fine-grained and typically botryoidal, and has pyrite, sphalerite, and galena volume ratios of 1 : 0.1 : 0.01. Pend Oreille is one of the few deposits that contains both the Fe-poor and Fe-rich types of MVT mineralization.

After a short presentation by Dave outlining the regional and mine geology, mineralization, mining techniques, and logistics, we geared up for an underground mine tour. For many of us this was our first trip underground and donning the weighty safety gear was daunting and cumbersome, with numerous people (including myself) becoming tangled in the headlamp cable as we attempted not to look like complete novices. After splitting into 2 groups, we piled into SUV’s and drove down to the Josephine horizon, where we walked along one of the old drifts to look at some of the textures in the ore, including multiple phases of fluid activity, faulting and brecciation. Mineralization was visible as clusters of crystalline sphalerite with lesser galena and accessory pyrite.

Next we headed up to the core shed where we could look at and compare the Josephine and Yellowhead ore types. Our guides had kindly placed core, hand and type specimens on display for us to look at, labelled with the Pb-Zn-Fe grades, and there was even a ‘take home’ pile, which we were all really excited about! Finally, Warren took us to the office and showed us a number of mapping methods used to constrain and document the mineralization; contour mapping by grade clearly showed the distribution of the ore, allowing the complex geometry of ore shoots to be unravelled and followed at depth.

Optically continuous, Pb-Zn mineralized calcite breccia in the Josephine horizon.



Galena- and pyrite-rich ore from the Yellowhead horizon (pale yellow = sphalerite; bronze = pyrite).

Saturday, July 10

After several days on the road rushing to arrive for our tours on time, a leisurely weekend was planned, starting with a mid-morning tour of the historic Le Roi Au-vein mine in Rossland where we learned about the history of mining in the Rossland-Trail area and toured the historic mine site and museum. Afterwards, we piled into our vans for the short drive to our lunch destination: picturesque Nelson, a former Ag-mining and logging town that has successfully transitioned into an arts and cultural centre, providing a mountain haven for its mixed population of hippies, draft-dodgers, unemployed sawmill workers, and rich yuppies. After spending a couple hours wandering around the streets of Nelson, we continued driving north along Kootenay Lake for a soak in the Ainsworth Hot Springs where several developed pools are fed hot water from a dramatically lit, sauna-esque horseshoe-shaped cave filled with waist-deep water.

Sunday, July 11

On Sunday, we left our cozy hostel in Rossland and drove from the Monashee Mountains through the Selkirk and Purcell Mountains to Cranbrook, where we had a quick lunch stop and split into 2 groups: one to stay in Cranbrook and watch Spain win the World Cup Final match against the Netherlands, and the other to drive north to White Swan Provincial Park for a soak in the natural Lussier Hot Springs and multiple dunkings in the adjacent icy cold river. The group rendezvous'd in Fernie, Alberta (AB), in the Rocky Mountains for the night, refreshed after a great weekend of hot springs, soccer, wildlife, and adventure on backcountry logging roads.

Spain wins the World Cup, 2010.

Soaking in Lussier Hot Springs.

Monday, July 12: Elkview Metallurgical Coal Mine + the Frank Slide

by Stephanie Terwindt

We visited Elkview Coal Mine on Monday the 12th of July which was about halfway through our trip. The mine is located 3km east of Sparwood and has been owned and operated by Teck since 1993. There are 2 main areas of the Elkview mine. The southern part of the property has undergone extensive underground mining, but was shut down during the 1980's. The north side of the property was set up as an open pit mine in 1968 and is still in operation today. If prices for metallurgical coal remain economic, the Elkview Coal Mine should remain operating for at least 40 years. There is also the potential to increase the ore reserves by 60 Mt, bringing the total ore reserves for the area to 300 Mt.

David Endicott, Senior Mine Geologist, found the time to take us through the mine as well as showing us some of the geology of the mine and the surrounding area. We began our tour at the base of the stratigraphic succession that hosts the coal seams. The Mount Moose massive quartzo-feldspathic sandstone is a prominent unit that is used to indicate the base of the coal seams. The coal beds are overlain by a thick conglomerate deposit that marks the top of the stratigraphic section. The stratigraphic sequence at Elkview is thought to have formed in a deltaic setting in the inland sea that covered much of central North America during the Cretaceous, and it is believed that the termination in coal accumulation is the result of uplift related to large-scale compressional deformation along the western ancestral margin of North America.

Overlooking the open pit, through the haze of coal dust we could just make out many of the coal seams in the pit walls (there are up to 30 coal seams in the thrust-repeated package), and where the coal beds had been thickened by deformation. Most of the coal produced at Elkview Mine is high grade, with optimal volatile and sulphur contents; it typically has to be mixed with lesser quality material in order to burn properly in clients' furnaces. However, coal from the southern end of the property is of lower quality and is mostly used for thermal coal.

Overall, the visit to Elkview Coal Mine was very informative and fun. We came away from our tour realising that environments of deposition and structural complications can make coal mines particularly interesting, as well as with a few choice samples of ore and covered in a thin layer of black coal dust.

David Endicott explaining the environment of deposition for the coal seams at an outcrop of the massive Mt. Moose Formation sandstone.

Thrust-stacked, repeating coal seams (visible in the pit wall dipping to the right) has led to localized thickening of coal seams, allowing for profitable open pit mining.

After our visiting Elkview, the group carried on down the highway to stop for lunch at the Frank Slide, the site of a massive spring rockslide and avalanche off Turtle Mountain in 1903 that partially buried the town of Frank and obstructed the railroad. From the interpretative centre, we were view the entire valley floor covered with boulders (many larger than a house!) and the massive hole in the side of Turtle Mountain.

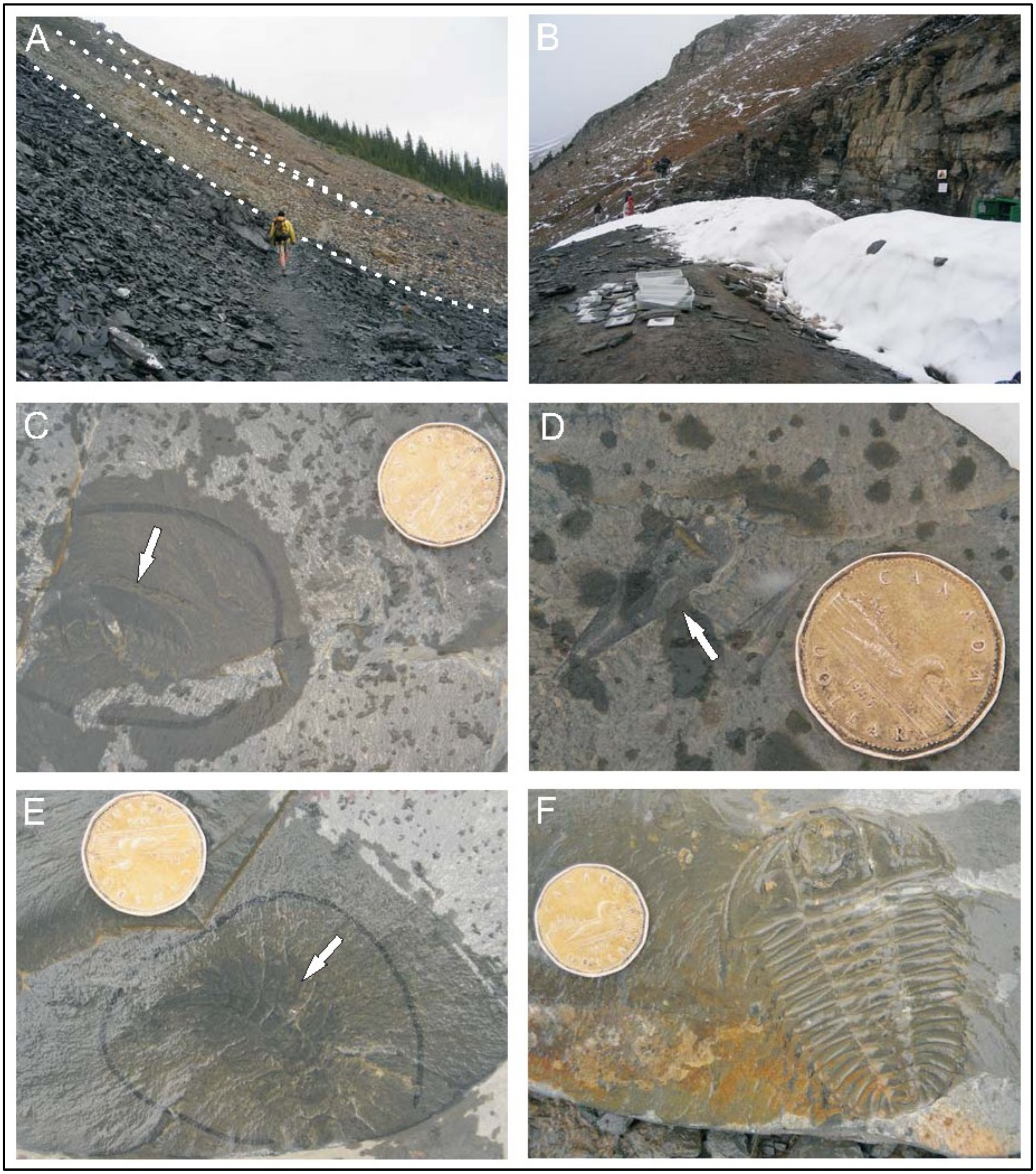
Site of the Frank Slide.

Turtle Mountain.

Tuesday, July 13: Burgess Shale

by Peter MacDonald

A highlight of the field trip was a guided excursion to the world renowned Burgess Shale, a UNESCO World Heritage Site. The hike was guided by Dr. Paul McNeil and commenced near Takakkaw Falls and concluded at the Walcott Quarry. The scenic return trip is approximately 20 km, return, with an elevation gain of 760 m. The first 2 km of the hike are dominated by a series of switch backs that gain nearly one-third of entire hike's the elevation. The grade of the trails then decreases to a comfortable incline, passing by Yoho Lake at ~4.5 km, and then into subalpine forest at ~6 km. The subalpine portion of the trail traverses multiple talus slopes and is highlighted by a beautiful view of Emerald Lake to the southwest. At approximately 8.5 km, the trail passes into the alpine and climbs a final series of switchbacks up to the Walcott Quarry.



Selected photographs from, or near the Burgess Shale - Walcott Quarry, including: (A) Fault interfingered Eldon and Stevens formations contact (Paul McNeil for scale); (B) the Walcott Quarry; (C) Anomalocaris; (D) Haplophrentis; (E) Leanchoilia; and (F) Olenoides.

Bedrock is only observable once into the subalpine. The trail transects down the stratigraphy as it climbs, which is a feature related to a NW-trending anticline. The first unit observable on the trail is the Eldon Formation, which is composed of light to dark grey massive limestones and mottled dolostones. The trail then passes over the Stephens Formation, which lies stratigraphically below the Eldon Formation and is composed of beige siltstones. The contact between the Eldon and Stephens Formations is structurally complicated by a series of small interfingering faults. The Stephens Formation continues for the remainder of the trail and is host to the Burgess Shale.

The Burgess Shale was deposited in the Cambrian Period and is important due to its preservation of the Cambrian "explosion of life". Although is it only one of 12 known sites in the Canadian Rockies, and one of over 40 sites around the world that where this "explosion of life" is preserved, the Burgess Shale remains the most significant due to its level of preservation, its biodiversity, and what it has taught about evolution. The Burgess shale owes its fame to the Cathedral Escarpment. It is thought that most of the fossils originated on the Cathedral Escarpment, as no trace fossils exist in the shale, and were transported down into the shale by landslides/slumping off the escarpment above. The landslides not only transported the fossils down, but also caused rapid burial. This rapid burial, along with an anoxic environment of deposition, enabled the remarkable preservation of the soft bodied organisms. The biodiversity of the Burgess shale is easily observable, and includes many species that having living relatives on earth today as well as many species that have gone extinct, including the possible ancestor to all vertebrates: *Pikaia*. Our group was shown numerous different organisms from the Walcott Quarry. Some of the more spectacular specimens included *Anomalocaris, Canadaspis*, *Haplophrentis*, *Leanchoilia*, *Marella*, *Olenoides*, *Ottoia*, *Sidneyia*, *Waptia*, and *Wiwaxia*, as well as numerous inarticulate brachiopods and various Cambrian plants.

At the end of our journey to the Burgess Shale, a few things about evolution were obvious. Life on Earth has always had great disparity between different organisms, continuity of life is somewhat related to luck, and the tree of life is actually a bush.

Wednesday, July 14: The Foreland Belt (Foothills, Front Ranges, and Eastern to Western Main Ranges)

by Kirsten Rasmussen

Our day with Dr. Margot McMechan and Dr. Barry Richards from the Geological Survey of Canada Calgary office began with a quick breakfast and coffee in Cochrane over the "triangle zone" that defines the western limit of exposed Cordilleran deformation, followed by a short drive west to Nicholl's Ridge behind Barry's home. Nicholl's Ridge, or "Pile of Bones Hill" is the second thrust into the foothills and comprising Oxfordian (Jurassic) basinal rocks deposited as several sequences of clastic ridges. Here, Margot gave us a brief overview of the basic construction of the Foreland Belt, which began with rifting of basal Archean to Mesoproterozoic crystalline basement (resulting in westward thinning of the basement). Thinned crystalline basement was then overlain by westward thickening packages recognized along the length of the Canadian Cordillera: (a) the Neoproterozoic Windermere Supergroup (clastic basinal rocks), (b) platform (east Foreland Belt) and basinal (west ForelandBelt) miogeoclinal or passive margin sedimentation through the Cambrian to Permian and earliest Triassic, and (c) a Triassic to Middle

Jurassic influx of siliciclastic sediments. Deformation of these sedimentary packages into a thin-skinned fold and thrust belt began during the accretion of the Intermontane Terrane(s) to the ancestral western margin of North America. An eastward migrating foredeep comprising the Upper Jurassic to Tertiary syn-orogenic clastic wedge eroded from the evolving fold and thrust belt caps the Foreland Belt sequence. Several clastic cycles in this package involve thick marine black shales and thick non-marine coastal plains sands with dinosaur bones and coal seams. These include the trough-cross-bedded channel fill deposits exposed on Nicholl's Ridge.

Dr. Margot McMechan explaining the geometry of the nearby Foothills Triangle Zone from Nicholl's Ridge.

Our second stop of the day was the Mount Yamnuska viewpoint. Here, the McConnell thrust, first recognized by R.G. McConnell in the late 1800's, daylights in Mount Yamnuska at the boundary between the Foothills and the Front Ranges. The McConnell thrust extends over a strike-length of ~480 km and has a maximum displacement of ~40 km. It has displaced highly deformed Middle Cambrian Eldon Formation carbonate rocks over top of syn-orogenic Upper Cretaceous Belly River/Brazeau Formation clastic (sandstones and mudstone) rocks. Darker Upper Devonian carbonate rocks sit unconformably over the Eldon Formation here and together with the Eldon Formation comprise the thinnest and most incomplete Paleozoic succession observed on the transect. The Eldon Formation is notable as the host of Pb-Zn breccia pipe mineralization further to the west.

Front Ranges panoramic of Mount Yamnuska (right peak), where the 480-km long McConnell Thrust (exposed only at the tree-line under Mount Yamnuska before it bends and plunges below the surface) has displaced Middle Cambrian limestone (Eldon Formation; light grey) up to 35^{+}km and on top of Late Cretaceous clastic rocks (Brazeau Formation; treed). Darker Upper Devonian carbonate rocks sit unconformably over the Eldon Formation.

Stopping at the Portland Cement Quarry, where the grey limestones of the Upper Devonian Palliser Formation and polymetallic (Ni, Mo, Zn; possible source of the tar sands deposits in northern Alberta) black shales of the Devono-Mississippian Exshaw Formation are well-exposed, Barry provided the group with a detailed handout and then gave an overview of Pb-Zn mineralization in the Foreland Belt. Essentially, easternmost MVT-like breccia pipes in platformal rocks are correlative with deeper water SEDEX mineralization to the west. Pb-Zn breccia mineralization is focussed in two locations in the Foreland Belt: along the Cambrian Kicking Horse Rim (or the western margin of the Paleozoic platform) that includes the Kicking Horse and Monarch mines in Field, BC, and along the western margin of the White River Trough. The breccia pipes are found in the Palliser and Eldon Formations along normal faults, and are described as dolomitized limestone with calcite matrix and mineralized with sphalerite, galena, and pyrite in their upper portions (with some similarities to the Cambrian-age Pend Oreille MVT deposit that we visited earlier in the trip). Several southwest-dipping thrust splays (e.g., Lac des Arc, Rundle) on the McConnell thrust sheet have led to repetitions of the cliff-forming Palliser and Eldon formations, and are linked by down-strike small thrusts separated by transform faults that may have played a role in focussing brecciating and mineralizing fluids. Also associated with the breccia pipes in the Kicking Horse Rim are magnesite deposits (e.g., Mount Brussilof mine) replacing dolostone in the Cathedral Formation, and abundant talc deposits (e.g., the Takakkaw mine) and occurrences at the edge of the platform escarpment. The age of breccia pipe formation is unknown but is not present in rocks younger than the Devonian, and may have began as early and the Cambrian (based on Cambrian SEDEX deposits associated with MVT-like mineralization in submarine debris flows further to the west). Mineralization is related to extension, either during Cambrian rifting along the ancestral margin of North America, and/or during Late Devonian extension associated with the mid-Paleozoic Antler Orogeny when alkaline intrusions (including nepheline-syenites, "kimberlite" diatremes, and carbonatites were emplaced into miogeoclinal rocks (e.g., Ice River Complex).

Dr. Barry Richards describing the localization of MVT Pb-Zn mineralization in the Foreland Belt from the Portland Quarry.

After our stop at the Portland Quarry, we proceeded to the Castle Mountain viewpoint for a quick lunch-stop and to switch our focus back to the evolution of the Rocky Mountains. To the northeast of Castle Mountain, the Sawback Ranges are formed by near-vertical exposures of the Triassic Spray River Group sandstones overlying the Rundle Group. In the hummocky valley between the Sawback Range and Castle Mountain lies a landslide deposit of the Triassic siltstones containing well-preserved fish bones. Castle Mountain itself is formed by a Cambrian platformal sequence that is emblematic of the flat-lying Eastern Main Ranges structural province where miogeoclinal platformal rocks have become significantly thicker than their equivalents in the Front Ranges. The basal hanging wall of the Castle Mountain thrust, which merges with the Simpson Pass thrust to the southeast, is notable for the first appearance of Neoproterozoic rocks related to the rifting of the ancestral margin of North America (e.g., the Miette Group).

Turning south along Highway 93 into the White River Trough, we stopped first at Marble Canyon where the Cathedral Formation limestone is flanked by the off-shelf Tukumm Formation, or "Tongue" (equivalent to the Lower Chancellor Formation). The Tukumm Tongue is composed of several debris flows originating from the correlative Eldon Formation, which has localized examples of Pb-Zn mineralization in sedimentary (i.e., debris flow) breccias. Exposed in the cliff face above Marble Canyon are large ostiliths in an argillaceous matrix and small pockets of pyrite +/- sphalerite-(galena) mineralization. Our next stock was the Paint Pots, a Hologene ochre deposit in the valley floor and overlying the Middle to Lower Chancellor Formation, and the underlying Cathedral Formation. The ochre deposits may be indicative of significant sulphide mineralization in the underlying carbonate rocks.

The last stop at the end of our day was Mount Field (on the opposite side of the Burgess Shale deposits) where Pb-Zn deposits in the Kicking Horse Rim were discovered in 1884 and mined from 1888 through to 1952 (e.g., the Monarch and Kicking Horse mines). Here, mineralization occurs as elongate pods along the Cathedral escarpment, at the base of widespread dolomitization of the lower Cathedral Formation. Breccias, including orange-weathering dolomitized but unmineralized pipes, are visible in the cliff-faces of the Cathedral Formation and are interpreted to represent all of syndepositional, hydrothermal, and tectonic processes. Although the deposits comprise primarily galena, sphalerite, and pyrite, they were actually mined for the silver content (697,000 oz Ag were extracted from 1929 to 1949 alone). Here, we scrambled up to the base of the scree slope on Mount Field to examine the adits and banged on rocks looking for examples of Pb-Zn mineralization until we were compelled by the fading light to return to Banff for the night.

Visiting the Painted Pots mineral springs, a historic source of ochre for First Nations people and pigment for later European settlers.

Looking northwest to Mount Field where tiny adits for historic MVT mines in cliffs near the top of the scree slope where Mt. Whyte Formation (thin-bedded black limestone) is overlain by the mineralized massive lime-(grey) and dolo-(orange) stone of the Cathedral Formation.

Thursday, July 15: The Foreland (Western Main Ranges) and Omineca Belts

by Kirsten Rasmussen

After the previous day's excellent introduction to Foreland Belt geology and tour of the foothills and Front Ranges to the Rocky Mountains by Dr.'s McMechan and Richards, and armed with a pre-programmed GPS we felt confident in continuing on our own from Banff to Revelstoke. Along the way, we pulled over at the road-side stops corresponding to the Geological Association of Canada's "A Transect of the Southern Canadian Cordillera" guidebook. Without a live guide, it took us a bit of extra time at each stop to sort out exactly where and what we were really looking for, and what the significance of each stop was. Working from the start of the Eastern Main Ranges where shallow-dipping thrust sheets of Cambro-Ordovician platformal carbonate sequences dominate, we travelled through the Western Main Ranges of the Rocky Mountains, where equivalent, but penetratively deformed deeper water carbonate and shale sequences form more complexly deformed thrusted and folded packages (e.g., Porcupine anticlinorium). The western end of the Main Ranges is marked by the Rocky Mountain Trench (RMT), a broad valley in which Golden, BC, is located. Although the contact between the Foreland and Omineca belts is transitional and obscured by metamorphism and post-accretionary magmatism, the mid-Cretaceous Purcell Thrust daylights along the western margin of RMT and corresponds with the start of Dogtooth Thrust Duplex/Complex in the eastern structural domain of the Omineca Belt (the "Selkirk fan structure", which actually extends across the suture zone into the Foreland Belt to include the Porcupine anticlinorium). The Selkirk fan structure extends 1500-km along the length of the Cordillera and formed in response to the accretion of the Quesnellia. Travelling through the Selkirk fan structure to Revelstoke we visited several stops where allochthonous, low-grade, supracrustal, Windermere Supergroup rocks are overlain by upper crustal metasedimentary rocks of the Omineca Belt.

Road-side exposure of the Miette Group Neoproterozoic sub-marine fan sandstones and conglomerates.

Bruce Madu gives an overview on Omineca Belt geology at a road-side stop for the Monashee Complex "cover gneisses".

The group met Bruce Madu, regional geologist for the BCGS Kamloops office, in Revelstoke and were treated to an overview of the geology of the Omineca Belt, which was well-illustrated by several maps and samples of mineralization from many of the area's deposits. In particular, the western edge of the Monashee Complex (an uplifted decollement) hosts Devonian-age VMS mineralization (e.g., Gold Stream, JC) in the exhumed Archean-Cambrian rocks. We also learned that obducted ophiolitic rocks in Cache Creek terrane host the Bralorne gold deposit (that we would be seeing later in the trip) as well as jade mineralization, and that the Devonian carbonitites +/- syenites and other alkalic intrusions previously mentioned by Barry Richards are prospective for rare metal mineralization (e.g., Ta-Nb at Blue River) and have a deep-seated upper mantle chemistry. Leaving Revelstoke, we crossed the Columbia River Fault, where Paleocene extension has exhumed middle to lower crustal metamorphic rocks comprising the western structural domain of the Omineca Belt: a package of Paleoproterozoic "basement gneisses", and 740-360 Ma "cover gneisses" ("Shuswap metamorphic core complex"). Crossing the extensional Okanagan-Eagle River Fault Zone near Sicamous, we transitioned from metamorphosed North American basement and supracrustal rocks into the peri-cratonic Kootenay terrane of the western Omineca Belt. Here, penetratively deformed, mainly greenschist and lower amphibolite grade, Proterozoic and Paleozoic clastic, carbonate and volcanic rocks with North American affinities are intruded by Devonian and Middle Jurassic through early Tertiary granitic plutons. The day ended in Squilax, where we feasted on burgers and salad and slept in old train cabooses converted to dorms on the shore of Okanagan Lake.

Friday, July 16: Hyland Valley Mine

by Santiago Vaca

After two and half days on outcrops of different geological terranes of the Southern Canadian Cordillera, we were ready to get back to the economic geology with a visit to the largest open pit Cu mine in Canada: Highland Valley Copper (HVC), owned and operated by Teck. HVC is Canada's biggest base metal mine and one of the largest Cu-porphyry deposits in the world! The mine is located 17 km west of the town of Logan Lake and 75 km southwest of Kamloops.

Highland Valley mine site.

There are five major Cu-Mo deposits at Highland Valley: Valley, Lornex, Bethlehem, Highmont and JA. Although mining in the area dates at least 100 years ago, the first blast signalling the start of large-scale mining did not occur until 1962, in the Bethlehem mine, which was followed by development of the Lornex pit in 1972, the Highmont pit in 1979, and the Valley pit in 1986. The JA orebody remains undeveloped and uneconomic. In 2009, Highland Valley Cu produced 336

000 tonnes of Cu sulphide concentrate containing 252 Mlbs Cu, and 5 800 tonnes of Mo sulphide concentrate containing 6.6 Mlbs Mo. Most of the Cu concentrates are sold to smelters in Pacific Rim countries and in Manitoba, Canada, whereas Mo is sold to the United States, Mexico, and South America.

Highland Valley Cu-porphyry deposits occur within the Guichon Creek batholith (210 Ma), which ranges in composition from granodiorite to diorite to quartz monzonite, and has textures ranging from equigranular to porphyritic. This intrusion is co-magmatic with, and emplaced in the calc-alkaline frontal island-arc rocks of Nicola Group of the Quesnellia (vs. more alkalic back-arc magmatism). Mineralization in the batholith is hosted in the youngest and most evolved intrusive phases. Most of the mineralization is associated with potassic alteration (K-feldspar + biotite) and a pervasively overprinting sericitic alteration, which is in turn superimposed by a latest argillic assemblage of mainly kaolinite. The ore is chiefly in fractures, faults, veins and breccias and the commodities are Cu and Mo, grading ~0.4% Cu and ~0.008% Mo. The main sulphide minerals are bornite, chalcopyrite, pyrite, and molybdenite.

Our visit started with a complete video on the geology, mining history, and a general overview of Highland Valley district. Prior to beginning our tour, our personal protective equipment (steel toe boots, safety glasses, helmets and reflected vests) was checked, and we were loaded onto a bus and driven to the actively mined, blindingly white Valley pit by Gerald Grubisa, Senior Mine Geologist for Teck. When we arrived to the bottom of the huge Valley pit (~1.5 km in diameter), Gerald explained to us the importance of the structural control for the mineralization at Valley deposit. Indeed, the intersection of the N-S trending Lornex fault and NW-SE trending Highland Valley fault produced an intense fracturing which favoured the mineralization. Quartz veinlets, fractures and faults are predominantly parallel to those major faults in the deposit. The 2 stops in the Valley pit were very exciting since we were allowed to sample the ore, we hammered and

Quartz vein stockwork in quartz monzonite with pervasive potassic alteration strongly overprinted by a phyllic assemblage.

Quartz vein with chalcopyrite + bornite in a strongly phyllic-altered quartz monzonite.

Sample collecting in the white Valley pit.

Looking south into the Lornex pit.

collected many samples of mineralized porphyry represented by a stockwork of quartz veins with bornite, chalcopyrite, molybdenite, and pyrite hosted in a potassic and strongly phyllic-altered quartz monzonite.

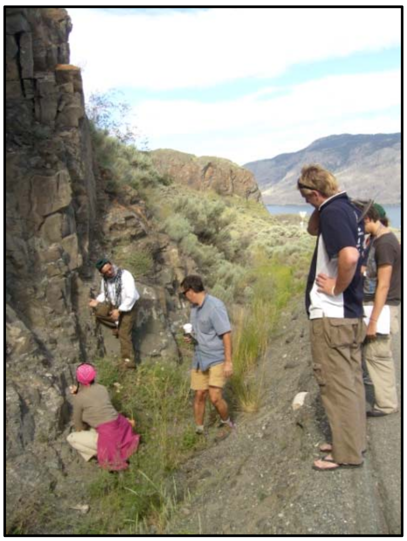
After our visit to the Valley pit, we then drove 2 km south to the Lornex pit while Gerald explained the new mine expansion program at Highland Valley, which is expected to extend the life of Highland Valley mine to 2020. One of the objectives of this program is to drill under the Lornex pit. Well-satisfied with our tour and samples, we left the mine with a big “thank you!” to Gerald.

Friday, July 16: The Intermontane Belt

by Kirsten Rasmussen

We had a big pancake breakfast and an early start in order to get on the road in time to visit out first outcrop of the day prior to our morning tour at the Highland Valley mine. After a quick break in Kamloops to fill up on coffee, Bruce generously distributed a special volume on the Highland Valley Cu-porphyry deposit to each participant. Although not part of the planned trip, we had a brief stop to look at the Afton-Ajax alkalic porphyry deposit just outside Kamloops, which was formerly mined out but is now being evaluated for block caving mining. We then pulled of the road for a longer stop at a road-cut through the eastern facies of the Nicola Group volcanic (finally seeing the unaltered host rocks to the Copper Mountain and Nickel Plate/Mascot deposits that we visited earlier in the field trip, and the volcanic rocks that are co-magmatic to Highland Valley Copper porphyries). The Niccola volcanic rocks are BC’s most productive for Cu-Mo mineralization! True to their description in the Geological Association of Canada guidebook, the late Norian exposure of eastern facies Nicola Group rocks comprised mafic augite porphyry volcaniclastics interbedded with tuffaceous shale, and several examples of the bivalve *Monotis salinaria* (of possible Tethyan affinity) were found by sharp eyes.

After touring the Highland Valley mine, we continued on our transect through the Intermontane terrane, crossing in the Thompson River valley from Quesnellia into the Cache Creek terrane, interpreted to be an accretionary complex. Several stops in Cache Creek terrane allowed us to see the easternmost belt of argillaceous and radiolarian cherty metasedimentary 'melange', and the middle belt of fusulinidiferous Marble Canyon Formation. The road-side stops concluded with a viewpoint over the Fraser River Fault immediately east of the town of Lillooet, with discussions on the extent and nature of the fault that has enough dextral strike-slip displacement (130-150 km) to restore the town of Lillooet to the latitude of Hope, BC. The Fraser Fault essentially separates Cache Creek terrane from the Niccola Group of Quesnellia. After a quick rest stop in Lillooet, we left for Bralorne, a long dusty drive dodging rockfalls along the very scenic, winding road following the long and skinny Carpenter Lake. Arriving after the local restaurant had stopped serving food, we scraped together enough scraps to eat for the night and proceeded down to the local pub for refreshments and several very intense pool matches with Bruce.



Examining the eastern volcanic facies of the Nicola Group.

Eastern volcanic facies of the Nicola Group.

Late Norian bivalve *Monotis salinaria* of possible Tethyan affinity.

Limestone block in radiolarian cherty argillite of the Cache Creek melange.

Looking south down the Fraser Fault (along the Fraser River) near Lillooet, BC.

Saturday, July 17: Bralorne Au-Vein Deposit

by Stephanie Martin

Come July 17th the group woke up to the sounds of bells: 3 mules with bell collars at our motel doorsteps. Very friendly and eager to eat anything we put near them (including any of the girls' long hair) we spent the early morning hours packing the cars and patting our new friends. Just before 8am we headed 5 minutes down the road to the Bralorne-Pioneer Mine Property: a historic underground Au mine undergoing the processes of re-establishing and a new mine operation. The Bralorne district has historically been BC's largest Au producer, and at the time of start-up was suggested to be the greatest lode Au mine in the world! The mine's peak activity was from 1932 to 1934, employing 100's of men during the Great Depression, but continued until 1971 when escalating costs and a low Au price forced the 3 main mines to close. Extensive underground workings down to 2000 m depth were developed to retrieve 4.1 Moz Au (averaging >0.5 oz/t) during the ~40 years of production from 3 main deposits: Bralorne, King, and Pioneer. Mineralization characterised by continuous, multi-metre wide veins and vein swarms that parallel major faults in the region. There is a strong 30^{o} trend of the faulting systems with sub-parallel ore shoots, but some are more east west.

Since closure, the mine site has reopened for various exploration projects. Bret Armstrong, Mine Geologist for Bralorne Gold Mines and our tour guide for the day, has been involved in researching and locating newly feasible Au mineralization between the historic Bralorne and King mines. Historically, the region has been mined by separate companies that developed different areas, but the sectors in between were poorly explored, and due to the ease of following mineralization, no surface exploration was done. However, recent geochemical surveys led to the discovery and trial mining of the Peter vein and the 51BFW, and in 2006, drill exploration intersected bonanza grades hosting numerous mineralised shoots in the gap between the Bralorne and King mines.

Bret described the major lithologies of the region to be intrusive dolerite, and sodic granite with late porphyry dikes following major structures parallel to the veins, although Bret noted that the geology is still uncertain and needs further work. Mineralized regions have some very high grade mineralization locally, up to 0.6 oz/t, but the average grade is 0.38 oz/t. The main focus of the current project is mapping and locating where the Au is. Various techniques in underground sampling are being utilized, following major structures and determining ore shoot trends and plunges. The issue at Bralorne is proving that the mine has economic potential and viability, and an adequate reserve. The project cannot start until a year's worth of Au reserve is proven and is attainable to validate operations. Bret and Bralorne Gold Mines have high hopes that further exploration will prove-up high-grade deposits and that the Bralorne mine site will be reopened in the near future. Before leaving, we given a brief tour of the 120 t/day mill, and then were absorbed into the search for VG in the stock piles! Some of us got lucky, others found only pyrite, and the rest may have been sleeping in the car.


One of several very friendly mules in Bralorne village.


Bret Armstrong (no hard hat) explains the layout of the mill.


Scouring the mill stockpile for VG.

As we haven't even had breakfast yet, we headed to the next town's cafe to have late breakfast/brunch/even just an early lunch for some of us. We hit the road afterwards, heading to Pemberton, stopping at a few geological sites along the way...

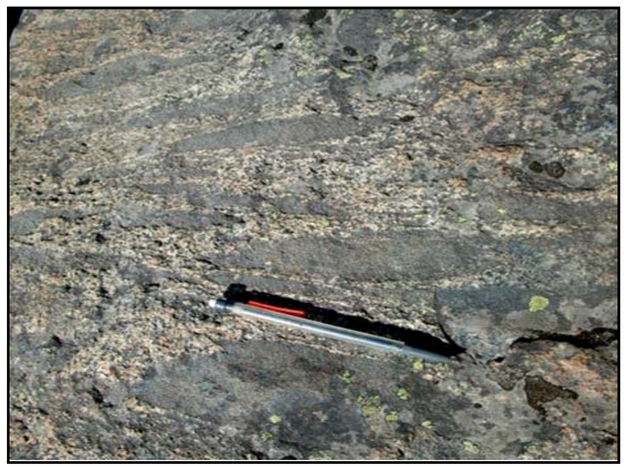
Sunday, July 18: The Cascade Arc + Coast Belt

by Marc Waugh

The day began at Petro Canada, in Pemberton, where we had a coffee run followed by an introductory lesson on the volcanology and the Cascades by Professor Kelly Russell, who had driven up to join us for the day with post-doctoral fellow Marion Carpentier, both from UBC. After spending the last few days in the Intermontane 'plateau' between the Coast and Rocky Mountains, where the geology was comprised mostly of relatively metamorphosed rocks, we all welcomed the change to pristine igneous rocks, particularly the 37 Ma to present Cascade Arc. Kelly began by introducing us to the physiological differences in the volcanic arc structures of the American and Canadian portions of the 1100-km long Cascade Arc. Though both were formed from the same subduction driven magmatism, the Canadian portion tends to have greater relief and young volcanic rocks of the northern Cascade Arc (known as the <4 Ma Garibaldi Volcanic Belt) are found on the mountain tops as opposed to the valleys. This is because of the subduction of a mid-ocean ridge off the coast of Vancouver Island in the recent past, causing increased buoyancy and uplift in the area due to upwelling asthenosphere and subduction of relatively young (and hot) oceanic crust. Due to the subduction of the mid-ocean ridge, the Canadian arc is also more heterogeneous and lower in volume than the American arc.

We drove about half an hour from Pemberton along the Sea-to-Sky highway to our first outcrop at Brandywine Falls. The outcrop itself was located about a 300-metre walk from the road along a local railway line. Next to the railway line was a massive, poorly sorted and unconsolidated deposit of angular clasts deposited after a major rock avalanche that fell from a neighbouring mountain; these deposits are typical of much of the floor of the Pemberton Valley and hint at the risk of living and building in an area with such high level of geohazard (in fact, developers had initially wanted to put housing developments on these elevated, well-drained deposits in the valley floor!). The bedrock below these deposits at Brandywine Falls is a Jurassic pluton with coarse-grained granodioritic material flooded with orientated, fine-grained dioritic enclaves. There are several theories on the formation of these textures, however Kelly proposed that an injection of a hotter mafic dyke into a cooling felsic pluton and the subsequent difference in viscosity between the magmas caused partial mixing and the break-up of the mafic magma. The lack of an early fabric in the elongated mafic enclaves indicates that this is not a metamorphic texture and that stretching occurred while the melt was still above its solidus. Subsequent upward expulsion of magma out of the magma chamber due to volatile exsolution from the mafic magma upon rapid cooling may have resulted in the pervasive orientation and stretching of the mafic enclaves.

Dr. Kelly Russell giving an overview of the geology of the Coast Mountains.


Stretched dioritic enclaves in granodiorite of a Jurassic pluton.

We continued our drive west past Whistler and stopped in a valley on the highway to look at numerous outcrops of spectacularly columnar-jointed basaltic lava flows of the 1.3 Ma to 9 300 year old Garibaldi volcanic centre. Kelly discussed the flow paths of these lavas that followed old drainage paths including valleys and tunnels into glaciers from previous ice ages. The basalts had textbook examples of columnar jointing as well as some not so textbook jointing patterns but Kelly stressed the importance of defining a system's properties before trying to sort out the depositional environment and deformation. We applied this concept to the basaltic outcrops and with Kelly's help, defined 3 rules of columnar jointing:

1. Heat flow - Columnar joints form parallel to the direction of heat flow. Hence, changes in heat flow causes a change in the cooling direction (and may be responsible for curvature of columns).
2. Size – Different parts of lava flows have different thermal regimes and hence form different sized columns, narrowing with proximity to cooler fronts.
3. Transit – Jointing occurs in segments and propagates to form these columns.

Using these rules, we were able to interpret the unusual structures in the basaltic outcrops, and thus determined that the main controlling factor for anomalous columnar jointing in the basalt flows was a result of how the lavas interacted with overlying glaciers and melt water during the last ice age.

Dr. Russell explaining the 3 rules of columnar joints in front of a spectacularly columnar-jointed outcrop.

An example of a columnar-jointed outcrop with a dramatic change in column orientation.

Our final stop was at Rubble Creek, an alluvial fan where rock avalanches continue to occur and are considered to be a major hazard in the area. Basalt flows, known as The Barrier, from the Garibaldi volcanic centre during the last ice age stopped abruptly at glacial contacts to the produce high, jointed, now unsupported cliffs that today have sealed off glacial Garibaldi Lake. These cliffs are unstable collapse erratically to feed the Rubble Creek alluvial fan in the valley floor, and the instability of the area has halted adjacent development although portions of down-valley settlements (e.g., Squamish) could experience catastrophic flooding should the 300-m wide Barrier be breached one day. The Pemberton Valley is one of the few places in BC where there has been successful use of geological information for land use decisions.

This last day concluded our field trip through southern BC, and after cleaning out vehicles and unloading gear, we convened at the same brew pub that we had started out trip at for one last dinner together before going our separate ways.