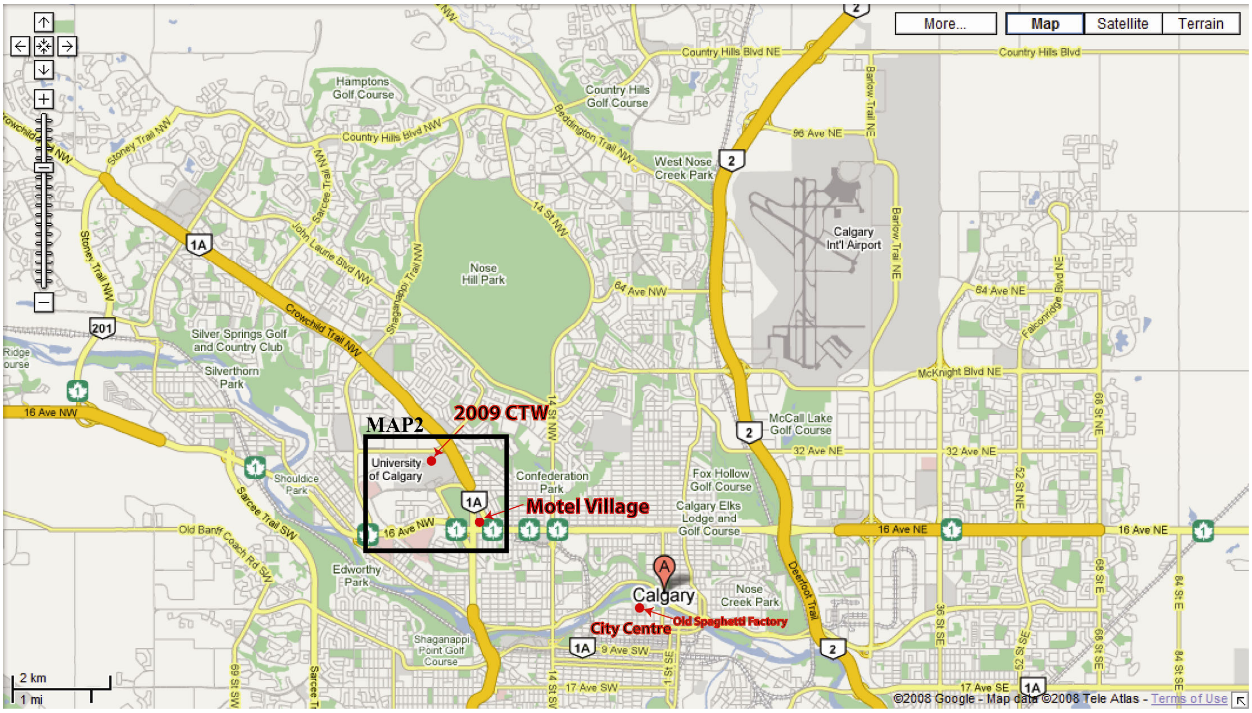
CORDILLERAN TECTONICS WORKSHOP 2009

FEBRUARY 20-22, 2009

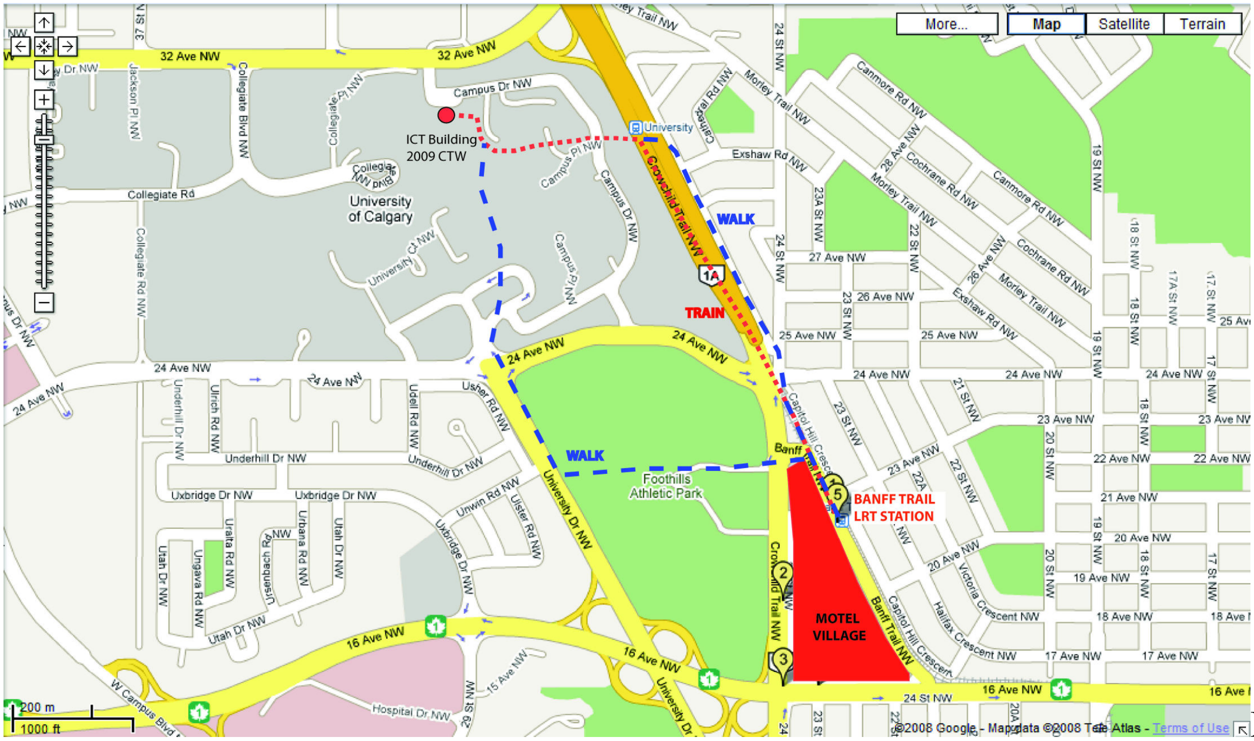
Department of Geoscience
UNIVERSITY OF CALGARY
CALGARY, ALBERTA

2009 Cordilleran Tectonics Workshop
Calgary, Alberta, February 20-22, 2008
The University of Calgary – Information Technologies Building



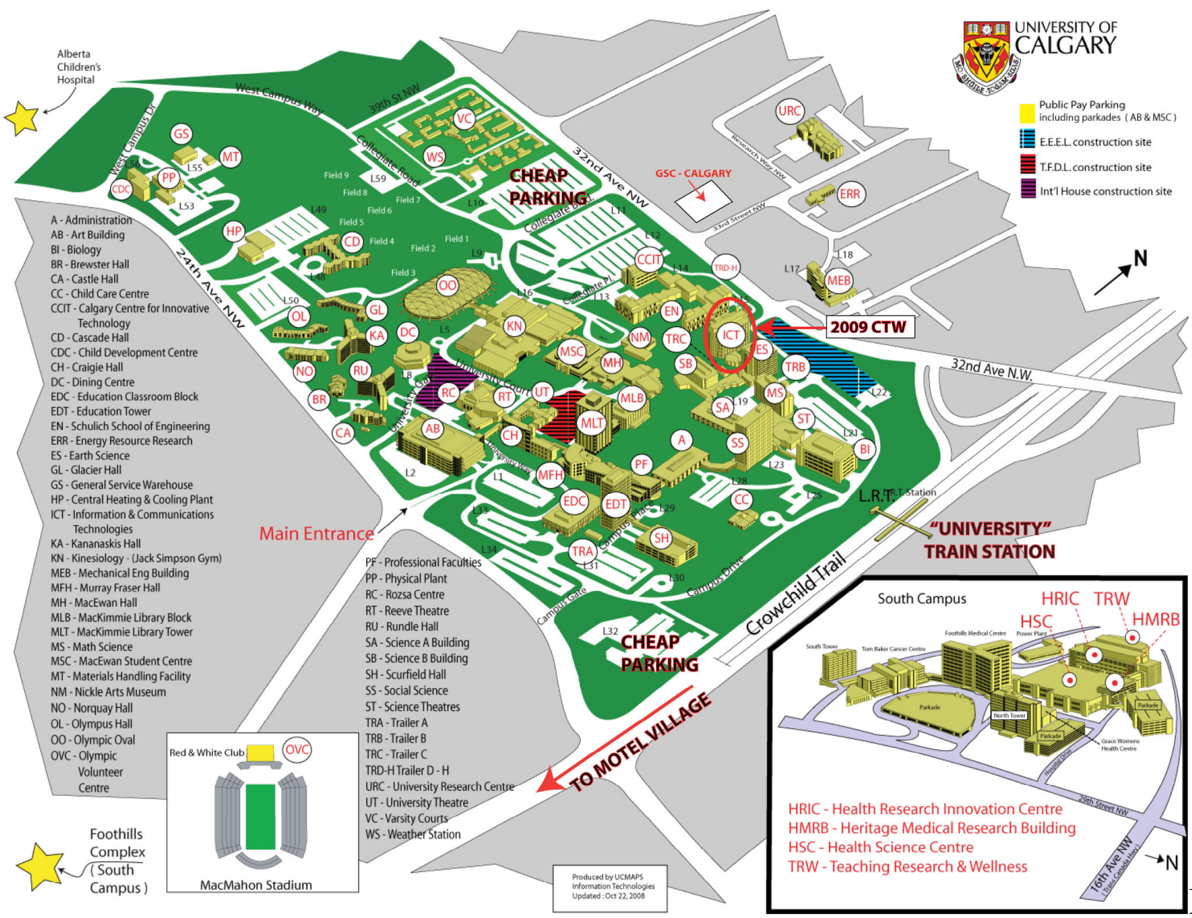
Map 1

This year's CTW is being held at the Information and Communication Technologies (ICT) Building, University of Calgary. The University of Calgary is located in northwest sector of the city (Map 1), about a 10 minute drive from downtown. Recommended lodging for the CTW is at Motel Village, a collection of various hotels located just off the Trans-Canada Highway. These hotels are a short 15-20 minute walk or a 1-stop train ride from the University (Map 2). The ICT building is located on the northern edge of campus, just off 32nd Avenue NW along Campus Drive (Maps 2, 3), and once inside, signs will direct you the conference venue.



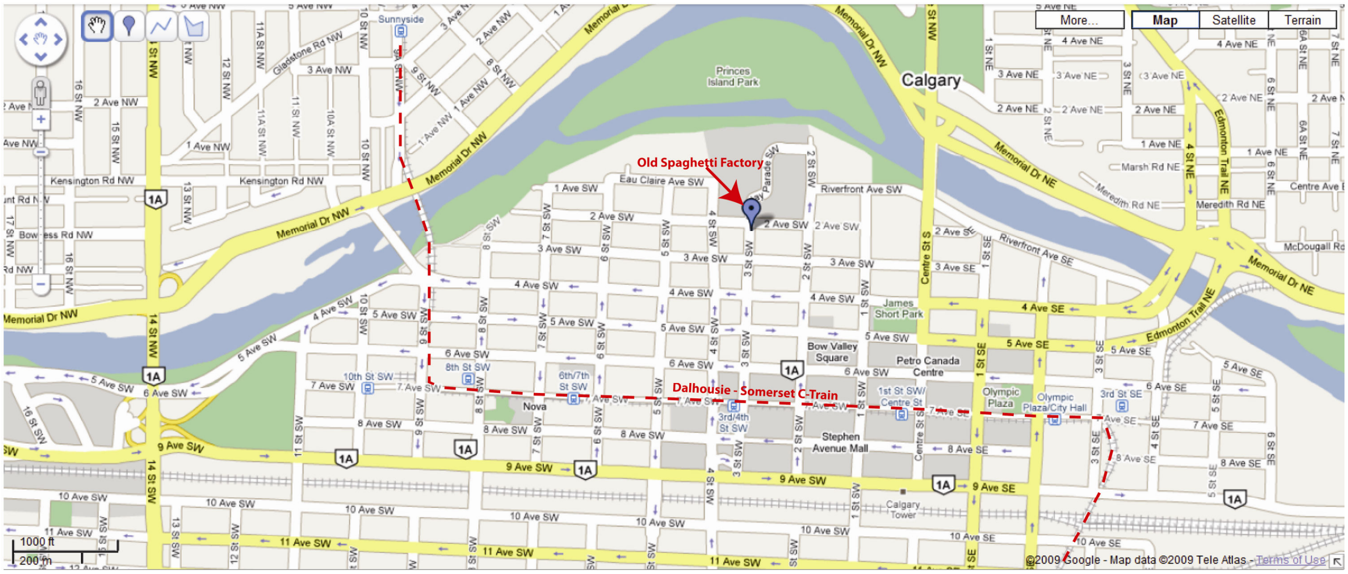
Map2

Walking and train routes from motel village to the ICT building, site of the 2009 CTW.



Map3

The 2009 CTW is in the ICT Building on the north edge of campus, just off 32nd Ave.



Map 4 – Downtown Calgary and Old Spaghetti Factory
To get to the Old Spaghetti Factory, take the C-Train (Dalhousie – Somerset train) to the 4th St SW station, then walk north along 3rd St SW until 2nd Avenue. Old Spaghetti Factory is a big red building on the corner of 3rd Ave. and 2nd St. SW. If you're driving, there is cheap parking (~$2.00) at the Eau Claire Market, which is just ~1 block north of the Old Spaghetti Factory (big grey square on the image above). Remember, avenues are E-W and streets are N-S!

Calgary Transit Information
Adult Fare on Calgary Transit for 1-way travel is $2.50. Train platforms have ticket dispensers than take coins only. Day passes can also be purchased from the ticket dispensers for $7.50 (consider this for Saturday if you are attending the dinner!). Ticket dispensers do not provide change. The trains operate on the honor system, and travel within downtown is free, but the fine for not having a ticket is humiliation and a $150 fine.

Schedule of Events

Friday, February 20th

5:00-8:00	**Registration**	**ICT 116**
	Poster Setup	**ICT 116**
8:00-done	**Pub Night Icebreaker (within walking distance of University)**	
	Kilkenny Irish Pub (500-3630 Brentwood Road NW)	

Saturday, February 21st

8:00-8:40	**Registration**	**ICT 116**
	Poster Setup	**ICT 116**
	Downloading Speaker Presentations	**ICT 122**
8:40-12:00	**Technical Program (Talks)**	**ICT 122**
	Coffee, Tea, Juice and Muffins	
12:00-1:30	**Lunch**	
1:30-2:45	**Technical Program (Talks)**	**ICT 122**
	Coffee, Tea	
2:45-6:00	**Poster Session with Snacks/Beer/Wine;** ***1 free drink provided!***	**ICT 116**
8:00-done	**Dinner at Old Spaghetti Factory in Downtown Calgary**	

Sunday, February 22nd

8:00-8:50	**Downloading Speaker Presentations**	**ICT 122**
8:50-12:00	**Technical Program (Talks)**	**ICT 122**
	Coffee, Tea, Juice and Muffins	
12:00-1:30	**Lunch**	
1:30-2:30	**Technical Program (Talks)**	**ICT 122**
	Coffee, Tea	
2:30-3:00	**Poster Take Down**	

Technical Session Schedule – Room ICT 122
Saturday, February 21st

8:00-8:40 **Setup/Downloading Speaker Presentations**

8:40-8:50 **Welcome/Introduction**

8:50-9:10 **Sarah Brown** and H. Daniel Gibson: *New geochronological data from the Okanagan gneisses: insights into protolith, gneiss formation, and Eocene extension*

9:10-9:30 **Joel Cubley** and David Pattison: *Pressure contrasts along the eastern margin of the Grand Forks Complex, southeastern British Columbia*

9:30-9:50 **Félix Gervais**: *An objective and testable subdivision scheme for the southeastern Canadian Cordillera*

9:50-10:20 **Discussion, Coffee Break, Posters**

10:20-10:40 **Deanne van Rooyen** and Sharon Carr: *Cariboo Alp revisited: Structure and thermochronology studies on the southwest flank of Thor-Odin dome, BC do not support a syn- or post-metamorphic structural break*

10:40-11:00 Erik Parker, **Philip Simony**, and Edward Ghent: *Stratigraphy, structure and metamorphism of the Esplanade Range, southeastern Canadian Cordillera*

11:00-11:20 **H. Daniel Gibson**: *Insight into the rate of development of a major orogenic structure and evidence for a long, hot orogen within the southern Canadian Cordillera.*

11:20-11:40 **Graham Spray**: *Structure, metamorphism, and tectonism in the Mica Creek area, southeastern British Columbia*

11:40-1:30 **Discussion, Lunch Break, Posters**

1:30-1:50 **Andy Parmenter** and Paul Williams: *Late superstructure-style folding of the Monashee complex infrastructure*

1:50-2:10 **Edward Ghent** and Philippe Erdmer: *Epidote eclogites from Ross River area, Yukon, Canada, indicate very high pressure thus deep burial*

2:10-2:30 **Francis Macdonald**: *Neoproterozoic glaciations on a carbonate platform margin in Arctic Alaska and the origin of the North Slope subterrane*

2:30-2:45 **Discussion, Wrap-up**

2:45-6:00 **Official Poster Session with Snacks/Beer/Wine; *1 free drink provided!***

Technical Session Schedule – Room ICT 122
Sunday, February 22nd

8:00-8:50 **Setup/Downloading Speaker Presentations**

8:50-9:10 **Mustafa Al Ibrahim** and Paul Hoskin: *Heat modeling of the Nelson batholith and its contact aureole, British Columbia: constraining magma-chamber geometry*

9:10-9:30 **Francesca Furlanetto**, Derek J. Thorkelson, William J. Davis, H. Daniel Gibson, Robert H. Rainbird and Daniel D. Marshall: *Preliminary SHRIMP data on detrital zircons of the Wernecke Supergroup, Wernecke Mountains, Yukon*

9:30-9:50 **Graham D.M. Andrews**, J. Kerry Russell, Jacqueline Dohaney, and Robert G. Anderson: *Palaeotopographic evidence of Neogene epeirogenic uplift from the Chilcotin Group – evidence, implications, and what the heck do we do next?*

9:50-10:20 **Discussion, Coffee Break, Posters**

10:20-10:40 **Jamie.L. Kraft**, Philippe Erdmer and Robert.I. Thompson: *The sub-Mississippian unconformity at Trout Lake, BC: mid-Paleozoic deformation, 'extra' stratigraphy and stratigraphic linkages*

10:40-11:00 **JoAnne Nelson**, Maurice Colpron and Donald Murphy: *Terrane spotting: Origins and translations of Cordilleran exotic terranes and the geodynamics of their accretion – investigations by the Edges Project 2008-2012*

11:00-11:20 **Donald C. Murphy**, James K. Mortensen and Cees van Staal: *'Windy-McKinley terrane, western Yukon: new data bearing on its composition, age, correlation and paleotectonic settings*

11:20-11:40 **Elizabeth Westberg**, Maurice Colpron and Dan Gibson: *Relocating the boundary between Yukon-Tanana and Cassiar terranes, and the possible significance of Early Cretaceous extension in central Yukon*

11:40-1:30 **Discussion, Lunch Break, Posters**

1:30-1:50 **Charles Ferguson:** *What do Rubia and the Ribbon Continent have to do with the Canadian Cordillera?*

1:50-2:10 **Erik Katvala:** *Interpreting Paleontologic Data for Terrane Paleogeography*

2:10-2:30 **Discussion, Next Year's Meeting, Wrap-up**

Poster Session

[1] Heather L. Ainsworth, Kris Vasudevan and Frederick A. Cook: *Deep crustal structure of the Moyie Anticline, southeastern British Columbia: basement or no basement?*

[2] Yee Ping Chau, Paul W.O. Hoskin and Graham R. Davies: *Magnesium isotopes support a seafloor vent – dolomite – Burgess Shale genetic link*

[3] Rosie Cobbett: *Timing and kinematics of the Duke River Fault: preliminary results*

[4] Maurice Colpron: *A new structural interpretation for the Whitehorse trough in Yukon*

[5] Melissa J. Freeman, Jennifer P. Owen and Paul W.O. Hoskin: *The heterogeneity of dyke swarms in southeastern B.C. and corresponding tectonic interpretations*

[6] J.F. Gagnon and J.W.F. Waldron: *Slope instability in a tectonically active Jurassic sedimentary basin, northwest British Columbia*

[7] Steve Israel and Rosie Cobbett: *Geologic and tectonic evolution of Wrangellia: Perspectives from southwest Yukon*

[8] Duncan McLeish: *Geology of the eastern Williston Lake region as constrained by the Peace Reach transect: implications for the tectonic evolution of the Canadian Cordillera*

[9] Curtis A. Morrison and Jennifer P. Owen: *Geochemical and petrological characterization of the Summit Creek Stock*

[10] Donald C. Murphy, James K. Mortensen and Cees van Staal: *'Windy-McKinley' terrane, western Yukon: new data bearing on its composition, age, correlation and paleotectonic settings*

[11] Tyler W. Ruks, James K. Mortensen and Fabrice Cordey: *Stratigraphic and paleotectonic studies of the Middle Paleozoic Sicker Group and contained volcanogenic massive sulphide (VMS) occurrences, Vancouver Island, British Columbia*

[12] Adar Steinitz and Paul W. O. Hoskin: *The inside of a batholith is not boring!*

[13] Elizabeth Westberg, Maurice Colpron and Dan Gibson: *Relocating the boundary between Yukon-Tanana and Cassiar terranes, and the possible significance of Early Cretaceous extension in central Yukon*

[14] Davide Zanoni, Paul F. Williams, M. Iole Spalla and Guido Gosso: *P-T estimates on metapelites from Joss Mt., Selkirk allochthon, South East British Columbia*

[15] David P. Moynihan and David R.M. Pattison: *Structural geology around the bend in Kootenay Lake*

Participants

Charles Ferguson	Arizona Geological Survey	Tyler Ruks	U. British Columbia
Robert Leonardson	Barrick	Heather Ainsworth	U. Calgary
JoAnne Nelson	BC Geological Survey	Mustafa al Ibrahim	U. Calgary
Richard Brown	Carleton University	Yee Ping Chau	U. Calgary
Sharon Carr	Carleton University	Joel Cubley	U. Calgary
Deanne van Rooyen	Carleton University	Melissa Freeman	U. Calgary
Félix Gervais	Carleton University	Edward Ghent	U. Calgary
Nancy Joyce	GSC – Ottawa	Brett Hamilton	U. Calgary
Mike Villeneuve	GSC – Ottawa	Paul Hoskin	U. Calgary
Jim Ryan	GSC – Vancouver	Erik Katvala	U. Calgary
Bert Struik	GSC – Vancouver	Christian Kuehn	U. Calgary
Francis Macdonald	Harvard University	Curtis Morrison	U. Calgary
Toby Stier	Queen's University	David Moynihan	U. Calgary
Raymond Price	Queen's University	Jennifer Owen	U. Calgary
Sarah Brown	Simon Fraser University	Philip Simony	U. Calgary
Francesca Furlanetto	Simon Fraser University	Jenna Seitz	U. Calgary
Dan Gibson	Simon Fraser University	Graham Spray	U. Calgary
Kirsti Medig	Simon Fraser University	Adar Steinitz	U. Calgary
David Trippett	Simon Fraser University	Adriana Taborda	U. Calgary
Elizabeth Westberg	Simon Fraser University	Kris Vasudevan	U. Calgary
Yvon Lemieux	Talisman	Andy Parmenter	U. New Brunswick
Walter Loogman	Talisman	Paul Williams	U. New Brunswick
Nancy Schmidt	Talisman	Davide Zanoni	U. New Brunswick
Szandra Kisch	U. Alberta	Matthieu Dallaire	U. Victoria
Jamie Kraft	U. Alberta	Duncan McLeish	U. Victoria
Jennifer Voaklander	U. Alberta	Ruikun Liu	U. Western Ontario
John Waldron	U. Alberta	Maurice Colpron	Yukon Geological Survey
Graham Andrews	U. British Columbia	Steven Israel	Yukon Geological Survey
Rosie Cobbett	U. British Columbia	Donald Murphy	Yukon Geological Survey

Abstracts (in alphabetical order)

Deep crustal structure of the Moyie Anticline, southeastern British Columbia: basement or no basement?

Heather L. Ainsworth, Kris Vasudevan and Frederick A. Cook

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The Moyie anticline in southeastern British Columbia is the lowermost regional structure of the Purcell anticlinorium. At the surface, it is cored by Mesoproterozoic strata of the Belt-Purcell Supergroup, with the deepest strata being the ~1450 Ma Aldridge Formation (Prichard Formation in the U. S.). Because there are no exposures of the basement rocks underlying the Moyie structure, the lithology and origin of the rocks in the core of the anticline at depth have been debated. In this project, a network of more than 1000 km of two-dimensional seismic reflection data in the vicinity of the Purcell anticlinorium is being re-analyzed. Approximately 500 km of these data are located across the Moyie anticline and provide key geometric information for interpreting the deep structure. In addition to the anticlinorial geometry observed both on the surface and in subsurface reflection data, the Moyie anticline is characterized by a prominent gravity high on both Bouguer and Isostatic gravity maps. The gravity high has previously been interpreted as either a response to high density basement in the core of the anticline, or to uplifted high density gabbroic sills (~1430-1468 Ma Moyie sills). Modelling of the gravity field was accomplished with information on the density and thicknesses of the sills provided by the 3.477 km Duncan Energy Moyie #1 drill hole. Well logs from the drill hole were used to sample the densities of the sedimentary rocks of the Aldridge formation (~ 2667 kg/m^3) as well as the sills (~2858 kg/m^3). The detailed gravity analysis found that the large quantity of Moyie sills is sufficient to produce the observed high and thus that the core of the Moyie anticline is likely to be thickened, probably by tectonic contraction, lower Aldridge strata. A major implication for palinspastic reconstructions across this part of the Canadian Cordillera is that contraction was largely accommodated above the westward thinning North American basement now located beneath the Purcell anticlinorium.

Heat modeling of the Nelson batholith and its contact aureole, British Columbia: constraining magma-chamber geometry

Mustafa A. Al Ibrahim and Paul W. O. Hoskin

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Magmas transfer heat and mass within the crust and may be frozen in orogenic belts as voluminous plutonic rocks. These provide a record of the timing and mechanisms of mountain-forming processes. Many magma-chamber processes remain poorly understood and even the volume and 3-dimensional geometry of plutons and batholiths are largely unknown. Field studies and thermobarometry of metamorphic heat aureoles place constrains on batholith size and geometry. On the basis of published field and thermobarometric data, we have numerically modeled the heat aureole of a large Cordilleran batholith in order to assess emplacement volume and magma-chamber geometry. HEAT3D code [*1*] was used to model heat physics and magma-chamber construction in 3-dimensions and time. The code uses the finite difference method to solve the heat equation, taking into

consideration conduction, magma convection, latent heat, and decay heat. Numerous models were constructed and run for the Nelson batholith, a Middle Jurassic quartz monzonitic to granitic body in southeastern British Columbia, with a semi-rectangular fault- or shear zone-bounded main body, a 25 km-long 'tail' to the south, and a ~1,800 m-wide heat aureole. Magmatic emplacement pressure was about 2.2 –5.0 kbar based on aureole [*2*] and magmatic hornblene [*3*] barometry. Modeling results for the 'tail' region, assuming a single magma intrusion into pelitic host-rock and a dipping (~60°) magma-chamber from 8–12.5 km depth, reproduces key temperature characteristics of the aureole as described in [2]. Our models constrain the range of possible magma-chamber geometries and provide estimations of temperature-time relations for mineral growth. For example, we estimate that sillimanite, Al_2SiO_5, growth 300 m away from the intrusion occurred over an interval of about 30,000 years, starting about 9,000 years after magma emplacement.

References:
1. Wohletz, K. (2008) Available at: http://www.ees1.lanl.gov/Wohletz/Heat.htm
2. Tomkins, H.S. & Pattison, D.R.M. (2007) *Journal of Metamorphic Geology* **25,** pp. 401–421
3. Ghent *et al*. (1991) *Canadian Journal of Earth Science* **32,** pp. 1668–1680.

Palaeotopographic evidence of Neogene epeirogenic uplift from the Chilcotin Group – evidence, implications, and what the heck do we do next?

Graham D.M. Andrews[1], J. Kerry Russell[1], Jacqueline Dohaney[1], and Robert G. Anderson[2]

[1] *Volcanology and Petrology Lab, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4; gandrews@eos.ubc.ca*
[2] *Geological Survey of Canada, Natural Resources Canada, Vancouver, BC, V6B 5J3*

The origins and fates of orogenic plateaux, and the development of topography and relief, have become 'hot-topics' in tectonics in recent years, in particular in the Andean Altiplano and the Tibetan-Himalayan region. Studies in the Canadian Cordillera have tended to focus on Paleogene and Mesozoic orogenesis and Pleistocene isostasy as the important controls on the development of the Coast Belt in particular. However, there appears to be little information available on the Miocene-Pliocene physiography, nor its evolution into the Pleistocene despite knowledge of upland glaciations in British Columbia back to at least ~ 3 Ma, and significant drainage reversals (e.g., the Fraser River) within the last 3 Ma.

We wish to draw attention to the abundance of physiographic evidence for sustained surface uplift in the Intermontane Belt of southern and central British Columbia throughout the Neogene that is preserved in and adjacent to the Chilcotin Group basalts. This is recorded in part by (1) extensive plateaux repeatedly incised by steep-sided, valleys and canyons and then infilled; (2) several abandoned drainage systems perched-up on the plateaux; (3) proximal, immature, sedimentary rocks and placer-Au deposits in the Fraser River Basin; and (4) successive, locally-extensive terrestrial disconformities and unconformities within the Chilcotin Group basalts. We propose that the distribution, stratigraphy, and physical volcanology of the Chilcotin Group rocks directly result from the physiography and environment at the time of eruption between ca.18 – 0.001 Ma, and beginning at ~3 – 0.001 Ma in particular.

Three provisional conclusions will help guide our future studies. (1) That concepts of an extensive "plateaux-forming" flood basalt province can be discarded; rather the Chilcotin, Fraser, and Caribou Plateaux are inherited from the Eocene-Oligocene as they are elsewhere in southern BC. (2)

The Chilcotin Group adequately preserves the evolving Neogene drainage, and thus can be used as a first-order constraint on the location of the Fraser, Chilcotin, Thompson, and Clearwater Rivers and their drainage systems. (3) Combined thermochronological and paleoaltimetric studies, integrating the stratigraphy, geochronology, and paleo-environmental data within the Chilcotin Group, will record the vertical tectonic history of the Interior plateaux, and in turn add significantly to our knowledge of the Neogene vertical tectonics across the Canadian Cordillera – "when did the Coast Mountains get high?, and when did they get their relief?".

New geochronological data from the Okanagan gneisses: insights into protolith, gneiss formation, and Eocene extension

Sarah Brown and H. Daniel Gibson

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The Okanagan Valley Shear Zone (OVSZ) delineates the western margin of a large Eocene metamorphic core complex which juxtaposes sillimanite-grade and non-metamorphosed rocks across the Okanagan Valley. The OVSZ is characterized by a series of strongly prolate gneisses (the Okanagan gneisses; predominantly paragneisses) and associated intermediate and felsic intrusions in the footwall. Most regional-scale stratigraphic and isotopic studies have concluded that the Okanagan gneisses are correlative with gneisses in the Monashee complex, which represent Ancestral North American crust. If this is correct, then the Okanagan gneisses may represent the most westerly (outboard) segment of exposed North America basement in the southern Cordillera, or the remnants of a basin filled with sediment derived from it.

Very little is known in detail about the Okanagan gneisses, for example: (1) the proportion of para- to orthogneiss; (2) the age of its protolith(s); (3) the age of gneiss formation; and (4) how these factors relate to the formation of the adjacent OVSZ. Using U-Pb zircon ages (LA-ICP-MS and SHRIMP) from a suite of samples that include gneissic "basement" and variably deformed and cross-cutting felsic intrusions, we provide new insight into the timing of gneiss formation and duration of extension. By comparison, age constraints for the Monashee basement orthogneisses include ca. 2.08 – 1.86 Ga igneous zircon; in contrast, the Okanagan gneisses include magmatic zircon as young as 160 Ma, with 55-50 Ma rims that may be derived from anatectic melts. Few zircon grains in the gneiss and associated intrusions consist of >1.6 Ga inherited cores. The main pulses of zircon growth in the orthogneisses appear to be 165-155, 110-105, 95-90 and 60-50 Ma. Our preferred working model is that the Okanagan gneisses are dominantly paragneisses (meta-pelites and meta-psammites) with multiple amphibolite sheets (probably originally basic intrusions). The age of the paragneisses is unresolved, but they may represent Lower Paleozoic miogeoclinal and pericratonic rocks that include the Paleozoic basement to Quesnel terrane. Intrusion of basic sills at 160 Ma preceded metamorphism and gneiss formation during Mesozoic contraction associated with the Cordilleran orogeny; followed by exhumation and anatectic melting in the Eocene.

Magnesium isotopes support a seafloor vent – dolomite – Burgess Shale genetic link

Yee Ping Chau[1], Paul W.O. Hoskin[1], and Graham R. Davies[2]

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The source of Mg-bearing fluids required for the formation of replacive and void-filling dolomite is subject to ongoing debate. Often, the fluids are attributed to post-evaporation modification of seawater. However, converging lines of evidence now indicate that some magnesium may be derived instead from magmatic sources.

Magnesium isotope analysis of dolomite and associated carbonates may provide evidence for and insight into the source of Mg-bearing fluids. The research program reported on here focuses on Mg isotopes and Cambrian-hosted hydrothermal dolomite and magnesite from locations in western Canada. The carbonates are spatially and possibly genetically linked with the World Heritage Burgess Shale of southeast British Columbia for which newly published mineralogical and field-based data show that Mg-enriched black shale of the Burgess Shale Formation formed in proximity to ancient submarine escarpments and passive-margin extensional faults. Seeping onto ancient seafloor, the hydrothermal fluids supported animal communities (the Burgess Fauna) much as modern communities flourish around black-smoker vents.

Preliminary laser ablation MC-ICP-MS Mg isotope values of dolomite from Yoho, Wapta, and Vermilion Pass vary 0.5 per mil and 2.6 per mil for magnesite from the Brussilof Mine, B.C. Two clusters of data for magnesite are consistent with fluid-inclusion studies that show two separate fluids in Brussilof deposit formation. Magnesite Mg isotope data in one cluster straddles all dolomite data, indicating a genetic link between Brussilof magnesite formation near Cambrian seafloor faults and more landward dolomitizing fluids. These preliminary data support the supposition that hot seafloor-vent fluids in the Cambrian of western Canada supported diverse and complex life, the Burgess Fauna, and were responsible for dolomitization of limestones that in other locations may be significant hydrocarbon producers.

Timing and kinematics of the Duke River Fault: preliminary results

Cobbett, Rosie[1,2]

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The Duke River fault is a terrane bounding structure that separates two of the largest and least studied terranes in the Canadian Cordillera; Wrangellia and Alexander terrane. The Duke River fault runs from the southeast corner of Alaska (where it is named the Totschunda fault), across the southwest Yukon, continuing a short distance into British Columbia. Several exposures of the fault in the Yukon show that the history of deformation along this fault is complex. Preliminary mapping and petrographic studies of samples collected along the southern part of the fault trace suggest the latest movements were oblique, dextral normal faulting. Data collected for an exposure of the fault near Hoge Creek suggest that past strike slip faulting has been over printed by a phase of deformation that thrust Alexander terrane rocks

over Wrangellia. Lastly, data collected near the far northern part of the fault strand, near the Alaska-Yukon border, indicates that Alexander rocks were thrust to the northeast over a gabbro body of the Steele Creek Gabbro complex. A fault splay in the same area yields information that thrust the Steele Creek Gabbro body over Wrangellia rocks. U-Pb and $^{40}Ar/^{39}Ar$ dating techniques will be used to constrain the age of the latest phase of deformation along the fault. (U-Th)/He thermochronology of zircon and apatite from samples collected from transects across the fault will provide information about the recent tectonic uplift. Another season of field mapping is scheduled for the summer of 2009 that will extend current mapping limits of the areas mentioned above and look at up to two new fault exposures.

A new structural interpretation for the Whitehorse trough in Yukon

Maurice Colpron

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The Whitehorse trough is an elongated, northwest-trending, predominantly marine sedimentary basin that extends some 650 km from near Dease Lake in northern British Columbia to just north of Carmacks in central Yukon. It originated as a forearc basin that rapidly evolved into a piggyback, synorogenic basin during the Early to Middle Jurassic amalgamation of Quesnellia, Stikinia and Cache Creek terranes. The Whitehorse trough comprises primarily of the clastic sedimentary and subordinate volcaniclastic rocks of the Lower to Middle Jurassic Laberge Group (late Hettangian-Bajocian). The Laberge Group unconformably overlies volcanic, volcaniclastic and carbonate rocks of the Upper Triassic Lewes River Group (northernmost Stikinia) along most of the length of the trough. East of Carmacks, in the northernmost Whitehorse trough, conglomerate and sandstone of the Laberge Group (Tanglefoot formation) overlie volcanic rocks of the Upper Triassic-lowermost Jurassic Semenof formation (Quesnellia) in the 'hanging-wall' (i.e. northeast) of the Teslin fault. The Laberge Group is overlain by fluvial conglomerate, sandstone and coal of the Tantalus Formation, the age of which has recently been revised to Middle Jurassic (Bajocian-Bathonian), at least along the western flank of the trough near Carmacks and at Division Mountain.

Acquisition of seismic reflection profiles near Carmacks in 2004 and subsequent bedrock mapping of the northern Whitehorse trough in 2006 have led to a new interpretation of its structural style. The northern Whitehorse trough is characterized by a series of broad, northwest-trending open folds and southwest-verging thrust faults. The thrust faults are most readily mapped where they juxtapose Lewes River strata in their hanging-wall to Laberge Group rocks in the footwall. In seismic profile, the thrust faults appear listric to the northeast. This style contrasts sharply with previous interpretation of a random array of steep faults that conveyed an image of the trough as a series of disparate, jostled blocks.

This poster presents a preliminary 1:250 000-scale compilation map of the Whitehorse trough in Yukon, that extends the structural interpretation developed near Carmacks southward into the Lake Laberge area, and eventually the Whitehorse area. Reinterpretation of the Laberge map area benefited from access to archival GSC notes by D. Tempelman-Kluit and crew dating from the 1970s and early 1980s. This archival dataset was integrated with aeromagnetic and satellite images, and spot observations in the field by M. Colpron and G.W. Lowey.

The overall style that emerges from this new compilation is that of a regional, dextral, transpressional strike-slip duplex, bounded on the east by the Teslin fault and on the west by the Braeburn fault. The thrust panels and fold axial traces inside this zone have overall sigmoidal geometries consistent with a dextral wrench system. These structures involve strata as young as Bathonian (Middle Jurassic). Upper Cretaceous volcanic rocks of the Carmacks (ca. 70 Ma) and Mount Nansen (ca. 90 Ma) groups appear to lay flat over top of tilted Whitehorse trough strata, therefore suggesting that most of the deformation was over by Late Cretaceous time.

Pressure contrasts along the eastern margin of the Grand Forks Complex, southeastern British Columbia

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The Grand Forks metamorphic core complex (GFC) in southeastern British Columbia exposes North American metasediments metamorphosed to upper amphibolite to granulite facies. The complex is juxtaposed against upper greenschist to lower amphibolite facies Quesnel lithologies by two N-S trending Eocene detachment faults: the Granby Fault on the west and the Kettle River Fault on the east[1]. Estimation of metamorphic P-T conditions in the Grand Forks complex and adjacent Quesnel rocks allows constraints to be put on the pressure contrast across the Kettle River fault.

Normal faulting has long been identified as the principal mechanism of extension in the Cordillera, and stark metamorphic contrasts across the bounding faults to the GFC suggest large fault offsets. However, low displacement estimates have drawn this into question, and recent studies on the Monashee and Valhalla complexes[2,3] have identified a Paleocene high-temperature decompression event that precedes Eocene normal faulting. This high-temperature decompression, evidenced by spinel+cordierite assemblages in the GFC, significantly reduces displacement estimates along the detachment faults to only 25% of overall exhumation. Using a combination of isochemical phase diagrams, mineral composition isopleths, and traditional thermobarometry, the peak assemblage in the basal paragneiss unit of the Grand Forks complex, Bt+Grt+Sil+Crd+Kfs+Pl+Qtz, is estimated at 750±20°C, 5.8±0.6kbar. The low-pressure Spl+Crd+Ilm decompression assemblage is constrained to 735±35°C, 3.3±1.0kbar. Footwall resorption of garnet and sillimanite occurred at least 9Ma prior to any movement along the Kettle River fault and provides evidence for a high-temperature, ~2.5kbar exhumation event in the Late Cretaceous-early Paleocene. Hanging wall And+Crd-bearing siltstones in the contact aureole of the Jurassic Nelson suite were metamorphosed at 585±60°C, and 2.5±0.5kbar. The pressure contrast across the Kettle River fault is estimated at ~0.8kbar (~2.7km), significantly less than that suggested by the large contrasts in metamorphic assemblages.

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What do Rubia and the Ribbon Continent have to do with the Canadian Cordillera?

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Recent challenges (Johnston, Ann. Rev. EPS, 2008; Hildebrand, GSA abstract, v. 39, p. 230, 2007) to the autochthoneity of the Omineca belt of southern British Columbia focus on plate-tectonic theoretical arguments regarding its deeper, infrastructural levels.

It is in the Cassiar - Cariboo platform, an essential part of the suprastructure, where these arguments fall short of the mark. This is because they fail to address two key aspects of the structure and facies architecture of the platform. 1) The exotic McCloud fauna, cited as evidence for allochtoneity in the Cassiar, is carried in thrust sheets (Colpron, Nelson, and Israel, YGS OF 2007-3) and need not have evolved in proximity to the Devonian and older, Laurentian-flavored parts of the platform. 2) In the Cariboos, palinspastic reconstruction of Neoproterozoic – Early Cambrian strata indicate that the platform capped a west-facing slope of continental margin proportions. This observation, however clouded by its grey literature status (Ferguson, U of Calgary unpub. Ph.D., 1994), makes it nearly impossible to accept the platform as any sort of rifted and returned ribbon continent.

It is true that in many ways the Omineca belt resembles an accretionary wedge intruded by a continental arc batholith. It is our lack of an adequate explanation for the Omineca that has invited this iconoclastic view, but is it necessary to dismiss the view altogether? Why couldn't the Omineca be a Jurassic arc attached to North America?

The heterogeneity of dyke swarms in southeastern B.C. and corresponding tectonic interpretations

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Eocene dyke swarms in South-Eastern B.C. provide an important record of the tectonic and magmatic history of the Cordillera following orogenic collapse. This paper presents new field mapping, petrologic, and geochemical data on dykes located near the mining town of Trail, B.C. Previous work focusing on alkaline and calc-alkaline lamprophyres in the same area was completed by Sevigny and Thériault (2003). The fieldwork involved sample collection and mapping, the results of which demonstrated the morphological and compositional diversity of individual dykes within a swarm. Average strike was 335 degrees, and dip ranged from near vertical to 30 degrees, with most of the dykes dipping around 80 degrees to the west. The average thickness of the intrusions was approximately 1.5m, with a range from 4.5m thick to less than 1cm. A detailed mapping exercise was undertaken, tracing three parallel dykes for a length of approximately 2km. This emphasized the lateral heterogeneities of the intrusions and the irregularities of their boundaries. Thin-section analysis shows a wide variety of rock types within a single swarm, including: micro quartz syenite, micro syenite, micro monzonite, latite, basalt, basaltic andesite, and lamprophyre. Texturally, these samples are consistently porphyritic and heavily altered to chlorite and sericite. This alteration often occurs in concentric rims around phenocrysts. The samples are typically intergranular, although some show trachytic texture. While the rocks are texturally similar, their mineralogy ranges quite dramatically. This is confirmed by the geochemistry assays, which show a range in composition, particularly in silica, which runs from 76% SiO_2 to 45% SiO_2. The quantity of magnesium in this sample suite ranges from 0.13% MgO to 13.16% MgO. The results also revealed one dyke which is enriched in Ni, Cr, and Co, giving it a nearly undifferentiated composition. Future work on this project includes the completion of petrologic analysis, an in-depth interpretation of the geochemistry results, and electron microprobe work to determine the chemical makeup of individual grains. These interpretations and results will then be used to make inferences about the tectonic environment and emplacement history of the dykes.

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Preliminary SHRIMP data on detrital zircons of the Wernecke Supergroup, Wernecke Mountains, Yukon

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The Wernecke Supergroup is a >13 km-thick metasedimentary succession exposed in the Wernecke, Ogilvie and Richardson mountains of central and northern Yukon. A program of field and laboratory investigations was initiated in 2007 in the Wernecke Mountains in order to constrain provenance, age, and environment of deposition of the Wernecke Supergroup, as well as to better constrain the age of subsequent Proterozoic deformation (Racklan orogeny).

Clastic and carbonate samples were collected from the Wernecke Supergroup for analysis of detrital and metamorphic minerals, and whole rocks, using a range of isotopic methods.
The first phase of the project involved the processing of five quartz sandstones to separate detrital zircons. The minerals were analyzed with the Sensitive High resolution Ion Microprobe (SHRIMP) of the Geological Survey of Canada in Ottawa. The preliminary results show patterns of detrital zircon ages broadly comparable to other Paleo- to Mesoproterozoic basins in Canada, suggesting a common Laurentian source, although no known proximal source for the youngest grains is known.
The maximum age of the Supergroup of 1.61 ± 0.03 Ga is provided by the age of the youngest detrital grain, which is ~0.1 Ga younger than expected.

Slope instability in a tectonically active Jurassic sedimentary basin, northwest British Columbia

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Sedimentary rocks of the upper Hazelton Group exposed near Stewart in British Columbia, constitute an excellent modern analog of slope processes in siliciclastic-dominated depositional systems. These sediments were deposited over volcanic arc rocks in an evolving extensional basin during the Middle Jurassic. Frequent tectonic activity along basin-bounding faults created significant instability on the slope that resulted in incision of submarine channels along with deposition of thick mass-transport complexes (MTC).

The succession investigated in this study includes a wide range of gravity flows. The basal portion is dominated by unconfined thinly bedded turbidites which are overlain by incised channel complexes. This corresponds to progradation of the submarine slope over the basin floor during a normal regression. The proportion of MTCs gradually increases near the top of the succession. Incoherent debris flows are interbedded with amalgamated sandstone beds whereas fine-grained turbiditic intervals are generally absent. The uppermost unit of the succession consists of 500 metres of amalgamated slumps and debris flows. Overall, MTCs constitute more than 50% of the entire sedimentary succession.

Even though it is difficult to clearly separate the effects associated with shoreline shifts from those driven by tectonic processes, sediments of the upper Hazelton Group near Stewart indicate a strong influence of tectonic input. Sudden steepening of the slope in response to fault movement is likely to have triggered rapid incision, sediment bypass and deposition of abundant MTC in the higher portion of the succession. Syn-sedimentary faulting was a major component in determining the nature of the gravity flows. Thick MTC were deposited during fault reactivation which interrupted the overall regressive cycle responsible for progradation of the slope succession over the basin floor.

An objective and testable subdivision scheme for the southeastern Canadian Cordillera

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A quick review of papers published between 2000 and 2008 reveals that there is no consensus on the best subdivision scheme and terminology to use for regional maps of the southeastern Canadian Cordillera. For example, the westernmost high-grade rocks of the Omineca Belt located west of Revelstoke have been referred to as "Kootenay Terrane" (e.g. Johnston et al., 2000); "undivided high grade rocks" (Carr and Simony, 2006); "Middle Unit of the Shuswap Complex" (Teyssier et al., 2005); "Late Proterozoic-Mesozoic metamorphic assemblage of the Middle-crustal zone" (Kruse and Williams, 2007); "Neoproterozoic Windermere Supergroup of the Selkirk allochthon" (Gibson et al, 2005);

"Monashee Cover sequence" (Thompson et al., 2006). The boundaries between units also differ, which adds to the confusion. A unique terminology based on testable criteria would greatly facilitate the comprehension of tectonic issues for non-Cordilleran geologists, students starting Cordilleran studies, and Cordilleran geologists as well.

Three main *tectonometamorphic* units can be singled-out based on distinct timing of ductile deformation and thermal peak. These units are, from upper to lower structural levels: the **Suprastructure** that was deformed and metamorphosed before 120 Ma; the **Selkirk allochthon Infrastructure** that was mainly deformed and metamorphosed between 120 and 60 Ma; and the **Monashee Complex** that was deformed and metamorphosed between 59 and 47 Ma. Although less diagnostic, metamorphic grade, timing of cooling, timing of plutonic activity, and lithostratigraphic assemblages, also contribute to the definition of these three units. These names were chosen because they assure continuity with the traditional subdivision of Read and Brown (1981) and they carry tectonometamorphic information. A map of the southeastern Canadian Cordillera presenting the proposed subdivision scheme accompanies this abstract. With the acquisition of new data, the boundaries between the three units and the criteria used to distinguish them could be refined and/or modified.

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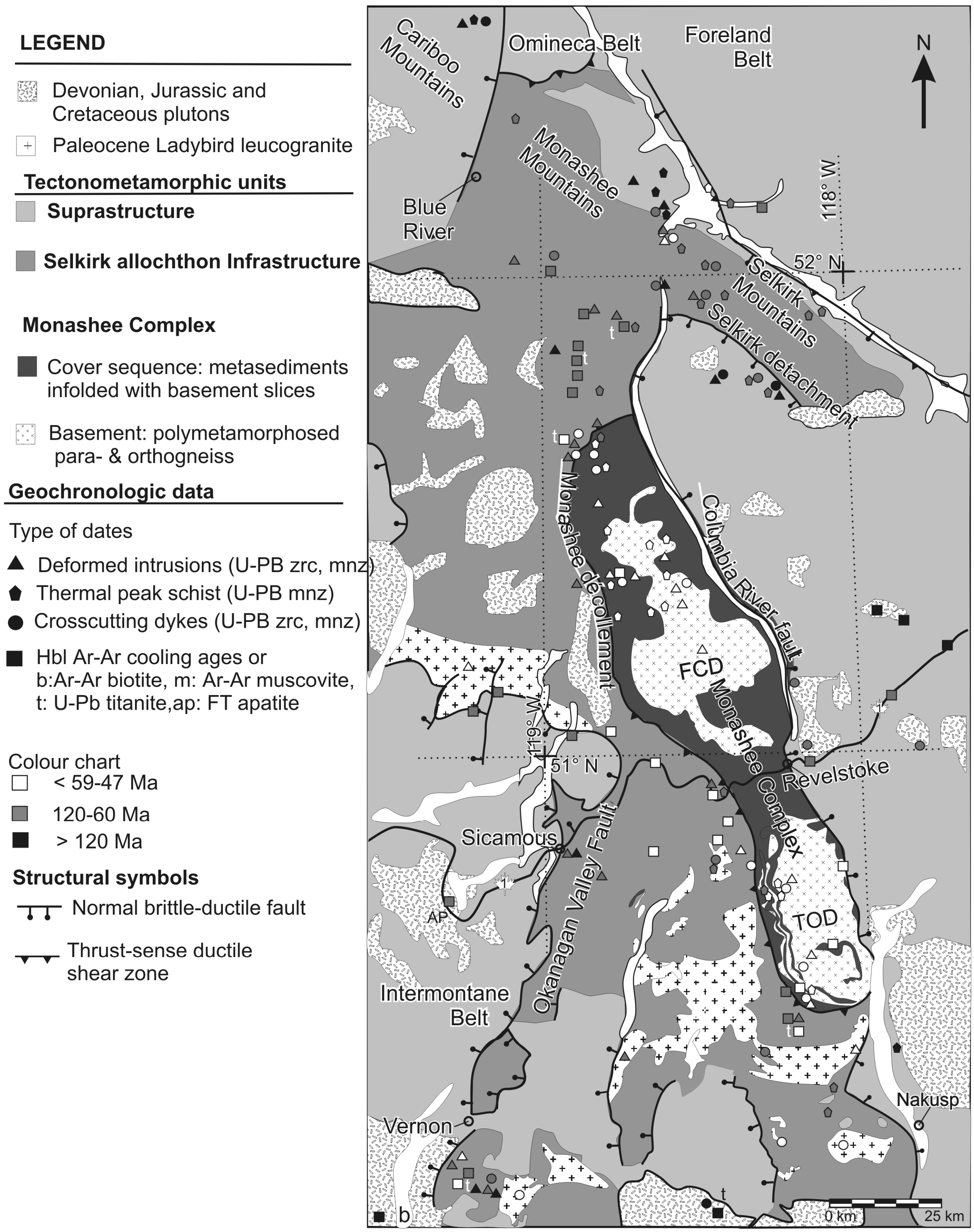

Figure 1: Subdivision scheme for southeastern Cordillera from Gervais et al. (above)

Epidote eclogites from Ross River Area, Yukon, Canada, indicate very high pressure and thus deep burial

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Eclogites occur as tectonic inclusions in metasedimentary rocks at several locations within Yukon Territory (Erdmer 1987, Erdmer et al. 1998). In the Ross River area the eclogites contain omphacite-garnet-Ca-Na amphibole-epidote-rutile-quartz. Phengite, paragonite, and titanite are local additional phases. The matrix of omphacite and Ca-amphibole is fine-grained and strongly deformed. Using bulk X-ray fluorescence analyses we have calculated isochemical phase diagram P-T sections (P-T pseudosections) using Theriak-Domino software (de Capitani and Brown 1987). The chemical system used is SiO_2–TiO_2–Al_2O_3–FeO-MgO-CaO-Na_2O-K_2O-H_2O. We have not modeled MnO and ferric iron because of the lack of activity-composition data for minerals other than garnet. The P-T boundary of lawsonite-out provides approximate lower P and T limits on the stability of epidote with garnet and omphacite. The results are: 480-520 °C at 20 kbar. This is near the lawsonite-eclogite/epidote-eclogite boundary at ~500°C and ~23 kbar (Krogh-Ravna and Terry 2004). Garnet analyses indicate compositional zoning with Mn-rich cores. Using Domino we have calculated grossular and pyrope isopleths and used the intersections of the observed grossular and pyrope compositions to estimate P and T at the time of crystallization of garnet cores. The results range from 475-493 °C and 19.7-23.5 kbar. We estimated temperatures using the Zr in rutile geothermometer. At 20 kbar the estimated minimum T using the minimum detection limit for Zr (22 ppm) is 511°C. The T range is 521-557°C. The metasedimentary host rock yielded three matrix results with 560 ± 54°C. These last results lead us to suggest that the host rocks experienced a similar T history to the eclogite inclusions. The Ross River eclogite was formed by the subduction related metamorphism, but did not involve continental collision. Ultrahigh pressures (coesite stability field) are usually associated with metamorphism involving continental collision. The implied tectonic uplift of Ross River eclogite is greater than previously thought.

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Insight into the rate of development of a major orogenic structure and evidence for a long, hot orogen within the southern Canadian Cordillera

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Investigations of the Selkirk fan, a composite orogenic structure within the southern Canadian Cordillera, provide evidence for a long, hot orogen whose mid- to lower crust appears to have remained deeply buried (>25 km), hot (>600-800°C), and laden with melt for ≥90 Myr. Based on the absence of data from other orogens (ancient to modern) that suggest similar durations of time for sustained deep burial associated with orogenesis, this feature appears to be unique to the Canadian Cordillera, or is it?

The Selkirk fan represents a zone of structural divergence where structures change from SW- to NE-verging as they transition eastward from the core zone of the southern Omineca belt into the "thin-skinned" deformation of the Foreland belt. The Selkirk fan initially developed in the Middle Jurassic, but was in part, substantially reworked and overprinted during the Cretaceous to Tertiary as it was translated northeastward during the main phase of Mesozoic contraction. More specifically, the SW-vergent structures and low- to medium-grade metamorphic assemblages in the fan's west flank developed in the Middle Jurassic (ca. 172-167 Ma), and were exhumed to upper crustal levels at this time. Conversely, the NE-vergent structures and high-grade assemblages currently exposed in the east flank of the fan were buried to deep crustal levels (>25 km), perhaps trapped beneath a plateau, where they were substantially reworked and overprinted during the Cretaceous to Tertiary (ca. 144 to 56 Ma). The degree of tectono-metamorphic overprinting appears to have been a function of structural level, and was most intense in the deepest levels of the east flank.

Some other important implications of this study include: 1) Even though there is a significant temporal disparity (>100 Myr) for the thermo-structural development of the Selkirk fan, there is generally a uniform consistency across the fan of geologic and geometric relationships between deformation and metamorphism. 2) The age of the metamorphic assemblages used to establish the regional isograds vary significantly across the fan from west (Middle Jurassic) to east (Cretaceous-Tertiary), yet the isograds all trend NW-SE with no significant break or jump in grade from one isograd to the next.

Geologic and tectonic evolution of Wrangellia: Perspectives from southwest Yukon

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The bedrock geology of southwest Yukon is characterized by Wrangellia and the Alexander terrane, two of the largest and most exotic of the Cordilleran terranes. Information on their internal stratigraphy and tectonic relationships with each other and the rest of the Cordillera is limited. New mapping of southwest Yukon by the Yukon Geological Survey has increased the knowledge of Wrangellia geology and a comparison with recent studies from Alaska and British Columbia allows for a new interpretation of its tectonic framework.

The majority of Wrangellia in Yukon is found in a southeast tapering wedge between the Denali and Duke River faults, where it comprises late Paleozoic volcanic rocks and associated sedimentary rocks, overlain by Triassic flood basalt, carbonate and marine siliciclastic rocks. The Alexander terrane in Yukon is characterized by Cambro-Ordivician volcanic and sedimentary rocks, Ordovician-Devonian carbonate and Devonian-Triassic siliciclastic rocks, calcareous sedimentary rocks and minor basalt. The Alexander terrane rocks are in fault contact with Wrangellia along the Duke River fault, a large and presently active terrane bounding structure with unknown kinematics and timing. Wrangellia and the Alexander terrane share an early history and are stitched together by a Middle Pennsylvanian pluton, suggesting that, at least in part, Wrangellia may have been built upon a portion of the Alexander terrane. However, by the Triassic the two terranes exhibit different histories with the Alexander terrane undergoing extension resulting in rift-related sedimentation and bimodal volcanism, whereas the Triassic of Wrangellia is characterized by thick accumulations of plume related flood basalt.

New geochemical data from the Pennsylvanian Station Creek Formation of Wrangellia in Yukon suggests a period of back-arc basin development prior to initiation of the overlying arc. This is in contrast with Wrangellia stratigraphy in Alaska but may be similar to rocks on Vancouver Island. The differences in the stratigraphy of Wrangellia along strike suggest that prior to Triassic Wrangellia was made up of disparate tectonic entities or, at the very least, encompassed a large area of variable tectonic environments.

Interpreting Paleontologic Data for Terrane Paleogeography

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Paleogeographic interpretations of tectonostratigraphic terranes in western North America frequently use paleontologic data to assist determinations of position and relative proximity to known continents. Fossils and paleontology contribute to these interpretations by providing data on climate, water temperature, depositional environment, and, through information provided by fossil provinces and endemism, relative proximity to continental fossil deposits. However, some studies still use overly simplistic models that misinterpret paleontologic data when interpreting terrane paleogeography. By combining basic theories of paleoclimate, ocean circulation, water temperature, and facies with known fossil distributions in space and time, these simplistic models are replaced by models that are more complex and provide more accurate paleogeographic interpretations.

When placing a fossil in a paleogeographic reconstruction, oceanic circulation must be considered. Water temperature can change across longitude as well as latitude due to upwelling and the Coriolis effect. Additionally, oceanic circulation and associated changes in water temperature can form barriers to migration for adult and larval or juvenile organisms. These factors can also affect the distributions of related species or genera of one organism type (i.e. conodonts) in very different ways. Adequate sampling and consideration of various sedimentary facies and depositional environments are further required to assert absence of fossils from an area. For example, the record of many Carboniferous to Triassic calcareous-shelled marine organisms is poor in the Canadian Rocky Mountains due to depositional environments with high sedimentation rates that were unfavorable to such organisms.

When reconstructing fossil provinces, the paleobiogeographic distribution of a given fossil must be determined by multiple geographically disparate samples spanning the time range of the fossil.

Accurate reconstruction of this paleobiogeographic distribution thus accounts for changes to that distribution through time and simultaneously requires precise geochronology. Ongoing studies of various fossil groups have recognized changes in fossil distributions over time, demonstrating that comparisons are most accurate when made between areas with contemporaneous data.

Individual fossil distributions can span vast areas of ocean, both latitudinally and longitudinally. They can also be restricted to single islands or groups of islands. This results in a map with many overlapping and non-overlapping areas of distribution that ultimately can be different for every fossil species. While general provinces for groups of different organisms can be constructed, there is rarely an easily quantifiable west to east or north to south transition of fossil groups as you leave one province for another. Thus, multiple factors affecting fossil distributions and more than one or several species known from a tectonostratigraphic terrane should be considered simultaneously when making paleogeographic interpretations. Finally, in order to mitigate possible discrepancies between imperfectly understood fossil organisms, the history of the terrane over geologic time must be considered.

The sub-Mississippian unconformity at Trout Lake, BC: mid-Paleozoic deformation, 'extra' stratigraphy and stratigraphic linkages

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In 1968, J.O. Wheeler first reported that the Mississippian Milford Group contains clasts of the underlying lower Paleozoic Lardeau Group that were foliated prior to their incorporation in Upper Mississippian conglomerate. Several geologists have since reported other lines of evidence for Middle Paleozoic deformation in the Kootenay Arc. Our observations from the Mount Thompson locality in 2009 strongly support the notion of pre-Upper Mississippian deformation. A previously unrecognized metasedimentary sequence underlies the Milford Group with apparent unconformity, but post-dates Paleozoic deformation that is clearly preserved in underlying strata of the Lardeau Group. The 'extra' stratigraphy may be a unique record in the Kootenay Arc of Early Mississippian or Devonian time (or possibly earlier) and could represent a stratigraphic link between the Lardeau Group and the Eagle Bay assemblage to the west. North of Trout Lake, the westernmost McHardy assemblage of the Milford Group depositionally overlies the Lardeau Group, thus its current assignment to the oceanic Slide Mountain terrane may need revision.

Neoproterozoic glaciation on a carbonate platform margin in Arctic Alaska and the origin of the North Slope subterrane

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The rotation model for the opening of the Canada Basin of the Arctic Ocean predicts stratigraphic links between the Alaskan North Slope and the Canadian Arctic islands. The Katakturuk Dolomite is a 2080 m thick Neoproterozoic carbonate succession exposed in the northeastern Brooks Range of Arctic Alaska. These strata have previously been correlated with the pre-723 Ma Shaler Supergroup of the Amundson Basin. Herein we report new composite $\delta^{13}C$ profiles and detrital zircon ages that test this connection. We go further and use stratigraphic markers and a compilation of $\delta^{13}C$ chemostratigraphy from around the world, tied to U-Pb ages, to derive an age model for deposition of the Katakturuk Dolomite. In particular, we report the identification of ca. 760 Ma detrital zircons in strata underlying the Katakturuk Dolomite. Moreover, a diamictite present at the base of the Katakturuk Dolomite is capped by a dark-colored limestone with peculiar roll-up structures. Chemostratigraphy and lithostratigraphy suggest this is an early-Cryogenian glacial diamictite-cap carbonate couplet and that deposition of the Katakturuk Dolomite spanned much of the late Neoproterozoic. Approximately 500 m above the diamictite, a micropeloidal dolomite with idiosyncratic textures that are characteristic of basal Ediacaran cap carbonates, such as tubestone stromatolites, giant wave ripples, and decameters of pseudomorphosed former aragonite crystal fans, rests on a silicified surface. Chemostratigraphic correlations also indicate a large increase in sedimentation rate in the upper ~1 km of the Katakturuk Dolomite and in the overlying lower Nanook Limestone. We suggest that the accompanying increase in accommodation space, along with the presence of two low angle unconformities within these strata, are the product of late Ediacaran rifting along the southern margin of the North Slope subterrane. There are no strata present in the Amundson Basin that are potentially correlative with the late Neoproterozoic Katakturuk Dolomite, as the Cambrian Saline River Formation rests of the ca. 723 Ma Natkusiak Formation. Detrital zircon geochronology, chemostratigraphic correlations, and the style of sedimentation are inconsistent with both a Canadian Arctic origin of the North Slope subterrane and a simple rotation model for the origin of the Arctic Ocean. If the rotation model is to be retained, the exotic North Slope terrane must have accreted to northwest Laurentia in the Early to Middle Devonian as part of the Ellesmerian orogeny.

Geology of the eastern Williston Lake region as constrained by the Peace Reach transect: implications for the tectonic evolution of the Canadian Cordillera

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The majority of Cordilleran orogenic models implicitly assume that all Cordilleran continental sedimentary sequences are autochthonous with respect to the North American craton. Many of these autochthonous models are based on the acceptance that a key boundary in the Cordillera, the Carbonate-Shale (C-S) facies boundary, is a primary, little-strained feature delineating the pre-orogenic ancient rifted west margin of the continent. Recent work has, however, shown several problems with interpreting the C-S boundary as a primary feature: (1) deformation on the west side of the boundary is asynchronous with that on the east; (2) paleomagnetic and sedimentological evidence indicate that rocks to the west of the C-S boundary are far-traveled relative to the rocks of the east; and (3) imbrication of deep marine shales to the west of the C-S boundary was accompanied by voluminous magmatism in the Omineca belt, whereas rocks to the east of the boundary are amagmatic. Such observations suggest that the C-S boundary is tectonic and support the interpretation that all material to the west of the C-S boundary is exotic.

This study aims to test the tectonic vs. primary nature of the C-S boundary by completing an E-W transect across the boundary in the Williston Lake region of NE BC. Particular attention will be paid to: (A) the geometry of C-S boundary and its relationship to bends of the fold and thrust belt to the east and (B) the Aley carbonatite intrusion along the C-S boundary. A calcite twin test will determine the relative age of bending in the fold and thrust belt. According to the Autochthonous model, bends should be primary features, whereas they are considered secondary features in the Exotic model. Through the collection of basic structural data and U-Pb geochronological sampling of the Aley carbonatite, the study will attempt to understand the implications of carbonatite magmatism for models of Cordilleran evolution.

Structural geology around the bend in Kootenay Lake

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Early Tertiary extension resulted in formation of an elongate, partially fault-bounded metamorphic high parallel to the Purcell Trench in southeastern British Columbia. Metamorphic grade ranges from the biotite zone on its flanks to the sillimanite zone in the centre of the metamorphic high. The metamorphic high is controlled by two major normal faults - the Purcell Trench and Gallagher faults.

The Purcell Trench trends NNW-SSE from the U.S. border northwards to Crawford Bay. The east-side-down Purcell Trench Fault occupies the trench and forms the eastern boundary of the amphibolite-facies belt until it dies out around Crawford Bay. Northward from this point the trench trends N-S, parallel to the west-dipping Gallagher Fault, which forms the western boundary of the amphibolite-facies belt. The gross structure of the metamorphic high is that of two oppositely-facing, partially overlapping footwall uplifts. The overlap zone, around the bend in Kootenay Lake (where the Purcell Trench Fault dies out) coincides with a change in the nature of D3.

D1+2 (Jurassic-Cretaceous) resulted in formation of a west-dipping foliation and gently-plunging stretching lineations and fold axes in the central Kootenay Arc. North of the bend in Kootenay Lake, west-dipping S2 is affected by oblique-west-down shear bands and associated open folds ($D3_N$). These structures are developed exclusively in the footwall of the Gallagher Fault and extend several kilometres to the east into the amphibolite-facies belt. They are developed along the entire length of the northern part of Kootenay Lake but end around the bend in the lake. South of here, extensional shears are absent. Instead, crenulations and buckles of S2 are developed on scales ranging from 1 cm to 100's of metres. $F3_S$ folds plunge SW or NW and cause large variations in the orientation of L2. There is no spatial overlap of $D3_N$ and $D3_S$ structures.

D3 structures are an expression of ductile footwall deformation associated with the two major normal faults. S2 lay in the extension field in the footwall of the west-dipping Gallagher Fault whereas it was in the shortening field in the footwall of the Purcell Trench Fault. This difference led to the formation of two distinct, but broadly coeval styles of D3 deformation ($D3_N$ and $D3_S$). These relationships imply an early Tertiary age for D3 in the central Kootenay Arc.

Geochemical and petrological characterization of the Summit Creek Stock

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The Summit Creek stock is a Mid-Cretaceous granitic pluton [*Archibald et al.,* 1983] that is located within the Cordilleran Omineca belt in the SE corner of British Columbia. It is a relatively small intrusion, and is part of a regional group of larger Jurassic, Upper Cretaceous, and other similar aged plutons. Included within the stock are both basketball-sized xenoliths, and a prominent 1m-wide dyke in the northern part of the stock. Samples collected from the stock proper are predominantly equigranular; however porphyritic xenoliths contain phenocrysts of both quartz and plagioclase, as well as large glomerophyric aggregates of biotite. According to the QAP diagram, the stock is classified as a biotite-granite, with a typical sample containing 35% quartz, 25% plagioclase, 30% K-feldspar, 7% biotite, 2% muscovite, and 1% accessory phases. New field and petrological observations indicate that the Summit Creek stock may have an outermost shell of K-feldspar-poor and biotite-rich tonalite. Minor accessory phases include pyrite, molybdenite, apatite, magnetite, ilmenite, monazite, and zircon. Detailed study of mineral chemistry has shown that unzoned plagioclase crystals have a principal composition of oligoclase. Those grains which do show zonation commonly have a spectacularly predictable array of oligoclase cores, and albite rims. The plagioclase contained within the dyke shows much more variation in mineral chemistry, with cores of zoned crystals ranging from bytownite to relatively Ca-rich andesine, and rims varying from Ca-rich andesine to more Na-rich andesine. Probed muscovite grains all have an unexpectedly high molar Fe content, and bear some resemblance to the species aluminoceladonite. Biotite grains are found to range from 32% annite, up to 60% annite, with the Mg-rich species occurring within xenoliths. Whole rock geochemistry indicates that the stock, and contained xenoliths are felsic, and weakly peraluminous (72.77wt%, and 65.51wt% SiO_2 respectively), and the intrusive dyke is mafic, and slightly metaluminous (48.98wt% SiO_2). Further examination of major element and trace element geochemistry will be used to investigate the tectonic setting of the Summit Creek stock, and compare it to proximal Mid-Cretaceous plutons in the Omineca belt.

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'Windy-McKinley' terrane, western Yukon: new data bearing on its composition, age, correlation and paleotectonic settings

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'Windy-McKinley' terrane of western Yukon and eastern Alaska comprises a schist-gabbro subdivision and the structurally overlying Harzburgite Peak – Eikland Mountain ophiolite. Both subdivisions are faulted above Yukon-Tanana terrane.

U-Pb age determinations on igneous zircons from felsic meta-volcanic rocks and gabbro from the schist-gabbro subdivision are Late Devonian and late Middle Triassic, respectively. Detrital zircon data from the schist-gabbro subdivision resemble those of nearby Yukon-Tanana terrane with prominent peaks at 1.7-1.9 Ga and 2.5-2.7 Ga, but differ in having large numbers of Mesoproterozoic (1.0-1.5 Ga) and Early to mid-Paleozoic grains.

The igneous age determinations substantiate the previously proposed correlation of the schist-gabbro subdivision with successions on strike to the northwest (Pingston, unit Trcs, Hayes Glacier, Jarvis Creek, Yanert Fork). This correlation defines a belt of schist and Triassic gabbro lying outboard of, and in fault contact with, Yukon-Tanana terrane. Detrital zircon data suggest that the younger part of the schist-gabbro subdivision and the westwardly correlative Pingston 'terrane' (unit Trcs) may unconformably overlie both Insular and peri-Laurentian assemblages.

Geochemical data from Triassic gabbro of the schist-gabbro subdivision define two suites, one resembling enriched mid-ocean ridge basalt (EMORB) but overall more enriched, and the other resembling modern island arc tholeiitic basalt (IAT). Data from diabase and gabbro of the ophiolite define three suites, one resembling EMORB, one resembling IAT, and the third resembling calc-alkaline basalt.

The geochemical data suggest that magmatism in both subdivisions occurred in a supra-subduction zone setting. The age of the ophiolite has not been determined however and the possibility that the two subdivisions are unrelated, having been formed above different subduction zones at different times, cannot be ruled out. Without age data, any correlation of the ophiolite would be speculative, but its arc chemistry affirms a previously proposed correlation with the Chulitna terrane of the southern Alaska Range.

Terrane spotting: Origins and translations of Cordilleran exotic terranes and the geodynamics of their accretion - investigations by the Edges Project 2008-2012

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Paleozoic Cordilleran terranes probably originated in three paleogeographic realms, based on faunal affinities, detrital zircon provenance, and tectonic history: 1) western peri-Laurentia/eastern paleo-Pacific, 2) the western paleo-Pacific, and 3) the Arctic region including the northern Caledonides, Baltica and Siberia. The peri-Laurentian terranes form an inner belt that encloses the western Pacific Cache Creek terrane. The Arctic terranes occupy an outer belt, north and west of the peri-Laurentian realm. They include Arctic Alaska and Farewell terranes, which are primarily of Siberian affinity; and Alexander, Yreka/Trinity and the Sierra City melange, which more closely resemble the northern Caledonides and Timanide orogen of northern Baltica, Novaya Zemlya and northern Taimyr. Geological correlations and shared endemic faunas suggest early linkages between Arctic Alaska, Farewell and Alexander; and Alexander, Yreka and Sierra City melange. Silurian faunas and Caledonian magmatic ages place all of these terranes within the Arctic realm until mid-Paleozoic time. First interactions with western peri-Laurentia varied temporally from Early Devonian for Yreka and Sierra City melange, to mid-Jurassic for Alexander terrane. The geodynamics for their travel and accretion are speculative at present.

The Edges project is a 5 year, cooperative endeavor between GSC, Yukon Geological Survey, BC Geological Survey, Geoscience BC, USGS, and university partners. It aims at understanding the origins and translation and accretion history of exotic Cordilleran terranes. Fundamental questions include: Why were the Arctic terranes expelled into the eastern paleo-Pacific ocean? Why and how did this process apparently act over a 200 Ma period (Devonian to Triassic)? Was the Cache Creek terrane incorporated within the peri-Laurentian belt by oroclinal enclosure, or some other mechanism; and how did this relate to accretion of the Arctic terranes? Is the Devonian inception of subduction and arc activity on the western Laurentian margin linked to westward expansion of Arctic plate boundaries?

Stratigraphy, structure and metamorphism of the Esplanade Range, Southeastern Canadian Cordillera

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The Esplanade Syncline is part of a fold train (anticline-syncline-anticline) just east of the Selkirk Fan Axis, north of Rogers Pass (SE British Columbia). The fold train deforms strata of the Neoproterozoic Kaza Group and underlying units of the Mica Creek succession. The Lower Cambrian Hamill Group overlies these rocks in a syncline along the Fan Axis.The axial surface of the Esplanade

Syncline dips southwest. Its vertical to overturned west limb is truncated by the Esplanade Thrust such that the west limb of the syncline is progressively eliminated southward toward Rogers Pass. The thrust repeats a panel of west-dipping strata over the west-dipping east limb of the syncline. The syncline is part of a fold propagation fold pair related to the thrust, and, in part, predates the thrust. The Rogers Pass region lies at the southern limit of the 400 km long Selkirk-Monashee-Cariboo (SMC) metamorphic complex, bounded on the east side by the garnet isograd. The garnet and staurolite isograds outline metamorphic highs and lows with the metamorphic synform roughly coinciding with the Esplanade Syncline. The metamorphic antiforms and synforms continue soutward to where the strata form a thrust-repeated homocline. The isograd pattern can therefore not be explained by folding of the isograds. The critical index minerals form porphyroblasts superimposed on the deformation fabric suggesting that metamorphism was syntectonic with the peak reached late in the deformation. Pressure-temperature pseudosections with coexisting staurolite and kyanite suggest pressures of about 6 kbar. The fold train described above and the narrow southern continuation of the SMC are truncated by the mid-Cretaceous (~100 Ma) Battle Range pluton suggesting tht the deformation and metamorphism are older than the mid-Cretaceous. The available geochronologic results are consistent with this interpretation. The metamorphic and deformation style suggest that the Esplanade Syncline formed in the deeper part of an Early Cretaceous suprastructure in the transition to the infrastructure.

Late superstructure-style folding of the Monashee complex infrastructure

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In the classic infrastructure-superstructure association upright folds of the superstructure become progressively more recumbent downwards into the infrastructure zone, accompanied by an increase in metamorphism from greenschist- to amphibolite-grade conditions (e.g. Wegmann 1935). Rock units are continuous through the transition zone and, in general, the earliest folds of the infrastructure are inherited from upright superstructure folds. With progressive deformation and changing boundary conditions, the position of the infrastructure-superstructure transition zone can migrate through the crust. Thus rocks previously deformed in the infrastructure zone might migrate into the superstructure and undergo further deformation there.

An example of this situation is observed in the Thor-Odin region of the Monashee complex in southeastern British Columbia. Here, an exposed section of the middle crust developed a transposition foliation and attendant structures characteristic of a metamorphic infrastructure between ca. 56 and 54 Ma (e.g. Hinchey et al. 2006). It was subsequently buckled into an open antiform by NW- to N-trending upright folds of superstructure affinity. Parasitic asymmetric folds verge towards the antiformal hinge. This late stage of folding is interpreted to have formed during the waning stages of a regional-scale top-to-NE verging deformation event associated with convergent boundary conditions along the western margin of North American.

At the highest structural level exposed in Thor-Odin a suite of subvertical and N-striking ca. 52 to 48 Ma lamprophyre dykes (e.g. Adams et al. 2005) cross-cut the macroscale upright antiformal structure. Dyke emplacement at this time is consistent with the regional transition to dextral transtensional boundary conditions. However, at the deepest structural level exposed in Thor-Odin a suite of mafic dykes interpreted to be contemporaneous with the lamprophyre dykes intrudes the host rock under non-coaxial top-to-NE conditions of deformation. Therefore the superstructure-infrastructure transition zone was migrating downwards through the middle crustal section at Thor-Odin during the time of dyke emplacement.

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Stratigraphic and paleotectonic studies of the Middle Paleozoic Sicker Group and contained volcanogenic massive sulphide (VMS) occurrences, Vancouver Island, British Columbia

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The Middle Paleozoic Sicker Group (SG) on Vancouver Island is believed to record the evolution of an oceanic island arc that represents the basement of Wrangellia. The SG is exposed in several structural uplifts on Vancouver Island and the Canadian Gulf Islands, including the Buttle Lake, Bedingfield, Nanoose and Cowichan Lake uplifts and potentially portions of the Westcoast Crystalline Complex. SG strata in the Buttle Lake uplift host the producing Myra Falls volcanogenic massive sulphide (VMS) deposit, the largest producing VMS deposit in western Canada. Other VMS occur throughout the SG in the Cowichan Lake and Bedingfield uplifts, and in possibly correlative rocks of the Westcoast Crystalline Complex. A paucity of isotopic and fossil age control, and lack of a detailed understanding of the stratigraphy of the SG, has impeded the development of a robust model to explain the origins of Wrangellia and hampered exploration for stratigraphically controlled VMS mineralization. Our research combines geological mapping with geochronological, biostratigraphic, isotopic, and lithogeochemical studies to better understand the tectonic history and metallogeny of the SG. New geological mapping of key parts of the SG is aimed at better constraining stratigraphic relationships within the SG, and in particular the geological setting of VMS deposits. We are employing U-Pb and Ar-Ar dating of intrusive and extrusive rocks as well as microfossil (radiolarian and conodont) biostratigraphy of sedimentary units to develop a coherent chronostratigraphic framework for each of the SG uplifts. Whole rock lithogeochemistry together with Nd and Hf isotopic studies is being used to constrain the petrogenesis of SG magmatism and test for possible linkages to continental (possibly Laurentian) crust. Lead isotopic compositions of sulphide occurrences are being used to discriminate between syngenetic or epigenetic occurrences, in order to evaluate the potential for additional large VMS deposits in the SG. Results of the study will enhance our knowledge of Wrangellian tectonic evolution and metallogeny, and lead to a better understanding of a critical part of the history of crustal growth in the North American continent.

Structure, metamorphism, and tectonism in the Mica Creek Area, southeastern British Columbia

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Rocks of the Neoproterozoic Horsethief Creek Group in the northern Monashee Mountains, southeastern British Columbia, have been exposed to P-T conditions up to 8 kbar and 750^{o}C in the muscovite-out zone south of Soards Creek. Structural, stratigraphic, and metamorphic continuity has been established between the Mica Creek area and the Selkirks to the east (Simony et al. 1980) and the Cariboos to the west (Pell and Simony 1987). The Scrip Nappe structure has been reinterpreted based on new structural and stratigraphic evidence from field mapping. Recent work (e.g. Sevigny et al. 1990, Digel et al. 1998, Crowley et al. 2000, Gibson et al. 2005, Ghent and Villeneuve 2006) has revealed that metamorphic events occurred at 170-150 Ma, 135-120 Ma, 100-90 Ma, and 70-60 Ma. This study shows how many of the apparent isograds in the area may be artifacts of metamorphic overprinting. Late Jurassic garnet grade metamorphism was overprinted by Early Cretaceous kyanite-staurolite and kyanite grade metamorphism, followed by Mid-Cretaceous sillimanite grade metamorphism in the south. An Early Tertiary thermal event introduced "pod sillimanite" in the west of the area (Digel et al. 1998). These thermal events appear to have encroached on the area from the south and west. Tertiary uplift was likely related to thrusting on the underlying detachment surface; D_3 buckle folds developed during this event.

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The inside of a batholith is not boring!

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Regional-scale geologic maps of the Cordillera typically render batholiths as semi-elliptical to irregularly shaped and brightly colored blobs with no internal features. Much attention is given to batholith-host contacts because these are often delineated by faults or shear zones of interest to structural geologists and are dotted with hydrothermal ore deposits, a result of the heat of intrusion. Detailed investigations of host-rock thermal aureoles [*1,2*] provide important information on orogenic processes and metamorphism; typically, however, the batholith is ignored apart from an acknowledgement that it provides heat to drive these processes.

The frozen magmas that now comprise batholiths are the major agent of heat and mass transfer during orogenesis. The range of processes recorded by these magmatic rocks includes crustal-scale processes such as mantle-derived magma input during orogenic crust formation and element cycling in the crust during long-lived orogenesis, and local-scale processes such as magma-mixing, deformation, ore formation, host-rock assimilation, and magma-chamber amalgamation.

Investigation of these processes as recorded *within the Nelson batholith*, southern B.C., has commenced and initial field observations and whole-rock compositions are reported here. **Field observations**: The batholith is intensely sheared on the east and north and this obscures internal structures and textures. On the west the batholith is truncated by the Slocan Lake Fault and there is intense localized hydrothermal alteration. Along Slocan Lake there are spectacular exposures of migmatite and magma-mixing. A record of magma-mixing is also exposed in the east near Balfour, and compositions and textures from Balfour to Atbara in the west (a distance of ~13 km) change rapidly. Contacts are typically cryptic. Significant concentrations of large (up to 12 cm long) alkali-feldspar crystals occur locally, sometimes aligned. **Whole-rock compositions**: Petrographically, dominant rock types include (Q-A-P classification) quartz monzonite and quartz syenite, with subordinate granite and micro-diorite. Compositions are dominantly in the 65–70 wt% SiO_2 range and are dominantly magnesian and calc-alkalic metaluminous-to-peraluminous, typical of other Cordilleran granitoids [*3*]. All major element oxides and important trace elements (except perhaps Rb) have more-or-less linear and decreasing abundances with increasing SiO_2.

A well-sampled (22 samples over ~36 km) E-to-W traverse across the batholith exposes rocks ranging quartz monzonite to granite. Most samples appear to comprise a single suite based on linear trends on Harker plots, suggesting that fractional crystallization of feldspar + pyroxene + amphibole + apatite + magnetite + biotite was the dominant differentiation mechanism. Linear compositional trends indicative of a single magmatic system are not accompanied by regular mineralogical zoning in the field where significant short-length-scale (over several hundred meters) variations invoke a dynamic magma-chamber.

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Cariboo Alp revisited: Structure and thermochronology studies on the southwest flank of Thor-Odin dome, BC do not support a syn- or post-metamorphic structural break

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Cariboo Alp, a well-exposed 2x3 km belt of Kfs-sil migmatitic paragneiss on the southwestern flank of Thor-Odin dome has been interpreted as: i) a duplex within a Cretaceous to Late Paleocene NE-directed ductile thrust zone; ii) part of a Cretaceous to Paleocene-Eocene zone of mid-crustal channel flow; and/or, iii) an Eocene ductile extensional shear zone.

Prominent structures at Cariboo Alp include a moderately S-SW dipping composite transposition foliation with concordant leucosome, granitoid lenses and boudinaged layers, W-SW plunging mineral and stretching lineations, and NE verging folds. NE-directed kinematic indicators, in the motion plane parallel to the SW plunging sillimanite and stretching lineation, include shear bands, S-C fabrics and fold vergence. These indicate that the predominant structures were formed during progressive top-to-the-NE flow. Deformation was ongoing at ca. 62 Ma, during thermal-peak Kfs-sil-melt metamorphism, and had mainly ended by ca. 58 Ma based on U-Pb zircon ages of leucosome and pegmatite generated during decompression melting. Structures indicating E-W extension include chlorite slickenlines on fracture surfaces and boudinaged pegmatites with muscovite and chlorite in pull-aparts, but these are of minor extent and importance.

Biotite and hornblende crystals from pegmatite and representative paragneiss from an ~12 km thick structural section were dated using $^{40}Ar/^{39}Ar$ thermochronology. Hornblende cooling dates throughout the section range between ca. 53-56 Ma, and biotite cooling dates are ca. 51-53 Ma, regardless of lithology or structural level. The cooling history indicates that any juxtaposition of structural levels that occurred at Cariboo Alp predated exhumation of the dome, and that rocks throughout the entire structural package, above and below Cariboo Alp, cooled at the same time. Together, the structural evidence and $^{40}Ar/^{39}Ar$ thermochronology do not support the interpretation of a regional-scale extensional shear zone, the top or base of a channel, or a significant syn- or post-metamorphic break at Cariboo Alp.

Relocating the boundary between Yukon-Tanana and Cassiar terranes, and the possible significance of Early Cretaceous extension in central Yukon

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The allochthonous, pericratonic Yukon-Tanana terrane is a northwest-trending belt of polydeformed metasedimentary, metavolcanic and meta-igneous rocks that lie within the central portion of the northern Canadian Cordillera. Detailed studies of the terrane have progressively established a coherent regional stratigraphic framework that records the evolution of a system of rifted continental fragments, island arcs and back-arc basins that evolved off the western Laurentian margin between mid-Paleozoic and early Mesozoic time. Yukon-Tanana terrane was subjected to four, and locally five, episodes of deformation and associated metamorphic events. However, the regional extent of these events remains unclear because knowledge of bedrock geology in some areas is based on reconnaissance-scale (1:250 000) mapping from the 1970s.

Detailed mapping (1:20 000-scale) associated with the present study focused on resolving the stratigraphic and structural relationships in the 'Mendocina Creek' (NTS 105F/5) and eastern Livingstone Creek (NTS 105E/8) map sheets of south-central Yukon. Fieldwork revealed that the regional structure in the 'Mendocina Creek' area is characterized by at least four phases of deformation. The latest, brittle phase of deformation is related to a period of Cretaceous(?) extension and is expressed on the map by abrupt unit truncations. Few studies document the extent to which Cretaceous deformation has affected Yukon-Tanana terrane. Details from our mapping and from continuing micro-structural analyses will be used to refine our current understanding of Cretaceous deformation in Yukon-Tanana terrane.

Our mapping also resulted in relocating the boundary between Yukon-Tanana and Cassiar terranes. Previous studies interpreted the d'Abbadie fault system – a north-trending system of Late Cretaceous brittle-ductile, dextral strike-slip faults – as the terrane boundary. Our mapping shows the Yukon-Tanana terrane extending east of the d'Abbadie fault zone. Numerous, previously unmapped, plutons of Early Mississippian meta-granite intrude the rocks east of d'Abbadie fault. These are of similar age and composition as the first cycle of widespread arc magmatism in Yukon-Tanana terrane (Finlayson cycle), thus suggesting correlation with that terrane instead of Cassiar terrane as previously suggested. In our interpretation, the Cassiar terrane is thrust over Yukon-Tanana along a west-verging, brittle-ductile thrust fault located approximately 20 km east of d'Abbadie fault zone.

P-T estimates on metapelites from Joss Mt., Selkirk allochthon, South East British Columbia

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The Joss Mt. area is located in the Selkirk allochthon, west of the Thor-Odin high strain zone [1], which bounds the western side of the Monashee complex. The Selkirk allochthon tectonically overlies the Monashee complex, which is one of the metamorphic complexes exposing the deepest crustal rocks of the whole Canadian Cordillera.

Outcropping rocks are metagranitoids, calcsilicates, marbles and metapelites penetratively transposed from micro to regional scale and recording the regional foliation S_T [2]. Analyses of microstructures and mineral compositions in metapelites allow to infer a P-T evolution. S_T is a composite foliation defined in part by shape preferred orientation and lattice preferred orientation of WmII and BtII. Locally coarse-grained WmI porphyroclasts and BtI are folded by intra folial folds preserved between S_T films, indicating that they predate at least part of S_T development. Coarse-grained Grt shows rare inclusion trails, which are oblique to S_T. They are straight in the core and bent in the rim of the porphyroblasts, and locally are continuous with S_T in the matrix, suggesting that Grt porphyroblasts grew during S_T development. Grt encloses BtI, Qtz, rare PlI and WmI. Fine-grained Grt shows rational grain boundaries with BtII. Post-S_T micro-shear zones are marked mainly by BtIII±Sil, and later locally replaced by WmIII and Chl. Sil grew at the expense of Wm (I and II).
The composition of successive generations of mineral phases, shows no significant variation, suggesting that either these phases developed under similar metamorphic conditions, or that diffusion during post-kinematic recrystallisation was effective. The indicated P-T conditions lie at lower temperature than the reaction curve: Wm+Ab=Sil+Kfs+L [3]. The post-S_T development of Sil suggests that the late re-equilibration occurred in a field characterised by a high T/P ratio, requiring a supplementary heat supply with respect to that consequent to crustal thickening.

References:

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