February 20-21, 2016
Schedule and Abstracts

CORDILLERAN TECTONICS WORKSHOP 2016

Cordilleran Tectonics Workshop

February 20-21, 2016

Hosted by School of Earth and Ocean Sciences (SEOS), University of Victoria

CTW Committee:
Gerri McEwen, Jeremy Beales, Travis Dawson

Volunteers:
James Balchin, Kellie Beck, Justin Szabo, Kevin Evancio, Simon Carroll

2016 Attendees

Carlee	Akam	University of Victoria	Brentwood Bay	BC
Joel	Angen	Mineral Deposit Research Unit	Vancouver	BC
Chris	Barnes	University of Victoria	Victoria	BC
Luke	Beranek	Memorial University of Newfoundland	St. John's	NL
Esther	Bordet	Yukon Geological Survey	Whitehorse	YT
Erin	Bros	Mapping Geologist	Prince Rupert	BC
Spencer	Brown	University of Victoria	Victoria	BC
Andy	Clark	Simon Fraser University	Burnaby	BC
Rosie	Cobbett	Yukon Geological Survey	Whitehorse	YT
Maurice	Colpron	Yukon Geological Survey	Whitehorse	YT
Mark	Cooper	Sherwood GeoConsulting Inc.	Calgary	AB
Jim	Crowley	Boise State University	Boise	ID
Yao	Cui	BC Geological Survey	Victoria	BC
Rita	Dubman	Simon Fraser University	Burnaby	BC
Athena	Eyster	Harvard University	Cambridge	MA
Curtis	Evans	University of Victoria	Victoria	BC
Peter	Fermor	Devon Canada	Calgary	AB
Fil	Ferri	Ministry of Natural Gas	Victoria	BC
Malcolm	Foo	University of Calgary	Calgary	AB
Dan	Gibson	Simon Fraser University	Burnaby	BC
Brian	Grant	Quadra Mining Corp	Victoria	BC
William	Howard	Structurally Fine Concepts	Calgary	AB
Steve	Israel	Yukon Geological Survey	Whitehorse	YT
Marji	Johns	Pacific PaleoQuest	Brentwood Bay	BC
Sandra	Johnstone	Vancouver Island University	Nanaimo	BC
Rachel	Kim	University of British Columbia	Vancouver	BC
Jamie	Kraft	Teck Resources Limited	Vancouver	BC
Lucinda	Leonard	University of Victoria	Victoria	BC
Ray	Lett	University of Victoria	Victoria	BC
James	Logan	JLoGeologic	North Saanich	BC
Siobhan	McGoldrick	University of Victoria	Victoria	BC
Dejan	Milidragovic	Geological Survey of Canada	Vancouver	BC
Kristin	Morell	University of Victoria	Victoria	BC
Andrea	Morgan	University of Calgary	Calgary	AB
Jim	Mortensen	University of British Columbia	Vancouver	BC
David	Moynihan	Yukon Geological Survey	Whitehorse	YK
JoAnne	Nelson	BC Geological Survey	Victoria	BC
Graham	Nixon	BC Geological Survey	Victoria	BC
Karin	Oberg	University of Victoria	Victoria	BC

Luke	Ootes	BC Geological Survey	Victoria	BC
Colin	Padget	University of Calgary	Calgary	AB
Dave	Pattison	University of Calgary	Calgary	AB
Barry	Penner	University of British Columbia	Vancouver	BC
Laurence	Pryer	University of Alberta	Edmonton	AB
Leanne	Pyle	VI Geoscience Services Ltd	Brentwood Bay	BC
Mana	Rahimi	Mineral Deposit Research Unit - UBC	Vancouver	BC
Chris	Rees	Imperial Metals Corp.	Victoria	BC
Steve	Rowins	BC Geological Survey/University of Victoria	Victoria	BC
Erica	Rubino	University of South Carolina	Columbia	SC
Alexei	Rukhlov	British Columbia Geological Survey	Victoria	BC
Jim	Ryan	Geological Survey of Canada	Vancouver	BC
Philip	Simony	University of Calgary	Calgary	AB
Paul	Starr	University of Calgary	Calgary	BC
Scott	Stephen	University of Calgary	Calgary	AB
Derek	Thorkelson	Simon Fraser University	Burnaby	BC
Cees	van Staal	Geological Survey of Canada	Vancouver	BC
Bram	van Straaten	BC Geological Survey	Victoria	BC
Lianna	Vice	Simon Fraser University	Vancouver	BC
Marian	Warren	Jenner GeoConsulting Inc.	Calgary	AB
Ewan	Webster	University of Calgary	Calgary	BC

Schedule – 2016 Cordilleran Tectonics Workshop

Friday Feb 19

18:00 - Informal Meet and Greet, early workshop check-in

Bard and Banker Scottish Pub
1022 Government Street, Victoria, BC

Saturday Feb 20

Bob Wright Center, School of Earth and Ocean Sciences Rm A104

8:00 - Breakfast/Check-in
9:00 - Talk Session
10:30 - Coffee Break
11:00 - Talk Session
12:30 - Lunch
13:30 - Talk Session
15:30 - Poster Session
18:00 - End of Second Day
18:00 - Drinks and dinner at The Sticky Wicket Pub

Sunday Feb 21

Bob Wright Center, School of Earth and Ocean Sciences, Rm A104

8:00 - Breakfast
9:00 - Talk Session
10:30 - Coffee Break
11:00 - Talk Session
12:30 - Lunch/End of Conference

Technical Program – CTW 2016

Saturday, February 20 (Bob Wright Center A104)

8:00	**Breakfast and Poster set-up**
9:00	**Welcome and Announcements**
9:05	**Evidence for late Quaternary rupture along the Leech River Fault, greater Victoria region, British Columbia** Kristin Morell[1], Christine Regalla[2], Lucinda Leonard [1], Colin Amos[3], Vic Levson[1] *[1]School of Earth and Ocean Sciences, University of Victoria, BC, [2]Boston University, MA, [3]Western Washington University, WA*
9:25	**Evidence for magma emplacement in the lower crust beneath the Anahim Volcanic belt, Central British Columbia, Canada from the results of 3He/4He isotope analysis of CO2-rich seepage gas.** Ray Lett *University of Victoria, BC Ministry of Energy and Mines – Geological Survey Branch, Victoria, BC*
9:45	**Tectonic evolution of the Tofino and Queen Charlotte basins, British Columbia: combining multiple data sets on Cenozoic micropalaeontology, strontium isotope stratigraphy, offshore wells and basin geology.** Marjorie J. Johns[1], Christopher R. Barnes[2], Julie A. Trotter[3], Clio J. Bonnett[2], Y. Roshni Narayan[2] *[1]Pacific PaleoQuest, Brentwood Bay, BC, [2] School of Earth and Ocean Sciences, University of Victoria, Victoria, BC, [3]University of Western Australia, School of Earth and Environment, Crawley, WA*
10:05	**Discussion**
10:30	**Coffee**
11:00	**Trace-element compositions of igneous apatite indicate tectonic settings** Alexei S. Rukhlov [1,a], Mao Mao [1], Stephen M. Rowins [1,2], Jody Spence [2], Laurence A. Coogan [2] *[1]British Columbia Geological Survey, BC, [2]School of Earth and Ocean Sciences, University of Victoria, BC*

11:20	**Linking Cordilleran deformation to extensional faulting, paleodrainage patterns, provenance and hydrocarbons in the foreland basin: Examples from the Lower Cretaceous of southern Alberta** Marian J. Warren *Jenner GeoConsulting Inc., Calgary, AB*
11:40	**Stikinia in southern Yukon: a perspective from the Teslin Mountain area** Esther Bordet *Yukon Geological Survey, Whitehorse, YT*
12:00	**Discussion**
12:30	**Lunch**
13:30	**Syncollisional late Early to early Late Jurassic volcanism, plutonism and porphyry-style mineralization on the northeastern margin of Stikinia** Bram I. van Straaten[1] *and JoAnne Nelson[1] *[1]British Columbia Geological Survey, Ministry of Energy and Mines, Victoria, BC, Canada*
13:50	**Pre-Early Jurassic mid-crustal tectono-metamorphism in Yukon-Tanana terrane at Aishihik Lake, southwest Yukon** A.D. Clark[1], H.D Gibson[1], S. Israel[2], J. Crowley[3] *[1]Simon Fraser University, [2]Yukon Geological Survey, [3]Boise State University*
14:10	**Detrital zircon data from basal Hazelton clastic strata in the Iskut region document the end-Triassic tectonic transition in northern Stikinia** JoAnne Nelson[1], Jeff Kyba[1] and Rich Friedman[2] *[1] BC Ministry of Energy and Mines – Geological Survey, [2] Pacific Centre for Geochemical and Isotopic Research, University of British Columbia, Vancouver, BC*
14:30	**Discussion**
15:30	**Posters**
18:00	**Drinks and Dinner (The Sticky Wicket Pub)**

Sunday, February 21 (Bob Wright Center A104)

8:00	**Breakfast and Poster set-up**
9:00	**Announcements**
9:05	**Paleozoic stratigraphy, tectonics, and metallogeny of the Pelly Mountains, central Yukon: project outline and preliminary results** Luke P. Beranek and Stephen J. Piercey *Department of Earth Sciences, Memorial University of Newfoundland, NL*
9:25	**Early Paleozoic volcanic rocks near Tay Mountain, central Yukon; Evidence for long lived crustal structures** Rosie Cobbett *Yukon Geological Survey, YT*
9:45	**New Constraints on the Age and Origin of Quesnellian Basement Assemblages in Southern BC and northern Washington from Detrital Zircon, Lithogeochemical and Fossil Age Studies** Jim Mortensen *Earth, Ocean, and Atmospheric Sciences, University of British Columbia, BC*
10:05	**Discussion**
10:30	**Coffee**
11:00	**Geochronology of the Gataga Volcanics of British Columbia and implications for Neoproterozoic glaciation and rifting** Athena Eyster *Harvard University, MA*
11:20	**Metallogenic evolution of the Mackenzie and eastern Selwyn mountains of Canada's northern Cordillera, Northwest Territories** Luke Ootes *BC Ministry of Energy and Mines – Geological Survey Branch*
11:40	**Discussion**
12:30	**Lunch**

List of Posters

(Alphabetical by Last Name of Presenter)

A structural history of the Nechako Basin, central British Columbia: A sinistral transtensional origin?

Joel J. Angen[1], Craig J.R. Hart[1], James M. Logan[2], Mana Rahimi[1], Rachel S. Kim[1],

[1]Mineral Deposit Research Unit, The University of British Columbia, BC
[2]Consulting Geologist, Victoria, BC

Pre-Early Jurassic mid-crustal tectono-metamorphism in Yukon-Tanana terrane at Aishihik Lake, southwest Yukon

Andy D. Clark[1], H. D. Gibson[1], S. Israel[2], J. Crowley[3]

[1]Simon Fraser University, Burnaby, BC
[2]Yukon Geological Survey, Whitehorse, YT
[3] Boise State University, Boise, ID

Geology of Tay Mountain area, central Yukon

Rosie Cobbett

Yukon Geologic Survey, Whitehorse, YT

New bedrock geology and plutonic suites maps for Yukon

Maurice Colpron

Yukon Geological Survey, Whitehorse, YT

Structural style variations in the BC foothills

Mark Cooper

Sherwood Geoconsulting Inc, Calgary, AB
University of Aberdeen, UK

Petrogenesis and emplacement of Schist Creek mafic-ultramafic complex, southwest Yukon

Rita Dubman[1], Dan Gibson[1], Jim J. Ryan[2]

[1]Simon Fraser University, BC,
[2]Geological Survey of Canada, BC

Geochronology of the Gataga Volcanics of British Columbia and implications for Neoproterozoic glaciation and rifting

Athena E. Eyster[1], Francis A. Macdonald[1], Filippo Ferri[2], and Mark Schmitz[3]

[1] Harvard University, Cambridge, MA
[2] Geologic Survey of Canada,
[3] Boise State University, Boise, ID

U-Pb age constraints on deformation of the Quatsino Formation, Quadra Island, British Columbia

Sandra Johnstone

Vancouver Island University, Nanaimo, BC

Stratigraphic and Lithological Constraints of Late Cretaceous Volcanic Rocks in the TREK Project Area, Central British Columbia (NTS 093E)

Rachel Kim

University of British Columbia

Middle to Upper Triassic picritic volcanism in northern Stikinia and comparison to other global arc-related and explosive picritic occurences

Dejan Milidragovic[1], Sebastian Bichlmaier[2], John Chapman[1], Alex Zagorevski[3]

[1]Geological Survey of Canada, Vancouver, BC
[2]University of Victoria, Victoria, BC
[3]Geological Survey of Canada, Ottawa, ON

Isograd map of the volcanic rocks of the Rossland Group, southeastern British Columbia

Andrea Morgan[1], Paul G. Starr[1], Matthew Polivchuk[1], David R.M. Pattison[1]

[1] University of Calgary, Calgary, AB

Stratigraphy and structure of the upper Hyland River area, southeast Yukon

David Moynihan

Yukon Geological Survey, Whitehorse, YT

Detrital zircon data from basal Hazelton clastic strata in the Iskut region document the end-Triassic tectonic transition in northern Stikinia

JoAnne Nelson[1], Jeff Kyba[2] and Rich Friedman[3]

[1] BC Ministry of Energy and Mines – Geological Survey Branch, Victoria, BC
[2] Ministry of Energy and Mines, Smithers, BC
[3] Pacific Centre for Geochemical and Isotopic Research, University of British Columbia, Vancouver, BC

Chemostratigraphy of late Proterozoic carbonate units in northern Selwyn basin, east-central Yukon

Colin Padget[1], David Moynihan[2], and Justin V. Strauss[3]

[1]Department of Geoscience, University of Calgary, Calgary, AB
[2]Yukon Geological Survey, Whitehorse, YT
[3]Department of Earth Science, Dartmouth College, Hanover, NH

Extracting Regional Structural Features from Airborne Geophysical Data in the TREK Project Area, Central British Columbia

Mana Rahimi[1], C.J.R. Hart[1] and J.J. Angen[1]

Mineral Deposit Research Unit (MDRU), The University of British Columbia, Vancouver, BC

Detrital zircon analysis of Eocene strata in southern British Columbia and northern Washington: preliminary results of Cordilleran provenance

Erica Rubino[1] , Andrew L. Leier[1], S. Bruce Archibald[2], Elizabeth J. Cassel[3]

[1] Department of Earth and Ocean Sciences, University of South Carolina, Columbia, SC
[2] Department of Biological Sciences, Simon Fraser University, Burnaby, BC,
[3] Department of Geological Sciences, University of Idaho, Moscow, ID

Geology of the Mount Nansen - Nisling River area, southwest Yukon

Jim Ryan[1], *Liz Westberg[2], Steve Williams[1], and John Chapman[1]*

[1] Geological Survey of Canada, Vancouver, BC,
[2] Geological Survey of Canada Calgary, AB

Greenschist and epidote-amphibolite metamorphism of basalts: examples from Salmo, British Columbia and Flin Flon, Manitoba.

Paul G. Starr[1], David R.M. Pattison[1], Doreen E. Ames[2], Matthew Polivchuk[1], Andrea Morgan[1]

[1]*University of Calgary, AB,*
[2]*Geological Survey of Canada (Ottawa)*

Petrographic and geochemical considerations for the formation of alkali plutonism in the southern Omineca belt near Ymir, British Columbia.

Scott Stephen, Dr. Edward Ghent, Dr. Jennifer Cuthbertson

University of Calgary, AB

Investigation of the tectono-metamorphic evolution of the Takhanne River and Kluhini River map area of southwestern Yukon

Lianna Vice[1], Dan Gibson[1], Steve Israel [2]

[1] *Simon Fraser University, BC*
[2] *Yukon Geological Survey, YT*

Significance of Cretaceous extension and thin- and thick-skinned thrusting in the "undeformed" southern Alberta Plains

Marian J. Warren[1], Mark Cooper[2]

[1]*Jenner GeoConsulting Inc., Calgary AB,*
[2] *Sherwood GeoConsulting Inc, Calgary AB*

Unraveling polyphase metamorphism and deformation on the eastern flank of the Shuswap domain, via in-situ U-Pb geochronology

Ewan R Webster[1], David R.M. Pattison[1], Andy Dufrane[2]

[1]*University of Calgary, AB,*
[2]*University of Alberta, AB*

Oral Presentations

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Abstract

Evidence for late Quaternary rupture along the Leech River Fault, greater Victoria region, British Columbia

Kristin Morell[1], Christine Regalla[2], Lucinda Leonard [1], Colin Amos[3], Vic Levson[1]

[1] *School of Earth and Ocean Sciences, University of Victoria, BC*
[2] *Boston University, MA*
[3] *Western Washington University, WA*

The seismic potential of crustal faults within the forearc of the northern Cascadia subduction zone has proven difficult to quantify, due in large part to the Cordilleran glaciation. The potential neotectonic activity of the Leech River fault has remained elusive in particular, despite its close proximity to Victoria, British Columbia. We use lidar and field data collected along the Leech River fault to identify >60 individual, sub-parallel, steeply-dipping, linear scarps, sags and swales that occur in en echelon arrays, that offset both bedrock and Quaternary deposits. We suggest these features are products of mesoscale faults that together comprise a steeply dipping fault array that is up to ~1 km wide and at least 30 km long (but most likely >60 km long). Reconstruction of fault slip across a deformed post-LGM (last glacial maximum) colluvial surface across the fault indicates ~6 m of dip displacement of the colluvial surface, and ~4 m of displacement of intervening channels. Collectively, these data argue that the Leech River fault has experienced at least two M6-M7 earthquakes since ~15 ka, and is likely one of a network of active crustal faults in the Canadian forearc. The Leech River fault array most likely accommodates forearc transpression and may merge along strike with active faults identified in western Washington state, USA.

Evidence for magma emplacement in the lower crust beneath the Anahim Volcanic belt, Central British Columbia, Canada from the results of 3He/4He isotope analysis of CO2-rich seepage gas.

Ray Lett

University of Victoria, BC Ministry of Energy and Mines – Geological Survey Branch, Victoria, BC

The Nazko Cone is the youngest and most easterly of several Pleistocene-Holocene age volcanoes that together form the east-trending Anahim volcanic belt in Central British Columbia, Canada. Souther et al. (1987) estimated that Cone last erupted forming an ash fall and mafic olivine basalt lava flow at around 7200 year BP. Bevier et al. (1979) proposed that the Anahim volcanism reflected westerly migration of the North American tectonic plate over a mantle hot spot. While there has been no volcanic activity in Anahim volcanic belt the since the last eruption of ash and larva, a mild earthquake swarm in 2007, centered 20 km west of the Nazko, Cone (Cassidy et al. 2011; Kim et al. (2014) was interpreted to reflect the injection of magma into the lower crust.

High 3He/4He ratios measured in surface seepage gas, hot spring water and rock samples have been proposed as an indicator of a magma heat source for geothermal activity (Poreda et al. 1992), a mantle plume source for mid Atlantic Ridge basalt (Kurz et al. 1998) and a distinguishing factor between fore arc and back arc tectonic regimes in Japan (Horiguchi et al. 2010). This paper describes sampling CO2-rich gas from seepages in two wetlands, informally named the North and South bogs, one kilometer north west of the Nazko Cone and the analysis of the gas samples for He and for 3He/4He ratios.

Among the unusual features of the North and South bogs are deposits of CaCO3-rich mud, and travertine and CO2-rich gas seepages (Lett and Jackaman, 2015). Five of the CO2-rich gas seepages were sampled in 2015 and the gas samples analysed at the Woods Hole Oceanographic Institution Isotope laboratory for He and for 3He/4He ratio. Reliable 3He/4He ratios, measured in 4 of the 5 seepages sampled, ranged from 2.55 to 5.94RA (relative to the atmospheric 3He/4He ratio). A South bog CO2-rich gas seepage sample has the highest 3He/4He ratio and a He concentration of 120 ppm (v/v). The 3He/4He ratios support an interpretation of seismic data by Hutchinson (2012) that the Nazko earthquake swarm was caused by brittle failure and fracturing of rock accompanying the emplacement of two mantle magma bodies that formed sills and branching dikes in the lower crust between 27 and 29 km depth. The absence of present day volcanism in the area could be explained by waning hot spot activity and magma upwelling into the lower crust along a lithospheric fracture rather than from a deep mantle plume.

Tectonic evolution of the Tofino and Queen Charlotte basins, British Columbia: combining multiple data sets on Cenozoic micropalaeontology, strontium isotope stratigraphy, offshore wells and basin geology.

Marjorie J. Johns[1], Christopher R. Barnes[2], Julie A. Trotter[3], Clio J. Bonnett[2], Y. Roshni Narayan[2]

[1]*Pacific PaleoQuest, Brentwood Bay, BC*
[2] *School of Earth and Ocean Sciences, University of Victoria, Victoria, BC*
[3]*University of Western Australia, School of Earth and Environment, Crawley, WA*

The two largest and mainly offshore Cenozoic basins in coastal British Columbia are the Tofino and Queen Charlotte basins (TB and QCB). Over a dozen wells were drilled for Shell in the 1960â€™s to depths of about 4000m. New micropalaeontological and strontium isotope data were combined with existing geophysical and geological data to further interpret the complex evolution of the basins.
A high resolution Cenozoic chronostratigraphy is constrained by strontium isotope ages (36.9â€“1.3 Ma) from 59 analyses of Late Eocene to Pleistocene foraminifers together with revised biostratigraphies (foraminifers, ichthyoliths) from both offshore wells and outcrop samples. New specimen thermal alteration values were integrated with existing well log and offshore multichannel seismic and magnetic data. Data were obtained from over 2,145 drill cutting samples from 6 offshore wells and 1,035 coastal surface samples within the TB, and from over 3,550 offshore samples from 8 offshore wells in the QCB. Sample subsets were analyzed for microfaunas, strontium ages, lithology, mineralogy, and other data.
Different regional geologic, tectonic and deformation events are documented that elucidate the timing of dynamic changes between and within these Cenozoic basins. Six regions, multiple sub-basins, and different thrust fault styles are recognized as the Crescent terrane and related sediments were deformed and fragmented following accretion in the TB. Whereas in the southern QCB, extension and sediment transport resulted in thick Miocene basin infill.
Similarities between the TB and the southern QCB include: development of offshore sub-basins containing thick Miocene sedimentary sections, transport of neritic faunas and sediments into bathyal environments, and changes in deformation and sedimentation styles during the Miocene. The main differences are structural, with the effects of subduction, thrust faults, and accretion in the TB contrasting with transform strike-slip, extension, and compression and uplift in the Hecate Strait area of the QCB.

Trace-element compositions of igneous apatite indicate tectonic settings

Alexei S. Rukhlov [1,a], Mao Mao [1], Stephen M. Rowins [1,2], Jody Spence [2], Laurence A. Coogan [2]

[1]*British Columbia Geological Survey, BC*
[2]School of Earth and Ocean Sciences, University of Victoria, BC

Apatite, $Ca_5[PO_4]_3$(F, OH, Cl), is the most abundant phosphate mineral in igneous rocks, and is able to incorporate most elements in minor or trace amounts. Variations in relative abundances of halogens, OH, S, V, Mn, As, Sr, Y, REE, Pb, Th and U contents in apatite are sensitive to fluid and melt compositions, oxidation state, and crystallization history of a magmatic-hydrothermal system. Apatite can survive glacial transport and post-glacial weathering, making it an effective petrogenetic and mineral-exploration indicator. Mao et al. (2015) discriminated between different types of ore deposits and barren rocks using trace-element compositions of apatite from many metallic deposits and unmineralized igneous rocks in Cordillera and elsewhere. Here we use a subset of 537 analyses of igneous apatites by both electron probe and laser ablation ICP-MS after Mao et al. (2015) to test their chemistry as a proxy of tectonic setting. The examined apatites are from 29 intrusive carbonatite complexes (2691–95 Ma) from continental rifts worldwide and the ancestral North American passive margin; the Mid-Atlantic, Southwest Indian, and East Pacific ocean ridges (4 localities); the Bonanza, Quesnel and Stikine accreted island arcs (6 plutons, 209–183 Ma) and 4 post-accretionary intrusions (157–73 Ma), marking Cordilleran continental arc; and 5 late- to post-collisional (terminal) syenitic complexes (2714–2678 Ma) of the southern Abitibi belt, Canadian Shield. Apatite in silicic rocks has lower Sr and higher Mn contents and stronger negative Eu anomalies than those of apatite in intermediate and mafic rocks, consistent with fractionation of feldspar and Fe-Mg minerals during magmatic evolution. Apatite from carbonatites is distinguished by low Mn (<510 ppm) and high Sr (>1800 ppm) contents, high $(Ce/Yb)_{CN}$ (35–872), a lack of Eu anomalies, and by weak positive Ce anomalies (Ce/Ce* = 1.0–1.7). Apatite from mid-ocean ridge (MOR) gabbros has low Sr (<230 ppm) and Th (<20 ppm), high Mg (47–1327 ppm), Y (440–2025 ppm), and Zr (mostly 3–65 ppm) contents, and lower $(Ce/Yb)_{CN}$ (<6) than apatite in other rocks. Apatite in late- to post-collisional syenitic rocks from the southern Abitibi belt shows the highest Sr (up to 2.6 wt.%), Pb (6–114 ppm), and $(La/Sm)_{CN}$ (1.5–29), whereas apatite from arc rocks has the highest Mn (mostly 200–9350 ppm) and the widest range of Eu anomalies (Eu/Eu* = 0.08–1.36) compared with those of other studied apatites. Similar to apatite discrimination of deposit types of Mao et al. (2015), we separated apatite trace-element compositions by tectonic setting using three discriminant-function diagrams. Six linear discriminant functions (DP) recast the apatite compositions as a sum of constant and log10-transformed concentrations of up to 10 elements (Mg, Mn, Sr, Y, La, Ce, Eu, Yb, Lu, Pb, Th, and U) in ppm, multiplied by a coefficient for each element for a given function. Our results suggest that trace-element chemistry of detrital apatite can discriminate tectonic settings of igneous rocks.

Reference cited: Mao, M., Rukhlov, A.S., Rowins, S.M., Spence, J., and Coogan, L.A., 2015. Detrital apatite trace-element comopsitions: a robust new tool for mineral exploration. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey GeoFile 2015-9.

Linking Cordilleran deformation to extensional faulting, paleodrainage patterns, provenance and hydrocarbons in the foreland basin: Examples from the Lower Cretaceous of southern Alberta

Marian J. Warren
Jenner GeoConsulting Inc., Calgary, AB

Cretaceous crustal thickening in the thrust belt, coupled with properties of Proterozoic basement underlying the adjacent foreland basin and with regional magmatic events, directly influenced local faulting in the foreland basin, local facies changes, sedimentary provenance and thus distribution of key petroleum system elements (reservoir, seal, stratigraphic traps).
Lithospheric flexure during crustal thickening in the thrust belt drove not only overall subsidence of the foreland basin but also resulted in intermittent local extensional faulting and rotation of underlying Paleozoic basement blocks. A detailed study from the Lower Cretaceous Lower Mannville Group shows how subtle extensional half-grabens controlled distribution and orientation of quartz-rich sandstone reservoirs during deposition. Half-graben asymmetry controlled the position of low-stand fluvial/estuarine channels and high-stand shorefaces. It also controlled local sedimentary provenance (hangingwall versus footwall) and thus reservoir quality. Continued motion on the faults during deposition of a younger sequence resulted in superposed incision and erosion by younger channels. However, these younger channels are primarily filled with lithic sandstones that serve as locally important lateral seals rather than reservoirs. Their age overlaps with or is slightly younger than the range of widespread mid-Cretaceous plutons exposed in the deformed belt to the west, and these widespread lithic sandstone channels may represent an eroded contemporaneous (volcanic?) igneous source and change in regional paleodrainage patterns.
A more regional, integrated dataset from southern Alberta (discussed in Zaitlin et al., 2002) illustrates association between basement structural trends and extensional fault trends in the foreland basin sedimentary succession, and perhaps between basement mechanical properties and overall accommodation space during Cretaceous-Tertiary foreland basin subsidence. The Medicine Hat (Montania) basement terranes in northern Montana and southern Alberta has a notable NW-SE anisotropy in aeromagnetic signature, which is associated with a region of abundant, seismically mapped NW-SE extensional faults at top Paleozoic and with NW-SE Lower Cretaceous fluvial system trends. NW-SE pre-existing basement weaknesses would have been favourably oriented for reactivation as extensional faults in the stress regime of thrust-related lithospheric flexure. In contrast, the basement terranes immediately to the north have a strong NE-SW aeromagnetic signature, but Lower Cretaceous channel orientations are more variable and seismic-scale faults are more difficult to map in the sedimentary section. Finally, overall accommodation space was lower over the Medicine Hat-Montania terrane than to the north during both Paleozoic and Mesozoic deposition, perhaps indicating stronger lithosphere to the south. This resulted in N-S contrasts in regional Lower Cretaceous sedimentary facies and hydrocarbon play distributions.

Reference: B.A. Zaitlin, M.J. Warren, D. Potocki, L. Rosenthal, R. Boyd, 2002: Depositional styles in a low accommodation foreland basin setting: an example from the Basal Quartz (Lower Cretaceous), southern Alberta; CSPG Bulletin, v. 50, pp 31-72.

Stikinia in southern Yukon: a perspective from the Teslin Mountain area

Esther Bordet

Yukon Geological Survey, Whitehorse, YT

Stikinia is the largest terrane that accreted to the North American margin during the Mesozoic to form the Canadian Cordillera, with a total area of 375 000 km2 across BC and Yukon (Gabrielse et al., 1991). Stikinia comprises Early Devonian to Middle Jurassic volcanic and sedimentary strata and comagmatic intrusions (Monger et al., 1991). Arc volcanism is represented by the Upper Triassic Takla and Stuhini Groups and Lower-Middle Jurassic Hazelton Group in BC. In Yukon, the Upper Triassic Lewes River Group is underlain by Middle Triassic arc volcanic strata of the Joe Mountain Formation, which constitute a unique occurrence in the Cordillera. In the Teslin Mountain area, southern Yukon, the Joe Mountain Formation and Lewes River Group are overlain by overlap assemblages of the Whitehorse trough (Early-Middle Jurassic Laberge Group). The Joe Mountain Formation is dominated by a thick sequence of aphyric basalt produced by subaqueous volcanism. The Lewes River Group displays complex lateral and vertical lithological and facies changes. It illustrates synvolcanic terrane exhumation, with erosion of the volcanic upland leading to deposition of thick volcaniclastic sequences, in parallel with ongoing clastic and carbonate sedimentation in marginal basins. Elucidation of the origin of the Joe Mountain Formation and Lewes River Group is critical in understanding the initial and latest stages of Stikinia arc volcanism respectively, and to constrain how Stikinia evolved prior to final amalgamation of the Intermontane terranes with North America.

Syncollisional late Early to early Late Jurassic volcanism, plutonism and porphyry-style mineralization on the northeastern margin of Stikinia

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The Hazelton Group of northern Stikinia comprises widespread Early Jurassic arc volcanic rocks, Early-Middle Jurassic sedimentary rocks, and local Middle Jurassic primitive volcanic rocks of the Eskay rift. Here we describe a previously enigmatic volcanic succession on the northeastern margin of Stikinia that we interpret to have formed by re-melting of subduction-modified lithosphere during Stikine-Quesnel arc-arc collision; it represents the youngest known volcanic sequence of the Hazelton Group. Based on field, lithogeochemical and geochronological studies, we have formally defined the succession as the Horn Mountain Formation. The formation (ca 5.4 km thick) consists mainly of green to maroon augite-plagioclase-phyric trachybasalt volcanic breccias and lesser plagioclase-phyric trachyte. It conformably overlies Toarcian sedimentary rocks of the Spatsizi Formation, which unconformably overlies the Cake Hill pluton (Late Triassic). The top of the Horn Mountain Formation interfingers with Bajocian synorogenic sedimentary rocks of the Bowser Lake Group. Petrographic observations and lithogeochemistry indicate that the volcanic rocks are largely quartz deficient, K-feldspar-rich, alkaline in composition, and have a volcanic arc signature. Regional evaluation indicates that the Horn Mountain Formation extends for least 50-110 km in a west-northwest to east-southeast trending belt that parallels the King Salmon thrust, at the boundary between the Stikine and Cache Creek terranes. A revised structural interpretation extends the Kehlechoa thrust to juxtapose rocks of the Whitehorse trough above Toarcian to Bajocian rocks of the Horn Mountain Formation and Bowser Lake Group. The Snowdrift Creek pluton (early Late Jurassic) stitches the fault and constrains movement to Bajocian-Oxfordian. The study area hosts several early-stage mineral exploration projects associated with ca 173-160 Ma predominantly calc-alkaline intrusions, including the Tanzilla porphyry system. The protracted late Early to early Late Jurassic syncollisional magmatism represents a potential new metallogenic epoch for the Canadian Cordillera, and is prospective for calc-alkalic to alkalic porphyry- and epithermal-style mineralization.

Pre-Early Jurassic mid-crustal tectono-metamorphism in Yukon-Tanana terrane at Aishihik Lake, southwest Yukon

A.D. Clark[1], H.D Gibson[1], S. Israel[2], J. Crowley[3]

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The exhumed Paleozoic to Cretaceous metamorphic rocks underlying much of the Yukon-Tanana terrane in Yukon are an excellent resource for studying the protracted mid-crustal development of the northern Canadian Cordillera. However, our understanding of this orogenesis is limited by relatively few precise mineral ages that can be directly correlated with metamorphic and deformation events recorded in these high pressure and temperature rocks.

In the Aishihik region of southwest Yukon, widespread occurrences of kyanite, staurolite, garnet, biotite and muscovite define a regional metamorphic assemblage within Snowcap and Finlayson assemblage rocks of the Yukon-Tanana terrane. Pressures and temperatures attained during peak metamorphism were around 6 to 8 kbar and 600 to 650°C. However, within 5 to 10 km of the Early Jurassic Aishihik batholith the regional metamorphic assemblage is overprinted by a high temperature contact aureole that appears well-preserved in thin section and contains abundant fibrolitic sillimanite. Garnet belonging to the peak regional metamorphic assemblage locally contains inclusion trails of quartz and mica (S1). Inclusion trails are generally discontinuous with a regional transposition fabric (S2), which wraps around garnet, kyanite, staurolite and plagioclase and generally dips gently to the east. Both S2 and the Aishihik batholith have been overprinted by upright, north-northwest trending open to tight folds and an associated crenulation cleavage (S3). Approximately 30 km to the west of the Aishihik batholith, two gneissic quartz diorite plutons intruded Finlayson assemblage rocks and were transposed into the regional S2 foliation. CA-TIMS dating of six zircon crystals from each pluton yielded weighted mean 206Pb/238U igneous crystallisation ages of 258.39 ± 0.38 and 257.27 ± 0.38 Ma. The precise age of the regional metamorphism and deformation preserved in the Aishihik region is in the process of being determined via In-situ U-Th-Pb dating of monazite using SHRIMP.

This previously undocumented Permian magmatic episode in the Aishihik region, combined with a pre-Early Jurassic regional mid-crustal metamorphic assemblage, increases the likelihood that southwest Yukon locally preserves evidence of Permo-Triassic orogenesis. This would increase the geographic extent of Permo-Triassic crustal thickening in the Yukon-Tanana terrane, suggesting compression may have been the product of arc-continent collision rather than just intra-arc thickening.

Detrital zircon data from basal Hazelton clastic strata in the Iskut region document the end-Triassic tectonic transition in northern Stikinia

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The Hazelton Group overlies the Stuhini Group on a diachronous Late Norian-Early Jurassic unconformity. Lowermost Hazelton units include well-sorted, clast-supported polymictic conglomerates with rounded clasts. Their sedimentary maturity contrasts with the volcaniclastic Stuhini Group. Clasts are of coarse-grained equigranular to porphyritic felsic intrusive rocks, radiolarian chert, and minor volcanic rocks. Clasts of Stuhini origin are rare. Conversely, no large Late Triassic plutonic bodies have been recognized in the region. The mismatch between local Stuhini basement and clasts in overlying Hazelton conglomerates indicates non-representational sedimentation: distant sources, deep erosion, and long surface residence time.
Detrital zircon populations: An uppermost Stuhini sample shows peaks at 212 Ma and 203 Ma, which is taken as the M.A.D. (maximum age of deposition). Above the unconformity, two Late Triassic conglomerates show peaks at 221 Ma, substantially older than that of the immediately underlying Stuhini Group. Late Triassic (222-225 Ma) peaks also occur in Early Jurassic samples. The sample taken near the top of the siliciclastic succession shows a subsidiary peak at 197 Ma (M.A.D.). Above a second, higher unconformity on Snippaker Ridge, the basal conglomerate contains a main 204 Ma peak and two subsidiary peaks at 216 and 198 Ma, the latter considered M.A.D. The older peaks correspond to local and regional Stuhini sources.
A pronounced shift to older detrital ages took place across the sub-Hazelton unconformity, from 212-203 Ma below to ca 220-225 Ma above. Penecontemporaneous arc-derived extrusive and hypabyssal sources gave way to deep erosion of the Stuhini arc and its basement. Abundant plutonic clasts were derived from large surface exposures of ca 220 Ma granitoids. At present, extensive exposures are only seen in the Hotailuh, Hickman and associated batholiths of far northern Stikinia. Stuhini arc activity was abruptly terminated in the latest Triassic (ca 203-204 Ma), succeeded by the development of a broad tectonic highland that shed debris towards the south.

Paleozoic stratigraphy, tectonics, and metallogeny of the Pelly Mountains, central Yukon: project outline and preliminary results

Luke P. Beranek and Stephen J. Piercey

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Paleozoic rocks of the Pelly Mountains, central Yukon, preserve >150 m.y. of sedimentation, magmatism, and base-metal mineralization within the Cassiar terrane. Key issues that must be resolved include the precise timing of magmatism, nature of tectonic and mineralization processes, and lithosphere-scale controls on metal fertility. A multi-year field project on Paleozoic stratigraphy was initiated to answer these questions. The short-term goals are to constrain the field geology, age, and geochemistry of Cambrian-Ordovician and Devonian-Mississippian strata. The long-term objectives are to identify secular trends in continental margin tectonics and test genetic relationships with coeval strata of the Selwyn basin and Yukon-Tanana terrane.

Cambrian-Ordovician strata were deposited in a marine environment characterized by mafic volcanism and fine-grained sedimentation. Vent-proximal successions consist of coherent lava and sediment-matrix to monomictic volcanic breccia. Vent-distal successions are comprised of black to tuffaceous shale with minor sills and flows. Cambrian-Ordovician strata yield non-arc, ocean island basalt-like trace element and Nd-Hf isotope signatures and were likely generated by the partial melting of enriched lithospheric mantle during rifting along the Cordilleran margin. Future research will focus on lithosphere-scale structures that presumably influenced the magmatic history and metal fertility of the Pelly Mountains.

Mid-Paleozoic successions consist of Upper Devonian black shale and lithic sandstone units that conformably grade upwards into Lower Mississippian tuffaceous shale, volcaniclastic rocks, and felsic flows. Volcanic rocks yield non-arc and arc-like geochemical signatures that are consistent with felsic magmatism in a rift setting. VMS mineralization and felsic magmatism in the Pelly Mountains are confirmed to be coincident with that of the Selwyn basin and Yukon-Tanana terrane. Upper Devonian strata likely comprise part of a turbidite basin that developed during regional extension and initial felsic volcanism, whereas Lower Mississippian strata were deposited in a metalliferous volcanic rift basin that was located behind an adjacent continental arc system.

Early Paleozoic volcanic rocks near Tay Mountain, central Yukon; Evidence for long lived crustal structures

Rosie Cobbett

Yukon Geological Survey, YT

Periodic extension affecting the western edge of ancestral North America in the early Paleozoic is primarily recorded in the rock record through the presence of volcanic rocks that range in age from lower Cambrian to Late Devonian. New geological mapping near Tay Mountain along the west central part of the Tay River map sheet and the east central part of the Glenlyon map sheet highlights volcanic rocks from three different levels of stratigraphy. Meta-basalt and meta-tuff form a small lens within the lower Cambrian Gull Lake Formation just east of Tay Mountain. Within several kilometers west and north of this occurrence significant proportion of Ordovician to Silurian strata comprises basalt, volcanic breccia and volcaniclastic rocks that have been assigned to the Menzie Creek Formation. North of Tay Mountain, strata of the Devonian to Mississippian Earn Group contains crystal tuff, intermediate to felsic flows and volcaniclastic rocks.

The geochemistry of several samples of Menzie Creek Formation from within the mapped area indicates they are alkaline basalts from a within-plate tectonic setting. The Earn Group volcanic rocks are rhyolite and andesite based on geochemistry of several samples within the mapped area. The presence of volcanic rocks, quartz-rich clastic rocks with rapid lateral facies changes and local unconformities within the Earn Group are explained by deposition in graben and half graben features that formed in response to rifting.

The occurrence of rift derived volcanic rocks that range in age from lower Cambrian to Mississippian may indicate a long-lived crustal-scale structure exists within the Tay Mountain area. A good candidate for such a feature is the Twopete thrust. This northwest trending fault may be a reactivated growth fault that has controlled the deposition of volcanic rocks since at least the lower Cambrian.

New Constraints on the Age and Origin of Quesnellian Basement Assemblages in Southern BC and northern Washington from Detrital Zircon, Lithogeochemical and Fossil Age Studies

Jim Mortensen

Earth, Ocean, and Atmospheric Sciences, University of British Columbia, BC

Paleozoic rock units that form the basement of Quesnellia in southern BC and northernmost Washington State include a diverse range of volcanic and sedimentary assemblages whose age, paleotectonic setting, and relationship to each other and/or to the North American craton are poorly understood. We have dated detrital zircons from a total of 21 samples of clastic rocks from within most of the Paleozoic assemblages, and have also examined the lithogeochemistry of volcanic rocks within each assemblage to assess the paleotectonic setting of formation. In addition we have obtained several new macro- and microfossil ages from some of the units. Our new data, together with results of recent work by other workers, indicate that the basement rocks range in age from Middle Devonian to Middle Permian. The oldest rocks (including the Knob Hill assemblage in the Greenwood area and probably the Palmer Mountain Greenstone near Loomis in Washington) were erupted in a magmatic arc setting. Younger volcanic rocks yield a mix of arc, N-MORB and E-MORB signatures. Our detrital zircon data indicate a close linkage between the various assemblages that comprise the Paleozoic basement of Quesnellia and in particular strongly support a previously proposed correlation between the Anarchist and Harper Ranch groups. The results also demonstrate that the Paleozoic basement of Quesnellia formed in close proximity to the northwestern margin of the North American craton.

Geochronology of the Gataga Volcanics of British Columbia and implications for Neoproterozoic glaciation and rifting

Athena Eyster

Harvard University, MA

In Northern British Columbia, mafic flows, felsic flows, and volcaniclastic deposits of the Gataga Volcanics are exposed at Gataga Mountain. A previous study reported a bulk fraction U/Pb TIMS age of 689.1 ± 4.6 Ma (Ferri et al., 1999) from a rhyolite within the volcanics. This age has been cited as a constraint on rift-related magmatism on the western margin of Laurentia. This age along with recent age constraints on the global Sturtian glaciation (716.5-662.4 Ma; Rooney et al., 2013) suggest that these volcanics were erupted during glaciation, however, no glacial deposits were previously identified. Here we present U/Pb single grain zircon ages, new stratigraphic and mapping relationships, and carbon isotope chemostratigraphic data to better understand the tectonic evolution of the western margin of Laurentia during the breakup of Rodinia. We have distinguished three informal sequences exposed in the Gataga area, the Frog quartzite, the Gataga Volcanics, and the Matulka group. The oldest rocks, belonging to the Frog quartzite, are dominated by cross-bedded sandstone and include a horizon with mud-cracks, indicative of non-glacial deposition. The overlying Gataga Volcanics are over 1 km thick, comprising both mafic and felsic units and with volcaniclastic breccia common throughout. Iron formation was identified near the base of the volcanics. We also identified cosmopolitan clasts, multiple matrix-supported diamictite units and potential ice-rafted dropstones. These features suggest that the Gataga Volcanics could have erupted in a sub-glacial environment, however, we acknowledge it is difficult to distinguish sub-glacial from sub-aqueous explosive volcanic facies. Overlying the volcanics is the Matulka group, a mixed carbonate-siliciclastic succession with minor basalt. Based on chemostratigraphic and lithostratigraphic similarities, the Matulka group can be correlated with Ediacaran strata to the north. We interpret the cosmopolitan clasts, diamictite and dropstones within the Gataga Volcanics as representing sub-glacial volcanism during the 55 My Sturtian Glaciation. Additionally, we suggest that the stratigraphy at Gataga Mountain records two episodes of extension, the first indicated by the Neoproterozoic Gataga Volcanics and the second by the Ediacaran non-glacial Matulka group.

Metallogenic evolution of the Mackenzie and eastern Selwyn mountains of Canada's northern Cordillera, Northwest Territories

Luke Ootes

BC Ministry of Energy and Mines – Geological Survey Branch

The Mackenzie and eastern Selwyn mountains, Northwest Territories, Canada, are the northeast expression of the Cordilleran orogen and have a geologic history that spans the last one billion years. The region has undergone a diverse tectonic evolution, which is reflected in an equally diverse collection of mineral deposits and prospects. More than 300 of these deposits and prospects have been documented in this area. In this study they are categorized into mineral deposit types, their mode of formation evaluated, and the regional and temporal distribution is highlighted. These assignments will be a useful guide for future mineral deposit research in the region, allow comparison with southern equivalents (southern Canada, United States, and Mexico), and assist the mineral explorationist in searching for and classifying new discoveries.

Stratiform/stratabound Cu-Ag occurrences are hosted in the Neoproterozoic Coates Lake Group (ca. 750 Ma), generally preserved in the hanging wall of the Cretaceous Plateau fault, and define a belt through the central part of the Mackenzie Mountains. Low-grade phosphatic stratiform iron (47.5% Fe) is preserved as iron formation in the Neoproterozoic Rapitan Group in the very northwest of the Mackenzie Mountains (ca. 700 Ma). Sedimentary exhalative Zn-Pb (± Ba) deposits are preserved in Cambrian through Devonian Selwyn Basin strata in the eastern Selwyn Mountains. A number of carbonate-hosted Zn-Pb (± base-metals) prospects and vein-hosted emerald occur within the Paleozoic Mackenzie Platform strata of the Mackenzie Mountains. Cretaceous felsic to intermediate plutons, which are present throughout the eastern Selwyn Mountains, are associated with Tungsten-skarn (proximal to intrusions), base-metal skarn (distal from intrusions), rare-metals and semi-precious tourmaline related to pegmatites, and vein-hosted emeralds. Other types of potential interest include coal deposits, placer gold, and possible Carlin-type gold deposits that have recently been identified to the west in the Yukon.

Poster Presentations

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Abstracts

A structural history of the Nechako Basin, central British Columbia: A sinistral transtensional origin?

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The northern Interior Plateau region of British Columbia is considered highly prospective yet underexplored owing to poorly understood bedrock geology (Clifford and Hart, 2014). The Targeting Resources through Exploration and Knowledge (TREK) project is a Geoscience BC-funded multidisciplinary endeavour to develop a better geological framework for this region which includes southern Stikine terrane, adjacent Cache Creek terrane, the Nechako Basin, and other overlap assemblages. Integration of geophysical data, bedrock mapping, and geochronology has allowed for the identification of new through-going structures and the development of an evolving structural framework for Middle Jurassic through Eocene time that includes Early(?) to Middle Jurassic sinistral transtension, mid-Cretaceous compression, and Eocene dextral transtension.

The SW-dipping Tatuk Fault (new*) marks the northeastern limit of upper Hazelton Group and Bowser Lake Group marine strata. The Bowser Lake Group includes a northeastward thickening wedge of coarse clastic rocks suggesting that the Tatuk Fault was a basin-bounding feature at least by the end of the Middle Jurassic. Locally-exposed pyritic mudstone and tuff of the upper Hazelton Group may indicate earlier normal displacement along this fault. Sinistral shear along the N-striking Bobtail Shear Zone (new*) may overlap in time with normal shear along the Tatuk Fault, consistent with NE-SW directed extension, or sinistral transtension.

The upper Hazelton Group and Bowser Lake Group strata were deformed during subsequent E- to NE-vergent fold and thrust deformation. Field structural evidence and geophysical anomalies in the Nechako Basin exhibit a curvature from NNW-SSE to WNW-ESE with proximity to the Tatuk Fault. The predominantly volcanic and plutonic rocks to the north of the Tatuk Fault were apparently not affected by the mid-Cretaceous deformation so it was reactivated as a sinistral fault to accommodate the shortening within the basin. The Nazko-Redstone belt formed along the eastern margin of this fold and thrust belt in a fashion similar to the Sustut Basin to the north. Deformation continued at least until the Campanian as indicated by palynology of well logs showing Albian to Cenomanian strata on top of Campanian strata (Riddell, 2011).

The Eocene was characterized by extensional deformation that can be separated into two phases. The early phase represents nearly E-W extension and is recorded by NW-SE striking dextral faults, including reactivation of the Tatuk Fault; and N-S striking normal faults, including reactivation of some mid-Cretaceous thrust faults (Bordet, 2014). The late phase represents NW-SE extension recorded by N-S striking dextral faults, including reactivation of the Bobtail Shear Zone; and NE-SW striking normal faults.

This new structural framework represents a significant step towards unravelling the geological history of the northern Interior Plateau of British Columbia and understanding its metallogeny.

Pre-Early Jurassic mid-crustal tectono-metamorphism in Yukon-Tanana terrane at Aishihik Lake, southwest Yukon

A. D. Clark[1], H.D Gibson[1], S. Israel[2], J. Crowley[3]

[1]*Simon Fraser University*
[2]*Yukon Geological Survey*
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The exhumed Paleozoic to Cretaceous metamorphic rocks underlying much of the Yukon-Tanana terrane in Yukon are an excellent resource for studying the protracted mid-crustal development of the northern Canadian Cordillera. However, our understanding of this orogenesis is limited by relatively few precise mineral ages that can be directly correlated with metamorphic and deformation events recorded in these high pressure and temperature rocks.
In the Aishihik region of southwest Yukon, widespread occurrences of kyanite, staurolite, garnet, biotite and muscovite define a regional metamorphic assemblage within Snowcap and Finlayson assemblage rocks of the Yukon-Tanana terrane. Pressures and temperatures attained during peak metamorphism were around 6 to 8 kbar and 600 to 650°C. However, within 5 to 10 km of the Early Jurassic Aishihik batholith the regional metamorphic assemblage is overprinted by a high temperature contact aureole that appears well-preserved in thin section and contains abundant fibrolitic sillimanite. Garnet belonging to the peak regional metamorphic assemblage locally contains inclusion trails of quartz and mica (S1). Inclusion trails are generally discontinuous with a regional transposition fabric (S2), which wraps around garnet, kyanite, staurolite and plagioclase and generally dips gently to the east. Both S2 and the Aishihik batholith have been overprinted by upright, north-northwest trending open to tight folds and an associated crenulation cleavage (S3). Approximately 30 km to the west of the Aishihik batholith, two gneissic quartz diorite plutons intruded Finlayson assemblage rocks and were transposed into the regional S2 foliation. CA-TIMS dating of six zircon crystals from each pluton yielded weighted mean 206Pb/238U igneous crystallisation ages of 258.39 ± 0.38 and 257.27 ± 0.38 Ma. The precise age of the regional metamorphism and deformation preserved in the Aishihik region is in the process of being determined via In-situ U-Th-Pb dating of monazite using SHRIMP.
This previously undocumented Permian magmatic episode in the Aishihik region, combined with a pre-Early Jurassic regional mid-crustal metamorphic assemblage, increases the likelihood that southwest Yukon locally preserves evidence of Permo-Triassic orogenesis. This would increase the geographic extent of Permo-Triassic crustal thickening in the Yukon-Tanana terrane, suggesting compression may have been the product of arc-continent collision rather than just intra-arc thickening.

Geology of Tay Mountain Area, central Yukon

Rosie Cobbett

Yukon Geological Survey, YT

The southern half of the Tay Mountain area is made up of lower Cambrian to Silurian Selwyn basin strata, thrust over Devonian to Triassic strata in the northern half. The Selwyn basin strata are metamorphosed and range from mildly foliated to completely recrystallized. The late Paleozoic strata are deformed by a northwest trending fold and thrust belt. The Anvil batholith and several small, coeval granitic plugs intrude both successions and impose a contact aureole that ranges from 10's of metres to several kilometres in width.

New bedrock geology and plutonic suites maps for Yukon

Maurice Colpron

Yukon Geological Survey

The Yukon Geological Survey has recently completed the update of the Yukon bedrock geology map. The new map is based on an updated GIS dataset that builds upon the previous GIS compilation by Gordey and Makepeace (1999, 2001, 2003). It includes new, detailed bedrock geology maps and regional compilations that have been published by the Yukon Geological Survey and the Geological Survey of Canada between 1999 and 2014, as well as some recent thesis works. This update of the GIS dataset includes an expanded attribute structure (compared to the 1999 dataset) that facilitates searching of the geodatabase. The bedrock geology GIS dataset will now be regularly updated as new maps are completed, and posted on the Yukon Geological Survey's website: www.geology.gov.yk.ca/update_yukon_bedrock_geology_map.html. The data can also be viewed and queried online using the Yukon Geological Survey interactive map service: http://mapservices.gov.yk.ca/YGS/SL/. The new Yukon bedrock geology map is also being released as a static 1:1,000,000-scale map in PDF format together with a new legend (Colpron et al., 2016). This map and legend will be on display during the workshop.

Another derivative product that is being developed alongside the updated bedrock geology map is a map displaying the various Paleoproterozoic to Miocene plutonic suites in Yukon. The aim of this map will be to highlight the petrogenetic and metallogenic affinities of the various plutonic suites. A preliminary version of this map will also be on display during the workshop.

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Structural style variations in the BC foothills

Mark Cooper

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In contrast to the Alberta Foothills the foothills in British Columbia typically contain smaller displacement thrusts, thrusts at surface are less common and folds predominate. A change in structural trend and style occurs across Williston Lake due to a major lateral ramp. This lateral ramp marks the northern limit of the Peace River Re-entrant and to the north the foothills belt becomes significantly wider. This lateral ramp probably has its origins in a failed Paleozoic rift system and it appears to be the southern limit of inversion structures that can strongly control foothills deformation north of Williston Lake; most of these inversion structures originated as late Devonian faults.

South of the Williston Lake lateral ramp the surface structure of this region is dominated by NW-SE trending folds and SW dipping thrust faults in the late Jurassic to Cretaceous clastic sediments. The foothills belt is bound to the west by the Front Range Fault which carries (variously) Triassic and Paleozoic rocks. It is limited to the east by a prominent frontal monocline and the width of the foothills is only 30-40 kms but the belt begins to widen northwards as the lateral ramp is approached. The strata can be divided into 3 major tectonostratigraphic packages, each with an individual structural style, bounded by detachments. There are only a handful of well penetrations of the lowest tectonostratigraphic unit, Upper Devonian - Lower Triassic, thus the observations of structural styles are based almost entirely on folds observed in the Front Ranges. In the subsurface of the foothills seismic data suggests that the Mississippian Carbonates within this package may be deformed into a series of large ramp anticlines with the lower detachment in Devonian shales and the upper detachment in the Toad-Grayling shales. These ramp anticlines control the position of the major regional structural highs and intervening synclines.

The Toad Grayling is also the basal detachment of the Lower Triassic to Fernie tectonostratigraphic package dominated by shales and silts. The exceptions are the massive carbonates of the Baldonnel and Upper Pardonet, the Halfway Sandstone and occasional massive sands and dolomites within the Charlie Lake Formation. The seismic data suggest that the dominant tectonic style within the Triassic package is fault propagation and detachment folding with the carbonates providing the rigid beam that controls the periodicity of the structures. The folds can have amplitudes of up to 1000m and typical wavelengths of 2km throughout the fairway. The elevation of the structures is due to the amplitude of the Triassic structures and the deeper broader wavelength structures that appear to control the major regional structural highs and lows.

The Jurassic - Cretaceous tectonostratigraphic sequence is characterised by multiple detachments and short wavelength structures often with imbricate faulting. Superimposed on the short wavelength structures are larger wavelength features that reflect the structural geometry of the deeper tectonostratigraphic units. Within this sequence there are fault-propagation folds, ramp anticlines and detachment folds. The main detachment levels are the Fernie Shale, an intra-Minnes Group detachment, and the Moosebar and Hasler Shales. The geometry of the structures in all of the tectonostratigraphic sub-units can be illustrated by a regional cross-section through

Structural style variations in the BC Foothills cont…

the Sukunka River valley. The dramatic thinning eastward of the Minnes Group in the vicinity of the frontal monocline is due to a depositional change in unit thickness and which was then inverted at the basin hinge to produce the pseudo-triangle zone geometry.

North of the Williston Lake lateral ramp the structural style is dominated at surface by detachment folds with the major detachment lying within the Late Devonian to Early Mississippian Besa River Shales. The whole sequence from the Besa River shale detachment to the Cretaceous effectively behaves as a single tectonostratigraphic package. The Toad-Grayling is only locally significant as a detachment for thin-skinned thrusts that have relatively small displacements. There are also deeper detaching faults in this part of the foothills that penetrate the basement and often have trends dissimilar to those of the thin-skinned Laramide structures. These faults have a long and complex history; some of them originated as extensional faults in the Devonian whilst others appear to have their origins in compressional features related to the Antler orogeny. During the Late Paleozoic and Mesozoic some of these faults were reactivated as extensional faults across which thickening of the strata can be seen, e.g. the Daiber Fault. Many of these faults were reactivated compressionally during the Laramide orogeny to produce broad wavelength inversion anticlines. A few of these structures have significant amplitudes due to the compressional inversion but the majority only show subtle evidence of compressional reactivation.

The differences in structural style are due partially to the more extensive development of pre-Laramide faults north of the lateral ramp. However, another very important factor in controlling the structural style is the nature of the mechanical stratigraphy being deformed. To the south of the lateral ramp the Mesozoic sequence is much more heterogeneous with, for example, rapid alternations of sand and shales seen in the Lower Cretaceous. To the north the whole sequence becomes dominated by shales and in addition many of the Triassic units subcrop the Cretaceous. Thus both basement fabric and lithological distribution are contributory factors to the style changes.

Petrogenesis and emplacement of Schist Creek mafic-ultramafic complex, southwest Yukon

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The Schist Creek mafic-ultramafic complex is a 7km long by 1km wide lensoidal body of foliated serpentinite located in southwest-central Yukon. It is hosted by amphibolite facies Yukon Tanana terrane (YTT) metasedimentary rocks of the pre-late Devonian Snowcap assemblage, and displays local structural interleaving with the host rocks. This body was initially identified during reconnaissance mapping in the 1970's, and exhibits high magnetic susceptibility in regional aeromagnetic data. Traversing allowed the contacts between the complex and its host rocks to be constrained to10's of m scale. However, the contacts were not exposed at crossing points and thus their exact nature (eg. structural, intrusive, etc.) remains uncertain. The serpentinite is cut by locally foliated sub-metre scale coarse-grained plagioclase-hornblende gabbro dikes and is interlayered with larger units of highly foliated, fine-grained amphibolitic gabbro. The amphibolitic gabbro is itself cut by a number of cm-scale felsic dikes that will be petrographically evaluated to determine if they are related to the complex (eg. trondhjemite melts). The Schist Creek complex appears to lie along a ~130 km long ENE-WSW structural trend, potentially highlighting a large unmapped structure that is highly oblique to the regional NW-SE structural grain of the North American Cordillera. This lineament is defined by breaks in different units along its length. Its eastern end offsets the 70 Ma Carmacks group volcanics, indicating that part of its history is relatively young in the evolution of YTT. However, it is currently unclear whether this young offset represents reactivation of a more important, older emplacement structure. The compositional make-up of this complex may be indicative of its origin and thus provide clues to its emplacement. For example, a lherzolite protolith composition would suggest that the Schist Creek complex is a sliver of sub-continental lithospheric mantle, potentially uplifted to its current position by motion along an ENE-trending structure. A harzburgite or dunite composition may indicate that it is a slice of oceanic crust or mantle obducted onto or entrained within YTT crust, potentially during the closure of Slide Mountain Ocean in late Permian time. A pyroxenite protolith allows the Schist Creek complex to be an Alaskan-type ultramafic intrusion whose ascent may have been accommodated by the presence of an ENE-trending structure. However, evidence of a high-temperature contact metamorphic aureole with significant partial melting that should have accompanied the mid-crustal emplacement of a molten pyroxenite pluton was not found. Field mapping carried out in summer 2015 and current petrographic and geochemical analyses are aimed at determining the protolith and petrogenesis of the Schist Creek mafic-ultramafic complex, and constraining the mechanism of its emplacement into the Snowcap assemblage.

Geochronology of the Gataga Volcanics of British Columbia and implications for Neoproterozoic glaciation and rifting

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In Northern British Columbia, mafic flows, felsic flows, and volcaniclastic deposits of the Gataga Volcanics are exposed at Gataga Mountain. A previous study reported a bulk fraction U/Pb TIMS age of 689.1 ± 4.6 Ma (Ferri et al., 1999) from a rhyolite within the volcanics. This age has been cited as a constraint on rift-related magmatism on the western margin of Laurentia. This age along with recent age constraints on the global Sturtian glaciation (716.5-662.4 Ma; Rooney et al., 2013) suggest that these volcanics were erupted during glaciation, however, no glacial deposits were previously identified. Here we present U/Pb single grain zircon ages, new stratigraphic and mapping relationships, and carbon isotope chemostratigraphic data to better understand the tectonic evolution of the western margin of Laurentia during the breakup of Rodinia. We have distinguished three informal sequences exposed in the Gataga area, the Frog quartzite, the Gataga Volcanics, and the Matulka group. The oldest rocks, belonging to the Frog quartzite, are dominated by cross-bedded sandstone and include a horizon with mud-cracks, indicative of non-glacial deposition. The overlying Gataga Volcanics are over 1 km thick, comprising both mafic and felsic units and with volcaniclastic breccia common throughout. Iron formation was identified near the base of the volcanics. We also identified cosmopolitan clasts, multiple matrix-supported diamictite units and potential ice-rafted dropstones. These features suggest that the Gataga Volcanics could have erupted in a sub-glacial environment, however, we acknowledge it is difficult to distinguish sub-glacial from sub-aqueous explosive volcanic facies. Overlying the volcanics is the Matulka group, a mixed carbonate-siliciclastic succession with minor basalt. Based on chemostratigraphic and lithostratigraphic similarities, the Matulka group can be correlated with Ediacaran strata to the north. We interpret the cosmopolitan clasts, diamictite and dropstones within the Gataga Volcanics as representing sub-glacial volcanism during the 55 My Sturtian Glaciation. Additionally, we suggest that the stratigraphy at Gataga Mountain records two episodes of extension, the first indicated by the Neoproterozoic Gataga Volcanics and the second by the Ediacaran non-glacial Matulka group.

U-Pb age constraints on deformation of the Quatsino Formation, Quadra Island, British Columbia

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The boundary between the Insular and Coast geomorphological belts of the North American Cordillera is well exposed at Open Bay, on Quadra Island, British Columbia. On the western side of the boundary at Open Bay is the upper Triassic-aged Quatsino limestone and Karmutsen basalts of the Wrangellia terrane. On the eastern side of the boundary are intrusive phases of the Coast Batholith. At Open Bay the Wrangellian Quatsino limestone (Upper Triassic) has been subjected to several episodes of strong ductile deformation resulting in re-folded transposed bedding. A U-Pb crystallization age from a basaltic dike that cuts steeply plunging D1 isoclinal folds, but is itself folded by more open, shallowly plunging D2 folds constrains a minimum age for D1 and maximum age for D2 at 164.8 +/- 1.6 Ma. Two undeformed intrusive phase cut the limestone and deformed intrusive phase. U-Pb crystallization ages of two undeformed intrusive phases, a granodiorite pluton and a plagioclase-phyric dacite dike, are constrained at 160 +/- 1.6 and 158.7 +/- 0.8 Ma, respectively, suggesting that ductile deformation along this corridor was complete by the end of the Middle Jurassic. The ages presented here are consistent with age constraints on contractional deformation from the Bowen Island group at Jervis Inlet to the south, and possibly also on West Thurlow Island to the North.

Stratigraphic and Lithological Constraints of Late Cretaceous Volcanic Rocks in the TREK Project Area, Central British Columbia (NTS 093E)

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Recent development of the Blackwater Au-Ag deposit in central British Columbia has prompted interest in the deposit host rocks, which belong to the Late Cretaceous Kasalka Group. The Kasalka Group is a package of intermediate to felsic volcanic rocks overlying the Stikine terrane in central BC. Mineral exploration efforts in this region are hindered by the extensive glacial till and Miocene to Pliocene basalt cover that obscures prospective bedrock. The characterization of the Late Cretaceous Kasalka Group in central BC will aid in the development of an improved regional geological context and highlight potential regions that may be more prospective for mineralization similar to the Blackwater deposit in the Canadian Cordillera. Targeted regional mapping undertaken as part of the TREK Mapping and Integration project has identified new exposures of the Kasalka Group. Comparisons between preliminary geochronology results to existing data show differing ages between the Kasalka type section, and mapped Kasalka Group in the TREK area. This may reflect an eastward-younging magmatic front across the Stikine terrane during the Late Cretaceous. New U-Pb zircon and 40Ar/39Ar hornblende dating as well as whole rock lithogeochemistry on collected samples collected from both localities will provide insight into timing, lithologic characteristics, and petrogenesis of the Kasalka Group.

Middle to Upper Triassic picritic volcanism in northern Stikinia and comparison to other global arc-related and explosive picritic occurences

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Primitive picritic (MgO ≥12 wt. %) magmas are rare in arc settings, and limited to several spatially and temporally restricted occurrences in the Solomon Islands, Vanuatu, Lesser Antilles, Japan, and the Aleutian Islands. Explosive picritic volcanism is even more unusual, and has been identified only in non-arc settings including at Etna Volcano (recent) and Gorgona Island (Cretaceous). The disparate terranes of the Cordilleran tectonic collage locally preserve anomalous picritic magmatism, including middle to upper Triassic explosive picritic volcanics in northern Stikinia.

Where examined in situ, pyroclastic picrite deposits from northern Stikinia comprise upward-fining sequences of normally graded tuff breccia to olivine tuff, capped by rhythmically stratified ash tuff. The tuff is largely altered to serpentine, chlorite and clay, but preserves primary textures, including pseudomorphed olivine-rich lapilli, and devitrified, cuspate bubble-wall glass shards. The pyroclastic rocks have high, but variable MgO concentrations (22-38 wt. %, LOI-free) and relatively constant FeOTOT contents (9-10 wt. %). Within-suite geochemical variation predominantly reflects variable amounts of olivine accumulation (20-65 % by mass) into a parental liquid with MgO content of ~16 wt. %. Similarly primitive parental liquids have been estimated for the Upper Triassic flows in central Quesnellia (15-21 wt. %), and the Quaternary flows in Vanuatu (~15 wt. %) and Solomon Islands (~14 wt. %). These geochemical similarities are explored further, and the role of volatiles in generating picritic magmas in arc setting is examined.

Isograd map of the volcanic rocks of the Rossland Group, southeastern British Columbia

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The area around the towns of Salmo and Nelson in southeastern British Columbia contains metamorphosed volcanics and sediments, and several large Jurassic intrusions belonging to the Nelson Suite. This study area is a zone of particular interest due to its proximity to the Waneta Fault, which separates the North American rocks during the Jurassic from the incoming rocks of oceanic affinity, the collision of which caused the Cordilleran orogenic event. The youngest member exposed in the area is the Hall formation, composed of argillites, siltstones, and conglomerates. The middle member is the Elise Formation, containing basaltic flows and tuffs. Below the Elise Formation is the Archibald formation, another sedimentary layer containing argillite, siltstone, and conglomerates. These units are intruded by a number of Jurassic plutons, the two largest being the Nelson batholith and Bonnington pluton, and have been metamorphosed to sub-greenschist through amphibolite facies. Previous work in the area has found a general increase in metamorphic grade in the northwards direction, which corresponds to the location of large intrusive bodies. As a result, there is uncertainty as to whether the changing metamorphic grades are due to regional burial metamorphism or contact metamorphism from the intruding bodies, and the depths to which these rocks were buried during Cordilleran orogenesis.

Due to the challenges in differentiating between different amphibole minerals and other important phases in hand sample or by petrographic microscope, there is considerable uncertainty in the identification of the locations of mineral-in and mineral-out isograds. This study has used both the petrographic microscope and the electron microprobe to examine new volcanic samples, and reexamine samples used in a previous study of the area. This has allowed for the location of the mineral assemblages and corresponding mineral isograds to be defined with increased confidence, and has allowed for the creation of a new meta-volcanic isograd map. Overall, the metamorphic grade appears lower than has been suggested previously, and the development of metamorphic minerals and textures is more complex than initially thought. This information is useful in determining the causes of metamorphism and forms part of a broader study into the tectonics of southeastern British Columbia as well as the study of greenschist and amphibolite metamorphism.

Stratigraphy and structure of the upper Hyland River area, southeast Yukon

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The upper Hyland River area of southeast Yukon is mostly underlain by rocks of the Neoproterozoic-Cambrian Hyland Group. The Yusezyu Formation, which forms the lower part of the Hyland Group, comprises an ostensibly monotonous sequence of brown shale, sandstone, grit and subordinate calcareous rocks at least 3 km thick. The lack of stratigraphic subdivisions of the Yusezyu Formation presents an impediment to understanding the structure of the Selwyn fold-thrust belt. Large structures (*e.g.*, the Dawson, Robert Service and Tombstone thrust faults have been recognized where the Hyland Group is juxtaposed with younger (Palaeozoic-Mesozoic) units, but the absence of known marker units in the Yusezyu Formation prevents recognition of faults and characterization of the structural geometry elsewhere. Good exposure in the upper Hyland River area facilitates the identification of marker horizons, including marble/limestone layers and thick units of quartz granule-pebble conglomerate. A new 1:50 000-scale map of part of the area includes ten stratigraphic subdivisions in rocks previously assigned to the Yusezyu Formation. From northeast to southwest, the structure of the area is characterized by: 1) a southwest-vergent fold and thrust belt, 2) a central region with upright, NW-trending folds, and 3) a highly deformed region characterized by tight-isoclinal folding, in which folds and stretching lineations are at a high angle to the trend of the orogen. Deformation in this region was accompanied by amphibolite facies, low-pressure metamorphism. A steeply-dipping fault is coincident with the upper Hyland River valley. This fault is probably continuous with the Acland fault in the Coal River area, and may extend northwest into the Little Nahanni River area.

Detrital zircon data from basal Hazelton clastic strata in the Iskut region document the end-Triassic tectonic transition in northern Stikinia

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The Hazelton Group overlies the Stuhini Group on a diachronous Late Norian-Early Jurassic unconformity. Lowermost Hazelton units include well-sorted, clast-supported polymictic conglomerates with rounded clasts . Their sedimentary maturity contrasts with the volcaniclastic Stuhini Group. Clasts are of coarse-grained equigranular to porphyritic felsic intrusive rocks, radiolarian chert, and minor volcanic rocks. Clasts of Stuhini origin are rare. Conversely, no large Late Triassic plutonic bodies have been recognized in the region. The mismatch between local Stuhini basement and clasts in overlying Hazelton conglomerates indicates non-representational sedimentation: distant sources, deep erosion, and long surface residence time.
Detrital zircon populations: An uppermost Stuhini sample shows peaks at 212 Ma and 203 Ma, which is taken as the M.A.D. (maximum age of deposition). Above the unconformity, two Late Triassic conglomerates show peaks at 221 Ma, substantially older than that of the immediately underlying Stuhini Group. Late Triassic (222-225 Ma) peaks also occur in Early Jurassic samples. The sample taken near the top of the siliciclastic succession shows a subsidiary peak at 197 Ma (M.A.D.). Above a second, higher unconformity on Snippaker Ridge, the basal conglomerate contains a main 204 Ma peak and two subsidiary peaks at 216 and 198 Ma, the latter considered M.A.D. The older peaks correspond to local and regional Stuhini sources.
A pronounced shift to older detrital ages took place across the sub-Hazelton unconformity, from 212-203 Ma below to ca 220-225 Ma above. Penecontemporaneous arc-derived extrusive and hypabyssal sources gave way to deep erosion of the Stuhini arc and its basement. Abundant plutonic clasts were derived from large surface exposures of ca 220 Ma granitoids. At present, extensive exposures are only seen in the Hotailuh, Hickman and associated batholiths of far northern Stikinia. Stuhini arc activity was abruptly terminated in the latest Triassic (ca 203-204 Ma), succeeded by the development of a broad tectonic highland that shed debris towards the south.

Chemostratigraphy of late Proterozoic carbonate units in northern Selwyn basin, east-central Yukon

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The stratigraphic relationships between Proterozoic successions on opposite sides of the Dawson thrust in central Yukon, Canada, have previously been ambiguous, but recent mapping suggests correlation of the Hyland Group (Selwyn basin) with the uppermost portion of the Windermere Supergroup (Yukon block). To further Substantiate this linkage, we have focused on the chemostratigraphic, sedimentological, and petrographic characteristics of two carbonate markers in Selwyn basin for comparison with well-studied strata of the Windermere Supergroup. $\delta^{13}C_{carb}$ chemostratigraphic results from these carbonate strata support correlation of the lower carbonate marker (part of the Yusezyu Formation of Selwyn basin) with the Gametrail Formation and the upper marker (Algae Formation of Selwyn basin) with the Risky Formation of the Windermere Supergroup. $\delta^{13}C_{carb}$ values in the Yusezyu Formation carbonate define a clear trend from ~-12‰ (VPDB) at the base to ~1.5‰ at the top of this unit. This $\delta^{13}C_{carb}$ excursion has been correlated with the Ediacaran Shuram/Wonoka Anomaly, which is documented globally in rocks deposited ~580 Ma. Preliminary $\delta^{13}C_{carb}$ data from the Algae Formation record subtle oscillations between -0.7 and 2.0‰, which is broadly similar to previously published results from the Risky Formation. The large negative excursion documented at the top of the Risky Formation in some platformal sections has not been identified in basinal strata of the Algae Formation.

Extracting Regional Structural Features from Airborne Geophysical Data in the TREK Project Area, Central British Columbia

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Regions covered by glacial till and vegetation are always challenging regions in which to confidently identify structural features, such as in the northern Interior Plateau/Nechako region of central British Columbia. One method to identify structures is by interpreting regional geophysical data to applying methods for detecting the edges of magnetic anomalies. This method has been widely regarded as an effective tool in structural studies (Li, 2013). Many derivative layers of the magnetic data such as analytical signal, vertical derivative, total horizontal derivative and tilt derivative (Ferreira et al., 2011; Verduzco et al., 2004) can be considered. In this research a multiscale enhanced edge detection method (worm's model) is used to identify lineaments and extract favourable information on the dip of structural features. The approach is based on upward continued levels (UCL), to which total horizontal derivative (THD) is applied. The tilt derivative (TDR) is then used to extract deep structures. This project aims to identify and to add value to deep structural information and, ultimately, to understanding structural constraints on mineralization.

Detrital zircon analysis of Eocene strata in southern British Columbia and northern Washington: preliminary results of Cordilleran provenance

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Eocene-age sedimentary strata in southern British Columbia and northern Washington record the topographic and tectonic conditions within the interior of the southern Canadian Cordillera during initial stages of crustal extension. Sediments were deposited in a variety of nonmarine environments and units in the region include clast- and matrix-supported cobble and pebble conglomerates, sandstones, coal, and finely laminated siltstones and claystones. The overall depositional settings are interpreted as fluvial, lacustrine, and palustrine environments. Here, we present preliminary uranium-lead detrital zircon data from Eocene strata exposed in southern British Columbia and northern Washington state. Detrital zircons from sandstones in Princeton, British Columbia have ages ranging from early Cenozoic to Paleozoic, with the greatest population of grains having Middle Jurassic ages (~170 Ma). We tentatively interpret the Jurassic zircons to be derived from surrounding plutons in southern British Columbia. Detrital zircons from age-equivalent strata exposed near Republic, Washington have ages ranging from early Cenozoic to Proterozoic. The largest age population of detrital zircons from the Republic region are Paleoproterozoic in age (~1800 Ma). The Paleoproterozoic zircons are likely to have been recycled from eroded sedimentary and metasedimentary strata that were exposed in nearby Belt Supergroup regions during the Eocene. The distinct difference in detrital zircon age populations between the two areas suggests sediment provenance in the interior of the Cordillera was strongly influenced by local geology. Additional sampling and analyses are needed to determine if these sedimentary units represent deposition in one or more intermontane basins.

Geology of the Mount Nansen - Nisling River area, southwest Yukon

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New regional geological mapping in the Mount Nansen – Nisling River area of southwest central Yukon during summer 2015 made significant improvements over the existing reconnaissance style mapping, utilizing the advances made in the understanding of Yukon-Tanana terrane and related rocks over the last 15 years. The main highlights include subdividing the geology on existing compilation maps into distinct tectono-stratigraphic units: the pre-Devonian Snowcap assemblage, metavolcanic and metasedimentary rocks of the early Mississippian Finlayson assemblage, metaplutonic rocks of the Early Mississippian Simpson Range plutonic suite, and minor possible metaplutonic and metavolcanic rocks of the middle Permian Klondike assemblage. Also evaluated during this field work was the existence and nature of major structural discontinuities in the maps area, and their role in the structural architecture of this portion of Yukon-Tanana terrane. One discontinuity focused in particular is one that it demarcated by the a complex of mafic and ultramafic rocks in the Schist Creek area in the northwest part of the map area informally referred to as the Schist Creek complex (see Dubman et al, this volume). The Schist Creek complex is dominated by serpentinite, that typically preserves bastite pseudomorphs after strongly stretched orthopyroxene, and metagabbro. The true significance of the structure is unknown at present.
Significant gains were made in in understanding Mesozoic to Cenozoic successor rocks the overprint Yukon Tanana terrane in the area. Mapping also set out to investigate previous ideas about the nature of emplacement of the dominating Jurassic Aishihik batholith (ie. was structurally emplaced via thrusting against Yukon-Tanana terrane, or dies it preserve an intrusive contact). We conclude that the northwestern margin of the Aishihik batholith is an intact intrusive contact, which has implications for the depth of crust preserved, and thus the potential to preserve Jurassic porphyry versus Minto Style mineralization in the host country rocks in the area. A particularly interesting unit of quartz-feldspar porphyry that we correlate with the late Cretaceous (ca. 78-73 Ma) Casino suite was mapping in the area, and is generally internally hydrothermally altered. The rock bears striking similarity to a phase of the Patton porphyry at the Casino deposit in the central Dawson Range some 100 km to the northwest and should therefore be considered an exploration target for porphyry and epithermal mineralization potential.

Greenschist and epidote-amphibolite metamorphism of basalts: examples from Salmo, British Columbia and Flin Flon, Manitoba.

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The transition zone between greenschist and amphibolite facies assemblages is one of the most important facies boundaries due to its widespread development, particularly in greenstone belts, and its association with a number of major devolatilisation reactions that are a possible source for fluids linked to orogenic gold deposits. This study looks at two sequences of greenschist and epidote-amphibolite mineral assemblages developed within metamorphosed basalts and andesites: (1) a moderate-pressure regional sequence in the Flin Flon-Glennie complex (Manitoba/Saskatchewan) and; (2) a low-pressure contact sequence in the Salmo-Nelson-Rossland area (southeastern British Columbia).

This research suggests that across the greenschist facies, there are very few changes in mineral modes and compositions related to grade and that the main control on assemblages is bulk composition. In particular, bulk compositional variations related to pre-metamorphic seafloor alteration have a large control on the mineral assemblage, the proportions of hydrous mineralogy and the nature of the major devolatilisation reactions. Large changes in mineralogy occur at two major isograds: hornblende-in and oligoclase-in, suggesting kinetic controls rather than continuous equilibrium. Accurate determination of the changes in modal proportions of the hydrous mineralogy, and important accessory minerals such as carbonates and sulphides, has provided important information regarding the composition of fluids derived from the devolatilisation of these metabasites.

The greenschist-amphibolite transition zone consists of a complex set of reactions with multiple forms of different minerals coexisting across various postulated miscibility gaps. This study has shown that whilst there is strong evidence that a miscibility gap between actinolite and hornblende does exist, the amphibole pairs in these sequences, particularly at higher temperature, represent disequilibrium pairs. If the disequilibrium relationships observed here are common, the use of natural amphibole data to define an actinolite-hornblende miscibility gap (and potentially other miscibility gaps and solvi involving amphibole and plagioclase group minerals) may be erroneous.

Petrographic and geochemical considerations for the formation of alkali plutonism in the southern Omineca belt near Ymir, British Columbia.

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Field mapping and petrographic work was conducted on the alkalic, early Eocene-aged (Berndt, 1983) Salmo River and May Blossom intrusions, to obtain more information about their magmatic source(s). They are located approximately 30km south of Nelson, British Columbia, and lie within the southern portion of the Omineca belt. Both intrusions intrude the siltstones of the Ymir formation and greenschist facies meta-volcanics of the Elise formation. The Salmo River and May Blossom Intrusions are oval-shaped and have a topographic area of approximately 1.0km by 0.5km. Texturally, both intrusions are phaneritic, which indicates that they cooled slowly at depth. Mineral modes on the main bodies of both intrusions were made, and the following phases were observed: orthoclase (35%), normally-zoned aluminian diopside (25%), normally-zoned olivine (15%), biotite (13%) and andesine (12%). Both of these intrusions are classified as syenites. Phenocrysts of diopside and olivine display normal zoning. The cores of the diopside are Mg-enriched, and the rims are Fe-enriched. In olivine, the same trend occurs, where the cores have an average composition of Fo65 and the rims Fo62. This zoning pattern is interpreted to be the result of fractionation during cooling without crystal homogenization. There is a small circular leucocratic core, approximately 300m in diameter, cropping out in the northeastern portion of the Salmo River intrusion. This core is dominated by: perthitic orthoclase feldspar (60%), diopside (15%), biotite (15%), and plagioclase (10%). The core is also classified, as a syenite**.** Whole-rock analyses of the Salmo River (excluding the core) and the May Blossom intrusions were conducted. Total alkali (Na2O+K2O) values are 7.01wt% and 7.44wt%, with SiO_2 contents of 50.51wt% and 51.49wt% for the Salmo River and May Blossom intrusions, respectively. Major and trace element analyses of the Salmo River and May Blossom intrusions indicate enrichments in the LILEs and depletions in the HFSEs relative to the primitive mantle. Significant depletions in mantle-normalized Nb and Ti values in both intrusions, indicate a source modified by subduction-related processes. The chondrite-normalized REE diagrams for the intrusions show enrichment of the LREEs with respect to the HREEs, without an Eu anomaly. This implies that plagioclase was present in the cooling history of the intrusions without fractionating from the melts. This study considers the possibility of the Salmo River and May Blossom intrusions originating from an enriched lithospheric mantle source contaminated by a pre-Mesozoic subduction process, and the tectonic settings that could have caused such phenomena.

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Investigation of the tectono-metamorphic evolution of the Takhanne River and Kluhini River map area of southwestern Yukon

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The tectono-metamorphic evolution of southwest Yukon records a long, complicated history that lead to the reorganization of the western edge of the northern Cordillera. Although regional and more detailed 1:50,000 scale bedrock mapping has been completed in the area, the detailed geologic evolution has yet to be resolved. The goals of this study will be to better characterize and constrain the metamorphic, structural and tectonic history of the region. In order to achieve these goals, detailed bedrock mapping within the Takhanne River and Kluhini River map areas will be undertaken in the summer of 2016. Along with the new mapping, detailed metamorphic and structural analyses will also be undertaken.

The field area is located to the south of Haines Junction, southwest Yukon, near the British Columbia border. Previous bedrock mapping of this study area has defined it as the zone of juxtaposition of the Insular terranes with the Intermontane terranes. Regionally, the primary units that make up the area include the Proterozoic to Permian Yukon-Tanana terrane, the accreted Insular terranes and Jura-Cretaceous deep basinal and arc assemblages that once separated the Insular terrane from the Intermontane terrane until later in the Mesozoic. These assemblages include from east to west: Late-Cretaceous metasedimentary rocks of the Kluane Schist, the Triassic to the Middle Jurassic Bear Creek assemblage and Jura-Cretaceous turbidites of the Dezadeash formation. The Tatsenshini shear zone separates the Dezadeash formation from the Paleocene Ruby Range batholith, the Bear Creek assemblage and the Kluane schist, all of which are juxtaposed by seemingly west-verging thrust faulting. This project will focus on the relationship between metasedimentary rocks of the Yukon Tanana terrane and the poorly constrained Paleozoic to Mesozoic rocks to the west, and how they fit into the regional tectonic framework for the northern Cordillera. There is uncertainty as to whether or not the high grade metamorphism of rocks within the map area coincides with Late Cretaceous southwest-directed shortening and associated foliation development in the Late Cretaceous intrusives. To address these problems, the field mapping and structural analyses will be coupled with thermobarometry of metasedimentary rocks to determine the relationship between deformation and P-T conditions attained in the region. In addition, U-Th-Pb dating of the Paleozoic to Mesozoic metasedimentary rocks will be done using metamorphic accessory minerals such as monazite and zircon to constrain the timing of deformation relative to metamorphism in the field area. Detrital zircon analyses may also be undertaken to further constrain the provenance ages for the Mesozoic stratigraphy, which can be used to assess their relationship to the rocks of the Yukon-Tanana terrane to the east and the Insular terranes to the west.

Significance of Cretaceous extension and thin- and thick-skinned thrusting in the "undeformed" southern Alberta Plains

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The foreland basin of southern Alberta, east of the mapped Rocky Mountain Foothills thrust front, has experienced a complex Cretaceous-Tertiary deformational history of flexural extensional faulting, thin-skinned thrusting and later thick-skinned compression, including inversion of earlier Cretaceous and perhaps older extensional faults. Deformation styles and sequence are revealed by integrating outcrop, seismic and well data.

Numerous NNW-SSE trending extensional faults have been documented previously on seismic data, and many extend from Precambrian basement upward through the entire Cretaceous section. At least one of these faults is exposed at surface within U. Cretaceous strata near Lethbridge. Many of these faults were intermittently active throughout Cretaceous-Tertiary deposition in the foreland basin. They locally control isopach/isochron variations and facies changes including fluvial channel locations and orientations.

A seemingly anomalous zone of thin-skinned thrusting and significant shortening within Upper Cretaceous strata is exposed in the Oldman River near Monarch, more than 50 km east of the limit of the Foothills. The approximately 1 km long outcrop exposes structural geometry that implies a partly eroded, small-scale "triangle zone," similar to the structural trend that is well documented in many parts of southern and central Alberta at the eastern limit of the Foothills. The inferred detachment level beneath the observed deformation at Monarch is at or only slightly stratigraphically higher than the inferred "blind" detachment east of the Foothills deformation front and triangle zone, and we infer that thin-skinned slip is transferred from the Foothills into the foreland on this detachment.

However, the stratigraphy and zone of thin-skinned deformation at Monarch have been structurally elevated about 150 m above a "regional" datum. Seismic data show the outcrop coincides with a steep NNW-SSE reverse fault rooted in the basement, possibly an inverted extensional fault. In the outcrop, low-angle thrust faults are cut by younger steep thrusts.

The economic significance is that extensional faulting has influenced reservoir and seal facies distribution, and late thick-skinned uplift has influenced hydrocarbon migration and trapping. Several hydrocarbon fields are associated with the broad structural culmination to the west of the Monarch fault outcrop. The overall deformational history also has influenced development and distribution of fractures critical for enhanced permeability in unconventional reservoirs.

Unraveling polyphase metamorphism and deformation on the eastern flank of the Shuswap domain, via in-situ U-Pb geochronology

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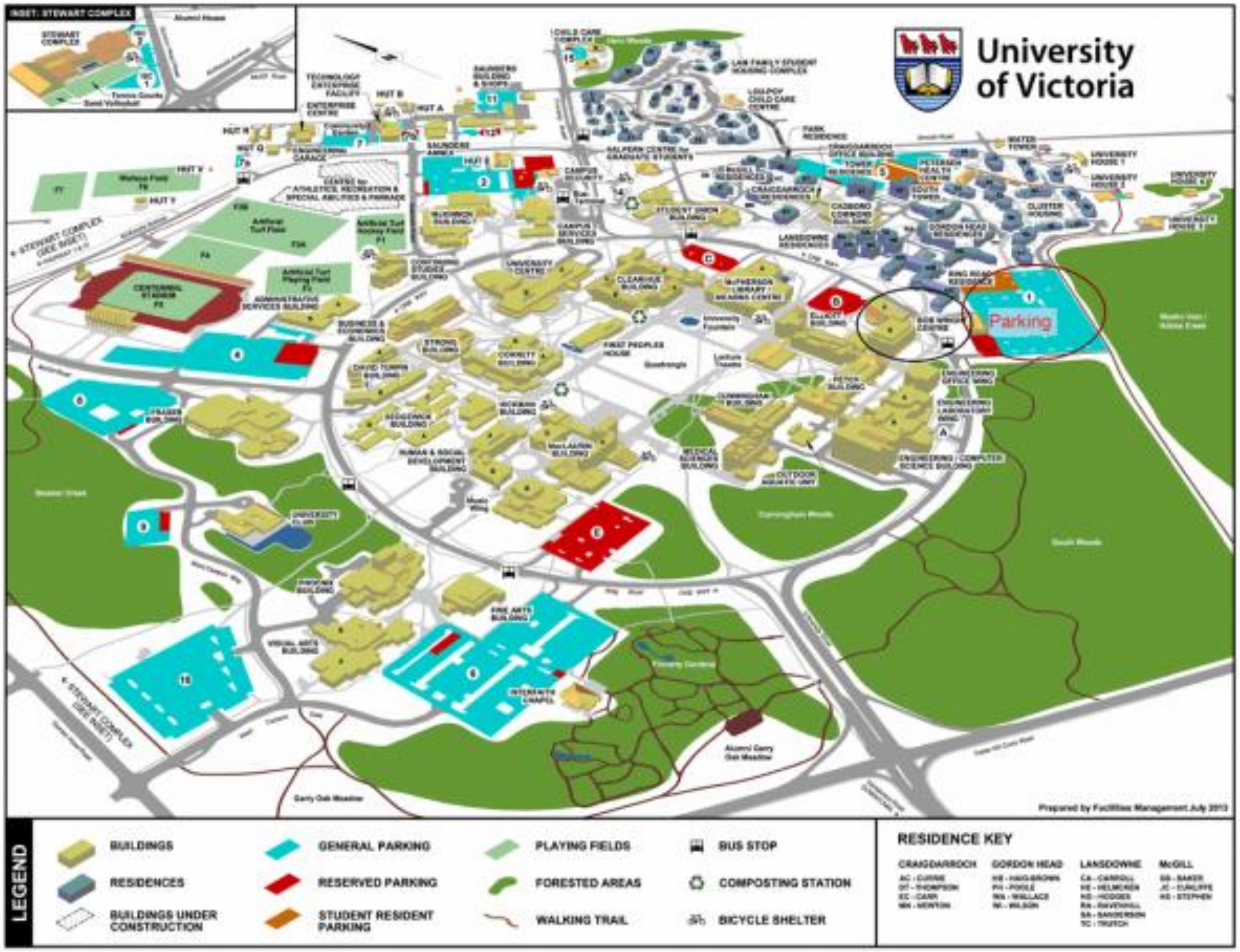
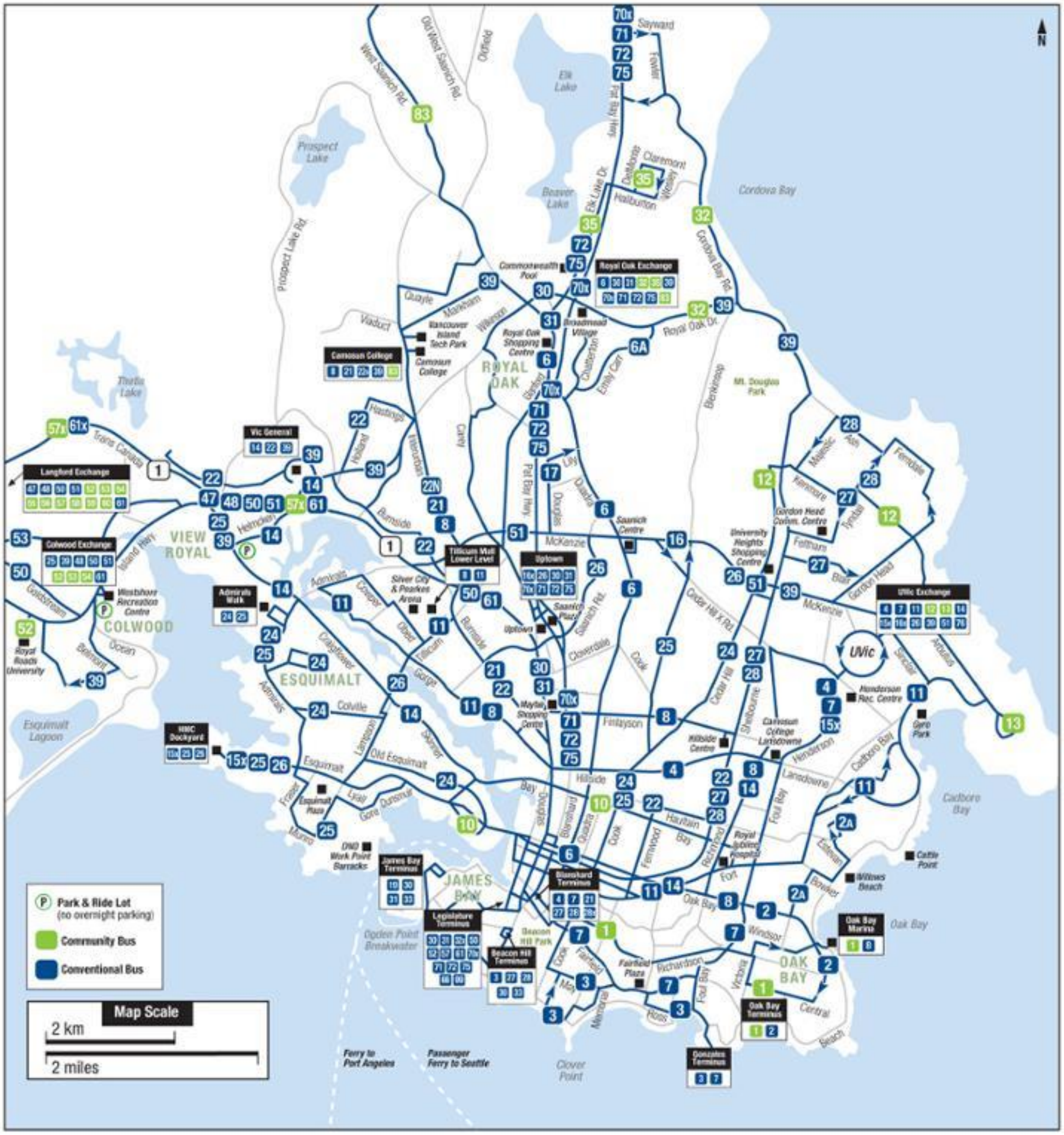
On the eastern flank of the Shuswap domain, southeastern British Columbia is a partly fault bounded, north-south trending belt of amphibolite facies metamorphism that spans the length of Kootenay Lake and extends southward into northern Idaho, merging with the Priest River Complex. This region experienced multiple pulses of prograde metamorphism and deformation that occurred under nearly identical conditions during Cordilleran orogenesis. Zircon and in-situ monazite U-Pb geochronology data were collected by LA-ICP-MS analyses and help constrain the timing of discrete periods of regional metamorphism and deformation. Monazite from metapelite in the contact aureole of Nelson suite intrusives contain ca. 158 Ma monazite grains that are interpreted to have formed after Jurassic deformation and low grade regional metamorphism. Monazite growth is attributed to a thermal pulse from extensive plutonic activity at this time. During the Early Cretaceous, the orogen began to expand and thicken and was accompanied by a second pulse of monazite growth that is interpreted to reflect prograde amphibolite-facies metamorphism during the interval 143-134 Ma. Metamorphism was accompanied by penetrative deformation that was still ongoing at 118 Ma. Deformation was waning by ca. 111 Ma when structures are crosscut by undeformed igneous intrusive bodies. In the footwall of the Purcell Trench fault, monazite from metapelitic samples yield ages spanning the interval 80-70 Ma. The monazite grains are intergrown with sillimanite and are interpreted to reflect peak metamorphic conditions that are contemporaneous with penetrative deformation. This population of monazite grains is interpreted to reflect a Late Cretaceous period of amphibolite-facies metamorphism and deformation, all of which is related to events of the northern Priest River Complex, the Selkirk Crest. Improved geochronological constraints on the timing of deformation and metamorphism in this region have identified three discrete orogenic events: Middle Jurassic, Early Cretaceous and Late Cretaceous.

Map – University of Victoria



Regional Map of Greater Victoria



Map – Bard and Banker Pub