Ottawa – Carleton Geoscience Centre

Carleton UNIVERSITY

Cordilleran Tectonics Workshop 2010

February 19-21, 2010

Ottawa – Carleton Geoscience Centre

Carleton University

124 Leeds House

Ottawa, Ontario K1S 5B6

Canadian Tectonics Workshop - Feb 19 – 21, 2010
Carleton University, Ottawa

CONFERENCE PROGRAM

Saturday, Feb 20th CTW Workshop Program

8:00 - 8:55: Coffee, Continental Breakfast, Registration & Poster Setup

8:55 - 9:00: Introduction & Announcements

9:00 - 9:15: **Steve Israel**. *"Geologic relationships of Wrangellia in Yukon and their implications for Insular terrane tectonics"* by Steve Israel, Cees van Staal, Rich Friedman & Jim Mortensen

9:15 - 9:30: Cees van Staal. *"New data and ideas on the Paleozoic-Triassic evolution of the Insular superterrane of the North American Cordillera"* by Cees van Staal, Luke Beranek, Steve Israel, Bill McClelland, Mitch Mihalynuk JoAnne Nelson and Nancy Joyce

9:30 - 9:45: Rosie Cobbett. "*The Duke River fault, southwest Yukon; Preliminary examination of the relationships between Wrangellia and the Alexander terrane"* by Rosie Cobbett, Steve Israel, Jim Mortensen and Cees Van Staal

9:45 - 10:00: Discussion

10:00 - 10:30: Coffee

10:30 - 11:00: Introduction of Posters

10:30 - 11:00: Introduction of Posters

11:00 - 11:30: Introduction of Posters

11:30 - 12:00: Introduction of Posters and Poster Session

12:00 - 12:30: Poster Session

1:30 - 2:00: Poster Session

2:00 - 2:15: Liz Westberg. "*Late Paleozoic to Mesozoic deformation and metamorphism in the Mendocina Creek area of south-central Yukon"* by Elizabeth Westberg, Maurice Colpron, and Dan Gibson

2:15 - 2:30: Duncan McLeish. "*Geology of the Aley Creek Area, Northeastern BC Rocky Mountains: A record of Mississippian orogenesis in the Cordilleran Foreland Belt?*" by Duncan F. McLeish and Stephen T. Johnston

2:30 - 2:45: Ray Price. "*Subduction, asthenospheric flow, and the evolution of foreland thrust-and-fold belts: Insights from the southern Canadian Cordillera" by* Raymond A. Price

2:45 - 3:00: Discussion

3:15 - 3:45: Poster Session & Coffee

3:45 - 4:00: Andrew Leier. "*An early sedimentary record of tectonic loading associated with the development of the Canadian Cordillera*" by Andrew L. Leier, Tannis McCartney, Michele Asgar-Deen

4:00 - 4:15: Bill Arnott. "*Regional Geology of the Windermere Supergroup, Southern Canadian Cordillera and Stratigraphic Setting of the Castle Creek Study Area*" by Gerry Ross and Bill Arnott

4:15 - 4:30: Shann Khan. "*An Alternative Model of Producing Levee Topography in Deep-Water Systems – a Matter of Disparate Sedimentation"* by Zishann Khan, Bill Arnott and André Pugin)

4:30 - 4:45: Sharon Carr. "*Criteria for evaluating channel flow in ancient orogens, and an example from the SE Canadian Cordillera in support of couette (transport) rather than poiseuille (channel) flow"* by Sharon Carr & Philip Simony

4:45 - 5:00: Discussion

5:00 - 7:00: Skate or walk to restaurant (or go for a beer).

7:00 PM: Arrive at Malone's Restaurant - Pavillion on Dow's Lake; Dinner will be served at 7:30 PM

Sunday, Feb 21st CTW Workshop Program

8:00 - 9:00: Coffee, Continental Breakfast, Poster Session

9:00 - 9:15: Felix Gervais. "*The Hellroar Creek shear zone: A major tectonic boundary in the northern Monashee Mountains of the southeastern Canadian Cordillera*" by Félix Gervais, Andrew Hynes, Edward D. Ghent

9:15 - 9:30: Iole Spalla. "*Pre-Cordilleran history in mantle rocks of the Monashee Complex?*" by M. Iole Spalla, Patrizia Fumagalli, Roberta Zuccarello, Davide Zanoni, Paul F. Williams and Guido Gosso

9:30 - 9:45: Davide Zanoni. "*Deformation vs metamorphism in the western Thor-Odin dome, Monashee Mountains, Canadian Cordillera"* by Davide Zanoni, M. Iole Spalla, Paul F. Williams & Guido Gosso

9:45 - 10:00: Discussion

10:00- 11:00: Poster Session & Coffee

11:00 - 11:15: Deanne van Rooyen. "*A-ICP-MS detrital zircon results from quartzites in the Thor-Odin – Pinnacles area: Constraints on age and provenance, and implications for models of allochthnous vs authochthonous deposition*" by Deannve van Rooyen, Sharon Carr and Don Murphy

11:15 - 11:30: Joel Cubley. "*Structural evolution and high-temperature exhumation of the Grand Forks Complex, southeastern British Columbia"* by Joel F. Cubley and David R.M. Pattison

11:30 - 11:45: David Moynihan. "*Mid-Cretaceous Metamorphism and Deformation in the Central Kootenay Arc, Southeastern British Columbia"* by David P. Moynihan & David R.M. Pattison

11:45 - 12:15: Discussion

12:15 - 2:00: Lunch & Poster Session

2:00: End of conference

POSTERS (ordered in alphabetical order of surname of first author)

1. Arnott, R.W.C., Khan, Z., and Navarro, L. *"Stratal Architecture of Highly-Confined and Poorly-Confined Deep-Marine Sinuous Channel Systems – An Outcrop Perspective Arnott, R.W.C., Khan, Z., and Navarro, L"*

2. Chakungal, Joyia. "*Wernecke Mountains, Yukon: reasons for new mapping in 2010"*

3. Witold Ciolkiewicz, [Vee-told Tsiol-kyev-ich] and Craig Hart. *"Dawson Range and Beyond: Late Cretaceous Metallogeny in West-Central Yukon. Project outline and preliminary results"*

4. Maurice Colpron. "*Crustal structure of the northern Intermontane terranes, Yukon"*

5. Maurice Colpron, James J. Ryan, Nathan Hayward and Nancy Joyce. *"Bedrock Geology of southwest McQuesten (115P) and part of northern Carmacks (115I) map sheets"*

6. Keith D'Arcy, David Baque, Dale Issler, Bernard Guest, Daniel Stockli & Michael McDonough, Keith. "*Low temperature thermochronology from the Athabasca river valley, Rocky Mts., Alberta."*

7. Leena Davis, Zishann Khan, Andres Altosaar and Bill Arnott. *"Differentiating Deep-Marine Overbank from Crevasse Splay Deposits in Outcrop: an Example from the Windermere Supergroup, Castle Creek, Southern Canadian Cordillera, British Columbia"*

8. Zishann Khan, R.W.C. Arnott, Ernesto Schwarz and Andres Altosaar. *A Detailed Analysis of Crevasse and Overbank Splay Units in the Isaac Formation (Windermere Supergroup), of the Southern Canadian Cordillera"*

9. Andrew L. Leier, Cassandra L. Frosini, & George E. Gehrels. *"Detrital zircon provenance of Lower Cretaceous conglomerate beds in Canada and the U.S."*

10. Kirsti P. R. Medig. Derek J. Thorkelson, Roberta L. Dunlop. *"Proterozoic Pinguicula Group: Stratigraphy, Contacts, and Correlations"*

11. Mélanie Mercier, Sharon D. Carr and Maurice Colpron. *"Conditions of deformation and timing constraints on the d'Abbadie fault zone, south-central Yukon (NTS 105E/8), northern Canadian Cordillera"*

12. Nancy Joyce. *"Overview of the geochronology for the Gem "Multiple Metals northwest Canadian Cordillera" project"*

13. Navarro, L. & Arnott, R.W.C. *"Stratigraphic relationships between the uppermost Kaza and the lowermost Cariboo Groups, Neoproterozoic Windermere Supergroup"*

14. Nielsen (Oscar), Alexander B.1 and Thorkelson, Derek J. *"The Origin of Igneous Clasts in Proterozoic Breccia Zones, Yukon, Canada: Testing the Feasibility of Tectonic Emplacement"*

15. Steven Scott, Sharon Carr, Don Murphy & Eric de Kemp. *"I can't believe it's not Windy-McKinley: New insights into the western margin of the Yukon- Tanana terrane in the Tincup Lake area, southwest Yukon"*

16. Benjamin F. Stanley, Shoufa Lin and Cees van Staal. *"Regional folding of the Kluane Metamorphic Assemblage in the Ruby Range, northern Canadian Cordillera"*

17. Reid Staples. *"Regional tectono-metamorphism and exhumation history of Yukon-Tanana terrane"*

18. Viktor Terlaky, Jonathan Rocheleau, Hugues Longuépée, Kelsey Privett, Greg van Hees, R. William C. Arnott. *"Comparison of Basin-Floor Deposits along a Proximal to More Distal Transect: Upper and Middle Kaza Groups, British Columbia, Canada"*

19. Zagorevski and N. Joyce. *"Provenance of the Lewes River Group, Yukon"* A. Zagorevski and N. Joyce

LIST OF CONFERENCE PARTICIPANTS

Arnott, Bill	U of O
Auston, Jeff	CU
Baque, David	U of C
Bordett, Esther	UBC-MDRU
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Chakungal, Joyia	YGS
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Cobbett, Rosie	UBC
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Davis, Leena	U of O
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ABSTRACTS FOR TALKS AND POSTERS

Stratal Architecture of Highly-Confined and Poorly-Confined Deep-Marine Sinuous Channel Systems – An Outcrop Perspective

Arnott, R.W.C., Khan, Z., and Navarro, L.

Deep-marine strata of the Neoproterozoic Windermere Supergroup, western Canada, exhibit two end-member kinds of sinuous channel fills – poorly-confined and highly confined. Poorly-confined channels are larger-scale composite features up to about 100 m thick and over 1 km wide. Channel deposits tend to amalgamate vertically. Highly-confined systems, on the other hand, are smaller-scale, typically isolated features that are of the order of 10 m thick and separated vertically by thin-bedded turbidites.

In both poorly- and highly-confined channel systems coarse-grained channel deposits are flanked on both sides by levee deposits, however the make-up of these latter deposits are starkly different. In poorly-confined channels, the outer levee, at least in its proximal reaches (<400 m from channel margin) tends to be sand rich, and was constructed by flow overspill and inertial run-up. The contact between coarser-grained channel deposits and sandy levee strata is erosive. On the inner-bend side, by contrast, channel strata grade laterally into finer, thinner levee deposits, suggesting continuity of the flows that deposited in the channel and over the inner-bend levee. In highly-confined channels the outer bend is similarly erosive, but everywhere in contact with fine-grained levee deposits (thin-bedded turbidites) related to an older (underlying) channel. Sandstone injection complexes are locally well developed. On the inner-bend side of the channel, a distinctive obliquely-upward interfingering pattern of coarse-grained channel deposits terminating abruptly where they onlap fine-grained levee deposits is observed. This intercalation suggests episodes of fine- and coarse-grained sediment deposition on the inner-bend levee related to recurring variations in local flow and/or channel conditions. Moreover, the abrupt upward termination of coarse levee deposits against conterminous fine-grained levee strata suggests emplacement from the lower part of highly stratified turbulent flows that at least locally were depositional on the inner bend of a deep-marine sinuous channel.

Criteria for Evaluating Channel Flow in Ancient Orogens, and an Example from the SE Canadian Cordillera in Support of Couette (transport) rather than Poiseuille (channel) Flow

Sharon D. Carr[1] & Philip S. Simony[2]
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Discrimination between Couette (transport) vs Poiseuille (channel) flow modes requires characterization of: timing and nature of deformation and metamorphism throughout both the flow zone, or infrastructure, and the overlying suprastructure; timing and amount of dislocation on the upper and lower boundaries of the flow zone; the nature of the leading edge of the flow zone and, importantly, a 4D approach – an understanding of infrastructure migration through time and space. Evaluation of the significance of channel flow requires integration of results with regional geology (e.g. origin of rocks in the flow zone and whether there is geologic coherence or incoherence; 3D size of a potential channel; geologic and geometric evolution of the orogen through time including timing constraints and provenance of sediment deposition in flanking basins). The channels that have been proposed for the Canadian Cordillera in southeastern British Columbia lie primarily within two adjacent thrust sheets. They are limited in thickness and in width along strike, have a possible extrusion "porthole" of width along strike of <150 km, contain coherent markers, and have retained links to their suprastructure. Thus channel flow can not be considered to be a tectonically effective process. The ~ 400 km wide thrust belt of the southeastern Canadian Cordillera is constituted largely of four major composite thrust sheets that evolved and were emplaced "in sequence" in the Cretaceous and Paleocene during the westward underthrusting of the North American craton. In the external zone of the Rocky Mountains, each sheet is thin skinned and was carried by a thrust system with a common basal thrust fault. In the internal zone, there is a westward increase in thickness of each sheet toward the core zone, and a westward increase in the importance of ductile shear within each sheet. In the core, each sheet has an infrastructure of metamorphic and migmatitic rocks that includes interfolded cover and basement under a suprastructure of rocks that were previously deformed during older (e.g. Middle Jurassic and Early Cretaceous) events. There is no doubt about the importance of "transport" (Couette) flow and ductile shear in the infrastructure of each sheet. That infrastructure had an eastern margin or "tip line" where the flow and shear within the part of the sheet, in the internal zone, was transferred eastward into transport on the basal thrust of the eastern, external part of each sheet. This geometric – kinematic framework of great thrust sheets is based on the facts of stratigraphy, mapped geometry and geochronology, and can form the basis for dynamic modeling. Channel flow (Poiseuille) models, with or without extrusion, must be considered within this framework.

Wernecke Mountains, Yukon: Reasons for New Mapping in 2010

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In north and central Yukon, Paleo- and Mesoproterozoic sedimentary and volcanic 'basement' (Laurentia), and overlying Paleozoic basinal (Selwyn Basin) and correlative platformal rocks are exposed in the Wernecke and adjacent Ogilvie Mountains. Results of recent and ongoing research activities in these areas are of sufficient detail to permit more comprehensive, regional correlations between the Proterozoic and Paleozoic strata, except for a notable lack of data in the south Wernecke Mountains. Also, recent exploration activity and new, somewhat enigmatic, gold discoveries occurring within a northwest trending structural corridor bound by the Robert Service (south) and Dawson (north) thrusts necessitate improvements to available geoscience information to better constrain the context of gold mineralization.

Our current understanding of the Laurentian sedimentary basement and evolution of its western margin from the Precambrian through to present, is largely based on 1:250k scale mapping of the geology exposed in the Coal Creek, Hart River and Wernecke inliers. Stratigraphic details and associated nomenclature differs from west to east reflecting the most recent scale of mapping (more detail = larger scale mapping). From oldest to youngest, the sedimentary pile common to all three inliers includes:

- i) Rift-related Paleo - Mesoproterozoic rocks of the Wernecke Supergroup;
- ii) Mesoproterozoic - Neoproterozoic rift-related rocks of the Pinguicula Group (Wernecke & Hart River inliers); Fifteenmile Group (Coal Creek inlier); Mackenzie Mountain Supergroup (Wernecke & Northwest Territory);
- iii) Rift-related early Neoproterozoic Windermere Supergroup;
- iv) Upper Neoproterozoic - middle Devonian basinal and associated platform rocks of the Selwyn Basin;
- v) Late Devonian rift-related clastic rocks of the Earn Group.

Of interest to this new YGS multi-year mapping project are sedimentary successions and associated igneous rocks that comprise the Wernecke inlier, particularly those exposed in the southern-half of the Nash Creek (106D), and Nadaleen River (106C) map sheets. In the area of interest stratigraphic details are largely absent; geochronological constraints are out-dated and few in number; and the structural setting is very poorly understood. It is known, however, that rocks in this area are situated in the northwest trending structural corridor described above, and are host to a variety of syn- and epigenetic mineral occurrences. The most recently discovered of these occurrences is the carbonate-replacement hosted Au mineralizing system in the Rau property (ATAC Resources), situated in the southeast corner of the Nash Creek map sheet (1:50k sheet - 106D/01).

An overview of the geoscience information currently available for the southern Nash Creek and Nadaleen River map sheets is presented in this poster, together with a series of outstanding, first-order questions that remain to be addressed with new mapping that is scheduled to begin in summer 2010.

Dawson Range and Beyond: Late Cretaceous Metallogeny in West-Central Yukon. Project outline and preliminary results.

Witold Ciolkiewicz and Craig J.R. Hart
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Late Cretaceous intrusions in Yukon are volumetrically insignificant but have high geological significance and are metallogenically prolific. These intrusions have a wide spatial distribution, a large range in lithological and geochemical characteristics, and generate significant mineral deposits. They may be cogenic with the intermediate to mafic Carmacks Group volcanic rocks.

This project will develop an integrated tectonic and metallogenic framework for the Late Cretaceous (74-69 Ma) intrusions within the Yukon Tanana Terrane. A greater understanding of these rocks will facilitate more focused, efficient and successful

exploration decision-making within the Dawson Range – White Gold Belt. This project is jointly sponsored by the Geological Survey of Canada through the GEM program, the Yukon Geological Survey and the Mineral Deposit Research Unit at UBC.
Key objectives include:
(1) determine the spatial and temporal distribution of the Late Cretaceous intrusions throughout west-central Yukon and adjacent Alaska;
(2) characterize the intrusions trough mapping, 3D modelling, petrography, geochronology and geochemistry;
(3) evaluate associated mineral occurrences and determine the features that make these intrusions preferential mineralizers.

In the summer of 2009 reconnaissance mapping was carried out in the following intrusive bodies: Carcross (105D/6,2), Mt. Lorne (105D/10), Mt. Freegold (115I/6), Casino (115J/10,15), Swede Dome (116C/1), Connaught – Mt. Hart (115N/15-16).

Petrographic and geochemical investigation of collected samples begun in the fall of 2009. Concurrently, geochemical, geospatial and temporal data is being compiled from all existing sources, including unpublished literature, into an integrated database of Late Cretaceous intrusives and associated mineral occurrences.
Regional as well as pluton-scale mapping is planned for the summer of 2010, followed by advanced geochemical and petrographic studies and integrated modelling. Project completion date is set for summer of 2011.

The Duke River fault, southwest Yukon; Preliminary examination of the relationships between Wrangellia and the Alexander terrane

Rosie Cobbett[1], Steve Israel[2], Jim Mortensen[1] and Cees Van Staal[3]
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The Duke River fault is a terrane-bounding structure that separates the Alexander terrane from Wrangellia in southwest Yukon. To determine the history of movement, detailed geological mapping and sampling of three key areas along the fault were completed in August 2009. In these areas, the fault is juxtapositioned between pervasively foliated greenschist facies rocks of the Alexander terrane that record multiple phases of folding and low-grade Wrangellian rocks that record only one phase of folding. Multiple lines of evidence indicate the Alexander terrane has been thrust over Wrangellia. Preliminary $^{40}Ar/^{39}Ar$ ages from muscovite grains, which may have grown during faulting or been reset by motions along the Duke River fault, range from 90-104 Ma suggesting that movement along the fault is at least as old as Cretaceous. Results also indicate that Miocene felsic intrusions and Miocene to Pliocene crustal tuffs of the Wrangell lavas have been deformed by the Duke River fault which, in turn, suggests that fault movement has occurred as recently as the Pliocene.

Crustal structure of the northern Intermontane terranes, Yukon

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The northern Intermontane terranes in Yukon have a semi-concentric distribution with mid-Paleozoic pericratonic terranes on the outside (Yukon-Tanana) and progressively younger arc successions of Stikinia and Quesnellia towards the centre. The core of the belt in southernmost Yukon and northern B.C. is occupied by more exotic, oceanic rocks of the Cache Creek terrane, including chert/argillite, basalt, serpentinite, and late Paleozoic carbonate with Tethyan fusilinid fauna. Arc volcanic rocks of Stikinia and Quesnellia are overlain by Lower and Middle Jurassic clastic strata of Whitehorse trough – a synorogenic basin that developed during Early to Middle Jurassic amalgamation of the Intermontane terranes. Deposition in the Whitehorse trough is coeval with intrusion of Early Jurassic batholiths into rapidly exhuming rocks of the Yukon-Tanana terrane. Rapid exhumation is indicated by (1) widespread Early Jurassic (~190-185 Ma) mica cooling ages in Yukon-Tanana terrane; and (2) presence of magmatic epidote (>6 kbar) in early phases of the granitoid plutons, but younger phases locally contain miarolitic cavities and pegmatite (<2 kbar). Detrital zircons from Whitehorse trough indicate local sources dominated by Early Jurassic plutons, but also including grains with mid- to late Paleozoic ages similar to magmatic ages in the Yukon-Tanana terrane. The concentric distribution of the Intermontane terranes has been ascribed to oroclinal entrapment of the Cache Creek terrane by once contiguous arc terranes of Stikinia and Quesnellia.

The overall structural pattern of the northern Intermontane terranes is that of a southwest-verging fold-and-thrust belt dissected by a series of transcurrent faults. Of these, the most prominent is the Teslin fault – a major northwest-striking, northeast-dipping fault that can be traced down to ~9 seconds in seismic profiles (1999 SNORCLE line 3 and 2004 Carmacks surveys), and for which up to 125 km of dextral displacement has been suggested on the Thibert fault, the southern extension of the Teslin in northern B.C. Near the 60th parallel, the Teslin-Thibert fault juxtaposes Quesnellia (and Yukon-Tanana), on the east, to Cache Creek terrane, on the west. Farther north in Yukon, the Teslin fault progressively loses stratigraphic separation (and presumably displacement), juxtaposing Laberge Group strata (Whitehorse trough) or similar augite-phyric volcanic rocks of Stikinia and Quesnellia on either sides. Yet, the Teslin remains a major crustal feature in the Carmacks seismic survey. This apparent lack of offset along Teslin fault in central Yukon represents one of the major structural conundrums in the northern Cordillera.

The apparent loss of displacement along the Teslin fault could be accounted by progressively 'bleeding' displacement to a series of subsidiary faults, including the d'Abbadie, Big Salmon and Tadru faults, which show collectively up to 125 km of dextral displacement (~35, 57 and 33 km, respectively). These subsidiary faults are curvilinear and have a more northerly strike than the Teslin. They are truncated by the Tintina fault, which has an estimated 430 km of Eocene dextral displacement. Possible counterparts of the Big Salmon-d'Abbadie-Tadru fault array northeast of the Tintina fault may be found in poorly understood structures of the Hyland River region of southeast Yukon (north of Watson Lake). Dextral strike-slip displacement along the Teslin and related faults is mostly constrained to be mid-Cretaceous in age (*ca*. 125-95 Ma).

The early history (Jurassic?) of the Teslin fault is even more enigmatic. The overall geometry of the northern Intermontane terranes and the apparent northeast dip of the Teslin fault in seismic profiles suggest that it originated as a thrust fault bounding the upper part of the Cache Creek subduction complex; it may represent the remnant of the megathrust that rooted into the subduction zone that consumed Panthalassa ocean floor (represented in the Cache Creek terrane) and gave rise to the Quesnellia arc in Triassic time. This interpretation and the observed magnitude of the Teslin fault in seismic sections provide the basis for separating Quesnellia from Stikinia in central Yukon, where the intervening Cache Creek terrane is absent. Accordingly, Quesnellia is now interpreted to extend as far north as the Pelly River (~62° 50'N) and includes rocks previously assigned to the Lewes River Group (Stikinia).

The structural style of the Whitehorse trough, southwest of the Teslin fault, is characterized by anastomosing, curvilinear, south-southwest-verging folds and thrust faults that are bounded by the Teslin and Braeburn faults. These structures involve strata as young as Bathonian (Middle Jurassic), but Cretaceous volcanic rocks of the Carmacks (*ca*. 70 Ma) and Mount Nansen (*ca*. 90 Ma) groups appear to lay flat over top of tilted Whitehorse trough strata, therefore suggesting that most of the deformation is Late Jurassic to Early Cretaceous in age. It is possibly coeval with dextral strike-slip faults northeast of the Teslin fault. The geometry of structures in the northern Whitehorse trough is consistent with dextral transpression linked to development of the Teslin and Braeburn faults. Overall, the pattern of Cretaceous faults affecting the northern Intermontane terranes resemble that of a dextral wrench system.

The observations and interpretations summarized above are primarily derived from extensive mapping in various parts of central Yukon and ongoing compilation of a 1:250,000-scale geological map, parts of which will be on display during the workshop.

Bedrock Geology of southwest McQuesten (115P) and part of northern Carmacks (115I) map sheets

Maurice Colpron[1,2], James J. Ryan[3], Nathan Hayward[3] and Nancy Joyce[3]
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3 Geological Survey of Canada

Regional bedrock mapping of SW McQuesten and N Carmacks map areas was conducted in summer 2009, as part of a joint initiative of the GSC and YGS under the auspices of the GEM Edges project. Last mapped in the 1940's, little was known about its mineral potential. Bedrock is typically poorly exposed, thus a detailed aeromagnetic survey was acquired in the winter of 2008-09 to assist mapping in this region.

The northern two thirds of the map area is primarily underlain by rocks of the Yukon-Tanana terrane (YTT), exposed in two distinct northwest-trending belts separated by the Willow Lake fault. Southwest of the fault, YTT includes a variety of polydeformed and metamorphosed rocks that include: siliciclastic, pelitic (commonly carbonaceous) and carbonate sedimentary rocks; mafic, intermediate and felsic volcanic rocks; and a wide variety of plutonic rocks, ranging in composition from ultramafic to felsic. These rocks are typical of much of the YTT in Yukon which comprises a basement complex of metasedimentary origin (Snowcap assemblage) overlain by three unconformity bounded Devonian to Permian volcano-sedimentary sequences of predominantly arc affinity, and intruded by cogenetic plutonic suites. Northeast of the Willow Lake fault, YTT rocks contrast markedly with those southwest, and are essentially unmetamorphosed. They comprise primarily intrusive rocks, and near the eastern limit of our map area, intermediate to felsic volcanic and volcaniclastic rocks coeval with the main plutonic body, the Reid Lakes batholith, now dated as Mississippian. Stark contrast in state of strain and metamorphic rank across the Willow Lake fault implies that is has a large component of vertical displacement.

The southeast corner of our map area is primarily underlain by rocks of the mid-Paleozoic Boswell assemblage of Quesnellia. These include intermediate metavolcanic rocks, amphibolite (± garnet), minor ultramafic rocks, and prominent marble bluffs south of the Pelly River. These rocks are strongly deformed and show evidence of retrogression of an earlier high-grade (amphibolite?) metamorphism. They are also characterized by a strong east-west trend of structures that is discordant with the prominent northwest-trending structures in the YTT to the north. An Early Mississippian tonalite intrudes amphibolite of the Boswell assemblage in northern Carmacks map sheet.

The southwest corner of our map area is primarily underlain by rocks of Stikinia, comprising augite-phyric volcanic rocks typical of the Upper Triassic Povoas formation of the Lewes River Group, and Bt±Hbl granodiorite to monzogranite of the Early Jurassic Aishihik plutonic suite. Rocks assigned to the Povoas formation are commonly cleaved and show chlorite-grade metamorphic assemblages. Granitoids of the Aishihik suite are generally undeformed, commonly contain magmatic epidote, and represent the northwest extension of the Minto pluton which hosts the high-grade Cu-Au Minto mine.

Structural evolution and high-temperature exhumation of the Grand Forks Complex, southeastern British Columbia

Joel F. Cubley and David R.M. Pattison
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Metasedimentary gneisses of the Proterozoic Grand Forks Group experienced rapid high-temperature, ~2.5kbar exhumation in the late Paleocene to early Eocene (Cubley and Pattison, 2009), coincident with orogenic collapse in the hinterland of the Canadian Cordillera. Recorded within the complex are at least five deformational episodes that postdate Late Cretaceous peak metamorphism at 84±3 Ma. The first episode (D1) is evidenced by a strong gneissic fabric developed throughout the complex, and in the well-exposed upper structural levels, this fabric is distinctly mylonitic and arches across the top of the dome. Missing is the less deformed “core zone” as described in northeastern Washington State by Cheney (1980) and others. The gneissic fabric is in turn deformed by two episodes of non-coaxial folding (D2 and D3), with the age of dominant, orogen-perpendicular D3 folding bracketed by new U-Pb zircon ages on deformed anatectic pegmatite (51.2±0.6 Ma) and undeformed Eocene biotite leucogranite (50±0.85 Ma). Leucogranite emplacement was controlled in part by the D2 axial plane, as evidenced on a map-scale by parallel fingers of undeformed leucogranite trending 340-160 through all structural levels of the core complex. Crenulations and mineral lineations linked to the dominant D3 folding event have been refolded by a late D4 deformation, characterized by broad, gentle folds that also appear to weakly fold the Eocene leucogranite. Minor brittle faults in the upper structural levels of the complex parallel the trend of this D4 fold axis. Post-51 Ma brittle deformation related to the Eocene Kettle River and Granby detachment faults (D5) crosscuts the high temperature deformational fabrics and Eocene leucogranite, but timing relationships between D4 folding and faulting are unknown. The date of last movement along the Kettle River fault is not sealed by the emplacement of the Eocene Coryell Batholith (51.5±0.5Ma; Carr and Parkinson, 1989), as previously suggested by Tempelman-Kluit (1989) and others. Instead, quartz monzonites of the Coryell Suite along the eastern shore of Christina Lake show strong, high-angle brittle deformation features.

Three high-temperature ductile shear zones have been mapped in the hanging wall to the Kettle River fault (KRF), the largest of which juxtaposes migmatitic paragneisses of the Grand Forks Complex against 167.9±1.4 Ma granitoids of the Nelson suite (U-Pb zircon, this study). Abundant within this shear zone are foliation-concordant sheets of 59.5±0.56 Ma two-mica leucogranite (U-Pb zircon, this study), variably deformed but strongly mylonitic within the center of the shear zone. Leucogranite volume and degree of deformation decreases strongly as one moves southward (and upward) through the hanging wall stratigraphic sequence. Mylonitic features in Jurassic Nelson suite granitoids and the Paleocene leucogranite are strongly overprinted by high-angle brittle deformation features related to subsequent movement along the Kettle River fault. It is tentatively proposed that the rheological contrast between the cool, rigid Jurassic Nelson suite granitoids and the hot, weak Paleocene leucogranites pooled beneath them may have localized extensional shear on the eastern margin of the Grand Forks Complex. This is similar to that proposed for the Valhalla Complex by Simony and Carr (1997).

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Differentiating Deep-Marine Overbank from Crevasse Splay Deposits in Outcrop: an Example from the Windermere Supergroup, Castle Creek, Southern Canadian Cordillera, British Columbia

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Deep-marine rocks are typically exposed in orogenic belts where mountain building processes commonly complicate or completely obliterate the primary sedimentary features and make stratal relationships equivocal. Mud-rich facies, such as interchannel deposits, are particularly susceptible to metamorphic and structural modification. Further complicated by surface cover and inaccessibility, good quality outcrop analogs for mud-rich deep-marine interchannel deposits are uncommon in the sedimentary record. Castle Creek, however, is an easily accessed, thick succession of vertically dipping deep-water strata wherein interchannel deposits, including the fine-grained fraction, are superbly exposed. This outcrop presents a rare opportunity to make detailed millimetre- to decametre- scale sedimentological and stratigraphic observations.

Important lithologic and spatial scale differences are observed in overbank and crevasse splay deposits. Flows that overtop the levee form overbank splays, whereas those that breach or puncture the levee form crevasse splays. Based on seismic, overbank splays are an order of magnitude smaller in area, typically hundreds m^2 compared to several km^2 for crevasse splays. Two end member overbank splays are recognized: multiple bed complexes and isolated beds. Multiple bed complexes extend for at least 300 m laterally, range from 2-4 m thick, and consist of amalgamated, normally graded, medium grained, Ta turbidites. In addition, interbeds of dune cross stratified and planar laminated sandstone occur. Individual beds are laterally discontinuous because of compensational stacking. Isolated beds are well sorted, medium grained Tabcd, but more commonly Tbcd or Tbd turbidites. Typically the planar laminated division is anomalously thick, comprising 75-90% of the bed, and generally is ungraded. Isolated beds occur as a single or at most 2-3 bed assemblage of thick to very thickly bedded (40 – 200 cm) sandstone turbidites encased in thin to very thinly bedded turbidites. Isolated beds have sharp, planar, non-erosive to shallowly erosive (less than 10 cm) bases with a tabular morphology.

Crevasse splay deposits consist of poorly sorted, structureless and ungraded or coarse-tail graded, coarse or medium to fine grained sandstones with a high (30-50%) mud content. The poorly sorted character and high mud content reflects rapid deposition possibly downflow of a hydraulic jump. Two end member kinds of crevasse splay deposit are recognized: tabular and amalgamated, the former being more common. Tabular units range from 2-8 m thick and beds from 5-125 cm. Sandstones commonly contain a small number of large, isolated, tabular mudstone clasts. Beds generally show negligible change in facies or thickness laterally. Amalgamated units are approximately 4 m thick with beds from 25-100 cm thick. Mudclasts tend to be smaller (< 50 cm) but more abundant, often forming breccia layers. Individual beds cannot be traced for more than 150 m laterally, which is interpreted to be the result of a complex history of cut and fill.

The Hellroar Creek Shear Zone: A Major Tectonic Boundary In The Northern Monashee Mountains Of The Southeastern Canadian Cordillera

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There is a tectonic conundrum in the northern Monashee Mountains. On the one hand, field-based studies indicated that rocks of the area were deformed and metamorphosed as a coherent block, which resulted in three phases of folding and a series of well-defined metamorphic isograds. On the other hand, later geochronological studies pointed to the presence of three domains with distinct timing of metamorphism and deformation, which would imply the presence of unrecognized shear zones or of spatially heterogenous thermal/fluid flow events.

Our fieldwork conducted east of the town of Blue River (BC;52°7'N; 118°53'W) revealed the existence of a major SE-striking shear zone, herein named *Hellroar Creek Shear Zone* (HCSZ). We mapped it for ~20 km along the ridge between Mud and Hellroar creeks and then east of Mud Creek valley. The HCSZ is characterized by a large volume (>60%) of highly sheared leucogranite and leucosome, whereas leucogranite in its footwall, although locally as abundant, forms a heterogenous mesh of highly discordant intrusions. The HCSZ separates a low-strain domain in its footwall, with preserved stratigraphic polarity and dominated by SW- to W-verging structures, from a high-strain domain in its hanging wall, with rocks recording complete transposition by top-to-the-NNE to top-to-the-E shearing. Whereas rocks of its hanging wall are generally at the Sil-Kfs-grade, rocks in its footwall are at the Ky-Ms-grade. Preliminary U-Pb in-situ Mnz and Tnt geochronology agrees with previous studies and indicates a retrograde path in the Sil field between ~90 and 75 Ma in hanging wall rocks, while footwall rocks were on a prograde path in the Ky field. The presence of pods of footwall rocks, with diameters ranging from < 2 m to >50 m, included in highly sheared rocks of the HCSZ, highlights the complexity of the zone.

Interestingly, the HCSZ is located along-strike from, and separates the same lithologic packages as the boundary between two of the geochronological domains previously identified ~20 km to the SE. We thus propose that the HCSZ connects with this boundary to form a >40 km long shear zone. The HCSZ is interpreted as the base of a channel flow system that was active for >30 Myr in the Late Cretaceous. If this interpretation is correct, the HCSZ would be the NE extension of the Monashee décollement that bounds the western flank of the Monashee Complex, ~60 km to the SSW.

Overview Of Geochronology For The Gem "Multiple Metals - North West Canadian Cordillera" Project

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As part of the Geological Survey of Canada's GeoMapping for Energy and Minerals Program, the goal of the "Multiple Metals - North West Canadian Cordillera" Project is to provide vectors to potentially economic mineral occurrences in the northern Cordillera. Since geochronology is a key method for validating the timing of terrane accretion, faulting, burial, exhumation and magmatism, events which are commonly conducive to formation of mineral deposits, it plays a central role in the project. The GSC is employing several complementary geochronological methods to help give a full-featured view of rates and timing of the processes related to ore formation. The only Canadian Sensitive High Resolution Ion Microprobe (SHRIMP) is being directed towards unravelling complex metamorphic zircon samples and reconnaissance dating using U-Pb. High precision U-Pb work is being done by the TIMS method. Meanwhile, tectonothermal events between 250°C-500°C are targeted using $^{40}Ar/^{39}Ar$ geochronology. In addition to conventional $^{40}Ar/^{39}Ar$ step-heating of micas, hornblendes, and K-feldspars, there is also a significant focus on developing quantitative thermochronological models for micas from a wide range of thermal regimes across the Northern Cordillera. All $^{40}Ar/^{39}Ar$ analyses are being done using the new Nu Noblesse multicollector noble gas mass spectrometer at the Geological Survey of Canada in Ottawa.

We present a snapshot of recently acquired U-Pb and $^{40}Ar/^{39}Ar$ results for the McQuesten, Stikinia and Alexander Terrane projects and touch briefly on how some of these results complement previously unpublished U-Pb and $^{40}Ar/^{39}Ar$ results obtained from the Stewart River NATMAP project. Particular focus is on Permian magmatism and thermal overprinting of the hallmark Devono-Mississippian ages for the Yukon-Tanana Terrane, and on regionally extensive Jurassic resetting of $^{40}Ar/^{39}Ar$ systematics. Finally, we present a synopsis of the new developments in thermochronological analysis being undertaken by Ellie Knight (University of Ottawa) as part of the GSC Research Affiliate Program.

An Alternative Model of Producing Levee Topography in Deep-Water Systems – a Matter of Disparate Sedimentation

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Deep-water levees are commonly expressed as "gull wing" shaped elements in seismic images where the dip angle of reflectors typically steepen upwards and decrease laterally away from the channel. This distinctive morphology is generally thought to reflect the vertical stacking of individual beds that dip away from the channel at progressively lower angles. Basal contacts of levee strata in the Neoproterozoic Isaac

Formation, however, show no discernible change in bed dip over hundreds of meters laterally or tens of meters vertically and therefore are likely not the major source of levee topography. Notwithstanding, medium-bedded strata in the proximal levee thin appreciably over hundreds of meters laterally, causing their upper surfaces to form subtle topography. However this topography becomes later infilled and accordingly also does not likely contribute significantly to the overall development of levee topography.

An alternative model proposes that levee topography is formed mainly by thin-bedded turbidites that have a tabular geometry and terminate abruptly instead of tapering laterally. The upward, progressively more channelward (backstepping) stacking of these thin beds is interpreted to form an overall concave-up, lateral-thinning profile. This stacking pattern is a consequence of progressively diminished flow magnitude causing more limited lateral bed extent (i.e. flow run-out), which in turn reflects increased channel confinement related to levee growth and reduced overspill into overbank areas. This model was then used to generate a synthetic seismic model that forms dipping reflectors similar to those observed in many modern deep-water systems. Importantly, the reflectors produced in the model reflect a lateral change in lithofacies and not stratal dip. Moreover, these reflectors cross-cut stratigraphy.

A Detailed Analysis of Crevasse and Overbank Splay Units in the Isaac Formation (Windermere Supergroup), of the Southern Canadian Cordillera

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Crevasse and overbank splay deposits have been studied in detail within the Isaac Formation. Crevasse splay units (CSU) range from 10 – 20 m thick and extend the length of the study area (> 4 km). Strata within CSU comprise medium to coarse sandstone Ta-c turbidites that range from 0.2 – 1 m thick and are interstratified with thinly-bedded tc-e turbidites. In addition, distinctively matrix-rich sandstone form up to 7 m thick packages intercalated with the turbidites. CSU are interpreted to have been deposited outboard of a crevasse channel that most likely breached the outer-bend channel margin. Episodically a number of high-energy expanding flows went through a hydraulic jump and deposited the matrix-rich sandstone. At other times, or at least locally, flows remained subcritical and deposited the more common turbidites.

OSU are common in the outer-bend distal levee setting of a significant channel-levee complex and encased by thinly-bedded turbidites. OSU consist of amalgamated normally graded to planar and cross-stratified medium-bedded, medium sandstone turbidites. OSU are 2 – 4 m thick and extend up to 1 km laterally, however, individual beds within units are laterally discontinuous. Lateral discontinuity is likely the result of rapid flow thinning, filling of topography on the distal levee, and to a lesser extent erosion. As a result, OSU comprise a complex arrangement of sandstone turbidites that commonly offlap and onlap one another locally creating high N:G within the predominantly muddy distal levee. OSU were deposited by turbidity currents that overtopped the channel margin without breaching the levee. These overspilling flows bypassed the proximal levee area because of the steep slope on the backside of the levee, and deposited much of their sediment on the reduced slope over the more distal levee.

Detrital zircon provenance of Lower Cretaceous conglomerate beds in Canada and the U.S.

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Lower Cretaceous deposits in western North America are characterized by a relatively thin, but widespread, interval of conglomerate beds that overlie a sub-Cretaceous unconformity. Although well documented, the tectonic and basinal significance of these units remains unclear. We employed detrital zircon uranium-lead (U-Pb) geochronology to better understand the provenance of Lower Cretaceous conglomerate units, constrain their depositional ages, and elucidate the large-scale depositional history of the region during Early Cretaceous time.

Lower Cretaceous samples from the Cadomin Conglomerate in British Columbia and Alberta contain populations of detrital zircons with ages between 115-170 Ma and large populations with ages of ca. 1800 Ma. We postulate these sediments were derived from the erosion of Mesozoic arc-related rocks and Proterozoic through Lower Paleozoic strata exposed in thrust sheets in the Cordilleran Orogen. Maximum depositional age for these units varies, but is generally ca. 116-120 Ma. Detrital zircon U-Pb ages from the Pryor Conglomerate in south-central Montana and the Cutbank Sandstone in central Montana differ from those in northern Montana, Alberta, and British Columbia. The Lower Cretaceous Pryor Conglomerate contains numerous detrital zircons evenly distributed between 200-700 Ma and a large population of ca. 1000 Ma grains. We interpret these zircons to have been derived from more southwesterly-located sources, including Mesozoic-age eolianites in Wyoming, Utah, and Arizona.

Based on our samples and those from previous work in the southwestern United States, we are able to delineate two distinct detrital zircon U-Pb age signatures in Lower Cretaceous conglomerates in western North America. One, we term the “northern” signature, contains detrital zircon populations of 115-180 Ma and ca. 1800 Ma, and occurs in proximal areas of the foreland basin in northern Montana, Alberta and British Columbia. The other, we label the “southern” signature, contains detrital zircon populations of 200-700 Ma and 1000 Ma, and occurs throughout most of the western United States and also extends into more northerly latitudes in the distal (eastern) portions of the foreland basin. These data provide a means for evaluating paleogeographic reconstructions and also make testable predictions for future provenance studies.

An early sedimentary record of tectonic loading associated with the development of the Canadian Cordillera

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The transition from a passive margin to a retroarc foreland basin during Jurassic time in western Alberta remains unresolved. Moreover, with current stratigraphic interpretations, this transition appears to occur approximately 30 myrs after deformation and crustal loading along the western margin of North America in the southern Canadian Cordillera began. Here we use new subsidence data, lithologic trends, and isopach patterns to reinterpret Jurassic strata in western Alberta and place these units into a new tectono-stratigraphic model.

We propose that portions of Lower Jurassic strata (e.g., Gordondale, Red Deer, and possibly the Nordegg members of the Fernie Formation) were deposited in a backbulge depozone, on the cratonward side of a nascent, tectonically produced forebulge. Depositional reconstructions of the region during Early Jurassic time indicate western Alberta was characterized by a broad, shallow, restricted marine basin that was bounded on the western margin by a bathymetric high. We interpret this submarine high to have been the forebulge, which at the time was located near western Alberta-Eastern British Columbia. A backbulge depositional setting is further supported by subsidence histories in the area, which indicate Early Jurassic subsidence was followed by diminished accommodation and erosion, interpreted to be the passage of a flexural forebulge. These patterns manifest themselves in the stratigraphy of western Alberta, where relatively thin Lower Jurassic units are overlain by numerous unconformities, which are in turn overlain by beds that indicate more rapid subsidence and are generally agreed to be foredeep deposits.

Our interpretation of the Lower Jurassic strata makes these units some of the earliest sedimentary deposits to record deformation along the western margin of North America in the southern Canadian Cordillera. This interpretation resolves the temporal discrepancy between the initiation of deformation and the formation of a foreland basin and helps to explain several enigmatic aspects of the Lower Jurassic strata in western Alberta.

Geology of the Aley Creek Area, Northeastern BC Rocky Mountains: A record of Mississippian orogenesis in the Cordilleran Foreland Belt?

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Detailed, 1:10,000 scale field mapping of the Aley Creek area (NTS sheet 094B-042) reveals a record of pre-Laramide age orogenesis previously unrecognized in the foreland belt of the Canadian Cordillera. Specifically, the area is host to a Mississippian-age deformation event that is manifest by a penetrative, bedding-parallel cleavage (S1) and a younger crenulation cleavage (S2) that locally transposes bedding and is axial

planar to large-scale Laramide folds. Polystage deformation is regionally expressed in fold interference patterns where symmetric, small-scale isoclinal folds (F1) are folded about asymmetric, large-amplitude chevron folds (F2) of the Laramide orogeny.

Lithologically, the Aley Creek area is characterized by: (1) fine-bedded, silt-rich ramp carbonates, phyllitic siltstone, and altered volcanic tuff of the Kechika Formation; (2) thick-bedded to massive platform carbonates with interlayered alkali volcanic tuff and pillow basalt of the Skoki Formation; and (3) basinal shale, calcareous mudstone, and minor sandstone of the Road River Group. A sill of fersmite-bearing dolomite-apatite-carbonatite and pyrochlore-bearing calcite-apatite-carbonatite intrudes the base of the Kechika Formation. The amphibolitic margin of the carbonatite sill, previously interpreted as being an early magmatic phase of the carbonatite, is now recognized as a separate volcanic unit at the base of the Kechika Formation based on its overall stratiform structure and the identification of well-developed pillow textures and brecciaed conglomeratic quartzite clasts in the unit.

Our mapping shows the entire Kechika-Road River stratigraphic sequence to be part of the lower, overturned limb of a major south-verging nappe emplaced synchronously with the D1 deformation event. This interpretation provides an effective explanation for the development of bedding-parallel cleavage (S1), south-verging isoclinal folds (F1), and uniformly overturned nature of Paleozoic strata.

Although largely concordant with S1, carbonatite dykes locally cross-cut phase-one structures in low-angle thrust faults, thereby providing a unique constraint on the age of D1. Two K-Ar dates on phlogopite from the carbonatite sill by Cominco Ltd. (1986, unpublished) yielded ages of 339 +/- 12 Ma and 349 +/- 12 Ma, suggesting a Mississippian age for the synchronous D1 event. Zircons from the carbonatite were sampled during the field mapping component of this study; U-Pb dating efforts are underway at UBC in order to better constrain the carbonatite emplacement age.

The implications of a Mississippian deformation event in the Cordilleran foreland belt are manifold. First, western Laurentia is believed to be host to a well-established passive margin by the Carboniferous, as no Middle Paleozoic age deformation event is known in the southern Foreland Belt. If the Kechika/Skoki/Road River succession of strata mapped in the Aley creek area is indeed correlatable with a similar succession of strata in the southern Canadian Rockies (Survey Peak/Outram/Skoki/Owen Creek/Mount Wilson Formations), as widely reported, the southern Foreland Belt must also be host to a Mississippian deformation event previously unrecognized. Alternatively, a genuine difference in the tectonic record of the respective Paleozoic strata may exist, indicating that the two successions are not correlatable. This study views the latter explanation as more likely given: (a) the Paleozoic strata of the southern Foreland Belt have been extensively studied with no Mississippian-aged deformation event being found; and (b) major differences in lithology exist between the southern and northern Paleozoic foreland successions – most notably, northern strata, as observed at Aley Creek, contain an extensive record of Paleozoic volcanism unseen in the south. Lastly, the major nappe structure mapped at Aley is the first of its kind to be identified in Cordilleran Foreland Belt and suggests that Mississippian deformation in the NE BC Cordillera was a significant orogenic event.

In conclusion, the tectonic history and lithological record of Paleozoic strata in the Aley Creek area are inconsistent with that of Paleozoic foreland strata in the southern Canadian Cordillera. These along-strike variations in tectonic history and lithology are most effectively explained through considering large parts of the northern foreland exotic with respect to the North American craton. As this finding is not supported by the majority of Cordilleran orogenic models, which implicitly assume that all Cordilleran foreland sedimentary sequences are autochthonous, a reevaluation of our understanding of Cordilleran tectonic evolution is in order.

Proterozoic Pinguicula Group: Stratigraphy, Contacts, and Correlations

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The Pinguicula Group is a Proterozoic succession of clastic and carbonate rocks exposed in the Wernecke Mountains of northern Yukon (Eisbacher, 1981). The strata were deposited with angular unconformity on the Wernecke Supergroup following the Racklan orogeny (Eisbacher, 1978; Thorkelson, 2000). Over the last three decades workers in the Wernecke and Ogilvie Mountains have pieced together lithologic descriptions and mapped a portion of the succession in detail; however, the remaining areas have yet to be thoroughly mapped and several questions regarding the age, contact relations, depositional environment, and relations with other Proterozoic successions in adjacent inliers remain unresolved.

The basis of current research is to provide a detailed characterization of the Pinguicula Group including age, lithology, and stratigraphic relationships as well as to define the extent of the Pinguicula Group by correlating it with similar strata in adjacent mountain ranges.

Two contact relationships have been resolved in the 2009 field season. The first, a 1.38 Ga dyke previously thought to crosscut Pinguicula Group unit A, has instead been recognized to crosscut the underlying Wernecke Supergroup strata. This relationship is significant because it once again places the lower age limit of the Pinguicula Group into question and may reposition the Pinguicula Group within the history of geologic events. Secondly, the previously undefined contact relationship between units B and C has been identified as a gradational contact confirming the placement of unit C within the Pinguicula Group.

In addition, preliminary data collected from the western Ogilvie Mountains draws similarities between units PR1 and PR2 of the Lower Fifteenmile Group and units A, B, and C of the Pinguicula Group. Although preliminary results from the 2009 field season have resolved some of the unknowns surrounding the Pinguicula Group, they have also raised more questions.

Conditions of deformation and timing constraints on the d'Abbadie fault zone, south-central Yukon (NTS 105E/8), northern Canadian Cordillera

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The d'Abbadie fault zone in south-central Yukon is a strike-slip fault that is part of the regional Cretaceous fault system that dissects the northern Canadian Cordillera. The d'Abbadie fault zone is a north-striking, steeply dipping, strike-slip fault with a strike length of ~70 km. In the study area, it is a 1.5 km wide corridor of predominantly brittle cataclasites, with some ductile mylonites, and a network of brittle faults. Faults and fault rocks cross cut and overprint metasedimentary, metavolcanic and meta-igneous Upper Devonian to Lower Mississipian (?) rocks of the Yukon-Tanana terrane. They have been polydeformed and metamorphosed to upper greenschist – facies conditions. The map pattern outside the d'Abbadie fault zone is predominantly controlled by steeply dipping refolded folds in the area. The rocks were likely deformed in the mid-Permian to mid-Triassic (Mortensen, 1992) and, on the basis of $^{40}Ar/^{39}Ar$ mica dates, they had cooled by Early Jurassic time.

For this project, detailed 1: 10 000 scale geological and structural mapping of the d'Abbadie fault zone was carried out to characterize the structural style of the fault zone itself, and to see whether or not adjacent rocks were involved in the deformation. Dextral strike-slip mylonites in Devonian and Cretaceous granites, flanking the west side of the fault zone, raise the question of whether or not the fault zone was active in the middle crust, and at what time.

A predominantly brittle regime of deformation along the d'Abbadie fault zone is characterized by the following: i) outcrop- to micro-scale cataclastic zones with intense grain size reduction and 1 cm to mm angular, randomly oriented fragments; ii) sets of 10 to 15 cm long anastomosing faults, on a spacing of 1 mm to 2 cm, with cm-scale offsets and ultracataclasites lining the faults; iii) spaced fractures; and iv) fault planes with shallowly plunging slickenlines and stepped surfaces indicating a dextral sense of shear. Ductile deformation is localized within the eastern part of the ca. 96 Ma Last Peak granite – a 250 m thick, steeply dipping sheet of mylonitic, K-feldspar porphyritic, two-mica leucogranite.

Primary contact relationships of the Last Peak granite are consistent with an interpretation that it post dated regional metamorphic and structural events, and that it intruded into cold upper crust. This is indicated by: i) apophyses, with chilled margins, that cross cut the prominent regional foliation containing greenschist metamorphic minerals (Harvey, 1997); ii) foliation within a marble raft cut by the granite contact; and iii) a 70 cm thick coarse-grained calcite-tremolite-garnet-diopside skarn at the margin of the marble raft. These observations are consistent with the cross cutting relationships and the contact aureole documented by Gallagher (1999) around the ca. 112 Ma Dycer Creek stock located ~ 2 km east of the fault zone. $^{40}Ar/^{39}Ar$ mica dates in Yukon-Tanana rocks of the region indicate that cooling occurred below 300-350°C by Early Jurassic time (Hansen, 1991; 1992). All these observations, taken together, indicate that the Last

Peak granite intruded into cold upper crust. One would predict that the granite cooled rapidly and this can be tested with $^{40}Ar/^{39}Ar$ studies. In this model, $^{40}Ar/^{39}Ar$ muscovite and biotite dates should be the same or slightly younger than the granite U-Pb crystallization age.

The Last Peak granite S-C type mylonites, which range from protomylonites to ultramylonites, are characterized by a steeply dipping, north-striking shear foliation, and a stretching lineation composed of preferentially aligned elongate K-feldspar porphyroclasts and shallowly plunging north-trending elongate quartz aggregates and ribbon grains. Mylonites contain variably sized, but generally 0.5 by 1.5 cm K-feldspar porphyroclasts, and fine-grained sigma-type quartz-filled pressure shadows. The orientation of porphyroclasts with respect to the steep shear foliation along with a shallow lineation, are interpreted as a dextral sense of shear. On the map scale, the Last Peak granite mylonites gradually change across strike from protomylonite to ultramylonite, which suggests a strain gradient that increases to the east, towards the d'Abbadie fault. Microstructures observed in the Last Peak granite, such as flame perthite and antithetic fracturing in K-feldspar, kink banding in biotite and plagioclase, recovery and grain-boundary migration in quartz, are characteristic of deformation at temperatures of 250°C-350°C, and the mylonites in the Last Peak granite are thus low temperature mylonites. Taken together with the contact information and regional Jurassic cooling dates, these data are consistent with a scenario of emplacement of the granite into the upper crust (at 4-10 km depth above the ~ 350 °C brittle-ductile transition), and ductile deformation and strain during dextral displacement on the d'Abbadie fault zone while the pluton was rapidly cooling. This explains why ductile deformation is localized in the Last Peak granite.

The mylonitic foliation, lineation and dextral kinematic indicators in the Last Peak granite formed syntectonically during d'Abbadie fault zone displacement. Therefore, the mylonites constrain the sense of displacement of the d'Abbadie fault zone and prove that at least part of the motion on the fault zone occurred at ca. 96 Ma, the crystallization age of the Last Peak granite. This, taken together with the predominantly brittle deformation throughout the d'Abbadie fault zone corridor, indicates that the d'Abbadie fault zone was active in the upper crust at ca. 96 Ma.

Mid-Cretaceous Metamorphism and Deformation in the Central Kootenay Arc, Southeastern British Columbia

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Amphibolite-facies Barrovian rocks are exposed in an elongate, partially fault-bounded region running parallel to Kootenay Lake in the central Kootenay Arc, southeastern British Columbia. Metamorphic grade ranges from the biotite zone on the flanks of this metamorphic high to the sillimanite+K-feldspar zone in its centre. Regional amphibolite-facies metamorphism was accompanied by formation of the dominant (D2) west-dipping foliation and orogen-parallel stretching lineation.

New U-Pb monazite data indicate a mid-Cretaceous age for amphibolite-facies metamorphism and deformation along the northern half of Kootenay Lake. Metamorphic monazite from three samples of metapelite was dated in situ using LA-MC-ICP-MS. Analyses from a sillimanite+K-feldspar-bearing gneiss yield a concordia intercept age of 100±1.3 Ma, generated by anchoring to a common $^{207}Pb/^{206}Pb$ value of 0.86±0.06. Similarly, two kyanite+sillimanite-bearing schists yield ages of 98.14±0.96 Ma and 98.9±1.7 Ma. A mid-Cretaceous age for Barrovian metamorphism and D2 deformation is consistent with the deformed nature of the 117 Ma Baldy Pluton.

Low-P (3.5±0.5 kbar) contact aureoles on post-tectonic intrusions of known or presumed mid-Cretaceous age indicate rapid exhumation of these rocks from 20-25 km depth immediately following peak metamorphism. This was followed by cooling below the $^{40}Ar/^{39}Ar$ muscovite+biotite closure temperatures during early Tertiary normal faulting. Normal faulting on the western side of the amphibolite-facies belt juxtaposed these rocks against those from a higher structural level with a contrasting, older (Jurassic) metamorphic history.

Stratigraphic relationships between the uppermost Kaza and the lowermost Cariboo Groups, Neoproterozoic Windermere Supergroup

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One of the world's best ancient laboratories for studying the deep-marine sedimentary record crops out at Castle Creek in the Cariboo Mountains, southern Canadian Cordillera. Here the succession comprises two stratigraphic units: the uppermost Kaza Group overlain by the Isaac Formation (lowermost Cariboo Group). The contact between the Kaza and the Isaac is gradational and marked by a change from green/light-grey to dark grey mudstones. In addition it records the change from laterally-continuous, sand-rich deposits, interpreted to be proximal basin-floor lobes, to a mud-rich succession with thick but laterally discontinuous sandstones interpreted to be channels and leveed channels in a mud-rich base-of-slope environment.

Unlike any other ancient outcrop example, the section studied at Castle Creek represents an uninterrupted 500 m-thick interval that illustrates the basin floor to slope transition, which in this case was most likely caused by the long-term northwestward progradation of the Windermere turbidite system. Here, proximal lobe deposits, laterally offset-stacked slope channel deposits, mudstone-rich sheets and large-scale mass-transport deposits are the principal architectural elements. Stratigraphically-upward, however, the distribution and abundance of these elements changes, with the proximal lobe element dominating in the lower part, but replaced upward by mass-transport elements, isolated channels and mudstone sheets. These observations and interpreted stratigraphic relationships can act as a model for predicting the stratigraphic framework in other deep-sea turbidite systems where observations are restricted to core or where strata crop out poorly. Moreover, they provide much needed stratigraphic insight for input into building more realistic reservoir models, especially those based solely on seismic interpretation.

The Origin of Igneous Clasts in Proterozoic Breccia Zones, Yukon, Canada: Testing the Feasibility of Tectonic Emplacement

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A recently proposed paleo-tectonic model of Ancestral North America posits the tectonic emplacement of a thrust sheet over the Wernecke Supergroup, on the north-western margin of Ancestral North America at ~1.62 billion years before present (Ga). Following this event at 1.60 Ga, the region was invaded by surges of hydrothermal fluids, leading to the brecciation of kilometre scale zones of rock. Fragments of igneous rock previously dated at ~1.71 Ga that are entrained in these breccias zones are hypothesized to be derived from the thrust sheet through the foundering of fragmented blocks. The hypothesized terrane is nowhere present but in the model was entirely removed by erosion.

In order to test this hypothesis, field work was undertaken in the summer of 2009. Igneous clasts in the Wernecke Breccias were mapped in detail and sampled for geochemical and geochronological testing. Mapping indicates that the igneous material in the breccias did not intrude the Wernecke Supergroup at any level between the Fairchild Lake Group and the Gillespie Lake Group and confirms the existence of megaclasts in the Wernecke Breccias. Igneous zircon geochronology and geochemistry will be performed in order to further test this hypothesis and to determine the tectonic setting of formation of the igneous material.

Subduction, asthenospheric flow, and the evolution of foreland thrust-and-fold belts: Insights from the southern Canadian Cordillera

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The Cordillera of North and South America, the archetypical, asymmetrical, bivergent, continental-margin orogen, displays conspicuous contrasts between the retrograde-vergent back-arc foreland thrust-and-fold belt that occupies the continental margin of the orogen and the prograde-vergent fore arc thrust-and-fold belt that occurs locally along the oceanic margin. The back-arc belt is continuous for the length of the orogen, although variable in width and structure. It generally comprises supracrustal rocks that were scraped off the under-riding crystalline basement of the continental margin by the over-riding volcanic arc and back-arc basin rocks of the interior of the orogen; but locally it involves thrusting and related folding of the brittle upper part of the continental crust. The retrograde-vergent thrusting and folding has generally been viewed as a second-order effect of the subduction of oceanic lithosphere; it has been ascribed to crustal thickening during convergence between the interior of the continent and an adjacent continental-margin subduction zone, and to the ensuing lateral gravitational spreading of the thickened crust as a critical-taper thrust-and-fold wedge with an associated foreland basin. The fore arc belt, which is a first-order effect of the subduction, can be distinguished from the back-arc belt because it comprises material scraped off the under-riding oceanic lithosphere by the over-riding continent; moreover, it is commonly discontinuous, because the subduction zone is commonly a zone of tectonic erosion and removal of continental material rather than accretion and addition of oceanic material.

Continental collision orogens develop where a plate of continental crust is drawn into a continental margin subduction zone by the negative buoyancy of the attached oceanic lithosphere that is sinking into the mantle. Although continental collision orogens commonly involve the development of a prograde-vergent foreland thrust-and-fold belt comprising supracrustal rocks that are scraped off the under-riding continent by the over-riding continent, these can be distinguished from continental margin, retrograde-vergent, thrust-and-fold belts because they include a subduction scar comprising the fault zone that separates and juxtaposes rocks that came from two different continents.

The prevailing interpretation of the nature and tectonic significance of the foreland thrust-and-fold belt of the North American Cordillera as a second-order effect of the crustal thickening generated by subduction has recently been challenged with conjectures[1, 2] about the former existence of a “ribbon continent” located outboard of the North American continental margin, and separated from it by an ocean basin, and about the subduction, under this “ribbon continent”, of both the conjectural intervening ocean basin and the western continental margin of North America. These conjectures, which imply that the Cordilleran foreland thrust-and-fold belt is a prograde-vergent, first-order expression of the subduction of oceanic lithosphere, require that a previously (and still) unidentified plate-tectonic suture (subduction scar) occurs within the eastern part of the North American Cordillera, and that it extends from east-central Alaska to northwestern Mexico, separating North American supracrustal strata from supracrustal strata on a “ribbon continent” that originated elsewhere.

The basic tenets of the “ribbon continent” conjecture are incompatible with what is known about the geology of much of the North American Cordillera. For example, in the southeastern Canadian Cordillera: (1.) The integrity and continuity of the Crowsnest Pass cross-strike discontinuity (CPCD), a set of transverse, northeast-trending structures that extends across the foreland thrust-and-fold belt from southwestern Alberta to the Cordilleran accreted oceanic terranes of northeastern Washington and south-central British Columbia, precludes the existence of the subduction scar that is required by the “ribbon continent” conjecture. The CPCD, which is aligned with the Vulcan low, a northeast-trending Paleoproterozoic crustal suture that marks the northern limit of the Archean Medicine Hat domain in the basement of the Western Canada sedimentary basin southeast of Calgary, comprises a set of faults that were reactivated and influenced basin subsidence and basin-margin uplift and erosion during the formation of the Mesoproterozoic Belt-Purcell basin, the Neoproterozoic Windermere basin, and the Paleozoic Cordilleran miogeocline continental shelf basin. Reactivation of these basin margin faults during Jurassic to Paleocene thrusting and folding influenced the location and orientation of the structural culminations that dominate the structure of the foreland thrust-and-fold belt. (2.) Furthermore, stratigraphic analysis of the undisturbed strata in the western Canada sedimentary basin and adjacent parts of the eastern Cordillera demonstrates that a distinctive sequence of tectonostratigraphic units, bounded by distinctive erosional surfaces, can be confidently correlated through the thrust-and-fold belt and into the interior of the southern Canadian Cordillera, where these North American rocks are in fault contact with accreted oceanic-volcanic-arc and ocean-floor rocks of Quesnel, and Slide Mountain terranes. (3.) Moreover, Archean and Paleoproterozoic crystalline basement rocks that are exposed beneath Eocene extensional detachment faults in the interior of the Cordillera can be correlated with tectonic domains in the subsurface of the Western Canada sedimentary basin that contain rocks of the same type and age. (4.) In addition, stratigraphic relationships among the accreted ocean-basin and oceanic volcanic-arc terranes, and between them and the North American supracrustal indicate that they formed above an east-dipping subduction zone and in a related back-arc basin, and that during Early Jurassic collapse of the back-arc basin, subduction generated arc magmatism migrated eastward into the North American supracrustal rocks. If a conjectural “ribbon continent” and a west-dipping subduction zone do not provide a viable tectonic process model for the origin of the Cordilleran foreland thrust-and-fold belt, what does?

The structure of the detached and displaced North American supracrustal rocks within the foreland thrust-and-fold belt in southern Canada provides unequivocal evidence for horizontal convergence (shortening) between the North American craton and the accreted terranes that varies from place to place from 100 to 300 km; it shows that some of this convergence was transformed northwestward into dextral displacements on large strike-slip faults. However, the related deformation that occurred at depth and involved both the subducting slab of oceanic lithosphere and the continental crust and mantle lithosphere from which these supracrustal strata were detached is much less clearly understood, even with the advantages of the geophysical deep imaging that has been provided by the Lithoprobe Project[3]. But the kinematics and geodynamics of this deformation is being elucidated now.

Recent discoveries about the nature and geodynamic significance of a wide zone of high heat flow and extraordinarily shallow asthenosphere above the subducting Juan de Fuca slab and in the back-arc region of the Cascade arc[4] have been extended to many other back-arc regions around the Pacific rim[5]. These discoveries help to elucidate the processes linking retrograde-vergent, critical-taper thrusting in the foreland thrust-and-fold belt to the prograde shear along the top of the subducting slab. The descending cold slab of oceanic lithosphere is a heat sink, and therefore the high temperatures documented in the back-arc mantle above the subducting slab are unexpected. The current consensus is that retrograde mantle flow (corner flow), driven by the viscous coupling between the subducting slab of oceanic lithosphere and surrounding mantle and by the thermal buoyancy of hot asthenosphere, carries heat from outside the subduction zone region into the mantle wedge[6]. This pattern of subduction related mantle flow provides the key to understanding several otherwise enigmatic aspects of the tectonic evolution of the southern Canadian Cordillera, and other continental margin orogenic belts.

In the southern Canadian Cordillera, the collapse of the Slide Mountain basin and the associated obduction of Slide Mountain terrane were followed by a minimum of between 100 and 300 km of convergence between the North American craton and Slide

Mountain and Quesnel terranes. Retrograde back-arc mantle flow helps to elucidate this process and much of the ensuing tectonic evolution of the southern Canadian Cordillera: (1.) The retrograde mantle flow above the subducting slab may provide an explanation for the collapse of the Slide Mountain back-arc basin and the Early Jurassic obduction of Slide Mountain terrane over North American strata. The oceanic lithosphere that formed the floor of the Slide Mountain basin, which has disappeared, evidently became entrained with the retrograde back-arc downward flow above the subducting Cache Creek oceanic lithosphere and was returned to the mantle. The outer edge of the North American continental slope and shelf probably was drawn, by the attached sinking Slide Mountain oceanic lithosphere, into the top of the subduction zone and thus thrust under the supracrustal rocks that comprise the Slide Mountain terrane. (2.) The retrograde back-arc mantle flow may also have facilitated the delamination and removal of the oceanic crust and lithosphere of Quesnel terrane when it was detached and displaced northeastward, as a “tectonic flake”, over the thin wedge of North American basement that has been imaged by Lithoprobe under central British Columbia; (3.) Heat transported by the upwelling hot asthenosphere may have reduced lower crustal ductility and facilitated the transformation of thrust displacement into ductile crustal flow in the root zone of the foreland thrust-and-fold belt; and (4.) following the termination of the Eocene episode of dextral transtension and crustal boudinage at ~40 Ma, the mantle upwelling that sustains the abnormally high elevation of the Interior Plateau may also have dynamically sustained rock uplift and high topographic relief near the edge of the upflow in the southern Canadian Rocky Mountains and the Columbia Mountains. Patterns of mantle flow associated with the gravitational sinking of subducting slabs of oceanic lithosphere may provide important insights on many aspects of Cordilleran geodynamics.

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Regional Geology of the Windermere Supergroup, Southern Canadian Cordillera and Stratigraphic Setting of the Castle Creek Study Area

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The Windermere Supergroup (WSG) represents nearly 9 km of Neoproterozoic sedimentary rocks that predominate the exposed geology within the western Main Ranges and Omineca Belt of the southern Canadian Cordillera. The WSG comprises two main stratigraphic components: siliciclastic and subordinate carbonate and mafic volcanic rocks deposited during extensional tectonic activity (rifting) and a more widespread succession of siliciclastic strata composed largely of turbidites deposited during passive margin sedimentation. Stratigraphic reconstruction of the passive margin component of this depositional system suggests that the turbidites are part of a single depositional system that may have been comparable in scale to the modern Amazon and Mississippi fans. Several key stratigraphic markers have been traced throughout the outcrop belt and can be used to reconstruct a synoptic view of this depositional system. The Castle Creek study area in the northern Cariboo Mountains represents some of the best exposed and well-preserved strata of the Windermere turbidite system. The Upper Kaza Group consists of more than 800 m of sand-rich turbidites deposited in weakly channelized environment on the basin floor; it represents some of the most basinal facies preserved. The overlying mud-rich Isaac Formation consists of 6 channel-levee complexes and a number of spectacular mass transport complexes deposited in a slope setting. The vertical transition from basin floor to slope is interpreted to represent slope progradation into the margin in response to decreased rates of thermally driven subsidence. The regional stratigraphic framework that has been established for this study area and the Windermere turbidite system in general, holds tremendous potential for continuing development of this region as an analog for improved understanding at the regional as well as subseismic scale of modern turbidite systems.

I can't believe it's not Windy-McKinley: New insights into the western margin of the Yukon- Tanana terrane in the Tincup Lake area, southwest Yukon

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The western part of Yukon-Tanana terrane and its relationships to neighbouring northern Cordilleran terranes, such as the so-called 'Windy-McKinley' terrane (Wheeler and McFeely, 1991), in western Yukon and east-central Alaska, are poorly understood. The stratigraphic character, structural and metamorphic evolution of the western portion of the Yukon-Tanana terrane is essentially unknown. New lithological, structural and geochemical data are vital to improving the current understanding of the geological evolution of this region.

Recent work to address these issues was initiated by the Yukon Geological Survey and Geological Survey of Canada. This work has shown the 'Windy-McKinley' terrane is a composite of two geological elements, the Eikland Mountain ophiolite, an imbricated oceanic assemblage of unknown age; and the White River assemblage, a succession of rocks which have many of the defining characteristics of the Yukon-Tanana terrane but also include voluminous Triassic gabbro (Murphy et al., 2008, personal communication). Regional mapping by Murphy (2010, personal communication) shows that the Eikland Mountain ophiolite sits in thrust fault contact on both the White River assemblage and other parts of the Yukon-Tanana terrane; all contacts have been isoclinally folded at a regional scale.

The 10 by 12 km study area is located between Tincup Lake and Toshingermann Lakes, approximately 20 km north of Kluane Lake's Brooks Arm, southwestern Yukon. This area contains the White River assemblage, which lies in fault contact with both the Eikland Mountain ophiolite to the south and rocks of the Yukon-Tanana Snowcap assemblage to the north (Murphy, 2009). A week of mapping has been carried out, but the main field initiative will be in the summer of 2010. The goals of this M.Sc. project are to characterize the detailed stratigraphic character, metamorphic and structural history of rocks of both the Snowcap assemblage and Wind River assemblages, as well as the nature of the contact between them. Objectives of the project are to establish the structural geometry, and geologic history of these two domains in the Tincup Lake map area, and to determine whether or not their evolution is related. These results can then be used to evaluate models of terrane evolution and accretion.

In the northernmost part of the study area there is a package of predominantly siliciclastic psammites, schists, phyllites, and marble marker bands, with apparently conformable greenschist and amphibolite. These rocks will be characterized and compared with Snowcap assemblage rocks of a less distal part of the Yukon-Tanana terrane. In the southern part of the study area, there is a second assemblage of supracrustal rocks with marble, felsic and mafic volcanics and carbonaceous phyllites. This southern assemblage will be compared to the White River assemblage for possible correlations, and will be examined to see whether or not it may represent a distal facies of the Yukon-Tanana terrane. The contact between the southern and northern assemblages will also be investigated to determine what the nature of the contact is (e.g. fault emplacement, faulted unconformity, etc). The nature of the contact of the southern assemblage with Eikland Mountain rocks at the southernmost tip of the study area may also be investigated but will not form a major component of this project.

In order to address the goals of the study, detailed mapping will be conducted using both traditional methods, feet on the ground, and remote predictive mapping, using satellite imagery to identify potential contacts between coarsely distinct lithologies like white marble and brown psammite before reaching the field. Data collected during mapping will be used to complete a detailed structural analysis of the Yukon-Tanana terrane and the Wind River assemblage. This data will then be used to create a 3D structural model of the study area. Rock samples will be collected in the field for mineralogy and microstructural analysis to support mapping and macrostructural analysis. Samples of mafic volcanics will also be collected for comparison to mafic volcanics of the Snowcap assemblage of the Yukon-Tanana terrane.

Pre-Cordilleran history in mantle rocks of the Monashee Complex?

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Boudins and lenses of ultramafic rocks occur in the Northern portion of the Thor-Odin dome (JOHNSTON, 1998), in the upper part of the Greenbush shear zone (JOHNSTON et al., 2000), which is part of the Thor-Odin high strain zone (e.g. KRUSE & WILLIAMS 2007). They are therefore located at the transition between the "Selkirk allochthon" and the Monashee complex. The Selkirk allochthon has been interpreted as a sheet thrust over the Monashee complex (e.g. READ & BROWN 1981; BROWN et al. 1986), or more recently, as an upper level of an infrastructure zone (that includes both the Selkirk allochthon above, and the Monashee complex below) down-dropped by a normal shear zone, during crustal extension (KRUSE & WILLIAMS 2007). The occurrence of peridotite boudins in a regional scale shear zone makes the investigation of their composition and structural evolution crucial in order to infer the tectonic context in which they were coupled with the surrounding continental crust. The ultramafics are embodied in Bt-Sil-bearing gneisses, with minor metabasics, and are crosscut by pegmatite dykes. Structural analysis at the mesoscale indicates that the peridotites are boudins aligned in the regional scale high-grade foliation. Locally the boudins contain an internal foliation ($S\pi$) that is at a high angle to the country rock foliation. The latter, is part of a regional transposition fabric, marked by SPO of microboudinaged Sil and red brown Ti-rich Bt, wrapping elliptic garnets. At the microscale, in the peridotites, two textural types are recognizable: granoblastic (polygonal texture with medium grain size) or poikiloblastic (with pyroxene poikiloblasts, partially replaced by amphibole). The granoblastic type, which occurs where the ultramafics show a foliated texture ($S\pi$), comprises Ol, Opx, Spl, minor Amp and Phl and opaque minerals. The poikiloblastic type is not foliated and comprises Ol, Amp, Opx, Spl, Phl, opaque and rare Cpx. Amp and Phl occur as porphyroblasts or in veins. This texture characterizes undeformed domains preserved in the granoblastic type ($S\pi$). Two kinds of Amp and Phl have been detected: (1) brown Amp which replaces Px and is partially replaced by a thin symplectite of green Amp and Spl and (2) green Amp which occurs where brown Amp recrystallizes, showing a foam texture. Whole rock chemical composition data indicate that these rocks are metasomatized mantle peridotites. Variations in mineral chemistry associated with superposed fabrics in peridotites and country rocks allow their metamorphic vs microstructural evolution to be inferred and help to unravel the emplacement history of mantle peridotites in the high-grade continental crust of the Thor-Odin dome.

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Regional folding of the Kluane Metamorphic Assemblage in the Ruby Range, northern Canadian Cordillera

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The Kluane Metamorphic Assemblage (KMA) is a 160 km long northwest-southeast striking belt of variably deformed pelitic sediments and interlayered ultramafic bodies in the southwest Yukon Territory. It is located within the Coast Belt, which marks the mid-Cretaceous 'welding' of the Insular Belt to the previously accreted Intermontane Belt of ancient North America. Geochemical and neodymium-isotope studies define the assemblage as a homogeneously mixed package of sediments with juvenile oceanic and mature continental affinity interpreted as a back arc basin setting. No detrital zircon ages have been recorded. Five phases of deformation have been previously documented. No regional marker horizon is observed in the KMA and therefore, geological mapping has dominantly relied on cleavage/fold vergence relationships. Precise dating of the deformation events using K-Ar remains ambiguous due to static recrystallization caused by the intruding granitic Ruby Range Batholith during the Early Tertiary. Consequently, peak metamorphism of the KMA is associated with this intrusion (K-Ar and ^{40}Ar-^{39}Ar ages range from 42.5 Ma to 61.7 Ma; Mezger, 1997).

Previous work has established a valid interpretation of the early deformation history of the KMA from deposition (D_n) to the second deformation event (D_{n+2}; Mezger, 1997). It is also been hypothesized the third deformation event, D_{n+3}, has folded the KMA into a broad, open antiform trending northwest-southeast with a wavelength of approximately 40 km and an amplitude of >10 km. As well, previous thin section analyses show that this deformation event is also characterized by axial planar foliations related to mesoscopic and microscopic folds whereby the shallow fold axes are all relatively parallel and trend northwest-southeast.

Data compiled for this study, thus far, reveals that both D_{n+2} and D_{n+3} have axial planar foliations (S_{n+2} and S_{n+3}) characterized by two distinct fold shapes. Fold shapes for D_{n+2} and D_{n+3} are defined by centimeter to meter, asymmetric isoclinal folds and tight, asymmetric centimeter to decimeter folds, respectively. Field observations of the asymmetric D_{n+2} folds indicate one overturned antiform/synform pair that verges to the southwest. D_{n+3} folds exhibit a consistent sense of vergence towards the west-southwest and have yet to reveal similar structures associated with D_{n+2}. Statistical analyses and map patterns show both S_{n+2} and S_{n+3} have been folded by a later deformation event to form a relatively open, doubly plunging antiform trending to the west-northwest/east-southeast. This regional folding is similar to that of Mezger's (1997) third deformation event. Given the characterization of D_{n+2} and D_{n+3} above, regional folding of the KMA is subsequently attributed to a later deformation event. However, this deformation event is enigmatic in its relationship with the adjacent Ruby Range Batholith. In regards to the discordant interpretations of present and previous work, the deformation history of the KMA has yet to be fully understood.

Future work will entail supplementary geological mapping to further delineate the internal geometry of the KMA based on the cleavage/fold vergence relationships mentioned previously. Work will also focus on locating fold closures, a composite microtectonic investigation of the S_{n+2}/S_{n+3} relationship, and multiple detailed cross-sections. U-Pb detrital zircon analyses will be undertaken to constrain the age of the protolith and, geochemical analyses of interlayered ultramafic rocks (i.e., olivine serpentinites) is also currently underway to understand their relationship with the KMA and adjacent rock units. Finally, results will be compiled and interpreted to give a better understanding of the tectonic model of the KMA during emplacement to ancient North America.

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Regional tectono-metamorphism and exhumation history of Yukon-Tanana terrane

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Preliminary metamorphic and structural mapping in the McQuesten and adjacent Stewart River map areas of Yukon-Tanana terrane (YTT) has revealed at least four phases of folding and deformation in garnet-, staurolite-, and kyanite-grade rocks. Early rootless isoclinal folds (F_T) have been refolded and tightened by F_{T+1} tight to isoclinal folds that are coaxial to F_T. F_T and F_{T+1} may be the result of a single progressive deformation phase that produced a composite S_{T+1} transposition foliation. Post-transposition asymmetric F_{T+2} tight folds are most readily observed as mm-scale crenulations and outcrop-scale folds that are overprinted by F_{T+3} open, upright folds. Structural and metamorphic correlation throughout YTT on the basis of style and observed peak-metamorphic assemblages is problematic due to the diachronous and transitory nature of both the transposition process and the thermal peak of metamorphism. Therefore, mapping and the construction of detailed P-T-t-D paths will be undertaken within key locations throughout the terrane. Recent advances in our understanding of REE partitioning between radiogenic accessory minerals (e.g., monazite) and major and accessory minerals useful for thermobarometry, presents an opportunity to link the timing accessory phase growth to P-T estimates, and deformation (i.e., P-T-t-D paths). These data will help to determine how the multiple metamorphic and deformation events are correlated throughout the terrane, which is critical to the construction of tectonic models for this portion of the northern Canadian Cordillera.

Comparison of Basin-Floor Deposits along a Proximal to More Distal Transect: Upper and Middle Kaza Groups, British Columbia, Canada

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The stratigraphy and architecture of proximal (Upper Kaza Group) and more distal (Middle Kaza Group) basin floor strata show many similarities, but also a number of important differences that might have significant impact on estimating reservoir continuity and connectivity. The most obvious similarity between proximal and more distal deposits is their “sheet-like” morphology when observed at large (several 100’s meters) scale. Strata consist generally of 5-35 m thick “sheets” of mostly stacked normally-graded coarse sandstone. Sandstone sheets commonly overlie a unit of medium-bedded, matrix-rich, structureless sandstone (“harbinger beds”), and in turn are overlain by thinly-bedded, fine-grained turbidites up to 35 m thick.

The most significant difference is that coarse sandstone and fine-grained turbidite intervals are thicker in more distal deposits. Furthermore, in proximal strata, sandstones invariably become increasingly interstratified with thin-bedded turbidites upward, a trend not always observed in more distal strata. In addition, net-to-gross ratio of more distal deposits change little laterally, compared to proximal deposits where values commonly change by 20-40% over 100-200 m laterally. Major scours, albeit uncommon in proximal strata (confined to a single observation), are absent in more distal deposits. Muddy debrites too are absent in more distal deposits, but present in proximal strata.

Collectively these observations suggest that although vertical connectivity is significantly better in sand-rich proximal basin floor reservoirs, their lateral continuity may be less compared to seemingly similar sand-rich units deposited in more distal settings.

LA-ICP-MS detrital zircon results from quartzites in the Thor-Odin – Pinnacles area: Constraints on age and provenance, and implications for models of allochthonous vs authochthonous deposition

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The focus of this study is U-Pb laser ablation ICP-MS geochronology on detrital zircon in quartzites from a panel of polydeformed mid- to upper amphibolite-facies supracrustal rocks from the metamorphic core of the southeastern Canadian Cordillera, carried out at Memorial University. The rocks are located west of Lower Arrow Lake in the Gold Range of the Monashee Mountains. They are situated on the southern flank of Thor-Odin dome, within a panel of rocks that lies structurally above the dome and in the footwall of the east-dipping Columbia River normal fault. In a recent model, Thompson et al. (2004, 2006) proposed that the rocks of the panel were deposited in situ on basement rocks of Thor-Odin dome and are therefore autochthonous with respect to the North American craton. Furthermore, they propose that overlying Devonian to Jurassic rocks unconformably overlie the Proterozoic rocks and therefore are also autochthonous. In contrast, other views are that: i) the lower part of the succession in the panel may correlate with the Windermere Supergroup and Hamill Group (Carr 1991, and references therein), were deposited outboard relative to the present day location of Thor-Odin basement rocks and were subsequently structurally emplaced on and/or infolded with the basement rocks of the dome (McNicoll and Brown, 1995; Williams and Jiang 2005; Carr and Simony, 2006); and ii) the upper part of the panel contains Paleozoic and Mesozoic rocks, correlative with parauthochthonous Kootenay terrane and allochthonous Slide Mountain and Quesnel terranes (Carr 1991). In the latter view, allochthonous rocks were juxtaposed against parauthochthonous or North American rocks during Paleozoic basin inversion, and Mesozoic terrane accretion and orogenesis (Evenchick et al. 2007, and references therein).

This detrital zircon study on marker quartzites forms one component of a larger study designed to address the age, origin and tectonic significance of the aforementioned panel of metasedimentary rocks, as well as basement and cover rocks in Thor-Odin dome. Here we present data from two quartzites in order to address their age and provenance, one sample from Mount Symonds (DC395) and one from south of Plant Creek (DC490). Analyses included 97 zircons for sample DC395 (48 are >90% concordant), 81 zircons for DC490 (24 are >90% concordant). A common practice in evaluating LA-ICP-MS detrital zircon data is to accept data within 10% of concordance as being meaningful; however, this is arbitrary and may not always be appropriate. In order to substantiate the interpretation of sub-populations from the 10% cut, we use data that are within 1% of concordance, and we base maximum depositional ages on analyses that are 100% concordant.

At Mount Symonds, two distinct quartzites occur within a heterogeneous package of amphibolite, paragneiss and marble. The rocks were penetratively deformed at kfs-sil-melt grade in the Late Cretaceous – Paleocene, and intruded by the Paleocene-

Eocene Ladybird granite suite (Hinchey et al. 2006, and references therein). The upper quartzite structurally underlies the Empress Marble, and together, they form a distinctive marker that is continuous for over 20 km along strike from Mount Symonds westward to Mount Fosthall, and beyond (Reesor and Moore 1971). The data presented here are from the lower quartzite (DC395), a southwest dipping marker exposed in an isoclinal fold closure that straddles the peak of the mountain. Höy and Godwin (1988) proposed a Lower Cambrian age for the Empress marble and the associated Ledge syngenetic Pb-Zn deposit, based on common-Pb model ages and a correlation with similar stratabound Pb-Zn deposits in Frenchman Cap dome. Carr (1991) included the lower quartzite in the Symonds quartzite-bearing unit, the basal part of the Gold Range assemblage, and suggested that it may correlate with the Hamill Group. The Hamill Group is considered to be Upper Proterozoic to Lower Cambrian in age, and the overlying Badshot and Mohican groups are Lower Cambrian (Fritz et al. 1991). However, Thompson et al. (2004) interpreted this quartzite as Meso-Paleoproterozoic, part of a map unit which also includes sil-gt-bt schist, calc-silicate, marble, and bt-qtz-fp paragneiss.

The detrital results from the lower Mount Symonds quartzite are consistent with a correlation of the lower Mount Symonds quartzite with the Hamill Group, or younger rocks, that have a North American provenance. The youngest zircon in the > 90% concordant population is 514 Ma ± 18 and the youngest concordant analysis is 608 ± 35 Ma. Of the data that are >90% concordant, nine out of the 48 grains are < 700 Ma. This sample contains populations in the ages ranges of 500 – 650 Ma, 1.1 – 1.2 Ga and 1.6 – 1.8 Ga, consistent with a source from the craton, or from recycled sediments that had an original cratonic source. The dates on the youngest grains in this sample indicate that the lower Mount Symonds quartzite is younger than Late Proterozoic (e.g. ~ 600 Ma). They rule out the interpretations of Thompson et al. (2004, 2006) that the rocks are Meso-Paleoproterozoic, and similarly, they rule out the possibility that the quartzite is from the basement.

The second sample of quartzite (DC 490) is from the headwaters of Plant Creek on the logging road 18 km south of Mount Symonds, and occurs within an assemblage of amphibolite and gt-sil-bt schist. The rocks were penetratively deformed at kfs-sil-melt grade in the Late Cretaceous – Paleocene, and intruded by the Paleocene-Eocene Ladybird granite suite (Hinchey et al. 2006, and references therein). The quartzite lies structurally below greenschist-facies metasedimentary and metavolcanic rocks interpreted as Triassic Nicola and Jurassic Rossland groups of the Quesnel terrane. These low-grade rocks have been interpreted as either a klippe of the hanging wall of the Columbia River fault (Read and Brown 1981; Parrish et al. 1988; and references therein) sitting structurally on sil-kf and sil-ms bearing rocks, or as part of a supracrustal assemblage that unconformably overlies higher-grade metamorphic rocks (Thompson et al. 2004).

Zircons from sample DC 490 are generally small (<100µm) and euhedral with bipyramidal terminations; oscillatory igneous zoning is prominent in BSE images. Based on the morphology of the zircons they are interpreted as having an immature igneous source. The youngest grain in the > 90% concordant population, is 151 Ma ± 6, and the youngest concordant grain (99% concordant) is 184 Ma ± 18. In total, 8 out of 24 grains from the 90% concordant data are younger than ~200 Ma. Based on the zircon date that is 99% concordant, the rock is Middle Jurassic or younger. Other populations in this sample are clustered between 300 and 450 Ma, and there is a notable lack of concordant Proterozoic dates. Age populations are inconsistent with a dominantly cratonic provenance, rather, Paleozoic and Mesozoic sources of detrital zircons in the Plant Creek quartzite are more likely to be terranes to the west. Possibilities include the Cache Creek and Quesnel terranes, including the Nicola and Rossland groups which contain Triassic to Jurassic volcanic rocks (Petersen et al. 2004, and references therein). These data resemble data from Mid-Late Jurassic sedimentary rocks in the Bowser Basin where western and southwestern sources from the Cache Creek and Quesnel terranes contributed Triassic to Jurassic zircons into the basin (Evenchick et al. 2007).

The juxtaposition of rocks with different tectonothermal history (ie. the Middle Jurassic or younger quartzite, situated in a Cretaceous – Paleocene kfs-sil-melt grade assemblage, and structurally overlying Jurassic rocks of greenschist facies) supports the interpretation that there is a fault contact between the two units, in this case the Columbia River Fault, and provides another line of argument showing that unconformable deposition of the greenschist facies rocks is not a viable model. The age, provenance and probable correlations for this quartzite are all inconsistent with the model of unconformable deposition (Thompson et al, 2004, 2006). Rather, they support interpretations of a transposed terrane boundary within the metamorphic package.

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New data and ideas on the Paleozoic-Triassic evolution of the Insular superterrane of the North American Cordillera

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Investigations this summer confirmed earlier claims that Alexander and Wrangellia were amalgamated together into an Insular superterrane during the Pennsylvanian. Syn-collision, terrane-stitching Pennsylvanian to Permian plutons intruded during a penetrative phase of deformation. This deformation is largely coeval with the Browns Fork orogeny of the Farewell terrane, suggesting the St. Elias subterrane of Alexander (mainly exposed in the Yukon and northern BC) and Farewell are the same. Prior to its accretion to Wrangellia, parts of Alexander underwent orogenesis during the Early Paleozoic Wales and Silurian Klakas orogenies. The Klakas orogeny resulted in amalgamation of the Early Paleozoic arc subterranes (exposed in southeastern Alaska) with the St. Elias subterrane along a cryptic suture, which is largely masked/buried by syn-orogenic Silurian turbidites (arc-trench gap-foreland basin). The St. Elias subterrane is mainly exposed in the Yukon and northern BC and is characterised by a well-preserved, Late Cambrian-Upper Silurian carbonate platform, which appears to rest conformably on Early to Middle Cambrian rift-related siliciclastics and volcanics. The inferred, late Cambrian rift-drift transition is unknown in Laurentia and suggests that the St. Elias subterrane is a tectonic tracer of its parent continent (Siberia?) We are investigating its provenance and subsequent drift mainly by means of detrital zircon studies and the faunal provinciality of its fossils.

Most of the Late Permian to Middle Triassic is missing in the Insular superterrane, which probably reflects deformation-induced uplift and accompanying erosion. In addition, the Paleozoic amalgamation of Alexander and Wrangellia indicates the existence of a tectonic linkage between the large outpouring of the Upper Triassic Karmutsen/Nikolai flood basalts in Wrangellia and the approximately coeval volcanic rocks in the Tats Group (St. Elias subterrane) and correlatives in southeastern Alaska. The Tats Group and correlatives form part of the Triassic Alexander metallogenic belt, which hosts several large VMS deposits (e.g Windy Craggy in Tats Group). Published geochemical data indicate that the volcanic rocks in the Alexander metallogenic belt range from bimodal in the south to mainly basalt in the north. Compositions are generally transitional between arc and non-arc settings. Combined the upper Triassic volcanics probably formed in a rift-setting with the arc-component in the volcanics diminishing to the north and over time. Based on the existing data, we propose that the Insular superterrane collided with a ridge during the Middle-Late Triassic in its northern half, which formed a slab-window above which the flood basalts and the Tats volcanics were erupted. Over time the rift locally may even have progressed into a relatively narrow, Gulf of California-type oceanic basin.

Late Paleozoic to Mesozoic deformation and metamorphism in the Mendocina Creek area of south-central Yukon

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Polydeformed and metamorphosed rocks of the allochthonous, pericratonic, Yukon-Tanana and parautochthonous Cassiar terranes underlie the Mendocina Creek area of south-central Yukon. New structural, geochronologic and metamorphic data combined with observations from detailed mapping at 1:20 000-scale indicate that the Mendocina Creek area underwent four phases of deformation and two phases of metamorphism between Middle Permian(?) and mid-Cretaceous time. D_1 is cryptic and only locally preserved. D_2 is characterized by northeast-verging, rootless, tight to isoclinal, overturned to recumbent folds. D_2 was accompanied by amphibolite facies metamorphism (M_1) that reached peak temperatures and pressures of 524-614 ± 50 ^oC and 627-830 ± 100 MPa. This was followed by a period of Early Jurassic exhumation indicated by widespread $^{40}Ar/^{39}Ar$ mica cooling ages (~190-185 Ma) in Yukon-Tanana terrane. Garnet compositional profiles for Mn and Fe/Fe+Mg indicate M_1 garnet growth occurred continuously from core to rim. Garnet resorbtion was only identified in those garnet located in close proximity to the mid-Cretaceous Dycer Creek stock, suggesting Early Jurassic exhumation was rapid and did not allow for compositional re-equilibration within the garnet. Exhumation was followed by D_3, which is characterized by broad, open, shallowly northwest-plunging folds and southwest-verging thrust faults, a local crenulation cleavage and shallowly northeast-plunging mineral lineations. D_3 was followed by a period of mid-Cretaceous extension (D_4), exhumation and plutonism. This is evidenced by extensive normal faulting, down-to-the-southwest (extensional) shear bands and the intrusion of the 112 Ma Dycer Creek stock. Coexisting andalusite and biotite in the aureole of the Dycer Creek stock suggest that plutonism occurred at shallow crustal levels, and was accompanied by high temperature, low pressure (≤ 300 MPa) contact metamorphism.

The new structural, lithological and thermobarometric results from this study provide insight into the tectono-metamorphic evolution of Yukon-Tanana and Cassiar terranes in the Mendocina Creek area. We interpret D_2 and M_1 to have developed in the latest Triassic to earliest Jurassic during the initial, northeast-directed emplacement of Yukon-Tanana and Slide Mountain terranes onto the western North American margin, similar in style to that documented in the Finlayson Lake area of southeast Yukon.

Regionally, the boundary between Yukon-Tanana terrane and parautochthonous North American strata (including Cassiar terrane) is delineated by northeast-verging thrust faults, imbricated slices of Slide Mountain terrane and local occurrences of ecologites. In Mendocina Creek area, the absence of oceanic rocks of the Slide Mountain terrane has complicated identification of the boundary between Yukon-Tanana and Cassiar terranes. Our evidence suggests that this terrane boundary is defined by a D_3 southwest-verging, brittle-ductile thrust fault that truncated the initial, northeast-verging terrane boundary and inferred remnants of the Slide Mountain terrane. This southwest-verging deformation is attributed to tectonic wedging of the Yukon-Tanana terrane beneath Cassiar terrane. Subsequent exhumation (D_4) and plutonism correspond to a period of mid-Cretaceous extension that, up to this point, has only locally been documented in the Yukon-Tanana terrane.

Provenance of the Lewes River Group, Yukon

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Stikinia is represented by Triassic to Jurassic volcanic, plutonic and sedimentary successions above a sporadically exposed Paleozoic basement comprised of supra-subduction zone rocks. In Yukon, Triassic Stikinia comprises the arc-related rocks of the Lewes River Group that unconformably overly the Takhini Assemblage Paleozoic basement. The Lewes River Group is overlain by the Jurassic Laberge Group that records the exhumation of the Triassic arc and establishment of a Jurassic arc. This study is focused on the Rhaetian Mandana Member of Lewes River Group that records the waning stages of the Triassic arc. The Mandana member is characterized by Raetian fluvial to tidal sandstone, siltstone and conglomerate. Sandstone was sampled to constrain detrital zircon provenance utilizing U/Pb SHRIMP geochronology. The sample yielded a dominant c. 210 Ma zircon population characterized by euhedral, oscillatory to sector zone stubby prism morphology typical of plutonic sources. Some zircons contained cores of predominantly Paleozoic age indicating that the c. 210 Ma source intruded Paleozoic basement similar to the Takhini Assemblage. Presence of a single Proterozoic zircon core is enigmatic. The age of the dominant population is indistinguishable from the nearby Triassic plutons of the Stikine suite that intrude the Takhini Assemblage suggesting that the Mandana sandstones were likely locally derived. The provenance of the Mandana sandstone is identical to the provenance of the Richthofen formation of the Laberge Group successor basin. These data suggest that the Norian arc plutonic complex was exhumed by Rhaetian and remained a major and stable source of sediment to the Lower Jurassic Laberge Group.

Deformation vs metamorphism in the western Thor-Odin dome, Monashee Mountains, Canadian Cordillera.

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In this contribution new micro-structural and mineral chemical data for high temperature metamorphic rocks from the Thor-Odin dome are presented and their tectono-metamorphic evolution are reconstructed. Metapelites and amphibolite boudins from a 5 km long E-W transect, from the core of the dome to the Greenbush Lake normal shear-band zone, which rims the western margin of the dome are analysed in detail. The Omineca belt, between the Foreland and Intermontane belts, consists of Precambrian intrusive and metamorphic rocks belonging to the North American craton. This belt has been exhumed as a consequence of the collisional accretion of the allochtonous terranes (Intermontane, Costal and Insular belts) on the North American margin (MONGER *et alii*, 1982; GABRIELSE *et alii*, 1991). The deepest metamorphic core complexes of the whole Canadian Cordillera are exposed in the Omineca belt and include the Monashee complex, in South East British Columbia. The southernmost part of the Monashee complex is the Thor-Odin dome, which consists of a Proterozoic basement sequence (migmatitic orthogneisses and paragneisses, with amphibolites) and of a Proterozic to Palaeozoic meta-sedimentary sequence (quartzites, schists, marble, calcsilicates, gneisses, and amphibolites). Both sequences are characterised by a penetrative transposition foliation (ST; JOHNSTON *et alii*., 2000). The margins of the Thor-Odin complex are bounded by a system of normal shear zones known as the Thor-Odin detachment, which is believed to extend down to the Moho (KRUSE & WILLIAMS, 2007).

<u>Meso-structures:</u> the transposition foliation, dominantly of high metamorphic grade, of the Thor-Odin dome typically displays two generation of intrafolial (mature) folds and is overprinted by more open asymmetric (immature) folds. Most of the folds indicate top-to-the-NE flow (JOHNSTON *et alii*, 2000; WILLIAMS & JIANG, 2005) and are a product of a progressive deformation involving repeated cycles of perturbation by folding of ST, followed by tightening of the folds to transpose folded surfaces back into ST.

In the western part of the Thor-Odin dome there is a regional westerly dipping normal shear zone, (Greenbush Lake shear-band zone; JOHNSTON *et alii*, 2000), which is part of the Thor-Odin detachment and which overprints the transposition foliation. The main foliation in this shear zone is the reactivated transposition foliation, which is rotated into a steep orientation and overprints the immature folds. The shear zone is associated with extensional tectonics, during which a westerly plunging Sil-bearing lineation, developed as a result of a top-to-the-W shear on ST (JOHNSTON *et alii*, 2000; KRUSE & WILLIAMS, 2007). This lineation overprints a gently Southwest plunging Ky-bearing lineation and there is a prominent micro-fracturing developed perpendicular to the Silimanite lineation in the shear zone.

The asymmetric immature folds are overprinted by melt filled faults, which locally are folded and intersected by top-to-the-W shear surfaces or zones.

Extensional structures of the shear zone are overprinted by brittle structures, which are mainly related to the N-S trending Victor Creek Fault (KRUSE & WILLIAMS, 2005). Large open folds related to the regional domal structure have a northerly trending vertical axial plane, and overprint ST. They are believed to pre-date the extension.

Micro-structures: samples were collected for a petro-structural investigation, on the northern slope of Blanket Mt. (core of the dome), between Blanket Mt. and the Victor Creek Fault and in the Greenbush Lake shear-band zone (flank of the dome).

Grt-amphibolite boudins show a dominant foliation marked mainly by the SPO of brown AmpII and Bt. AmpI shows a different orientation with respect to the pervasive foliation. Qtz lenses, with minor PlI and layers rich in Cpx are wrapped by the foliation. PlI also occurs as interstitial crystals between AmpII or as granoblastic aggregates of grains showing deformation twinning. Coarse-grained Grt is in contact with PlI and Cpx, and locally retains an internal foliation, inclined at a high angle to the matrix foliation. Ttn mainly shows a SPO parallel to the foliation. Green AmpIII grows along the rims and the cleavages of AmpII; AmpII can be greener towards the Grt and Cpx rims. AmpIII and PlII formed symplectites at the Grt rim. AmpIII also overgrows Cpx. Chl overgrows the symplectites at the Grt rim and, with sagenitic Rt, replaces Bt.

In Grt-free amphibolite boudins SPO of Amp (I and II), PlI and rare BtI define the foliation. Pl-rich layers, with rare skeletal Cpx, also mark the foliation. Ttn crystals are scattered and enclosed in AmpI and II and are roughly parallel to the foliation. Amp is greener towards the rim (AmpIII and IV). AmpIV fills fractures intersecting the foliation at a high angle.

Metapelites between the Victor Creek Fault and Blanket Mt. Locally preserve Ky porphyroclasts, which show SPO parallel and inclusion trails oblique with respect to ST. In these rocks ST is defined by SPO and LPO of BtII and Sil and feldspar-rich layers. Coarse-grained Ky and Grt are wrapped by ST and contain tiny inclusions of Qtz, BtI and Rt, rimmed by Ilm; Ky also encloses WmI. BtI is inclined to ST, which wraps it. GrtI (= cores) predates ST, according to inclusion trails, inclined at a high angle and progressively asymptotic to this foliation. GrtII forms rims at GrtI margins fine-grained crystals in the ST films. Between the coarse-grained Grt and BtII reaction rims with BtIII, Qtz, PlII and rare Kfs occur. Prismatic Sil marks ST and fibrous Sil replaces Ky. The feldspar-rich layers consist of Qtz, PlI and Kfs, which forms coarse-grained crystals showing a rough SPO parallel to ST. PlI shows growth twinning and locally Kfs forms continuous rims between PlI and rounded Qtz crystals or fills Ky fractures. These microstructures may indicate shallow depth partial melting. Fractures in Grt are filled mainly by Chl and minor BtIV. WmII ± Chl ± BtIIV fill necks of micro-boudinaged Sil; Bt is partially replaced by Chl, sagenitic Rt and Kfs. In Ky-free metapelites BtI, Sil, PlI, Kfs and Qtz have an SPO defining the ST. PlI shows growth twinning and rarer deformation twinning; myrmekites developed at the Kfs rims. Grt forms coarse-grained crystals, which are wrapped by ST, partially replaced by BtII, PlII and Qtz, and shows core-rim zoning (GrtI, II and III); where Grt is almost totally replaced green Bt and Pl occur as coarse-grained crystals. Rare Wm grew at the Sil rim.

Mineral chemistry and P-T estimates: the study of mineral chemical variations, guided by sequential microstructural development, reveals some systematic evolutionary trends. In Grt amphibolites Na content and Al^{tot} decrease from AmpII (pargasite and Mg-hornblende) to AmpIII (Fe-hornblende). This is compatible with a slight decrease in P and T during ST development. In the Grt-free amphibolites syn-ST AmpI to AmpII (K-pargasite) show a similar content in Ti and Al^{tot} compatible with T ˜725°C and P ˜0.7 GPa; AmpIII, in the symplectites (edenite and Mg-hornblende), shows higher Ti content indicating a slight T increase. AmpIV (Mg-hornblende and actinolite) shows the lowest content in Ti and Al^{VI}, indicating T ˜600°C and P ≤ 0.3 GPa.

In metapelites XFe increases from GrtI to Grt core to rim and the Ti content decreases from BtI to BtIV. In particular in Ky-Sil bearing metapelites the variation of Ti content from BtI to BtIV indicates a variation in temperature from 700 -750°C to 600 - 700°C to lower than 500°C.

Mineral assemblages marking fabrics pre-dating the ST foliation display contrasting $P_{max}T_{Pmax}$ conditions, both in metapelites and in metabasics.

In summary, in the polydeformed metamorphic rocks outcropping from Blanket Mt. to the Greenbush Lake shear-band zone, P-T estimates have been inferred by using mineral assemblages coeval with superposed fabrics in rocks of different bulk composition. Results indicate that P-T conditions changed under a high thermal regime, which exceeds the range limited by the stable continental geotherm and a maximally relaxed geotherm for reasonable heat supply after crustal thickening. Such a high geothermal gradient is compatible with an extensional tectonic setting. Varied PT conditions are displayed by scattered lithological (metre scale) or mineralogical (granular scale) relics predating the ST foliation. They probably represent small size remnants of earlier metamorphic units of undetermined age, that were almost pervasively re-equilibrated during the PT history accompanying the progressive development of the ST regional foliation.

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