Cordilleran Tectonics Workshop

February 22-24th, 2019
Vancouver, British Columbia

A view of Kluane lake looking south west.

2019 Cordilleran Tectonics Workshop

M.J. Wosk Centre for Dialogue, Simon Fraser University, Vancouver, British Columbia.

Friday, February 22nd, 2019			
6:00 – 9:00 PM	***Icebreaker, Registration & Poster setup***		
Saturday, February 23rd, 2019		***Speaker***	***Abstract***
8:30 AM	***Coffee, muffins & posters***		
9:30 AM	Opening remarks	*Dan Gibson*	
9:45 AM	Spatio-temporal evolution of the latest Triassic – Late Jurassic Hazelton volcanic arc of Stikinia (central British Columbia Cordillera) and closure of the Cache Creek ocean	*JoAnne Nelson*	***5***
10:10 AM	Late Triassic – Jurassic magmatism, metallogeny and tectonics in the Intermontane terranes of Yukon	*Maurice Colpron*	***7***
10:35 AM	Tectonic evolution and metallogeny of the Yukon-Tanana upland, eastern Alaska: Recent USGS findings and future directions	*Jamey Jones*	***9***
11:00 AM	***Discussion, coffee and posters***		
12:00 PM	***Lunch***		
1:30 PM	Metapelitic mineral assemblages: how well does thermodynamic prediction reproduce natural patterns?	*Dave Pattison*	***11***
1:55 PM	Metamorphism of the Klondike schist and the generation of orogenic fluids during regional exhumation	*Tyler Ambrose*	***12***
2:20 PM	Resolving the Mechanism for Monazite Growth in Orogenic Gold Settings: A Study from the Klondike Gold District	*Brodie Stroh*	***14***
2:45 PM	***Discussion, coffee and posters***		
3:45 PM	Twopete fault: a northwestern extension of the McEvoy-Cassiar platform-Selwyn basin boundary	*Rosie Cobbett*	***16***
4:10 PM	The structural evolution of the Nadaleen trend, Yukon: implications for Carlin-type Au-mineralization and Selwyn basin tectonics	*Andrew Steiner*	***17***
4:35 PM	The Middle Jurassic through Early Cretaceous needs more Tuff ages	*Terry Poulton*	***50***
4:50 PM	***Discussion, posters and beverages***		
6:00 PM	***Dinner; Old Spaghetti Factory, Gastown (53 Water St.)***		

Sunday, February 24th. 2019		*Speaker*	*Abstract*
8:30 AM	***Coffee, muffins & posters***		
9:30 AM	Magmatism of the Murray dyke swarm near Spences Bridge, southwest British Columbia	*Anastasia Ogloff*	***20***
9:55 AM	3-D Geophysical investigation of a middle Cretaceous to Paleocene regional décollement in the Cordillera of Northern Canada and Alaska	*Nathan Hayward*	***22***
10:20AM	Source to sink record of the Late Cenozoic Yakutat – North American collision	*Eva Enkelmann*	***23***
10:45 AM	Active faulting and evidence for large earthquakes on the Sadie Creek fault, northern Olympic Peninsula, WA	*Liz Schermer*	***25***
11:10 AM	***Concluding Remarks & Where Next?***		
11:25 AM	***Discussion and posters***		
12:30 PM	***END OF CONFRENCE***		

Posters		***Presenter***	***Abstract***
1	SWIR Spectroscopy Studies on the IKE copper-Molybdenum-Silver Porphyry Deposit, British Columbia	*Megan Binner*	**28**
2	A record of post Late Cretaceous ductile and brittle transpression and transtension along the Lake Clark Fault in south-central Alaska	*Jonathan Caine*	**29**
3	Structural vs stratigraphic controls on fracture orientation and abundance: a case study from Swift Anticline, NW Montana	*Adam Cawood*	**31**
4	Revised tectonostratigraphy of Yukon Tanana and Slide Mountain terrane units in the Thirtymile Range and Wolf Lake areas, southern Yukon: Preliminary field results	*Nathan Cleven*	**33**
5	Ore and breccia classification of Cu-Ag-Au tourmaline breccia pipes at the Giant Copper Property, southern British Columbia: a comparison study with the tourmaline breccias of the Rio Blanco-Los Bronces District in northern Chile	*Bill Fischer*	**34**
6	Framework for Late Cretaceous magmatism and metallogeny in the Dawson Range, west-central Yukon	*Melissa Friend*	**35**
7	Conodonts in the Canadian Cordillera: New Biostratigraphic Insights	*Martyn Golding*	**37**
8	Structural Evolution of the Little Owls Region, Selwyn Basin, Yukon	*Margaret Laverge*	**39**
9	New U-Pb zircon geochronology and Lu-Hf isotope constraints on the episodic evolution of felsic rocks in the Finlayson Lake district, Yukon	*Matthew Manor*	**40**
10	Stratigraphic and structural setting of the Big Bulk Cu-Au porphyry and Red Mountain Au deposit, northwest BC: Preliminary Field Results	*Emily Miller*	**41**
11	The case for a "Continental Bulldozer"	*Jim Monger*	**42**
12	Structural and metamorphic culmination in the Hyland River area of Southeastern Yukon	*David Moynihan*	**45**
13	Geochronology and tectonic setting of the Turnagain Alaskan-type intrusion, Canadian Cordillera	*Graham Nixon*	**46**

Spatio-temporal evolution of the latest Triassic – Late Jurassic Hazelton volcanic arc of Stikinia (central British Columbia Cordillera) and closure of the Cache Creek ocean

Nelson, JoAnne, BC Geological Survey emeritus, JoAnne.Nelson@gov.bc.ca

The latest Triassic to Late Jurassic Hazelton Group represents the fourth and final episode of pre-accretionary arc construction in the long-lived Stikine composite arc terrane (Stikinia) in the core of the Cordilleran orogen of British Columbia. Initiation of Hazelton volcanism and accompanying plutonism followed collision of northern Stikinia with parts of the pericratonic Yukon-Tanana terrane and primitive Permo-Triassic ophiolite in the Cache Creek terrane. The collision stalled a subduction regime that had given rise to areally extensive volcanism and plutonism of the Late Triassic (ca 230-215 Ma) Stuhini arc on Stikinia. Regional deformation and uplift focused in the northern part of the terrane, accompanied by coeval deep tectonic burial of rocks in the southern Yukon-Tanana terrane. A trend of ca 210 Ma, post-Stuhini, pre-Hazelton alkaline plutons were emplaced in a north-trending structural corridor in northwestern Stikinia, including the host to the very large Galore Creek porphyry deposit. Earliest Hazelton volcanism and intrusion at ca 205 Ma occurred in two widely-separated east-west belts near the Pitman fault in northern Stikinia and along the Skeena arch in southern Stikinia.

Main development of the Hazelton arc between 200 and 185 Ma shifted to >100 km south of the Pitman fault. The Toodoggone volcanic belt of eastern Stikinia is linked to the Telkwa Formation, which forms an east-west belt centred on the Skeena arch. Together, they form a southward-convex volcanic axis that terminates to the northeast near the southern end of the Whitehorse trough, a latest Triassic to Early Jurassic syncollisional clastic basin. The Hazelton arc probably developed through northward subduction of a slab that adjoined the collision zone, with asymmetric trench retreat causing it to advance more rapidly along strike to the south.

The Hazelton arc axis migrated rapidly south of the Skeena arch ca 178-175 Ma. Arc-related volcanic and intrusive activity ceased north of the arch, replaced by regional subsidence and development of the Eskay rift in western Stikinia. Highly alkalic, bimodal magmatism along the northern shoulder of Stikinia (Horn Mountain Formation; ca 176-173 Ma) may have been the result of slab break-off. Post-kinematic plutons (ca 176-160 Ma) intruded both Stikinia and adjacent

Cache Creek terrane. Coherent blueschist panels were exhumed in the northern Cache Creek terrane at this time. Clastic strata of the Middle Jurassic to Lower Cretaceous Bowser Lake Group, mainly derived from the collision zone to the north and east, accumulated in the Bowser basin in central Stikinia, eventually ponding against the northern side of the Skeena arch. It may have filled the back-arc basin north of and behind the Hazelton arc. Middle to Late Jurassic arc volcanism emerged in an east-west belt across southern Stikinia from Whitesail-Bella Coola to Nechako. This belt is considered a further southward migration of the Telkwa frontal arc segment through continued subduction retreat.

The current tectonic configuration of eastern Papua New Guinea provides a possible modern analogue for the Hazelton arc-Whitehorse trough-Cache Creek ocean system. The zone of ongoing collision in the Finisterre belt of eastern PNG resembles the Whitehorse trough. It passes along strike into the still-active New Britain arc, which is currently rotating clockwise towards Australia, consuming the remnant ocean floor of the Solomon Sea. In contrast to the "enclosure" model, which called for wholesale rotation of the Stikinia block to close the Cache Creek ocean, in this model the Hazelton arc impinged on the Quesnellia subduction zone by the well-known mechanism of slab rollback.

Late Triassic – Jurassic magmatism, metallogeny and tectonics in the Intermontane terranes of Yukon

Colpron, Maurice, Yukon Geological Survey, Maurice.Colpron@gov.yk.ca
Crowley, James L., Boise State University
Sack, Patrick J., Yukon Geological Survey

Late Triassic to Jurassic granitoid plutons that intrude the Intermontane terranes in the northern Cordillera are considered parts of the early Mesozoic arcs of Stikinia (ST) and Quesnellia (QN). In British Columbia these plutons are associated with prolific Cu-Au porphyry deposits. They extend into southern Yukon where Early Jurassic plutons locally host unusual high-grade Cu-Au mineralization.

In Yukon, the oldest, Late Triassic plutons (ca. 217-214 Ma) comprises mainly small, melanocratic monzodiorite to quartz diorite plutons that were emplaced at high crustal levels into metamorphic rocks of the Yukon-Tanana terrane (YT) and Upper Triassic volcanic rocks of ST. This suggests that YT formed the basement to Mesozoic ST in Yukon. These plutons are geochemically and isotopically juvenile and locally associated with Cu mineralization. The Minto suite (ca. 205-195 Ma) intrudes YT and ST in central Yukon and comprises variably deformed granodiorite that were emplaced at lower crustal depths (6-7 kbar) during crustal thickening and accretion of the Intermontane terranes. High-grade Cu-Au mineralization at Minto and Carmacks Copper is hosted in variably migmatized mafic xenoliths within Early Jurassic granodiorite. A detailed study of the xenoliths used combined LA-ICPMS and CA-TIMS techniques on zircons and Re-Os dating of molybdenite to show that protolith and mineralization are Late Triassic, and that migmatization resulted in upgrading of original porphyry mineralization. To resolve precise dating of complex zircons within the xenoliths at the Carmacks Copper deposit, we used a novel approach where CL images and LA-ICPMS analyzes (U-Pb and trace elements) were acquired from both sides of 30-40 µm-thick zircon wafers. This approach was used to identify domains of uniform age and chemical composition within these complex zircons. A total of 104 grains were analyzed with 191 LA-ICPMS spots, and five distinct groups were identified based on LA-ICPMS dates and chemical composition. From these results, 20 zircon fragments representative of each group were liberated from 14 wafers by cutting with a 6 µm wide laser beam, and then analyzed by CA-TIMS.

Granodiorite and granite of the Long Lake suite (ca. 188-182 Ma) were emplaced at shallower crustal levels (3-5 kbar) during continued convergence and development of the syncollisional Whitehorse trough (WT). Trace element patterns and isotopic analyses of the Minto and Long Lake suites show decreasing subduction influence and increasing crustal contamination consistent with syncollisional emplacement. Early Jurassic magmatism also migrated southward between ca. 205 and 178 Ma in Yukon. The Middle Jurassic Bryde suite (ca. 172-168 Ma) comprises post-collisional, alkalic plutons ranging from monzonite to syenite and granite that were emplaced at high crustal levels into ST, Cache Creek and WT. Their juvenile isotopic signatures combined with regional surface uplift reflect lithospheric delamination or slab breakoff.

Tectonic evolution and metallogeny of the Yukon-Tanana upland, eastern Alaska: Recent USGS findings and future directions

Jamey Jones, U.S. Geological Survey, jvjones@usgs.gov
Doug Kreiner, U.S. Geological Survey

The boundary between the allochthonous Yukon-Tanana terrane (YTT) and parautochthonous North America (PNA) in eastern Alaska comprises a series of low-angle penetrative structures that formed and(or) were reactivated during multiple episodes of regional Permian to mid-Cretaceous deformation. The boundary is difficult to identify because 1) rock assemblages juxtaposed across structures are similar in composition, early Paleozoic tectonic histories, and geophysical character; 2) overprinting kinematic indicators are complex; and 3) extensive mid-Cretaceous and younger plutons cross-cut and obscure key relationships. Mineralization occurred along the complex YTT-PNA boundary from the Paleozoic through the Paleocene, but its relation to individual tectonic events and physical processes that control mineralization is poorly constrained. Targeted geologic mapping, structural analyses, and geo- and thermo-chronology completed along the international border in eastern Alaska provide key constraints for delineating the terrane boundary and interpreting its complex kinematic evolution and tectonic history. Our data provide a new and essential framework for understanding the relationship between broadly coeval mineralization and younger magmatic and metallogenic overprints. Of particular interest, zircon U-Pb ages of meta-igneous rocks do not provide unique constraints, as ca. 366 to 355 Ma deformed granitoids (i.e., orthogneiss) are present in both the YTT and PNA assemblages. However, detrital zircon geochronology provides a useful discriminant, as metasedimentary rocks in the YTT typically contain early Paleozoic age populations that are absent in PNA quartzites. Allochthonous YTT rocks yield Jurassic and older $^{40}Ar/^{39}Ar$ ages, whereas PNA assemblages consistently produce mid-Cretaceous cooling ages. Our integrated datasets and observations suggest that, in eastern Alaska, the boundary between the YTT and PNA is a zone of low-angle, ductile to brittle-ductile deformation that juxtaposes thin (up to a few hundred meters) structural panels of allochthonous YTT assemblages from more deeply exhumed Late Devonian PNA assemblages. The YTT structural panels are volumetrically small and record predominately ductile deformation and amphibolite-facies metamorphism. Internally, the panels are structurally complex and contain a mix of Late Devonian to Permian rocks that were thrust onto PNA and then exhumed along low-

angle, predominantly extensional detachment structures. Our findings are consistent with previously published models and provide new quantitative constraints that illuminate this under-studied region of eastern Alaska. Unraveling the complex tectonic history experienced by the region is critical to deciphering the secular variation of contrasting styles of mineralizing systems throughout the region. Additionally, this new tectonic understanding of eastern Alaska allows for further investigation of subtle differences in the geochemical evolution recorded in Mesozoic and younger arc magmatism and the controls on the distribution and style of mineral systems in the region. Our findings lead to a better integrated understanding of the broader geologic controls on the distribution and style of mineralization related to younger orogenic gold and porphyry copper systems as well as placer resources.

Metapelitic mineral assemblages: how well does thermodynamic prediction reproduce natural patterns?

Pattison, David RM, Dept. Geoscience, U Calgary, pattison@ucalgary.ca

Metapelitic mineral assemblages and mineral compositions are widely used in estimating the pressure-temperature (P-T) conditions and P-T-time evolution of metamorphic rocks. Phase diagrams and associated isopleths calculated from recent thermodynamic datasets are increasingly trusted for this analysis – commonly uncritically, often blindly. Is this trust justified? Comparison of predicted phase equilibria with well constrained natural metapelitic data suggests it may not be.

Metamorphism of the Klondike schist and the generation of orogenic fluids during regional exhumation

Ambrose, Tyler K., MDRU-Mineral Deposit Research Unit at UBC, tambrose@eoas.ubc.ca
Allan, Murray M., Teck Resources Limited
Stroh, Brodie A., MDRU-Mineral Deposit Research Unit at UBC
Hart, Craig J.R., MDRU-Mineral Deposit Research Unit at UBC

Placer gold in the Klondike district is derived from the erosion of Late Jurassic orogenic quartz veins hosted in the Late Permian Klondike schist. These veins were produced by metamorphic fluids released during metamorphic dehydration reactions. Although metamorphism generated the fluids, and the veins are hosted in metamorphic rocks, few studies have focused on metamorphic processes in the Klondike district. Key questions remain regarding the metamorphic evolution of the region and how it relates to quartz vein formation and mineralization: 1) what are the pressure-temperature conditions recorded by the Klondike schist, 2) what package of rocks underwent dehydration to produce the fluids, 3) was gold introduced into the fluids at the point of dehydration, along the migration pathway, or near the site of deposition, and 4) what reactions contributed to fluid production?

To constrain the metamorphic conditions of the Klondike schist, we applied multi-equilibrium thermobarometry (avPT mode in THERMOCALC) and metamorphic phase equilibria modelling (Perple_X) on samples collected from different localities within the Klondike district. We integrated these results with new and previously published geochronological and thermochronological data to constrain the timing of burial, exhumation, fluid production, and mineralization. Our results are consistent with previously published studies that demonstrate mineralization and vein formation coincided with regional exhumation and a magmatic lull during the Late Jurassic.

Previous researchers have proposed that the vein-forming fluids were produced from dehydration reactions during burial of an underlying thrust sheet that was coincident with regional exhumation of the overlying thrust slices (Staples et al., 2016). We propose that exhumation itself could also have contributed to fluid production, as initially demonstrated by Vry et al. (2010) in the Southern Alps. We utilized metamorphic phase diagrams to calculate the total amount of water contained within hydrous minerals (e.g., amphibole, muscovite, chlorite) at different pressures, temperatures, and mineral assemblages. Changes in the amount of water contained within the mineral phases requires that fluid is either released through dehydration or consumed through hydration reactions. We calculated the volume of fluid produced along isothermal decompression and isobaric heating paths. Our results suggest that the amount of fluid produced during isothermal decompression is (1) less than, but on the same order of magnitude as, isobaric heating, and (2) dependent on the temperature at which decompression occurs. Thus, high erosion rates and associated rapid exhumation that leads to isothermal decompression provides an alternative mechanism for fluid production in the Klondike and other orogenic gold deposits.

References:

Staples, R. D., Gibson, H. D., Colpron, M., & Ryan, J. J. (2016). An orogenic wedge model for diachronous deformation, metamorphism, and exhumation in the hinterland of the northern Canadian Cordillera. Lithosphere, 8(2), 165–184. https://doi.org/10.1130/L472.1

Vry, J., Powell, R., Golden, K. M., & Petersen, K. (2010). The role of exhumation in metamorphic dehydration and fluid production. Nature Geoscience, 3(1), 31–35. https://doi.org/10.1038/ngeo699

Resolving the Mechanism for Monazite Growth in Orogenic Gold Settings: A Study from the Klondike Gold District

Stroh, Brodie, Mineral Deposit Research Unit – University of British Columbia, bstroh@eoas.ubc.ca
Ambrose, Tyler, Mineral Deposit Research Unit – University of British Columbia
Hart, Craig, Mineral Deposit Research Unit – University of British Columbia
Allan, Murray, Teck Resources Limited

Constraining the timing of orogenic gold mineralization is challenging because datable minerals are typically small, may be reset, or their relationship to gold mineralization is poorly constrained. The most common method, 40Ar/39Ar dating of hydrothermal micas, is susceptible to resetting and difficult to resolve from regional cooling. U-Th-Pb dating of hydrothermal or hydrothermally-modified pre-existing monazite can be a robust alternative method to date mineralization. However, linking monazite formation to the mineralization process, or even to vein formation, can be difficult because monazite may grow by multiple, possibly overlapping processes. For example, monazite can grow during both prograde and retrograde metamorphism. Additionally, it can also precipitate from fluids in and adjacent to veins. Distinguishing between these growth processes is vital in providing the correct geological significance to geochronological data.

The estimated 20 million ounces of placer gold mined in the Klondike gold district was derived from orogenic gold-bearing quartz veins. The timing of mineralization is broadly constrained to the Jurassic based on 40Ar/39Ar mica ages and a single U-Pb age from hydrothermal rutile. However, direct dating of gold mineralization and associated geological processes by U-Th-Pb dating of monazite has not been attempted. The Klondike provides an opportunity to study the growth processes of monazite and provide meaningful age constrains on mineralization. To do so, we collected samples from vein material, altered wall rock, and relatively unaltered host rock from several localities. Monazite dates, trace element geochemistry, and detailed petrographic analyses were integrated to distinguish between growth processes.

Our results reveal protracted monazite growth in the Klondike from the Early Jurassic to mid-Cretaceous. At one locality, monazite analyses with high ThO2 concentration correspond to older dates and grains elongate in the metamorphic fabric, consistent with a metamorphic origin. In contrast, analyses with low ThO_2 concentration are younger and correlate to grains intergrown with hydrothermal phases such as pyrite, consistent with a hydrothermal origin. These results suggest that ThO_2 concentration is a potential proxy for monazite growth mechanisms. However, at another locality, there is no relationship between monazite dates/texture and ThO_2 concentration. This may be explained by ThO_2 concentration not being a reliable proxy or monazite at this locality growing by a blended metamorphic-hydrothermal process. These results provide insight into identifying monazite growth mechanisms in orogenic gold settings and constrain the timing of veining in the Klondike.

Twopete fault: a northwestern extension of the McEvoy-Cassiar platform-Selwyn basin boundary

Cobbett, Rosie, Yukon Geological Survey, Rosie.Cobbett@gov.yk.ca

The Selwyn Basin is a part of the western Laurentian margin that was dominated by deposition of slope and basinal facies from the Neoproterozoic to middle Paleozoic. It is bounded to the southwest by Silurian to Middle Devonian carbonate rocks of the McEvoy-Cassiar platform. In the northeast Glenlyon area, the Twopete fault is a major thrust fault that is inferred to mark the transition from basinal to platformal facies. It separates middle to late Paleozoic continental slope facies in its footwall from lower Cambrian (?) to Ordovician, variably metamorphosed clastic and volcanic strata in its hangingwall. It is also spatially related to two subparallel belts of Late Devonian and Cretaceous intrusions.

Detailed mapping along the Twopete fault provides evidence that it was a synsedimentary fault that controlled deposition of Upper Devonian clastic sedimentary and volcanic rocks. Fossils collected during mapping provide constraints on the position of the Twopete fault; Ordovician fossils were found in its hangingwall and Late Devonian fossils in the footwall. This in turn shows that known mineralization is hosted in Upper Devonian sedimentary strata in the immediate footwall of the Twopete fault, suggesting a genetic link between mineralization and the fault, a relationship that can be traced for approximately 100 km to the southeast.

The hangingwall of the Twopete fault along its northwestern extent comprises a succession of Ordovician siliclastic rocks that are unlike coeval basinal strata found elsewhere in miogeoclinal rocks in Yukon. Thick-bedded, quartz-rich greywacke with ripple marks and cross-beds are interlayered with siltstone containing Ordovician graptolites. Minor chert pebble conglomerate, dark weathering phyllite and calcareous siltstone and sandstone are also interbedded with the grits. These slope facies are interpreted to be deposited along the edge of the McEvoy-Cassiar platform. Coeval rocks in the Selwyn basin (and north and northeast of the Twopete fault) are generally thin-bedded limestone and shales more typical of deep water sedimentation. The distribution of Ordovician slope and basin facies on either side of the Twopete fault, along with the long-lived nature of the fault, suggest it may represent the transition from platform to basin in central Yukon.

The structural evolution of the Nadaleen trend, Yukon: implications for Carlin-type Au-mineralization and Selwyn basin tectonics

Steiner, Andrew, University of British Columbia, astein@eoas.ubc.ca
Hickey, Ken, University of British Columbia

The Nadaleen trend, Yukon, is an array of Carlin-type Au-deposits situated in the eastern Rackla belt on the northern margin of the Selwyn basin. Bound to the north and south by the eastern termini of the Kathleen Lakes and Dawson faults respectively, the trend is structurally anomalous due to the presence of steeply-plunging folds that are absent regionally. Macroscopic versions of these folds, with several hundred-meter wavelengths, are present in competent carbonate units, while mesoscopic equivalents are extensive in argillaceous rocks. The steep axial plane of the folds varies from northeast- to east-striking, which is interpreted to be a function of refraction between carbonate and argillite layers of contrasting competencies. An axial-planar pressure-solution cleavage is extensive within the study area, although only locally well-developed. This cleavage was never observed to transect both limbs of a fold, even at the macroscopic scale, suggesting that the folds represent the latest folding episode. This relationship, coupled with the sub-vertical orientation of cleavage and axial planes, suggests that the folds either formed after the beds were steepened, or were rotated to their current steep orientation in the cleavage plane.

The most probable mechanism for steeping bedding is ramping along steepened thrust imbricates, since both bedding and faults dip steeply towards the regional hinterland. Such thrust imbricates are common in other mapped areas along the Dawson thrust sequence, albeit with a shallower attitude. Large, east-striking faults are therefore interpreted to be steepened thrusts, and their coalescence into the Dawson and Kathleen Lakes regional fault systems provides further support for this interpretation. Limb-rotation of imbricate thrust sheets during progressive shortening is common in thrust belts worldwide, and is the principal candidate for steepening the bedding and faults in the Nadaleen trend.

Several mechanisms for generating steeply-plunging folds in thrust systems are considered, such as non-coaxial strain associated with strike-slip deformation or vertical-axis rotation superimposed onto steepened thrust panels. Alternatively, a steepened lateral or oblique ramp could have acted to steepen upright thrust-parallel folds, such as those observed in the west of the study area, within the plane of the cleavage, or to produce thrust-orthogonal bedding orientations that can fold during progressive shortening. This latter model is favourable as it does not require extensive strike-slip deformation, for which there is no clear evidence.

Mechanical anisotropy during deformation and the steep orientation of fold axes were first order controls on Au-mineralization in the Nadaleen trend. Zones of high fracture-density such as faults, fold closures, and rheologically competent layers such as dolostones, were the dominant pathways for auriferous fluids. The steep orientation of bedding, faults, and hinge-parallel fracture networks promoted an overall vertically-focussed hydrothermal system. This is very different from the renowned Carlin-type Au-deposits of Nevada, where ore-fluids largely flowed laterally through confined aquifers.

Structural Evolution of the Brucejack High Grade Intermediate-Sulphidation Epithermal Deposit, Stikine Terrane, Northwest British Columbia

Peddle, Cameron, University of Alberta, cpeddle@ualberta.ca
Johnston, Stephen, University of Alberta

The Brucejack intermediate-sulphidation epithermal deposit is located in the western domain of the Stikine arc terrane (Stikinia) in the Intermontane Belt of the Canadian Cordillera. At this latitude, Stikinia is flanked to the west by the Coast Plutonic Complex and to the east siliciclastic strata of the Bowser basin. The Brucejack epithermal deposit is interpreted to have formed in the Hazelton Trough, a back-arc basin that records 75 m.y. of extension, from 195 to 120 Ma. Hazelton Trough strata overlie highly-deformed Triassic Stuhini Group arc-derived volcano-sedimentary rocks. The cessation of extension at 120 Ma, marks the onset of a compressional event that gave rise to the east-to-northeast verging Skeena Fold and Thrust Belt. Regional-scale north-to-northwest striking faults and folds, including the McTagg Anticlinorium, that overprint Early-to-Middle Jurassic Hazelton Trough strata and associated mineral systems formed at this time. The McTagg Anticlinorium is cored by Stuhini Group rocks. Overlying strata of the Hazelton and Bowser groups young to the east. The Brucejack deposit resides on the east limb of the anticlinorium along the north-south trending Sulphurets mineral district of the Golden Triangle. It is hosted in intermediate epiclastic and pyroclastic rocks of the Betty Creek Formation. These rocks have a U/Pb age of 188Ma and are interpreted to have formed as early basin-fill along extensional growth faults that was unconformably deposited on top of older basement rocks of the Stuhini Group during early basin evolution.

Determining the role of Early-to-Mid Jurassic syn-arc versus Cretaceous compression in development of the Brucejack deposit is vital to understanding the controls on mineralization. Preliminary results from the 2018 field season suggest that auriferous vein systems of the Brucejack deposit are syn-tectonic and coeval with formation of west trending, open-to-closed, parallel-style, buckle folds. Buckle folds appear to have formed during north-south directed compression and provide a first order control on vein generation and geometry. Folds and associated fabrics, mineralized veins and early faults are all cross-cut by mafic-to-intermediate dykes that constrain the age of the folds to between 188-183 Ma. Explaining the Brucejack deposit as a result of Early Jurassic syn-arc N-S compression is difficult to reconcile within the existing Stikinian paradigm of Early to Mid-Jurassic extension and Hazelton Trough formation.

Magmatism of the Murray dyke swarm near Spences Bridge, southwest British Columbia

Ogloff, Anastasia, Simon Fraser University, aogloff@sfu.ca
Thorkelson, Derek, Simon Fraser University
Crowley, Jim, Boise State University
Ickert, Ryan, Scottish Universities Environmental Research Centre
Marshall, Dan, Simon Fraser University

A dyke swarm in the western Intermontane belt of southern British Columbia provides the opportunity to gain understanding of magmatic processes that spanned the entire thickness of this region of the Cordillera, from generation of magma in the upper mantle to subvolcanic processes in the brittle upper crust. Located west of the town of Spences Bridge, the Murray dyke swarm is continuously exposed in >1100 m-high cliffs. Hosted in the volcanic rocks of the mid-Cretaceous (~104 Ma) Spences Bridge Group, the swarm is interpreted as a late pulse of Spences Bridge Group magmatism. Dykes are ~1 m wide, parallel, and north-striking. The uniformity of dyke orientations indicates the swarm has a sheeted morphology and was emplaced coeval with extension. Although other factors can affect dyke orientation during emplacement, such as magmatic pressure, the weight of an overlying volcanic edifice, and the presence of multiple pre-existing fracture sets in the Spences Bridge Group host rock, tensile conditions related to the regional tectonic stress field was likely the main control. The Murray dyke swarm represents 1.4 km of east-west crustal dilation within a 2x10 km area. The dyke swarm is interpreted to represent the subvolcanic conduit system to an overlying volcanic eruptive center coeval with extension.

The Murray dyke swarm ranges in composition from basalt and basaltic trachyandesite to dacite. All rocks are porphyritic with phenocrysts of clinopyroxene; plagioclase is common in the andesite dykes, and altered orthopyroxene or altered olivine, sometimes with hornblende reaction rims, occur in mafic members. Major and trace elements show the suite is dominantly calc-alkaline, with strong enrichments of large ion lithophile elements and light rare earth elements coupled with negative anomalies of Nb and Ta. These features indicate arc processes were involved during magma genesis. Sr and Nd isotopic data have narrow ranges and indicate juvenile mantle sources (initial $^{87}Sr/^{86}Sr$ range from 0.70292 - 0.70360 and initial εNd range from 5.23 - 7.74). The strong parallelism of the dykes along with local dyke intermingling suggest that the dyke swarm was

emplaced rapidly. Rapid dyke swarm emplacement is supported by indistinguishable U-Pb zircon ages for the host rock (104 ± 3 Ma, 2σ error) and the dykes (103 ± 1 Ma, 2σ error).

The most mafic rocks can be related to primary mantle melts by as little as 3% fractional crystallisation. However, the andesites cannot have evolved from the basalts because the andesites have significantly lower concentrations of highly incompatible trace elements such as K, La, and Zr. Likewise, geochemical modeling indicates this diverse suite of rocks cannot be related through closed-system fractional crystallisation. Variations in La/Nb and Dy/Yb throughout the suite suggest the swarm was derived from heterogenous mantle sources generated at a range of depths in the spinel and garnet stability field (estimated ~60 to ~100 km). Geochemistry of the Murray dyke swarm points to a complex magma plumbing system involving (a) variable mantle sources, (b) variable melting depths, (c) fractional crystallization and assimilation and (d) differential mixing of these magmas.

Figure 1. Sheeted dykes of the Murray dyke swarm. Dykes are generally 0.4-1.5 m wide, subparallel and dip steeply to the east. Thin black lines emphasize dyke margins; a sliver of host rock (Pimainus Formation of mid-Cretaceous Spences Bridge Group) is overlain with a pale green pattern. Field of view is ~20 m high and 9 m wide and contains more than 10 individual dykes.

3-D Geophysical investigation of a middle Cretaceous to Paleocene regional décollement in the Cordillera of Northern Canada and Alaska

Hayward, Nathan, Geological Survey of Canada – Pacific (Vancouver), Nathan.Hayward@Canada.ca

Unravelling the complex and protracted tectonic history of accretionary orogens, requires a multidisciplinary approach integrating geological and geophysical techniques. Multiple terranes, which comprise continental fragments, magmatic arcs and accretionary complexes, were accreted to Laurentia between the Late Paleozoic and early Cenozoic. During the middle to Late Cretaceous, prior to formation of the Mackenzie Mountains fold and thrust belt, the region was intruded by diverse suites of granitic rocks. The architecture of the fold and thrust belt has previously been investigated along a suite of geological and geophysical cross-sectional profiles, parallel to the shortening direction. A new approach to the 3-D inversion of gravity data, models the distribution and depth-extent of rocks with systematic density contrasts, such as intrusive or sedimentary rocks, a technique that could be applied in a range of tectonic settings. In the northern Cordillera, the model defines the geometry of low-density zones, primarily related to middle to Late Cretaceous granitic intrusions, and Neoproterozoic and Cretaceous sedimentary rocks. Variation in the depth-extent of these zones delimits a surface, interpreted herein as a décollement syntectonic with, or postdating, middle Cretaceous intrusions, but pre-dating and displaced ~430 km by, the Eocene aged Tintina fault. The décollement shallows from a depth of ~15-20 km beneath Selwyn basin, to ~11 km beneath the Mackenzie Mountains, and its trend suggests a N35°E shortening direction. Surface faults echo the décollement geometry, linked to fold and thrust belt development between the middle Cretaceous and Paleocene. To the south, the décollement continues for an unknown distance into northern British Columbia, but the Liard line forms a structural discontinuity between the fold and thrust belts of the Mackenzie Mountains and northern Rocky Mountains. Surface faults in the northern Ogilvie Mountains broadly define the décollement's northwestern extent, which prior to Tintina fault displacement, was likely connected to a fold and thrust belt and related décollement in east-central Alaska.

Source to sink record of the Late Cenozoic Yakutat – North American collision

Enkelmann, Eva, University of Calgary, eva.enkelmann@ucalgary.ca
Dunn, Catherine A., Stanford University, Stanford, California
Bootes, Nathaniel, University of Cincinnati, Cincinnati, Ohio

The St. Elias Mountains in Southeast Alaska and Southwest Yukon are the tallest coastal mountain range on Earth, and formed due to the ongoing subduction and collision of the Yakutat microplate with the North American Plate. Due to their high latitude and high elevation, the St. Elias Mountains are heavily glaciated and large tidewater glaciers have been the main agent of eroding and transporting sediments into the Gulf of Alaska since 6–5 Ma. In this study, we present a source to sink evaluation of sediment routing at this glaciated convergent margin. We investigate the efficacy of thermochronology to record spatial and temporal exhumation patterns in synorogenic sediments using late Miocene to Pleistocene strata from industry wells and boreholes drilled by Integrated Ocean Drilling Program Expedition# 341 in the Gulf of Alaska. We present U-Pb and fission track double dating results from >3000 detrital zircons, from strata deposited on the Yakutat shelf, slope, and deep-sea fans. Our data are compared with the large dataset of geo- and thermochronology data on-land and offshore in order to constrain sediment provenance.

We find that offshore strata deposited east of the fold and thrust belt are sourced from the rapidly exhuming areas along the entire Fairweather Fault, the northeastern part of the St. Elias syntaxial region (Kluane high ice field) as well as the slowly exhuming Insular superterrane. In contrast, the western strata, part of the fold and thrust belt, are sourced from the emerging fold and thrust belt and the Chugach Metamorphic Complex located north of the plate boundary. In these sediments we identified a significant change in sediment provenance, which we suggest to mark the capture of the Bagley Ice Valley by the proto-Bering Glacier around ~3.5 Ma. This implies that the modern Bagley-Bering Glacier System is much older than previously known. We find that the offshore Bagley-Bering Glacier sediment contains grains recording cooling ages much older (80–35 Ma) than those reported from the St. Elias syntaxis (3–2 Ma), indicating that extreme rapid exhumation does not extend west of the Seward-Bagley ice field divide since at least 3.5 Ma. This finding highlights the importance of tectonic uplift to cause extreme rapid rock exhumation when combined with efficient erosion. Data from sediments in the distal deep sea as well as on the shelf

show that extreme rapid and deep-seated exhumation was already ongoing at ~11–8 Ma. This is in agreement with findings on land that suggest localized extreme rapid exhumation started already prior to glaciation and north of the plate boundary.

Active faulting and evidence for large earthquakes on the Sadie Creek fault, northern Olympic Peninsula, WA

Schermer, Elizabeth, Western Washington University, schermer@wwu.edu
Amos, Colin, Western Washington University
Duckworth, Cody, Western Washington University.

Active faulting in the northern Olympic Peninsula of Washington reflects North-South shortening and dextral transpression of the forearc of the Cascadia subduction zone. The Sadie Creek fault (SCF), a recently discovered splay of the Lake Creek – Boundary Creek fault (LCBCF), extends for ~15 km WNW from the northwest shore of Lake Crescent, immediately south of the Strait of Juan de Fuca. The surface trace of the SCF, identified and mapped using airborne lidar, reveals abundant geomorphic offsets suggesting a history of repeated post-glacial earthquake surface ruptures dominated by dextral displacement along a steeply dipping fault zone. Our mapping shows the SCF is a NW-striking, subvertical, dextral fault with a subordinate dip slip component. Field and lidar measurements of scarp profiles and laterally offset stream channels indicate cumulative slip on Late Pleistocene and younger surfaces varies along strike, with vertical slip ranging from 1-6 m (average of 3.5 m) and cumulative dextral slip ranging from 6-26 m (average of 14.8 m). Preliminary 14C ages of deposits within offset stream channels suggest a slip rate of 1-2 mm/yr on the SCF since deglaciation at ~14 ka).

We excavated two trenches across the SCF to investigate the timing and extent of surface ruptures and to assess their relationship to earthquakes identified by previous work on the adjacent LCBCF. The SCF trenches, along the eastern and central portions of the fault, were sited in fault-bounded depressions where uphill-facing scarps locally pond N-NW-flowing drainages. Stratigraphy in these trenches reveals till and post-glacial outwash overlain in the footwall by progressively buried, organic-rich, forest and wetland soils developed on scarp-derived colluvial wedges. Complex faulting, fracturing, and tilting of these deposits strongly suggests a dextral sense of displacement together with a lesser dip-slip component similar in magnitude to the scarp height (~2-5 m). From these observations we infer 3-5 earthquake surface ruptures along the SCF since retreat of the Juan de Fuca lobe of the Cordilleran ice sheet. Preliminary radiocarbon dating of charcoal fragments in gouge cores extending beneath the trenches restrict these events to younger than ~13.4 ka. Dating of charcoal and woody plant fragments within the post glacial colluvial and

wetland sequence in one trench suggests preliminary ages of earthquakes at >9500, 8100-9300, 7000-7200, <6300, and <1300 cal yr BP. Less-precise age constraints on three earthquakes in the second trench are broadly consistent, with the most recent event at <2600 cal yr BP. Future radiocarbon and OSL dating will allow more precise constraints on the ages of these earthquakes and comparison with Holocene records in nearby Lake Crescent and the LCBCF to the east.

Poster Abstracts

SWIR Spectroscopy Studies on the IKE copper-Molybdenum-Silver Porphyry Deposit, British Columbia

Binner, Megan, Simon Fraser University, mbinner@sfu.ca
Marshall, Dan, Simon Fraser University
Mark Rebagliati, Amarc Resources Ltd

The IKE deposit is a Cu-Mo-Ag porphyry deposit located in the southwestern portion of the Canadian Cordillera in British Columbia, Canada. It follows a calcalkalic porphyry model, as it is hosted in plutonic rock and has a large alteration footprint. Amarc Resources Ltd. drilled 21 discovery holes from 2014-2016 that cover an area of 1.2 km by 1.0 km with a depth of 875 m, all of which intersect long intervals of mineralization. Significant amounts of early halo type veins are found throughout the deposit, and are typically associated with deep-seated porphyry deposits like Butte, Montana and Ann Mason, Nevada.

SWIR spectroscopy done on the host rock at IKE was used to identify subtle geochemical changes in the alteration minerals. Three different drillholes were evaluated using this method. They were chosen for their different positions in the system, high grade intervals, and high percentages of early halo type veins. The main mineral picks, white mica and chlorite absorption features, and illite crystallinity values were examined and compared to grade and the percentage of early halo type veins. These factors can be used to estimate the temperature and composition of the mineralizing hydrothermal fluids, and help to determine the fluid pathways within the system.
The SWIR spectroscopy studies done on IKE thus far have helped to further characterize alteration zones within a system dominated by potassic alteration. Future work using SWIR spectroscopy will involve additional drill holes as well as readings on vein alteration halos and how they change with depth.

A record of post Late Cretaceous ductile and brittle transpression and transtension along the Lake Clark Fault in south-central Alaska

Caine, J.S., U.S. Geological Survey, Denver, CO, jscaine@usgs.gov
Todd, E., U.S. Geological Survey, Anchorage, AK
Lease, R.O., U.S. Geological Survey, Anchorage, AK
Jones, J.V., U.S. Geological Survey, Anchorage, AK
Benzel, B., U.S. Geological Survey, Denver, CO

The Lake Clark fault (LCF) is expressed as a northeast-trending curvilinear valley ~200 km long and up to a few km wide. Previous geologic mapping and geophysical data indicated 12 to 26 km of dextral separation and as much as 1 km of SE-directed reverse separation since the Late Eocene. New data and observations from ~ 30 locations along the LCF trace shows weakly foliated granodiorite to the NW juxtaposed against foliated quartz diorite to granodiorite, that locally contain mafic screens, to the SE. The mafic screens and penetrative ductile fabrics within the plutonic rocks to the SE are parallel to the fault trace and show dextral-reverse kinematic indicators. Zircon U-Pb ages are ~74-69 Ma to the NW and ~85-76 Ma to the SE, and geochemically distinct fractionation trends exist on each side of the fault. U-Pb ages and ductile deformation are consistent with a component of NW directed reverse slip on a steeply SE-dipping fault, but it is unclear if the plutons on either side are different or if they represent distinct evolutionary stages in a cogenetic magmatic system. Penetrative deformation, mafic screens, and local migmatization also suggest melting and magma emplacement are possibly coupled with deformation.

An extensive zone of brittle damage at least 1.2 km in width overprints all lithologies and the ductile fabrics. The brittle damage is asymmetrically distributed along the mapped fault trace and is particularly well developed on the SE side of the fault. Damage consists of striated, hematite-coated, meter-scale slip surfaces associated with weak argillic alteration and unusual laumontite-filled syn-kinematic opening-mode fault veins. The surfaces reflect small strains at intensities of several surfaces per meter. Orientation analysis of 302 slip surfaces indicates a mean strike and dip of 250/87 that is subparallel to the regional-scale trace of the fault zone. Kinematic analyses of all slip surface data result in a best-fit shortening axis of 01/118 (plunge and trend) consistent with the long-lived, regional tectonic framework. However, slip varies from site to site and scales

from small slip surfaces to map-scale faults with components of oblique reverse, sinistral, dextral, and normal slip.

Size fractions of fault-related illite in the most central, highly altered and brittlely damaged exposures were dated using encapsulated 40Ar/39Ar. Resulting ages are 28.53 ± 0.80 Ma, 22.78 ± 1.56 Ma, and 32.97 ± 1.57 Ma in order of increasing grain size. New apatite (U-Th)/He thermochronology indicates Miocene to Oligocene cooling at ~ 35 m/m.y. that accelerated to ~ to 250 m/m.y. at ~10 Ma, without appreciable thermochronometric differences on either side of the fault. Argon illite geochronology overlaps with apatite thermochronology as well as the thermal stability of laumontite fault veins, effectively bracketing the age of coupled thermomechanical and fluid flow processes and fault kinematics.

Integration of our new data suggests the localization and evolution of the LCF was influenced by Cretaceous pluton assembly processes that produced initial plate margin-parallel rock fabric anisotropy, moderate exhumation rates, and distributed brittle deformation, fluid flow, and hydrothermal alteration. The resulting fault zone has small separation for its full mapped trace length as well as locally substantial width. It accommodated both transpressional and transtensional components of deformation within a complex accretionary plate boundary.

Structural vs stratigraphic controls on fracture orientation and abundance: a case study from Swift Anticline, NW Montana

Cawood, Adam J., School of Geosciences, University of Aberdeen, UK,
adam.cawood@abdn.ac.uk
Bond, Clare E., School of Geosciences, University of Aberdeen, UK
Watkins, Hannah, School of Geosciences, University of Aberdeen, UK
Cooper, Mark, University of Aberdeen & Sherwood GeoConsulting, Calgary, AB
Warren, Marian J., Jenner GeoConsulting, Calgary, AB

Swift Anticline is a thrust-related frontal structure of the Sawtooth Range, NW Montana. Excellent exposure of fractured Mississippian Castle Reef Fm carbonates across this reservoir-scale structure make it a suitable outcrop analogue to fractured carbonate reservoirs in fold-thrust belts, particularly of the laterally-equivalent Western Canada Sedimentary Basin. In this study we employ a multi-scale approach to understanding variation in fracture intensity and orientation. 3D photogrammetric reconstruction techniques are combined with field-based measurements and interpretation of satellite imagery.

Fracture abundance at Swift Anticline varies according to structural position on the fold, with forelimb and hinge zones marked by increased fracture intensities relative to backlimb positions. We find that structural influence on fracture intensity is subordinate to lithological control, however: grainstone and packstone lithologies exhibit lower fracture intensities than fine-grained, mud-supported units across the structure, irrespective of structural position. Fracture orientations at Swift are complex and variable, with six discrete fracture sets identified in the study area. Of these, only two sets, oriented approximately parallel and perpendicular to the axial trace of the anticline, show any clear evidence of fold-related fracturing. These fractures exhibit increased intensity values at hinge and forelimb positions, while the other four sets do not appear to show any systematic variation in abundance with structural position. Structurally controlled variation in overall fracture abundance at Swift Anticline, therefore, is primarily controlled by the occurrence of these two fold-related fracture sets. We find that sampling resolution significantly impacts observed fracture orientations. Data from isolated ground-based sites show little correlation in dominant fracture orientations with either lithology or structural position, while remotely acquired data more clearly highlights structural controls on fold-related fracture occurrence.

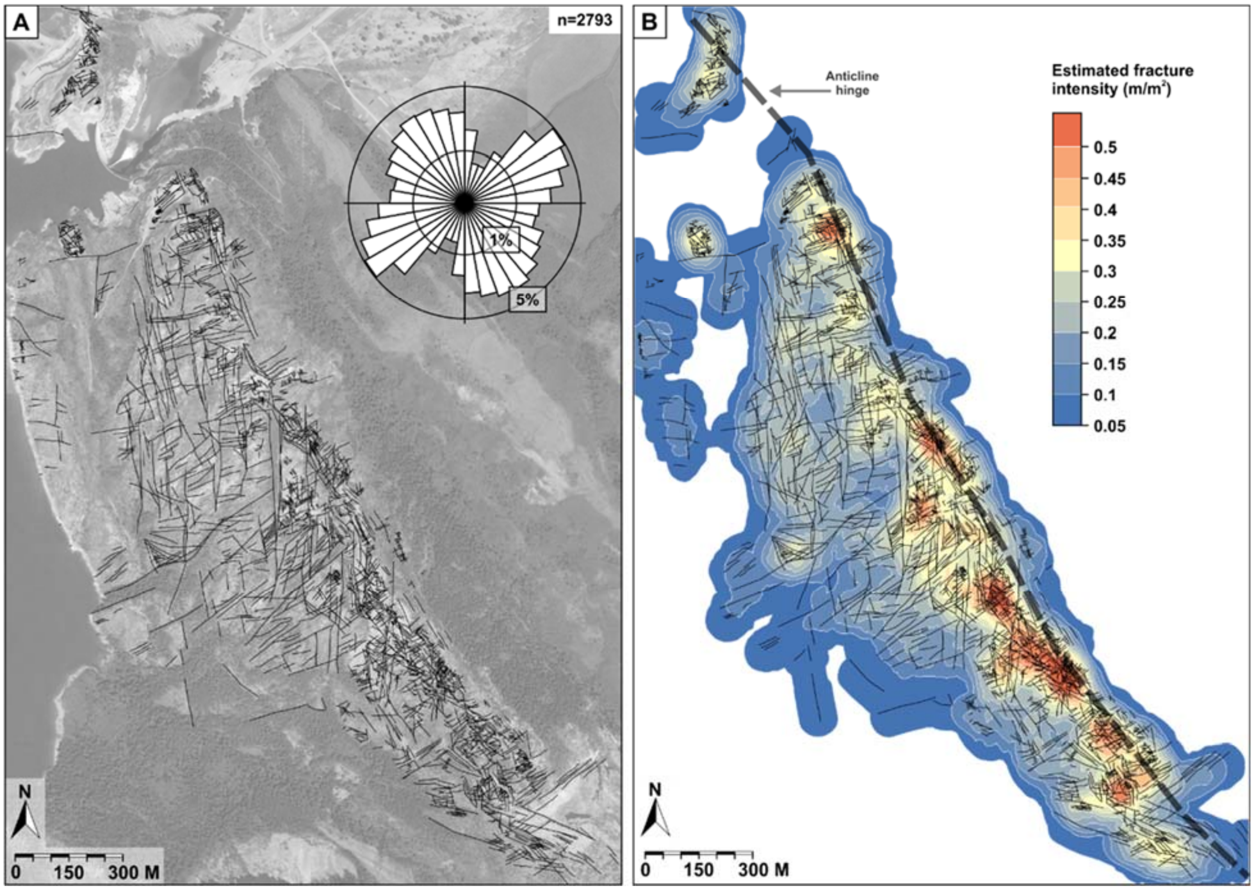

Figure 1. (A) Manually interpreted fracture trace map from satellite imagery (Google Images, 2018). Rose plot shows length weighted orientations for all fractures mapped at this scale. (B) Estimated 2D intensity (m/m^2) of fractures mapped at satellite-scale. Higher fracture intensities generally associated with positions proximal to the anticline hinge.

Based on our results, prediction of fracture attributes in the subsurface should consider the following: (a) structural controls are likely to be subordinate to lithological properties in controlling fracture intensity, particularly in deformed multilayers. Prediction of subsurface fracture abundance, therefore, should initially focus on mechanical-stratigraphic properties of units. (b) Increased fracture abundance in anticline forelimbs and hinges is well documented. It is of critical importance, however, to understand which fracture sets/orientations control this variability – this has implications for bulk permeability of deformed rock volumes. (c) Downscaling of fracture attributes from lower-resolution, large-scale datasets is likely to be more effective than upscaling from isolated, high-resolution sample sites (e.g. wells or ground-stations).

Revised tectonostratigraphy of Yukon Tanana and Slide Mountain terrane units in the Thirtymile Range and Wolf Lake areas, southern Yukon: Preliminary field results

Cleven, Nathan, Geological Survey of Canada, nathan.cleven@canada.ca
Ryan, Jim, Geological Survey of Canada
Zagorevski, Alex, Geological Survey of Canada
Hayward, Nathan, Geological Survey of Canada

The nature of individual terranes, relationships between terranes, and the timing of major accretion and orogenic collision events is still poorly understood in the northern Cordillera in Yukon, British Columbia and Alaska. The study area of this work is situated to encompass units that may span a suture zone, considering that the accretion of the Yukon Tanana terrane (YTT) to the North American (NA) margin must have involved a major collisional and orogenic event. Locally, supracrustal rocks on the eastern margin of the YTT are structurally juxtaposed with the Cassiar terrane, a sliver of the ancestral NA margin, presumably along a terrane boundary that is possibly a suture zone. However, the timing, extent and products of the collision and suturing process have yet to be explicitly defined in terms of what collided, and exactly when. The presence of Slide Mountain terrane (SMT) units as potential suprasubduction ophiolite slivers, units of eclogitic rocks, and regions with a steep metamorphic gradient are indications that the study area is suitable to examine collisional tectonic and accretionary processes and effects. The general objectives of field work carried out under the Geological Survey of Canada's GEM Cordillera project in the summer of 2018 were to map the the geology of the Thirtymile range, establish the petrogenesis of Slide Mountain ophiolite fragments in the Wolf Lake region, and evaluate the nature of late conglomerate deposits.

Ore and breccia classification of Cu-Ag-Au tourmaline breccia pipes at the Giant Copper Property, southern British Columbia: a comparison study with the tourmaline breccias of the Rio Blanco-Los Bronces District in northern Chile.

Fischer, Bill, Simon Fraser University & Imperial Metals Corporation, bill_fischer@sfu.ca
Marshall, Dan, Simon Fraser University
Miller-Tait, Jim, Imperial Metals Corporation, Vancouver, BC

The Giant Copper property, located 150 km east of Vancouver, consists of seven tourmaline breccia pipes. The pipes are spatially associated with the dioritic Tertiary Invermay stock and crosscut the Triassic sediments of the Ladner Group. Mineralization occurs exclusively within the breccia pipes consisting of Cu-Ag mineralization with local Au, Mo, Pb and Zn. The most explored breccia pipe is the A.M. breccia, which is an elongate, northwest trending, and sub-vertical breccia pipe that is 430m by 150m at surface and has been explored to approximately 450m below surface, where strong Cu-Ag-Au mineralization is still encountered. The A.M. breccia consist of rounded to subangular siltstone, sandstone and tourmaline clasts that are either cemented by quartz, pyrite, chalcopyrite, and pyrrhotite or occur within a rock flour matrix consisting of quartz, tourmaline, sulfides and/or actinolite. Alteration at the A.M. breccia is vertically zoned consisting of an upper oxidized zone with the mineral specularite and a lower phyllic zone easily identified by intense tourmaline alteration.

The geology of the A.M. breccia pipe, and the entire Giant Copper porphyry system, share several geologic similarities with the copper-gold mines of the Rio Blanco-Los Bronces district in Northern Chile. Preliminary results from the Giant Copper property indicate that fluids hosted within the quartz of the tourmaline breccia are saline and similar to those reported from the Rio Blanco-Los Bronces district. Both the North American and South American systems appear to terminate in typical porphyry mineralization. Additionally, the mineralogy and alteration of the tourmaline breccias are also similar, but unlike the deposits of the Rio Blanco-Los Bronces district, the presence of a deep Cu-rich biotite and magnetite alteration zone is inconclusive at the Giant Copper property. Similarities in mineralogy, fluids, and porphyry mineralization indicate that deeper zones of copper mineralization exist on the Giant Copper property.

Framework for Late Cretaceous magmatism and metallogeny in the Dawson Range, west-central Yukon

Friend, Melissa, MDRU - University of British Columbia, mfriend@eoas.ubc.ca
Hart, Craig J.R., MDRU - University of British Columbia

The Dawson Range in west-central Yukon is a regionally extensive northwest-trending metallogenic province hosts economically significant porphyry and epithermal-style mineralization. Two discrete magmatic episodes each generated magmatic-hydrothermal mineralization that contributes to this metallogenic province, suggesting multiple pulses of fertile magma generation. The concentration of mineral occurrences along major structures suggests a close link between magma emplacement and the structural evolution of the Dawson Range. Recent studies have improved the geochronological constraints on Late Cretaceous magmatism in the Dawson Range, but the petrogenetic and geochemical attributes of this magmatic event has not been established. Key questions remain regarding the tectonomagmatic history of Late Cretaceous magmatism in the Dawson Range and the source and controls of fertile magmas.

The early Late Cretaceous (79-72 Ma) Casino plutonic suite includes small intrusions that were emplaced in a narrow, discontinuous belt in the Dawson Range that is largely coincident with the Big Creek fault system. This suite is calc-alkaline and occurs as plutons, hypabyssal dikes, small stocks, and intrusive breccia bodies. Plutons and stocks of this suite range from quartz monzonite to granodiorite in composition. Hypabyssal dikes exhibit porphyritic textures and range from rhyolite to dacite in composition. Magmatic rocks of this suite are spatially associated with Cu-Au±(Ag-Mo) porphyry and epithermal style mineralization close to, and locally controlled by, the orogen parallel dextral strike-slip Big Creek fault system (e.g. Casino, Cash, Tad, Revenue-Nucleus). A marked interruption in the style and extent of Late Cretaceous magmatism occurred in the west-central Yukon at ca. 72 Ma. The late Late Cretaceous (72-67 Ma) Prospector Mountain plutonic suite comprises volumetrically small, but geographically widespread high-level magmatic bodies that typically consist of several small stocks. This suite is composed of a variety of granitoid compositions including quartz monzonite, monzogranite, and rare syenite. The Prospector Mountain suite is age equivalent to volcanic rocks of the Carmacks Group, which includes volcanic rocks with both high-K and high Mg contents as well as calc-alkaline trace element signatures.

Prospector Mountain suite rocks host several examples of Cu±Mo±Au±W porphyry mineralization (e.g. Mt. Cockfield, Swede, Pluto), as well as Ag-Pb rich, polymetallic epithermal veins (e.g. Prospector Mountain area, Connaught, Pika).

The petrogenetic and geochemical attributes of magmatic rocks that contribute to their fertility as mineralizing agents are being investigated through the integration of field mapping and observations, petrographic analysis, lithogeochemistry, and U-Pb dating and trace element analysis of zircon. Spatial and temporal relationships between the different magmatic and structural elements will constrain the role played by tectonics in the structural, magmatic and metallogenic evolution of the northern Cordillera during the Late Cretaceous. The metallogenic importance of the Late Cretaceous magmatic event will be emphasized with the generation of new data and knowledge to facilitate improved exploration targeting.

Conodonts in the Canadian Cordillera: New Biostratigraphic Insights

Golding, Martyn, Geological Survey of Canada, martyn.golding@canada.ca
Lei, Jerry, University of Victoria
Orchard, Mike, Geological Survey of Canada

Conodonts are the fossilized remains of extinct, jawless chordates, which are abundant in oceanic sedimentary rocks from the Late Cambrian to the end of the Triassic. Conodonts have been extensively used for biostratigraphic studies due to their abundance, rapid evolution, and facies independence. Within the terranes of the Canadian Cordillera, conodonts allow stratigraphic correlation in regions of extensive faulting, and across terrane boundaries. This presentation will highlight some of the work being undertaken on conodont biostratigraphy throughout the Cordillera.

Recent work on Late Triassic conodonts from the northern region of the Stikine terrane (near Atlin, BC, and Whitehorse, YK) has improved the resolution of the Late Triassic timescale, and in particular identified the position of the Norian-Rhaetian boundary in the Sinwa Formation on Mt. Sinwa. Although the Norian-Rhaetian boundary is easily recognizable in Europe, data from North America is lacking. Work on samples from the Sinwa Formation is ongoing, in order to integrate the conodont biostratigraphy with $\delta^{13}C$ chemostratigraphy. This will allow more precise correlation of the Norian-Rhaetian boundary in North America, whilst detailing the fluctuations in environmental conditions leading up to the end-Triassic mass extinction.

Conodonts from the type section of the late Paleozoic Antler Formation at Sliding Mountain (near Barkerville, BC) have been re-examined and re-identified using modern taxonomy. This has led to the recognition of several conodont species not previously recorded in the terranes of the Canadian Cordillera, including some of the oldest conodonts yet identified in the Slide Mountain terrane, from the Fammennian (Late Devonian). This revision has also allowed more refined stratigraphic assignments to be made for many of the Carboniferous and Permian samples from this important locality.

In the Nechako region (near Fort St James, BC), abundant collections of conodonts from carbonate of the Cache Creek terrane have been recovered, ranging in age from Pennsylvanian to Late Triassic. These conodonts provide an insight into the faunal composition of the Panthalassa Ocean, a relatively under-studied geographic area for this time interval. They also allow comparison and correlation between the Cache Creek terrane and the Slide Mountain terrane, with the conodont faunas of the two terranes showing a number of similarities and differences. In particular, several Carboniferous genera which are present in the carbonate samples from the Cache Creek terrane appear to be absent from the time-equivalent chert samples from the Slide Mountain terrane, which may reflect ecological constraints on these conodont genera.

Structural Evolution of the Little Owls Region, Selwyn Basin, Yukon

Laverge, Margaret, University of British Columbia, maggielaverge96@gmail.com
Penner, Barry, Department of Earth, Ocean, and Atmospheric Sciences, UBC
Hickey, Kenneth, Department of Earth, Ocean, and Atmospheric Sciences, UBC

In the southeast Selwyn Basin of the northern Canadian Cordillera recent fieldwork has identified multiple generations of overprinting foliations and/or fold structures, where previous research had concluded that only one main deformation event was expressed. Microstructural analysis supports field observations, and provides evidence for four distinct overprinting foliations. S_2 is the dominant foliation in the study area. It is moderately north dipping and is axial planar to 100 m-scale, inclined, NW-plunging folds. S_1 is locally preserved as a pervasive mica foliation that is crenulated by S_2. The S_3 and S_4 foliations both manifest as subvertical crenulation foliations. S_3 strikes west to WNW and overprints S_2 through the study area. S_3 is intensely-developed within many phyllitic units across the study area, but is less well-developed within interbedded quartzite layers. S_3 is axial planar to rarely developed 10 m-scale upright folds with a generally shallow westerly plunge. Where well-developed, S_3 can form the dominant foliation in the rock. S_4 strikes north to NNW and is less intensely developed and less pervasively distributed across the study area. Owing to the steep west to WNW-dipping orientation of S_3 across the Little Owls study, S_3 is tentatively correlated to the main WNW-striking, subvertical, S_1 foliation and upright F_1 folds developed in Selwyn Basin rocks to the east in the Flat River region.

New U-Pb zircon geochronology and Lu-Hf isotope constraints on the episodic evolution of felsic rocks in the Finlayson Lake district, Yukon

Manor, Matthew J., Memorial University of Newfoundland, mjmanor@mun.ca
Piercey, Stephen J., Memorial University of Newfoundland
Wall, Corey J., Boise State University

The Finlayson Lake volcanogenic massive sulfide (VMS) district contains rocks that mark one of the first arc–back-arc systems along the western Laurentian margin during the Late Devonian to Early Mississippian. Felsic volcanism, plutonic activity, and volcanogenic massive sulphide mineralization in the Grass Lakes group – the structurally deepest rock package in the Finlayson Lake district – began to dominate following a period of arc-related magmatism and sedimentation in the Fire Lake formation. New high-precision U-Pb zircon geochronological results define the timing of back-arc–related felsic volcanism in the upper Kudz Ze Kayah formation to ca. 363.4 to 362.3 Ma. Cross-cutting porphyritic dikes and granitic apophyses of the Grass Lakes plutonic suite are geochemically similar to the older felsic rocks, yet are distinctly younger (ca. 361.9 to 360.9 Ma); however, they overlap in age with mafic and volcanic rocks in the overlying Wind Lake formation (ca. 362.3 to 360.9 Ma). All of the samples collected contain abundant inherited zircon fractions that range from ca. 364 Ma to 2 Ga, consistent with previous studies in the district. Whole rock Hf isotopic systematics for all of the felsic rocks in the Grass Lakes group indicate they are evolved (i.e., $\varepsilon Hf_{WR} = -9$ to -23) and melt a pre-existing Laurentian basement. In contrast, in situ Hf isotopic compositions of zircon from whole rock samples, however, have elevated $^{176}Hf/^{177}Hf$ and less negative εHf values (i.e., median $\varepsilon Hf_{zircon} = -1$ to -15). The decoupling between whole-rock and zircon isotopic compositions can be explained by the episodic addition of juvenile material (e.g., upwelling basaltic melts) to evolved crustal or sedimentary sources. These new integrated U-Pb and Lu-Hf isotopic results indicate that zircon in the upper Grass Lakes group record subtle geochemical variations during the ~2.5 million years of pluton formation and felsic volcanism. Isotopic characteristics of zircon in the felsic rocks may provide further useful knowledge of composition and timing of mantle upwelling, crustal recycling, development of elevated upper crustal geotherms, and the formation of volcanogenic massive sulphide deposits that were developed above an isotopically heterogeneous basement domain.

Stratigraphic and structural setting of the Big Bulk Cu-Au porphyry and Red Mountain Au deposit, northwest BC: Preliminary Field Results

Miller, Emily A., University of British Columbia, emiller@eoas.ubc.ca
Kennedy, Lori A., University of British Columbia
van Straaten, Bram. I., British Columbia Geological Survey

Most porphyry Cu deposits are generated in a contractional environment, in a plate subduction or collisional environment marked by crustal thickening surface uplift and rapid exhumation (Sillitoe, 2010; Tosdal et al., 2009). Recent studies (e.g. Piquer et al. 2015; Cloos and Sapiie, 2013; Gow and Walshe, 2005) suggest they can also form in extensional regimes, or in zones of pre-existing extensional crustal architectures. In the “golden triangle” area of northwest British Columbia, the Kerr-Sulphurets-Mitchell (KSM) Cu-Au porphyry deposits, are interpreted to have been emplaced into a weakly extensional basinal environment (e.g. Nelson and Kyba, 2005; Febbo et. al. (accepted for publication Econ Geol).

To better constrain the local structural and tectonic environment into which Cu-Au porphyry deposits were emplaced in northwestern BC, we have begun an integrated stratigraphic, structural, geochronological and lithogeochemical study of the Big Bulk Cu-Au porphyry system (Kinskuch Lake) and the Red Mountain Au deposit.

We will present preliminary field observations and interpretations, including preliminary geological maps, stratigraphic columns, cross sections and structural interpretations.

The case for a "Continental Bulldozer"

Monger, James, Geological Survey of Canada-Vancouver (emeritus scientist), jimonger@shaw.ca
Gibson, H. Daniel, Earth Sciences, Simon Fraser University

Numbered paragraphs below correspond with poster sections.

(1) Linkages established by many workers over nearly five decades show all major arc terranes in the Canadian Cordillera had been accreted (somewhere) along the western North American craton margin by the Middle Jurassic (~174 Ma), less than 20 million years after initial spreading of the Central Atlantic Ocean in the Early Jurassic (~190 Ma). The regional tectonic framework established by Wheeler and Gabrielse (1972) showed the Canadian Cordillera contained an eastern "Columbian Orogen" that emerged in the Jurassic and a western "Pacific Orogen" initiated in the Cretaceous. However, minimal ages of terrane linkages make existing models of Cordilleran orogenesis driven by collisions of big arc terranes with the craton margin improbable, because the entire Canadian Cordillera only emerged in mid-Cretaceous-earliest Cenozoic time (~100-50 Ma). How, then, to account for the two episodes of crustal thickening, uplift and erosion that record the Columbian and Pacific orogenies?

(2) Consideration of the trajectory of the North American craton may shed light on the question posed above. Latitude changes of the craton since 220 Ma (Kent and Irving, 2010, their Fig. 7) combined with longitudinal changes based on spreading of the Atlantic basin and separation from the Africa craton, which is considered to have been geographically relatively immobile since ~300 Ma (Torsvik et al., 2008), provide a possible craton trajectory. At times (180-160 Ma; 120-60 Ma) the craton evidently moved due westward, which hints at an explanation for the formation of Columbian and Pacific orogens. Before and between these times the craton moved mainly northwestward and then, after 60 Ma, southwestward.

(3) The lithosphere of the present North American Plate margin is thin, warm and weak in comparison with flanking craton and oceanic lithospheres, and the rock record of axial and western parts of the Canadian Cordillera, which is dominated by arc-related magmatism, suggests similar conditions prevailed during Mesozoic-Cenozoic time. Today, coupling between the converging North American Plate and oceanic Pacific and Juan de Fuca plates causes deformation of the overriding "soft" plate margin that is documented by geodetic and GPS surveys. Similarly, coupling between converging and transforming plates occurred intermittently during the protracted evolution of the Canadian Cordillera, each time leaving tell-tale structural imprints on the western Laurasia-North America Plate margin.

(4) The structural record shows that the style and time of deformation correlates with vectors of the possible craton trajectory. Because orientation of the western North American craton margin was approximately north-south during the Mesozoic and Cenozoic, orogen-normal fold and thrust fault systems were developed when the craton moved due westward during ca. 180-160 and 120-60 Ma intervals. After 60 Ma, when the craton moved southwestward, the major structures are dextral strike-slip faults that disrupted the established ancestral Canadian Cordillera. At times before ~140 Ma, when the craton moved northwestward, there is scattered evidence for southward (sinistral) movement relative to the craton. The correlation suggests that the craton probably acted as a "continental bulldozer" whose movements were the primary controls on Cordilleran deformation. Furthermore, the size and crustal permanence of the craton suggests it is the only element involved in Cordilleran orogenesis that could form a continental-scale mountain system.

(5) Alvarez (1982) and others suggested that plates that contain continents with deep (≥200 km) cratonal roots, such as the North America Plate, are moved primarily by convection in the lower mantle (the engine that powers our "continental bulldozer") rather than conventional ridge-push, trench-pull plate tectonic forces. The Mesozoic to early Cenozoic structural record along western and eastern flanks of the North American craton supports this concept (Bokelmann, 2002). Compression resulting in Cordilleran orogenesis dominated the western margin and was coeval with rifting and extension along the eastern margin associated with opening/spreading of the Atlantic basin. The opposite would be true if ridge-push and trench-pull were primary drivers of craton movement, with compression along the eastern margin caused by ridge-push and extension along the western margin caused by trench-pull.

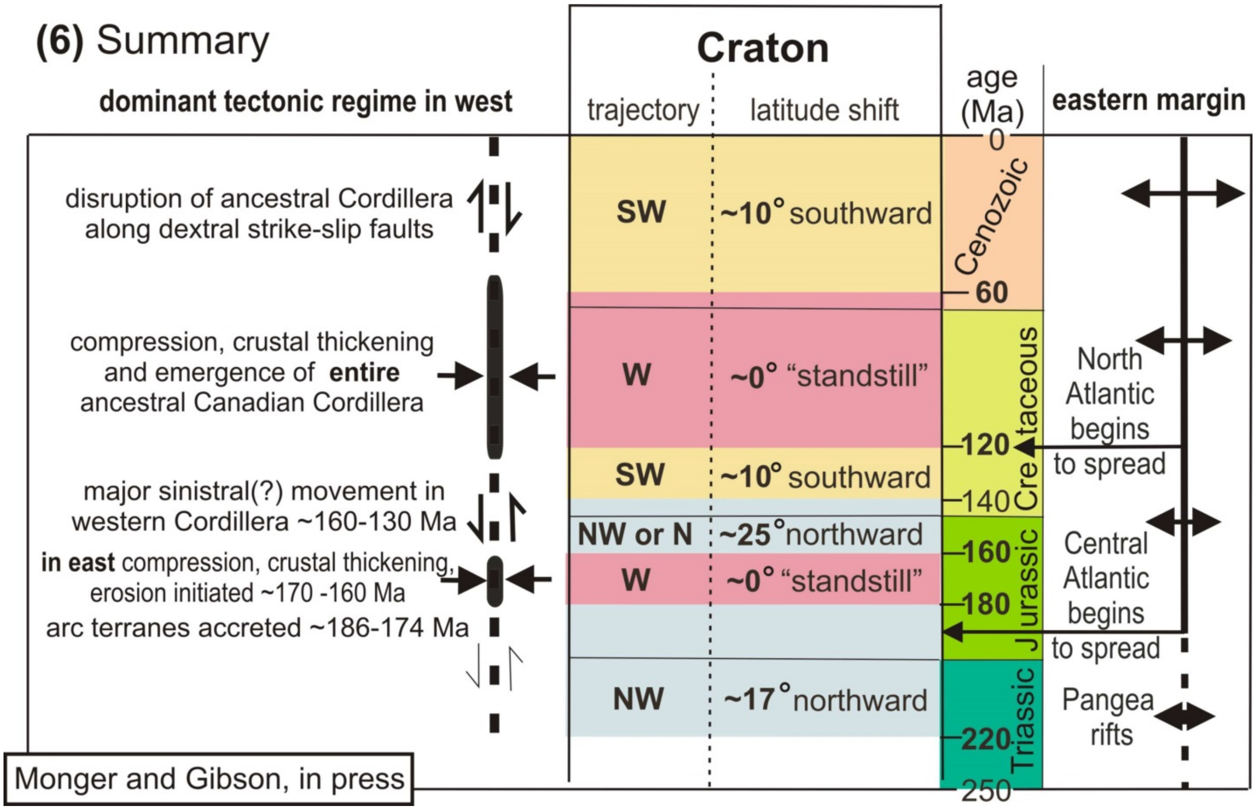

Figure 1. Correlation of tectonic events in the Canadian and Alaskan Cordillera with possible changes in the North American craton trajectory contrasted against the continuity of Atlantic Ocean floor spreading.

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Structural and metamorphic culmination in the Hyland River area of Southeastern Yukon

David Moynihan, Yukon Geological Survey, david.moynihan@gov.yk.ca
Jim Crowley, Department of Geosciences, Boise State University.

An elongate structural and metamorphic culmination underlies the upper Hyland River area of Southeastern Yukon. Deepest structural levels are exposed in the core of an upright, NW-trending anticlinorium (F3) centered around Anderson Lake in NTS 105H/10. The area is dominated by Neoproterozoic-Lower Cambrian siliciclastic and lesser carbonate rocks of the Hyland Group, and by voluminous granodioritic intrusions of the 105-106 Ma Hyland River suite. Layered rocks of the Hyland Group are deformed into tight-isoclinal, SW-verging folds (F2) with amplitudes up to 10-15 kms. These folds are arched over the crest of the anticlinorium (F3) and face downwards on its western flank. The Hyland Group was recrystallized during syn-kinematic (syn-D2) low pressure metamorphism, and isograds are approximately parallel to the dominant foliation (S2). In order of increasing metamorphic grade, the following metamorphic zones are developed: 1) a "background" phyllite zone (Chl + Ms), 2) An outer zone characterised by Bt + Ms ± Crd, St, 3) An andalusite zone (And + Bt + Ms ± St, Crd, Grt), 4) A sillimanite zone (Sil + Bt ± And, St, Grt) and 5) A sillimanite + K-feldspar zone (Sil + Kfs +Bt ± Crd, Grt). Monazite in sillimanite schist has yielded dates of 106-107 Ma (U-Pb TIMS), and syn-kimematic pegmatite was intruded into these schists during the interval 112-107 Ma (U-Pb TIMS). Deformation and peak metamorphism therefore appears to have immediately preceded intrusion of the post-kinematic Hyland River suite batholiths. The west side of the structural/metamorphic culmination is locally truncated by a west-dipping fault that juxtaposes schist/gneiss of the Hyland Group against low grade Paleozoic phyllite and calc-silicate. This fault is truncated by some parts of the Hyland River suite, and likely overlapped with its emplacement. Collectively, these constraints suggest syn-kinematic low-pressure metamorphism, formation of the anticlinorium and faulting of its western flank took place over a very short time interval during the mid-Cretaceous.

Geochronology and tectonic setting of the Turnagain Alaskan-type intrusion, Canadian Cordillera

Nixon, Graham T. - BC Geological Survey, Ministry of Energy, Mines and Petroleum Resources, graham.nixon@gov.bc.ca
Scheel, J.Erik, - Pacific Centre for Isotopic and Geochemical Research, University of British Columbia, Vancouver, B.C.,
Scoates, James S., - Pacific Centre for Isotopic and Geochemical Research, University of British Columbia, Vancouver, B.C.,
Friedman, Richard M., - Pacific Centre for Isotopic and Geochemical Research, University of British Columbia, Vancouver, B.C.,
Wall, Corey J., Department of Geosciences, Boise State University, USA
Gabites, J. - Pacific Centre for Isotopic and Geochemical Research, University of British Columbia, Vancouver, B.C.,
Jackson-Brown, Sarah - Pacific Centre for Isotopic and Geochemical Research, University of British Columbia, Vancouver, B.C.,

The magmatic evolution and Ni-Cu-PGE mineralization of the Early Jurassic Turnagain Alaskan-type intrusion is inextricably linked to accretionary events at the North American continental margin. We have calibrated the multi-stage evolution of the Turnagain ultramafic-mafic intrusion using high-precision air and chemical abrasion ID-TIMS U-Pb and $^{40}Ar/^{39}Ar$ geochronology. Three of four intrusive phases (Stages 1-4, oldest to youngest) were successfully dated. Cooling ages obtained on Stage 2 dunite-wehrlite include statistically identical $^{40}Ar/^{39}Ar$ plateau dates of 187.4 ± 1.5 (2σ) Ma on hornblende and 188.6 ± 1.2 Ma on phlogopite; and a concordant $^{206}Pb/^{238}U$ date of 190.3 ± 4.6 Ma on titanite. Stage 3 diorite has a $^{206}Pb/^{238}U$ zircon crystallization age of 188.11 ± 0.13 Ma; and Stage 4 wehrlite and leucodiorite yield $^{206}Pb/^{238}U$ zircon crystallization ages of 185.68 ± 0.19 Ma and 185.30 ± 0.12 Ma, respectively. The ca. 189 Ma phlogopite date represents a minimum crystallization age for Stages 1-2, indicating that assembly of the Turnagain intrusion spanned at least ~4 million years (ca. 189-185 Ma). Regional progressive contractional deformation in the Early Jurassic, constrained by the geochronological results (>189 to <185 Ma), initially generated northeast-vergent folds in the country rocks and deformed Stage 1 wehrlite-clinopyroxenite prior to emplacement of Stages 2-4; and subsequently thrust the intrusion and its host rocks onto the miogeocline. Mississippian meta-volcanic/sedimentary host rocks of the Turnagain intrusion are correlated with Upper Paleozoic arc and basinal assemblages of Yukon-Tanana and Quesnellia terranes. The Early Jurassic deformation records the initial accretion of allochthonous arc terranes in the northern Cordillera in accordance with current geodynamic models.

Bedrock Mapping near Spences Bridge, Southwest British Columbia defines extent of Murray dyke swarm and delimits timing of Cretaceous (Albian) deformational event

Ogloff, Anastasia, Simon Fraser University, aogloff@sfu.ca
Thorkelson, Derek, Simon Fraser University
Crowley, Jim, Boise State University

Recent geological mapping near Spences Bridge, B.C., reveals relations between the newly identified Murray dyke swarm and Cretaceous strata. The swarm consists of thousands of metre-wide north-striking dykes of basalt to dacite within a 2x10 km area. Volcaniclastic rocks and rhyolite dykes of the Pimainus Formation host the Murray swarm. Elsewhere the Pimainus is overlain by mafic lavas of the Spius Formation. These Formations compose the mid-Cretaceous Spences Bridge Group (~104 Ma), which is folded and metamorphosed to zeolite facies. Chert-pebble conglomerate overlies the group with angular unconformity and is unmetamorphosed. The conglomerate was derived from pre-Cretaceous units. Chert detritus is absent in the Spences Bridge Group. Taken together, folding, metamorphism, and erosion of the Spences Bridge Group and exhumation of pre-Cretaceous units indicates a deformational event that preceded deposition of the chert-pebble conglomerate. We correlate the chert-pebble conglomerate with the Pasayten Group and similar strata of Albian to Cenomanian age that collectively overlap the Intermontane and Insular terranes.

The core of the dyke swarm represents 1.4 km of east-west crustal dilation. The swarm is cross-cut by the sinistral Thompson fault, indicating that extension related to dyke emplacement was followed by transcurrent faulting. A recent U-Pb zircon result of 103 ± 1 Ma (2σ error) indicates the Murray dyke swarm is Cretaceous and part of the Spences Bridge Group in which it is hosted. Physically and geochemically indistinguishable dykes occur beyond the core of the Murray dyke swarm. Some of these outlying dykes cross-cut the chert-pebble conglomerate. If the outlying dykes are indeed part of the swarm, then the deformational event and chert-pebble conglomerate deposition coincided with the end of Spences Bridge Group volcanism and emplacement of the Murray dyke swarm at 103 Ma. A preliminary date of 48 Ma is interpreted to indicate that sparse, isolated, unrelated dykes of Eocene age cross-cut the Murray dyke swarm.

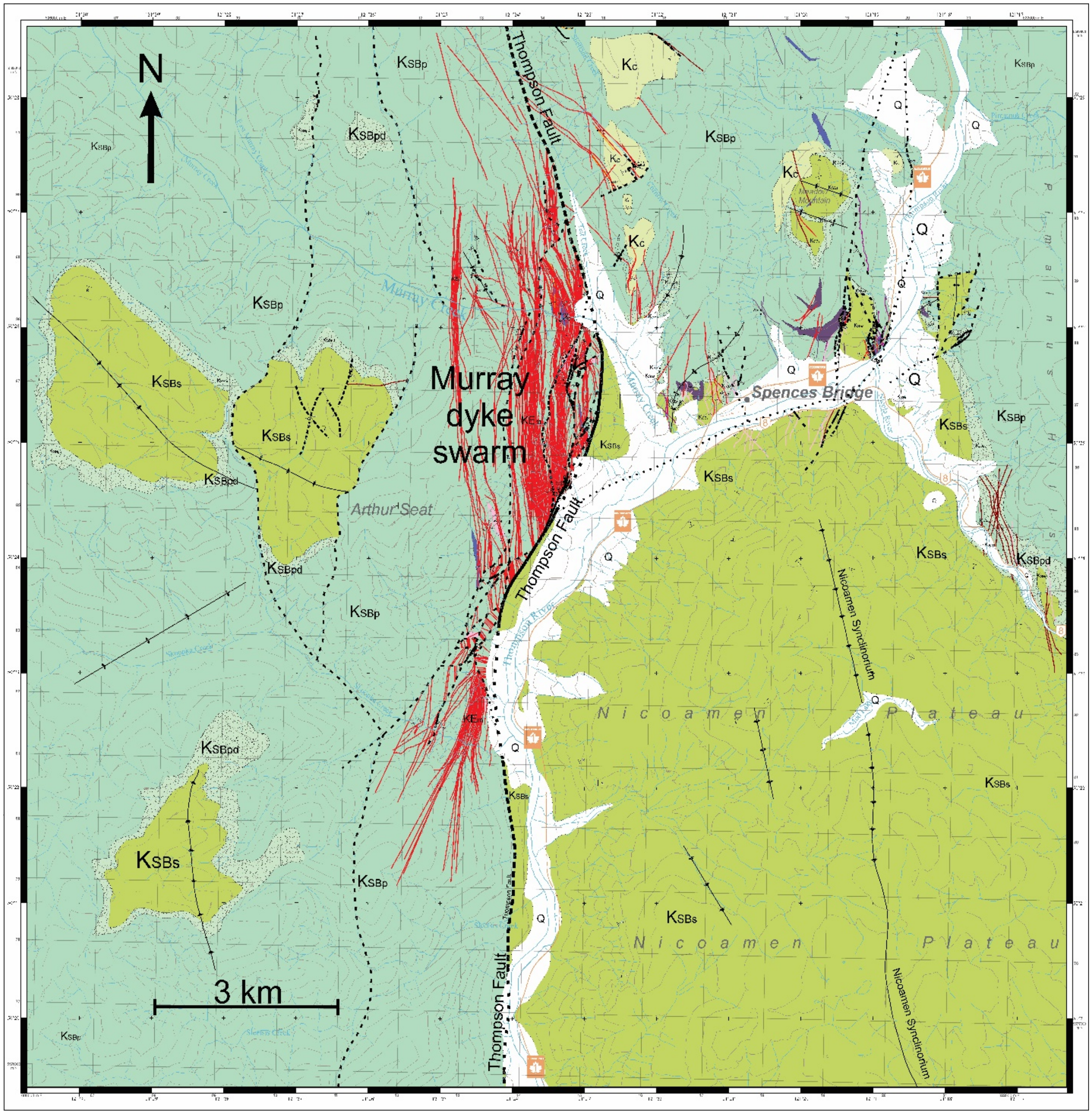

Figure 1. Map of bedrock geology near Spences Bridge, southwest British Columbia: Geological units: Q – Quaternary; Km – Cretaceous Murray dyke swarm; Kc – Cretaceous chert-pebble conglomerate; KSB – Cretaceous Spences Bridge Group (KSBp – Pimainus Formation volcanics; KSBpd – Pimainus Formation, Dot beds sedimentary rocks; KSBs - Spius Formation).

Petrography, geochemistry, and preliminary geochronology of xenoliths from the upper Hyland River region, southeastern Yukon

Padget, Colin D. W., University of Calgary, Calgary, Alberta, colin.padget@ucalgary.ca
Moynihan, David P., Yukon Geological Survey, Whitehorse, Yukon
Crowley, James L., Boise State University, Boise, Idaho
Pattison, David R. M., University of Calgary, Calgary, Alberta

A suite of over 50 upper mantle and lower crustal xenoliths were collected from undeformed basanite dykes that intrude Neoproterozoic-Palaeozoic metasedimentary rocks in the upper Hyland River region of southeastern Yukon. Ultramafic xenoliths are the most abundant and consist of spinel-bearing lherzolites, with lesser olivine websterites including four plagioclase-bearing samples and one amphibole-bearing sample. Dominantly granulite facies paragneisses, with subordinate felsic and mafic orthogneiss samples are interpreted to be crustal xenoliths. The xenoliths occur as discrete subrounded to subangular fragments up to 8 cm in maximum dimension. Lherzolite samples consist of olivine (~Fo90), orthopyroxene (Mg# 0.90), clinopyroxene (Mg# 0.88-0.90), brown spinel (Mg# 0.76; Cr# 0.1), and Fe-Ni sulphide, and exhibit a protogranular texture. Pressure conditions are constrained through the calculation of isochemical P-T phase diagrams in the Na_2O-CaO-FeO-MgO-Al2O_3-SiO_2-Cr_2O_3 system for spinel lherzolite samples. Estimated pressures range from 10-15 kbar. Two-pyroxene Fe-Mg exchange thermometry from 17 peridotite samples gives equilibrium temperature estimates of 980 – 1100℃ at 12.5 kbar, with a pressure dependency of less than 5℃/kbar. Granulite facies paragneiss samples contain plagioclase, K-feldspar, orthopyroxene, garnet, sillimanite, quartz, graphite, monazite, and zircon. Numerous samples contain 1-8 mm rounded domains of patchy, symplectic intergrowths of plagioclase, spinel, and orthopyroxene. These domains are interpreted as pseudomorphs after garnet, which may record various stages of post-peak metamorphic decompression. Estimates of pressure and temperature for these samples are approximately 11.5 kbar and 925℃, respectively. Preliminary U-Pb TIMS on zircon grains recovered from two lherzolite samples yielded Eocene ages of ~ 44 Ma. Initial U-Pb zircon analyses by LA-ICP-MS on mineral separates from a granulite-facies paragneiss sample gives ages as young as ~ 31 Ma, constraining the age of the intrusion of these dykes to the Oligocene or younger.

New U-Pb zircon ages from Jurassic strata, SW Alberta and SE British Columbia

Terence P. Poulton., Geological Survey of Canada
Dinu I. Panâ., Alberta Geological Survey, Alberta Energy Regulator
Larry M. Heaman., University of Alberta
S. A. Dufrane., University of Alberta

A project funded by the Alberta Geological Survey has produced new single grain ID-TIMS U-Pb ages from zircon grains in volcanic ash layers, as well as LA-MC-ICPMS detrital zircon (DZ) age spectra from clastic units throughout the ammonite-bearing, marine Jurassic succession in SW Alberta and SE British Columbia. The samples come from the Fernie Formation, dominantly shale with sandstones and limestones, which encompasses nearly the entire Jurassic succession in the foreland basin. The study included updating some ammonite biostratigraphy and the lithostratigraphic framework, requiring some revisions compared with previous compilations: the Nordegg Member, with *Amaltheus*, is late Pliensbachian and the Gryphaea Bed with early *Kepplerites* is about earliest middle Bathonian.

Episodic western volcanic input has long been recognized through the Jurassic sequence in western Alberta; the predominant ages coincide with major Cordilleran tectonic/igneous events in nearby Omineca and southeastern Quesnellia terranes, as well as with events farther west. Ash layers from the Nordegg Member (below the *Amaltheus* occurrences) and the Lower Fernie phosphatic shale (with only early Sinemurian ammonites known), produced U-Pb ages from 185.24 to 187.2 Ma, probably about mid-Pliensbachian. DZ samples from the Gryphaea Bed silty bioclastic limestone produced identical maximum depositional ages (MDA) of 169 Ma, in a narrow coherent group comprising nearly all the zircon ages and likely representing an ash fall redistributed in the carbonate sediment. The Green Beds glauconitic sandstone, with early and middle Oxfordian *Cardioceras* spp. and the late Oxfordian-early Kimmeridgian bivalve *Buchia concentrica*, produced TIMS single grain ages of 152.2 and 157.8 Ma. The laser ablation age spectrum for one sample forms a tight coherent group with an age of ca. 156 Ma, encompassing most of the grains and suggesting a single Oxfordian or early Kimmeridgian source.

Younging MDA's matching ammonite-controlled ages, characterize most of the Jurassic sequence, except for the Upper Jurassic Nikanassin and Morrissey (basal Kootenay Group) sandstones which only contain older grains. The DZ spectra are dominated by pre-depositional Phanerozoic and Precambrian ages, from eastern and southern original sources, introduced from elevated western basinal strata and from the continental western interior US. A minor component of Paleozoic grains throughout the Jurassic strata must have come from western accreted terranes ultimately.

We propose two alternative models within the conventional compressional accretionary paradigm, tying Early Jurassic Quesnellia obduction, mid-Jurassic Omineca orogen-building and Late Jurassic easterly thrust-transport to eastern foreland basin subsidence. Early Cretaceous (~125-115 Ma) Pb loss, recognized by modelling of discordant U-Pb data, coincides roughly with diagenetic remagnetization in front of the easterly-migrating tectonic wedge, with batholithic and tectonothermal activity in a wide transpressional zone on the west side of the Rocky Mountain thrust and fold belt, and with the widespread sub-Cadomin, sub-Mannville unconformity in the foreland basin.

The new and previously existing zircon age data for Alberta highlight the lack of high-precision radiometric control for the Middle and Upper Jurassic stage boundaries. It proved impossible to reconcile the combined U-Pb and ammonite ages with the current International Chronostratigraphic Chart. Therefore, we compiled our data in a correlation chart that uses certain other published age data for the Middle and Upper stage boundaries, which differ from those on the current time chart.

The Jurassic system badly needs more radiometric age control on biostratigraphically dated strata, and the Canadian Cordillera is a prime source of data.

The Interplay between Deformation and Metamorphism in the Interface between the Purcell Anticlinorium and the Kootenay Arc

Rioseco, Nicole A., University of Calgary, nicole.rioseco@ucalgary.ca
Pattison, David R.M., University of Calgary

The aim of this project is to elucidate the nature of the structural, metamorphic and thermochronological interface between two metallogenically prolific, yet contrasting, tectonothermal domains in southeastern British Columbia: the Purcell Anticlinorium (PA) and the Kootenay Arc (KA). The Purcell Anticlinorium mainly comprises strata of the Mesoproterozoic Belt-Purcell and Neoproterozic Windermere supergroups. The Kootenay Arc mainly comprises Windermere Supergroup strata, Paleozoic cratonic marginal sequences and obducted Jurassic arc-related rocks. The interface between the two domains is characterised by increasing intensity of deformation and metamorphism from the PA to the KA. Ar/Ar cooling ages in micas indicate that metamorphism and exhumation of the central part of Purcell Anticlinorium took place during the Proterozoic. The Kootenay Arc, however, records a metamorphic and exhumation history that is Mesozoic to Cenozoic in age. The structural boundary between the two domains is defined where an S_1 slaty cleavage (S_{1PA}) in generally undeformed rocks of the Purcell Anticlinorium is overprinted by a penetrative phyllitic schistosity (S_{1KA}) characteristic of the Kootenay Arc. This boundary occurs in strata of the upper part of the Belt-Purcell Supergroup. There is no discernable change in metamorphic grade across the structural interface, as both regions fall within the biotite zone, but differences in the timing of peak metamorphism are revealed by contrasting porphyroblast-deformation microstructures. Using these criteria, the metamorphic interface roughly coincides with the structural interface. New Ar-Ar data across the structural-metamorphic interface will constrain the timing of these events.

Mid-Cretaceous core complexes in Yukon: parautochthon exposed through a thin flap of allochthonous Yukon-Tanana terrane

Ryan, Jim., Geological Survey of Canada, Vancouver; jim.ryan@canada.ca
Zagorevski, Alex., Geological Survey of Canada, Ottawa
van Staal, Cees., Geological Survey of Canada, Vancouver
Joyce, Nancy., Geological Survey of Canada, Ottawa
Staples, Reid., Douglas College, New Westminster
McClelland, Bill., University of Iowa

Highly deformed and metamorphosed parautochthonous rocks of the ancestral North American margin (PNA) are structurally exposed beneath the allochthonous Yukon-Tanana terrane (YTT) in Yukon (Canada). The YTT is founded on Snowcap assemblage basement that was once part of the ancestral PNA, and thus both are very similar in composition and age, making their discrimination difficult. The timing of middle to upper amphibolite facies regional metamorphism recorded in both PNA and YTT is not well constrained, and the structural interface between them is obscured by the poly-episodic, high-strain deformation. The intensity of deformation in both PNA and YTT makes it difficult to distinguish contractional and extensional structures, and to precisely locate the contacts locally. Ongoing research demonstrates that the PNA is characterized by pre-late Devonian metasedimentary successions with voluminous latest Devonian to earliest Mississippian plutons and Middle Jurassic to mid-Cretaceous metamorphism. In contrast, the YTT is characterized by voluminous Mississippian to middle Permian magmatism, and Mississippian to Middle Jurassic metamorphism and tectonism, which are absent in PNA. Regional geologic relationships indicate that the Intermontane terranes, including YTT, currently form a relatively thin nappe on a footwall of semi-continuous PNA that extends southwest of the nappe to at least the Denali fault. Structural windows through the thinned allochthonous upper plate expose PNA in west-central Yukon and eastern Alaska as mid-Cretaceous extensional core complexes. These core complexes are characterized by Middle Jurassic to mid-Cretaceous metamorphism, and a lack of Mississippian to middle Permian magmatism.

Interactions Between Regional Deformation and Pluton Emplacement: Interpreting the Deformation history of the Cantung W-Cu-Au Skarn Deposit

Salmabadi, Ehsan, University of British Columbia; esalmabadi@eoas.ubc.ca
Hickey, Kenneth A., University of British Columbia,
Falck, Hendrik, Northwest Territories Geological Survey, Yellowknife, NT

The Cantung W-Cu-Au skarn is hosted in the hinge and lower limb of a sub-horizontal plunging, near-recumbent, fold (the “mine antiform”) that is discordant to the regional fold train. The mine antiform folds Cambrian Sekwi Formation carbonates and Neoproterozoic siliciclastic rocks of the Vampire Formation around a shallow south to southwest-dipping axial plane. Along the lower limb of the antiform, the sedimentary units are in contact with a Mid-Cretaceous felsic pluton of the Tungsten Suite (the “mine stock”). The regional fold geometry outside the mine consists of upright, sub-horizontal plunging, NW-SE striking macroscopic folds. Geological mapping conducted in the area around Cantung has not recognized any regionally developed structures or fabrics that can be kinematically associated with the mine fold antiform. The antiform is interpreted to be a localized feature related to pluton emplacement and upward “bulging” of the felsic intrusion that underlies the deposit. Sub-vertical shortening and flow of Vampire and Sekwi Formation rocks occurred during emplacement of the intrusion. Thermal weakening focused shortening within the contact metamorphic aureole. Shortening resulted in the development of a gently dipping S_2 crenulation cleavage. Sekwi units immediately above the mine stock flowed ductily. The sub-vertical shortening predates mineralization and may correspond to the emplacement of a larger parent magma body prior to final emplacement of Mine Stock.

Protracted Monazite Growth in the Klondike Gold District, Western Yukon

Stroh, Brodie, Mineral Deposit Research Unit – University of British Columbia, bstroh@eoas.ubc.ca
Ambrose, Tyler, Mineral Deposit Research Unit – University of British Columbia
Hart, Craig, Mineral Deposit Research Unit – University of British Columbia
Allan, Murray, Teck Resources Limited

Constraining the timing of orogenic gold mineralization is challenging because datable minerals are typically small, may be reset, or their relationship to gold mineralization is poorly constrained. The most common method, $^{40}Ar/^{39}Ar$ dating of hydrothermal micas, is susceptible to resetting and difficult to resolve from regional cooling. U-Th-Pb dating of hydrothermal or hydrothermally-modified pre-existing monazite can be a robust alternative method to date mineralization. However, linking monazite formation to the mineralization process, or even to vein formation, can be difficult because monazite may grow by multiple, possibly overlapping processes. For example, monazite can grow during both prograde and retrograde metamorphism. Additionally, it can also precipitate from fluids in and adjacent to veins. Distinguishing between these growth processes is vital in providing the correct geological significance to geochronological data.

The estimated 20 million ounces of placer gold mined in the Klondike gold district was derived from orogenic gold-bearing quartz veins. The timing of mineralization is broadly constrained to the Jurassic based on $^{40}Ar/^{39}Ar$ mica ages and a single U-Pb age from hydrothermal rutile. However, direct dating of gold mineralization and associated geological processes by U-Th-Pb dating of monazite has not been attempted. The Klondike provides an opportunity to study the growth processes of monazite and provide meaningful age constrains on mineralization. To do so, we collected samples from vein material, altered wall rock, and relatively unaltered host rock from several localities. Monazite dates, trace element geochemistry, and detailed petrographic analyses were integrated to distinguish between growth processes.

Our results reveal protracted monazite growth in the Klondike from the Early Jurassic to mid-Cretaceous. At one locality, monazite analyses with high ThO_2 concentration correspond to older dates and grains elongate in the metamorphic fabric, consistent with a metamorphic origin. In contrast, analyses with low ThO_2 concentration are younger and correlate to grains intergrown with hydrothermal phases such as pyrite, consistent with a hydrothermal origin. These results suggest that ThO_2 concentration is a potential proxy for monazite growth mechanisms. However, at another locality, there is no relationship between monazite dates/texture and ThO_2 concentration. This may be explained by ThO_2 concentration not being a reliable proxy or monazite at this locality growing by a blended metamorphic-hydrothermal process. These results provide insight into identifying monazite growth mechanisms in orogenic gold settings and constrain the timing of veining in the Klondike.

Tectonic Significance of Ductile Structures in the Chelan Mountains Terrane, North Cascades, WA

Weldon, Nyle, Western Washington University, weldonn@wwu.edu
Schermer, Elizabeth, Western Washington University

We investigate the metamorphism and deformation of the Chelan Mountains (CM) terrane in the NW Cascades to understand the relative roles of different proposed mechanisms of Late Cretaceous crustal thickening and the relationship to arc magmatism and plate boundary processes. Field observations confirmed the stratigraphy of a Permian to Triassic arc recognized by previous workers, including, from bottom to top: Marblemount Meta-Quartz Diorite (MMQD), Cascade River unit (CRu), consisting of metavolcanics overlain by metaconglomerate and metapelite, and Magic Mountain Gneiss (a Permian to Jurassic (?) sill complex). The first deformation (D1) is preserved as a strong foliation (S1) and weak lineation formed at greenschist to amphibolite facies in all units. The second deformation (D2) folded this fabric into map scale to outcrop scale, tight to isoclinal, rounded, parallel folds. The orientation of these folds varies from recumbent to upright due to later refolding. Recumbent F2 folds verge NW and SE. D3 is preserved as moderately to steeply dipping mylonitic foliation (S3) with moderately SE plunging stretching lineations along the contact of the CRu and the MMQD. Sense of shear indicators show top to the NW and dextral shearing during D3. Although the order of D2 and D3 is not certain, D3 shearing appears to be later because it is lower grade and F2 folds do not fold mylonitic fabric. D4 is preserved as small-scale open to close, rounded, parallel, upright folds that plunge NW to SE and a large-scale SE-plunging anticlinorium.

The following sequence of events is interpreted to reflect plate-boundary kinematics during Cretaceous time based on this and previous studies. D1 may have occurred during accretion of the CM terrane, with unclear kinematics. The vergence of F2 folds may reflect NW or SE translation and orogen-parallel motion. The dextral, NW-vergent mylonitic fabric reflects orogen-parallel shear similar to D2. The orientation of F4 folds suggests orogen-normal subduction. The more open folding of D4, compared to the large-scale isoclinal recumbent F2 folds (recognized by overturned stratigraphy), indicate that D4 accommodated less shortening than D2.

Jurassic synorogenic sedimentation along the Yukon-Tanana—Slide Mountain terrane boundary: Faro Peak formation, central Yukon

Wiest, Adam, Department of Earth Sciences, Memorial University of Newfoundland, acwiest@mun.ca
Beranek, Luke, Department of Earth Sciences, Memorial University of Newfoundland

Late Triassic-Early Jurassic plate convergence and collision along the northern Cordilleran margin resulted in the exhumation of Intermontane terranes and generation of overlapping synorogenic basins. The Whitehorse trough is one such basin that constrains the timing of Jurassic exhumation along the Stikinia-Quesnellia-Yukon-Tanana-Cache Creek boundary zone in central Yukon and northern British Columbia. Enigmatic strata informally referred to as the Faro Peak formation similarly crop out adjacent to the Yukon-Tanana – Slide Mountain terrane boundary in the Faro region of central Yukon. These strata may be correlative with synorogenic rocks in the Whitehorse trough or comprise an isolated sub-basin that developed during Intermontane belt exhumation. A two-year field project was initiated in summer 2018 to test these and other hypotheses and constrain the role of Intermontane tectonics on Faro Peak formation deposition.

The Faro Peak formation consists of two members that crop out immediately south of the Vangorda fault and sit unconformably on Yukon-Tanana basement. The lower member mostly consists of argillite and massive sandstone units with local evidence of soft-sediment deformation and tabular bedding. Angular plagioclase crystals and volcanic lithic fragments suggest a proximal mafic-intermediate igneous provenance for some lower member rocks. The stratigraphic features of the lower member are generally consistent with subaqueous deposition by concentrated density flows or turbidity currents. Massive, disorganized conglomerate units that contain up to boulder-sized clasts of local Yukon-Tanana schist and quartzite (Snowcap assemblage), Slide Mountain chert and argillite (Campbell Range formation), and limestone and intermediate-felsic intrusive rocks of uncertain origin characterize the upper Faro Peak formation. The massive, clast- to matrix-supported nature of these conglomerate units may indicate deposition adjacent to the Vangorda fault or its predecessor. Our working hypothesis calls for upper Faro Peak formation strata to record non-turbulent, concentrated debris or density flow deposition in a subaqueous environment.

Detrital zircon U-Pb-Hf studies of the Faro Peak formation are ongoing and designed to constrain maximum depositional ages, provenance of intrusive rock clasts, and source-to-sink pathways in central Yukon during regional exhumation. Analogous provenance studies of Snowcap assemblage metasedimentary rocks are also in progress to develop a detrital zircon U-Pb-Hf reference frame for local Yukon-Tanana basement that was exhumed during Faro Peak deposition. These data will be combined with field results to test stratigraphic correlations with the Whitehorse trough and published strike-slip/transtensional models for synorogenic basin development in central Yukon during the early growth of the Cordilleran orogen.

List of registrants, their affiliation and contact information;

Name	Affiliation	Email Address
Allan, Murray	Teck Resources	murray.m.allan@gmail.com
Ambrose, Tyler	UBC-MDRU	tyler.k.ambrose@gmail.com
Beranek, Luke	MUN	lberanek@mun.ca
Binner, Megan	SFU	megan_binner@sfu.ca
Caine, Jonathan	USGS	jscaine@usgs.gov
Calvert, Andy	SFU	acalvert@sfu.ca
Cleven, Nathan	GSC-Vancouver	nathan.cleven@canada.ca
Cobbett, Rosie	YGS	rosie.cobbett@gov.yk.ca
Colpron, Maurice	YGS	Maurice.Colpron@gov.yk.ca
Cooper, Mark	Sherwood Geoconsulting	mark@sherwoodgeo.com
Crowley, Jim	Boise State University	jimcrowley@boisestate.edu
Dyck, Brendan	SFU	brendan_dyck@sfu.ca
Enkelmann, Eva	U Calgary	eva.enkelmann@ucalgary.ca
Fischer, Bill	SFU	bill.fischer555@gmail.com
Friend, Melissa	UBC-MDRU	mfriend@eoas.ubc.ca
Gibson, Dan	SFU	hdgibson@sfu.ca
Golding, Martyn	GSC	martyn.golding@canada.ca
Hayward, Nathan	GSC - Vancouver	nathan.hayward@canada.ca
Holm-Denoma, Chris	USGS	cholm-denoma@usgs.gov
Huang, Chuqiao	SFU	stcr_2@Hotmail.com
Israel, Steve	Archer-Cathro	sisrael@archercathro.com
Jones, James	USGS-Alaska	jvjones@usgs.gov
Kennedy, Lori	UBC	lorikenn@gmail.com
Kraft, Jamie	Teck Resources	jamie.kraft@teck.com
Kreiner, Douglas	USGS	dkreiner@usgs.gov
Laverge, Margaret	UBC	maggielaverge96@gmail.com
Long, Darrel	Laurentian	dlong@laurentian.ca
Manor, Matthew	MUN	mjmanor@mun.ca
McClelland, Bill	University of Iowa	bill-mcclelland@uiowa.edu
Mckenzie, Will	SFU	willfmckenzie@outlook.com
Miller, Emily	UBC	emiller@eoas.ubc.ca
Monger, Jim	GSC	jimonger@shaw.ca
Mortensen, Jim	UBC	mortdunord@gmail.com
Morton, Jack	Archer-Cathro	jmorton@archercathro.com
Moynihan, David	YGS	david.moynihan@gov.yk.ca
Murphy, Don	YGS	dmurphy@northwestel.net
Naber, Tiera	UBC	tvnaber@eoas.ubc.ca
Nelson, JoAnne	BCGS	JoAnne.Nelson@gov.bc.ca
Nixon, Graham	BCGS	Graham.Nixon@gov.bc.ca
Ogloff, Anastasia	SFU	aogloff@sfu.ca
Padget, Colin	U Calgary	colin.padget@ucalgary.ca
Pattison, Dave	U Calgary	pattison@ucalgary.ca
Peddle, Cameron	U of Alberta	cpeddle@ualberta.ca
Poulton, Terence	GSC - Calgary	terry.poulton@canada.ca
Rabayrol, Fabien	UBC	frabayrol@eoas.ubc.ca

Rioseco, Nicole	U of Calgary	nicole.rioseco@ucalgary.ca
Ryan, Jim	GSC	jim.ryan@canada.ca
Salmabadi, Eshan	UBC-MDRU	esalmabadi@eoas.ubc.ca
Schermer, Liz	Western Washington U	schermer@wwu.edu
Schiarizza, Paul	BCGS	Paul.Schiarizza@gov.bc.ca
Schmitz, Mark	Boise State University	markschmitz@boisestate.edu
Skipton, Diane	YGS	diane.skipton@canada.ca
Staples, Reid	Douglas College	rstaple4@douglascollege.ca
Steiner, Andrew	UBC-MDRU	astein@eoas.ubc.ca
Strauss, Justin	Darmouth U	Justin.V.Strauss@dartmouth.edu
Stroh, Brodie	UBC-MDRU	bstroh@eoas.ubc.ca
Thiessen, Eric	SFU	ericjamesthiessen@gmail.com
Thompson, Gary	Brixton Metals	admin@brixtonmetals.com
Thorkelson, Derek	SFU	dthorkel@sfu.ca
van Staal, Cees	GSC-Vancouver	cees.vanstaal@canada.ca
Warren, Marian	Jenner GeoConsulting	marian@jennergeo.com
Weldon, Nyle	Western Washington U	weldonn@wwu.edu
Wiest, Adam	MUN	adamwiest20@gmail.com
Willms, Kelson	Archer-Cathro	kwillms@archercathro.com