



# **Cordilleran Tectonics Workshop**

**February 21-23, 2025**

**SFU, Burnaby, British Columbia**

*View of Breakenridge complex, looking north*

## 2025 Cordilleran Tectonics Workshop

*Diamond Alumni Centre, Simon Fraser University, Burnaby, British Columbia.*

### **Friday, February 21<sup>st</sup>, 2025**

6:00 – 9:00 PM ***Icebreaker, Registration & Poster setup***

### **Saturday, February 22<sup>nd</sup>, 2025**

***Speaker Abstract***

8:30 AM ***Coffee, muffins & posters***

9:25 AM Opening remarks *Dan Gibson*

9:35 AM Tribute to Ray Price *Maurice Colpron*

9:45 AM Evolution of Cordilleran concepts over the last three decades *Maurice Colpron* **6**

10:25 AM Silurian-Devonian syn-tectonic intrusive complex and clastic overlap sequence in southern Alexander terrane record interaction of peri-Laurentian and peri-Baltican lithospheric blocks in the paleo-Arctic realm *JoAnne Nelson* **7**

10:45 AM Geochemical, geochronological and metallogenic characteristics of Cretaceous magmatism in eastern Alaska: a new piercing zone along the Tertiary Tintina fault? *Douglas Kreiner* **9**

11:05 AM ***Discussion, coffee and posters***

12:00 PM ***Lunch***

1:00 PM Evidence for significant Cretaceous – Cenozoic dextral slip displacement north of the active Denali fault strand, Eastern Alaska Range *Sarah Roeske* **11**

1:20 PM Back to the future: highly radiogenic Pb in the Ogilvie platform, central Yukon *Tyler Ambrose* **13**

1:40 PM Sequence stratigraphic framework for sediment-hosted ore deposits in the Late Devonian Earn Group, Yukon, Canada *Sarah Schultz* **15**

2:00 PM Coffee Project open file update and results *Alex Brubacher* **16**

2:20 PM Lithospheric mantle density variations and thermally induced tectonics of the Canadian Cordillera from the seismically constrained modelling of gravity data *Nathan Hayward* **17**

2:40 PM ***Discussion, coffee and posters***

3:20 PM A review of inverted fault systems and inversion tectonics in the ancestral North American Canadian Cordillera and Foreland Basin *Marian Warren* **19**

3:40 PM Newly proposed regional correlations of Neoproterozoic Windermere Supergroup stratigraphy in the southern Canadian Cordillera *Bill Arnott* **21**

4:00 PM The Okanagan subterrane: a ‘Subduction Initiation Rule’ ophiolite in the Canadian Cordillera *Gerri McEwen* **22**

4:20 PM	Cretaceous to Miocene exhumation of the Purcell Mountains, southeastern British Columbia	<i>Douglas MacLeod</i>	<b>23</b>
4:40 PM	Contact-metamorphosed to regionally-metamorphosed pelites: the natural record	<i>Dave Pattison</i>	<b>24</b>

5:00 PM ***Discussion, posters and beverages***

6:00 PM **BierCraft Restaurant**

***Sunday, February 23<sup>rd</sup> 2025*** ***Speaker*** ***Abstract***

8:30 AM ***Coffee, muffins & posters***

9:30 AM	Two-Phase Delamination Magmatism and Exhumation: Refined Chronostratigraphy of the Challis-Kamloops Group and the Early Eocene Tectonic Evolution of the Pacific Northwest	<i>Eric Schmidtke</i>	<b>25</b>
9:50 AM	Late Triassic Kamloops picrites, southwestern British Columbia: Degassing-driven ascent and explosive eruption of picritic slurries in arc settings	<i>Dejan Milidragovic</i>	<b>26</b>
10:10 AM	Porphyry copper formation driven by water-fluxed crustal melting during flat-slab subduction: Insights from the Laramide Belt, SW USA	<i>Thomas Lamont</i>	<b>27</b>
10:30 AM	The Upper Crust of the Southwestern North American Cordillera was Eroded in Response to Laramide Flat-Slab Subduction	<i>Emilia Caylor</i>	<b>28</b>
10:50 AM	Taking the Pulse of Cenomanian-Turonian Cordilleran Magmatism using West Texas research cores with over 275 bentonites	<i>Steve Bergman</i>	<b>29</b>
11:10 AM	Forearc depression formation in warm subduction zones	<i>Chuiqiao Huang</i>	<b>30</b>

11:30 AM ***Concluding Remarks & Where Next?***

12:00 PM ***Lunch, Discussion, and posters***

1:30 PM ***END OF CONFERENCE***

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# *Talk Abstracts*



*Camp in Selkirk Mountains, SE BC, looking south ~along trend of Selkirk Fan axis; within Windermere Supergroup*

## Evolution of Cordilleran Concepts Over the Last Three Decades

*Maurice Colpron*

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The early 1990s marked a turning point in understanding of the Canadian Cordillera with publication of the comprehensive synthesis of current knowledge in *Geology of Canada No. 4 – Geology of the Cordilleran orogen in Canada (aka the DNAG volume)*. This synthesis summarized pioneering work in the Canadian Cordillera on the heels of the plate tectonics revolution and development of the terrane concept.

I began studying the Cordillera in 1990 using the framework of suspect terranes as guiding hypothesis. Over the last three decades, significant advances were made in resolving the paleogeographic affinities and tectonic evolution of Cordilleran terranes. In this presentation I will highlight some of these advances, including my contributions to this evolving understanding of the complexities of the Cordilleran orogen. My contributions are anchored on bedrock mapping and guided by two main principles: 1) a bedrock map is a working hypothesis; and 2) the *Truth* lies in the rocks. Analytical results for samples collected in mapping must be used to test and improve the map and always be reconciled with field observations.

Proposed links between the Paleozoic tectonic development of the Arctic and the western Laurentian margin highlight the role of strike-slip faults and the influence of cratonal drift as a driving force in orogenesis. Advances in U-Pb geochronology of igneous and detrital zircons are critical to developing new interpretations. The westward translation of terranes from the northern Caledonides to Panthalassa resulted in Late Devonian initiation of subduction along western Laurentia. The northward drift of Laurentia through the late Paleozoic accommodated southward propagation of subduction, sinistral transport of terranes and segments of the continental margin, and opening of the Slide Mountain Ocean. In the early Mesozoic, the westward drift of North America led to initial collision of the Intermontane terranes in the north and southward retreat of the Jurassic subduction accommodated by development of a sinistral transform system. This sinistral transform system led to development of the Whitehorse trough and enclosure and imbrication of the Atlin/Cache Creek terranes by the Middle Jurassic. This evolving tectonic framework provides a foundation for developing regional metallogenetic models for the northern Cordillera.

**Silurian-Devonian syn-tectonic intrusive complex and clastic overlap sequence in southern Alexander terrane record interaction of peri-Laurentian and peri-Baltican lithospheric blocks in the paleo-Arctic realm**

*JoAnne Nelson<sup>1</sup>, J. Brian Mahoney<sup>2</sup>, George Gehrels<sup>3</sup> and Mark Pecha<sup>3</sup>*

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The southernmost Alexander terrane in north coastal British Columbia comprises three major units. Oldest is the Descon Formation (Ordovician), a juvenile arc-related volcanic-sedimentary-intrusive complex that continues into southeast Alaska; farther north the Donjek assemblage (Cambro-Ordovician) in the St. Elias Mountains is interpreted as the corresponding pericratonic back-arc region. Prominent 565-760 detrital zircon peaks in the Donjek assemblage reflect a northern Baltican (Timanian) origin. In north coastal British Columbia, Descon volcano-sedimentary units are cut by gabbro-diorite-granodiorite-tonalite dikes, sills and plutons of the Ogden Channel syntectonic intrusive complex (Late Silurian-Early Devonian; 425-410 Ma). In the complex, the younger, less-foliated, greenschist-grade phases cut older highly foliated phases that contain amphibolite to epidote amphibolite-facies metamorphic assemblages, suggesting that burial followed by unroofing accompanied intrusion. The complex is bounded by regional west-northwesterly faults, the Grenville Channel and Kitkatla faults, that localized major Cretaceous sinistral-ductile motion. The prevailing northerly strike of flattening foliations in older phases suggests a sinistral shear couple between the proto-Grenville Channel and proto-Kitkatla faults. This deformation was coeval with the Klakas orogeny in its type area on southern Prince of Wales Island in southeast Alaska.

The youngest unit, the Mathieson Formation (Lower-Middle Devonian), is a siliciclastic sequence of arenitic to arkosic sandstone, siltstone, plutonic-volcanic cobble conglomerate, with minor limestone, basalt and rhyolite, that extends over 200 km along strike and 50 km across-strike. It is analogous to but slightly younger than the Karheen Formation (uppermost Silurian-Lower Devonian) on southern Prince of Wales Island, which has been interpreted as an Old Red Sandstone-like strike-slip basin. Two Mathieson facies belts are separated across the Grenville Channel fault: an eastern, proximal facies that includes conglomerates, rhyolites, basalts, and relatively thick limestones; and a western, distal facies of sandstone, siltstone, and thin-bedded to laminated siltstone-calcareous rhythmites. Along its eastern margin conglomerates and sandstones lie unconformably on Descon volcanic units. At one locale on Swindle Island south of Klemtu, the western facies overlies a basal sedimentary breccia composed of quartzite clasts. The main detrital zircon peak in the quartzite breccia is ca 1660 Ma, with lesser Mesoproterozoic peaks ca 1460, 1380, and 1150 Ma. The youngest grain is  $934 \pm 121$  Ma. Its source is probably a Tonian quartzose sedimentary unit that was exotic to the juvenile Alexander terrane of southeast Alaska. Detrital zircon signatures in the rest of the Mathieson Formation represent two distinct crustal sources: All eastern facies samples and some from the western facies show prominent Ordovician to Early Devonian peaks, corresponding to local Descon and Ogden Channel igneous ages; these profiles overlap detrital signatures from the Karheen Formation. These samples contain few or no Precambrian grains. Other western facies samples contain abundant Precambrian grains; their populations overlap with those from siliciclastic samples from Banks Island and other westerly islands, which are separated from the current study area by the Principe Laredo fault. The westerly siliciclastic occurrences were termed the Banks Island assemblage by Tochilin et al. (2014).

In depositional age, character and detrital zircon age-Hf signature, the Banks Island closely resembles the Icefield Ranges assemblage in the northern Alexander terrane in the St. Elias Mountains, a Silurian-Devonian clastic overlap assemblage that overlies the Donjek assemblage. In age-Hf space, the combined Banks-Icefield assemblage is distinct from the Donjek assemblage (Fig. 1), in lacking the major ca 565-760 Ma cluster attributed to Timanian (northern Baltican) sources. It contains a unique 700-900 Ma population with highly variable  $\epsilon_{\text{Hf}(t)}$  values. The likeliest sources for these grains are igneous bodies in the northern Atlantic region associated with the Valhalla orogeny of Cawood et al. (2010). Across all ages, the Banks-Icefield data shows a tendency to negative  $\epsilon_{\text{Hf}(t)}$  values, more similar to peri-Laurentian than to Baltican sources (Fig. 1). This suggests that the source for Banks-Icefield siliciclastic detritus was a peri-Laurentian crustal fragment, exotic to the peri-Baltican Alexander terrane, that included Valhalla orogen igneous bodies, and hosted Ordovician-Early Devonian arc magmatism coeval with but much more evolved than that in the Alexander terrane. Sediments derived from this exotic source mixed with locally-derived Alexander detritus in the Mathieson Formation. Our new interpretation of the Klakas orogeny is that it involved strike-slip suturing of the peri-Laurentian Banks-Icefield source terrane to the Alexander terrane during westward transport of terranes through the Arctic region in Silurian-Devonian time (Fig. 2).

Fig. 1

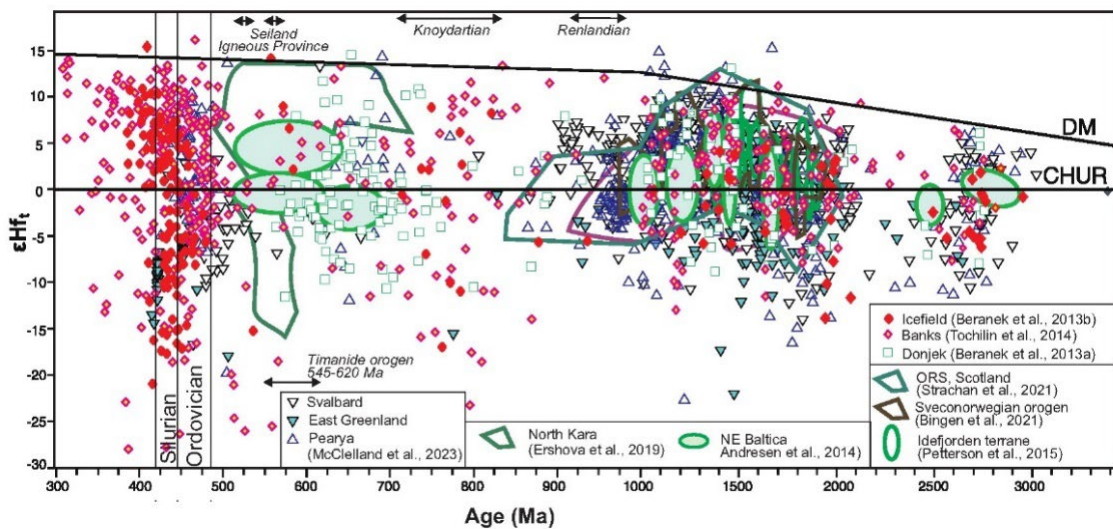
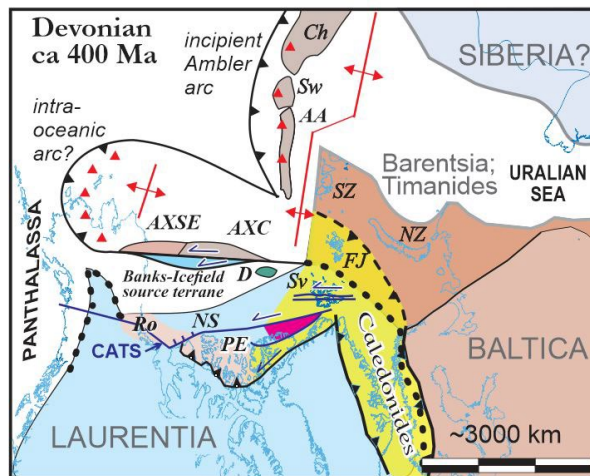


Fig. 2



## **Geochemical, geochronological and metallogenic characteristics of Cretaceous magmatism in eastern Alaska: a new piercing zone along the Tertiary Tintina fault?**

*Douglas C. Kreiner<sup>1</sup>, Erin Todd<sup>1</sup>, James Jones<sup>1</sup>, Chris Holm-Denoma<sup>2</sup>, and Laura Pianowski<sup>2</sup>*

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More than 150 new UPb zircon ages indicate that Cretaceous magmatism began at ca. 115 Ma and occurred episodically to ca. 65 Ma in eastern Alaska. Synthesis of the new geochronology and nearly 800 legacy and new geochemical analyses allow for the separation of Cretaceous magmatism into temporally and chemically distinct suites. These plutonic suites and correlated suites in the Yukon are associated with a variety of significant mineral deposits (e.g. Fort Knox, Manh Choh, Casino, Coffee, Dublin Gulch, etc.). Comparison of geochemistry between temporally related suites in Alaska and the Yukon suggest a correlation of plutonic belts displaced by the Tintina fault.

Plutons emplaced from 114-100 Ma are spatially and chemically broken into three suites. The Gardiner Creek suite is geochemically variable and located in the southeastern portion of the Yukon-Tanana upland. Monzogranite plutons are weakly to strongly peraluminous with strongly negative europium anomalies ( $\text{Eu}/\text{Eu}^*$ : 0.3-0.1). Granodiorite and monzodiorite are metaluminous with flat europium anomalies ( $\text{Eu}/\text{Eu}^*$ : 0.7-1). These are distinguished from the monzogranite plutons by anomalously high Sr, Ba, MgO, and alkali contents. Gardiner Creek pluton compositions exhibit magnetite fractionation patterns ( $\text{V}/\text{Sc} < 5$ ). The Goodpaster suite is in the central Yukon-Tanana upland. Monzogranite to granodiorite plutons are weakly to strongly peraluminous with moderate negative europium anomalies ( $\text{Eu}/\text{Eu}^*$ : 0.5). The Goodpaster suite has narrow ranges of MgO, Sr, Ba, and alkali contents and ilmenite fractionation trends ( $\text{V}/\text{Sc}$ : 5-9). The Goodpaster peraluminous suite is spatially restricted to the Goodpaster river drainage, is slightly older (114-110 Ma) and is distinguished by being strongly peraluminous with variable negative europium anomalies and uniformly low Sr, Ba, MgO, and alkali contents. Goodpaster peraluminous suite plutons are strongly magnetite fractionated ( $\text{V}/\text{Sc} = 1-2$ ). Sparse Mo-porphyr style mineralization is associated with plutons of the Gardiner Creek suite and largely absent from the Goodpaster and Goodpaster peraluminous suites.

Beginning at approximately 100 Ma, a widespread magmatic flareup occurred across the entire region. Four geochemically distinct plutonic suites young from southeast to northwest. The oldest plutons are part of Charley River suite located primarily in the Charley River drainage. It is characterized by strongly peraluminous monzogranite that is strongly fractionated with elevated alkali contents. Negative europium anomalies range from 0.25-0.8  $\text{Eu}/\text{Eu}^*$  (average of  $\sim 0.5$ ) and plutons are magnetite fractionated ( $\text{V}/\text{Sc}$ :  $< 5$ ). The next oldest is the Harper suite located in eastern-most interior Alaska, characterized by monzogranite-granodiorite with less abundant quartz monzodiorite. All phases are weakly to strongly peraluminous. Negative europium anomalies for intermediate phases range from 0.5-1  $\text{Eu}/\text{Eu}^*$ , and monzogranites exhibit distinctly more negative  $\text{Eu}/\text{Eu}^*$  ( $< 0.5$ ). The Shaw Creek suite is located in the central Yukon-Tanana upland characterized by metaluminous to weakly peraluminous monzogranite to quartz monzodiorite with negative europium anomalies ranging from 0.5-1 ( $\text{Eu}/\text{Eu}^*$ ). The northwestern-most Wolverine plutonic suite is characterized by compositionally zoned metaluminous syenite cores and quartz

monzonite outer zones. Wolverine suite is distinguished by the alkaline composition and strongly negative europium anomalies ( $\text{Eu}/\text{Eu}^*$ : 0.8-1). Metallogeny associated with these suites is spatially zoned from Mo-W in the eastern upland, to Au-Bi-W-As-Te in the central and Au-Cu-Bi in the western upland. The metallogenic assemblages are strongly spatially correlated with the Harper, Shaw Creek, and Wolverine suites, respectively.

Following a hiatus in magmatism, Late Cretaceous plutons emplaced from 72-65 Ma are widespread across the region. Plutons are metaluminous to weakly peraluminous monzogranite to granodiorite with modest negative europium anomalies ( $\text{Eu}/\text{Eu}^*$ : 0.7-0.9). Intrusions are characterized by hornblende fractionation (positive V/Sc vs. Sc slope) and nearly have associated porphyry Cu-Mo occurrences. In contrast, a distinct subset of strongly peraluminous monzogranite in the headwaters of the Charley River exhibit strong negative europium anomalies ( $\text{Eu}/\text{Eu}^*$ : <0.4). They display a magnetite fractionation (V/Sc: <5).

Superimposed on Cretaceous magmatism is the Cenozoic dextral slip on the Tintina fault. Restoring ~450 km of separation across the allows for the comparison of 100-90 Ma plutonic belts located on both sides of the Tintina fault. This suggests a genetic link and evolving geologic setting that transects the Tintina fault and correlates Yukon and Alaska plutonic suites and spatially and temporally associated mineralization. The Tombstone suite in the Yukon contains numerous globally significant deposits, such as Brewery Creek (Au-Cu-Bi), the Mayo suite generated the Dublin Gulch (Au-Bi-Te, W, As) deposit and the Tungsten suite hosts the Mactung (W, Cu-Zn-Mo) deposit. Numerous occurrences of similar metallogeny are found in Alaska associated with the Wolverine suite (Elephant Mtn Au-Cu-Bi), the world class Fort Knox (Au-Bi-W, As) deposit and small Mo-W porphyry occurrences in the Mayo suite. This new magmatic framework opens the door for untapped mineral exploration potential in Alaska through the temporal and geochemical correlations.

## **Evidence for significant Cretaceous – Cenozoic dextral slip displacement *north* of the active Denali fault strand, Eastern Alaska Range**

*Roeske, Sarah M., and Grant, Belyn*

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Of the major long-lived dextral fault systems in Alaska and Yukon, the Denali fault in the eastern Alaska Range is unique in that it has been undergoing continuous dextral slip on one fault strand since at least 52 Ma, resulting in ~480 km of displacement of rocks south of the fault in the eastern Alaska Range (Waldien et al., 2021). This section of the Denali fault (from approximately longitude 138° W to 145.5° W) also coincides with the boundary between mafic crust of the Wrangellia composite terrane (WCT) to the west and south and more silicic crust of the Yukon-Tanana composite terrane and thinned North America (NA) continental rocks to the east and north. Although Cretaceous collision between WCT and NA is well-documented in Yukon – British Columbia – northwest Washington, evidence for this collision is more cryptic in the Alaska Range and is recorded primarily in the transition of Cretaceous marine to non-marine basins. “Ribbon terranes” (Nokleberg and Richter, 2007) of dominantly Paleozoic to Triassic age that occur between Wrangellia and North America in the eastern Alaska Range have thus been difficult to fit in paleogeographic reconstructions.

Our research has focused on deformation and exhumation along the north side of the active Denali fault in the Mount Hayes Range, between the Hines Creek fault and the Denali fault. We discovered that rock units lumped together as the Aurora Peak terrane change dramatically along the strike of the fault along the north side of the restraining bend of the fault. We present here U-Pb detrital zircon ages and Hf isotopic data that support our field observations that at least three distinct lithologic assemblages occur along this section of the Denali fault. The most surprising results come from five metaclastic and one volcanoclastic sample from the most deeply exhumed rocks immediately north of the active trace. All are dominated by Paleozoic grains between 390 – 485 Ma, with lesser peaks in half of them around 540-560 Ma. Three samples have 5% or less Precambrian grains while the other three have 48-60% Precambrian zircon. Epsilon Hf values from the Neoproterozoic through Early Devonian zircon are almost all positive, between +5 - +16, particularly in the three samples lacking significant Precambrian grains. Determining maximum depositional ages (MDA) is challenging; all of these amphibolite facies rocks have metamorphic zircon and some are dominated by neocrystalline zircon formed during three major phases of plutonism between 100 – 50 Ma. Using the youngest statistical population method to approximate the MDA, we obtain ages from 297-478 Ma. The zircon peaks and populations bear a striking resemblance to Paleozoic strata from the Alexander terrane in Yukon and southeast Alaska (Beranek et al., 2013; White et al., 2016). The dominance of Ordovician – Silurian zircon with juvenile epsilon Hf values does not fit with an origin from the pericratonic terranes east of WCT nor from North America and is very similar to data from the Alexander terrane in southeast Alaska (White et al., 2016). Silurian – Early Devonian rocks from the Farewell terrane have similar

Silurian detrital zircon peaks but also usually contain some early Neoproterozoic zircon and the sparse epsilon Hf data from these rocks includes evidence for significant older crustal influence.

The occurrence of Paleozoic Alexander terrane strata on the north side of the modern trace of the Denali fault, exhumed by dextral oblique convergence since 30 Ma, requires a more complex fault history than previously documented for this fault system. A ‘fixist’ scenario would interpret these results to indicate that a pre-52 Ma collision occurred between Alexander terrane basement (and possibly Jurassic – Early Cretaceous strata) in situ and the evidence for this collision has been translated to the west and/or was subsequently buried by younger thrust faults. This scenario does not fit with observations along strike of the study area. Fifteen km to the west, greenschist facies metasediments have zircon ages dominantly between 280 – 380 Ma with negative epsilon Hf values, very similar to Yukon – Tanana terrane rocks exposed in Yukon (Kroeger et al., 2023). The boundary between these two rocks and the amphibolite facies schists is a high-angle NE-striking fault. East of the region of maximum exhumation the rock assemblage shows no evidence of continental or arc-derived strata and is dominated by chert, very-low grade mudstone, and metabasite, with minor marble and serpentinite. The boundary of this unit with the high grade rocks is buried under extensive ice. Nokleberg and Richter (2007) proposed a fault, the Nenana Glacier fault, to explain the uniqueness of the Aurora Peak terrane relative to NA-derived metasediments to the north and suggested it was also a dextral fault. We propose a more restricted version of the Nenana Glacier fault could have been a strand within an anastomosing dextral fault system that tracked along the original Cretaceous collisional margin in southeast Alaska, snaring bits of terranes possibly from both side of the collision, and translating them northward primarily before 52 Ma but potentially up until ~30 Ma when exhumation localized in the Mt Hayes Range restraining bend.

#### References:

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## **Back to the future: highly radiogenic Pb in the Ogilvie platform, central Yukon**

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Hundreds of carbonate-hosted Zn-Pb-Ag mineral occurrences occur along the southern margin of the Ogilvie platform, central Yukon. Host rocks range from Paleoproterozoic to Mississippian in age. However, the timing and drivers of mineralisation are largely unconstrained. The deposits are epigenetic and generally considered to be Mississippi Valley-type (MVT). To constrain the timing of mineralisation and source(s) of Pb (and other metals), we integrate geological mapping with new and previously published galena and whole-rock Pb-isotope data of samples collected from the Ogilvie platform.

Our data reveal 4 galena Pb-isotope populations when plotted on the Pb-isotope growth curve for the Canadian Cordillera (i.e., the shale curve). The oldest population, which includes the Blende deposit, has Pb-isotope ratios that fall along the Proterozoic part of the curve. Galena with this signature is hosted solely in Paleoproterozoic strata and is associated with Mesoproterozoic magmatism. A second population, which includes the Goz Creek deposit, has Pb-isotope ratios that form mixing arrays that intersect the Paleozoic section of the curve. Galena with this composition occurs in Devonian and older strata. The relatively well studied Pine Point and Gayna River MVT deposits, located to the east in the Northwest Territories, have a similar signature, suggesting the same mineralising event or mechanism. A third population (herein termed Rackla Pb), which includes the Clark, Cameron and Tiger deposits, has a radiogenic Pb-isotope signature that falls just beyond the young end of the curve. Galena with this anomalously radiogenic signature has been identified in strata as young as Devonian. Finally, a fourth population (herein termed North Rackla Pb) is even more anomalous and plots farther off the young end of the curve. Galena with this extremely radiogenic signature occurs in Mississippian and older strata.

Anomalously radiogenic Pb-isotope signatures (J-type or “future” Pb) are widely considered to be indicative of MVT deposits. However, both populations of anomalously radiogenic Pb that we have identified are spatially restricted and located along trend with Late Cretaceous–Paleocene intrusions. Moreover, the c. 64 Ma Rackla pluton Pb-isotope signature is identical to the Rackla Pb population, indicating a genetic relationship between mineralisation and magmatism.

The North Rackla Pb-isotope population requires an extremely radiogenic (i.e., old and uranium rich) source of Pb. Our whole-rock Pb-isotope analyses demonstrate that the sedimentary package is insufficiently radiogenic. However, whole-rock analyses of the c. 1.6 Ga Wernecke breccia are an order of magnitude more radiogenic than any of the galena Pb. For the more radiogenic North Rackla Pb population, we suggest mineralising fluids interacted with Wernecke breccia as well as the Proterozoic to Paleozoic host stratigraphy. The Pb-isotope values of North Rackla Pb tightly cluster, which requires the fluid circulation cell was large enough to homogenize multiple Pb sources.

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Preliminary fluid inclusion data for sphalerite at the North Rackla deposit indicate mineralisation occurred at depths of 8 km or more and Raman spectroscopy data show that the host rocks to the North Rackla deposit were metamorphosed to between 400 and 500° C. We suggest deposits with the Rackla Pb-isotope signature are proximal intrusion-related deposits, whereas deposits with the North Rackla Pb-isotope signature are distal intrusion-related deposits. The causative intrusions are likely deeply emplaced and coeval with the Late Cretaceous to Paleocene McQuesten suite and Rackla pluton.

## Sequence stratigraphic framework for sediment-hosted ore deposits in the Late Devonian Earn Group, Yukon, Canada

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The Late Devonian Earn Group contain significant Pb-Zn±Ag sediment-hosted ore bodies within organic-rich stratiform pyritic to calcareous mudstone of the Selwyn basin area. The Earn Group in the study area of Macmillan Pass was deposited in a deep-water setting near the slope-basin transition. Deep-water settings are sequence stratigraphically complex systems to model due to the interplay between multiple allogenic and autogenic processes that are active during deposition which can lead to rapid lateral facies variability over relatively short distances. The most prolific delivery of sediments to the deep-water setting occurs during the falling-stage and lowstand systems tracts. With each progressive lowering of relative sea level, the shelf becomes exposed and destabilized, leading to mass transport complexes and gravity-driven deposition into the basin. Sediment may also accumulate during this time in high-density and low-density turbidite complexes that are fed from deltas that rapidly approach the shelf edge with each lowering of relative sea level. Hemipelagic sedimentation may occur in all systems tracts when coarser sediment is being delivered to other areas of the basin leading to thick mudstone successions accumulating adjacent to coarser-grained units.

During the Late Devonian, Selwyn basin underwent intermittent periods of extension, which led to the reactivation of deep-seated normal faults. This reactivation created horst and graben features that constrained and localized the deposition of deep-water deposits in the study area. This complicates the recognition and correlation of genetically related units in the study area as the compartmentalization of sedimentary units leads to over-thickened mudstone packages occurring adjacent to thick conglomerate packages over relatively short distances. In extensional settings, turbidites may not form well-developed fan architectures due to sedimentation being compartmentalized within horst and graben features in the basin. This leads to rapid local variability in sediment thickness and lithology along strike.

Mineralization occurs extensively in the fault-bounded area within mudstone-dominated successions deposited during the highstand and transgressive systems tracts. Each systems tract has unique sedimentological and geochemical characteristics that are diagnostic to their identification. Mineralization may have occurred in two ways. The first is from a mineral-rich brine sourced from deep-seated faults interacting with an euxinic water column causing minerals to form and accumulate along depositional planes and within organic-rich intervals. The other way is through subsurface replacement of carbonate material within reduced and sulphide-bearing lithologies. Therefore, the distribution of facies that are suitable candidates to host mineralization becomes important when exploring for future locations that may host these types of deposits.

An x-ray fluorescence (XRF) and organic carbon isotope ( $\delta^{13}\text{C}$ ) study was conducted on four cores that intersect the Earn Group at Macmillan Pass. The results of this study are used to create a preliminary set of criteria for correlating in mudstone-dominated intervals and for identifying facies that may be candidates for hosting mineralization.

### Coffee Project open file update and results

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The Coffee project is a structurally-controlled gold-only deposit hosted in poly-deformed Paleozoic basement rocks of the Yukon-Tanana terrane and Mesozoic plutons situated in the northern Canadian Cordillera in west-central Yukon. The deposit has been interpreted as having characteristics of numerous deposit types over the project's history including epithermal, reduced intrusion related, Carlin-type, and orogenic-gold, as well as combinations of deposit types. Recent mapping efforts highlight a previously unknown secondary phase of the Permian Sulphur Creek suite and led to the relocation of the Coffee Creek fault which is interpreted as a primary controlling structure of the Coffee deposit. A new structural analysis builds on previous depth estimates and suggests that the deposit formed as shallow as 1-3 km depth, and together with the new map has outlined the structural history of the deposit in greater detail. New dike geochemistry demonstrates the similarities of some mineralized Coffee dikes to the Carmacks Group, which implies a potential Late-Cretaceous age for these dikes, and thus a potential Late-Cretaceous maximum age of Coffee gold mineralization. Field relationships and timing of regional faulting together suggest a minimum age of formation of ~57 Ma. Available multi-element geochemistry highlights a Au-As-Sb ± Ag-Pb-Te-W-Zn-K metal association that suggests a possible magmatic component to the mineralizing fluids at Coffee. Newly drilled shallow mafic intrusions adjacent to the Coffee Creek pluton serve as potential non-metamorphic fluid sources, perhaps related to slip on the Coffee Creek and Big Creek fault systems.

## **Lithospheric mantle density variations and thermally induced tectonics of the Canadian Cordillera from the seismically constrained modelling of gravity data**

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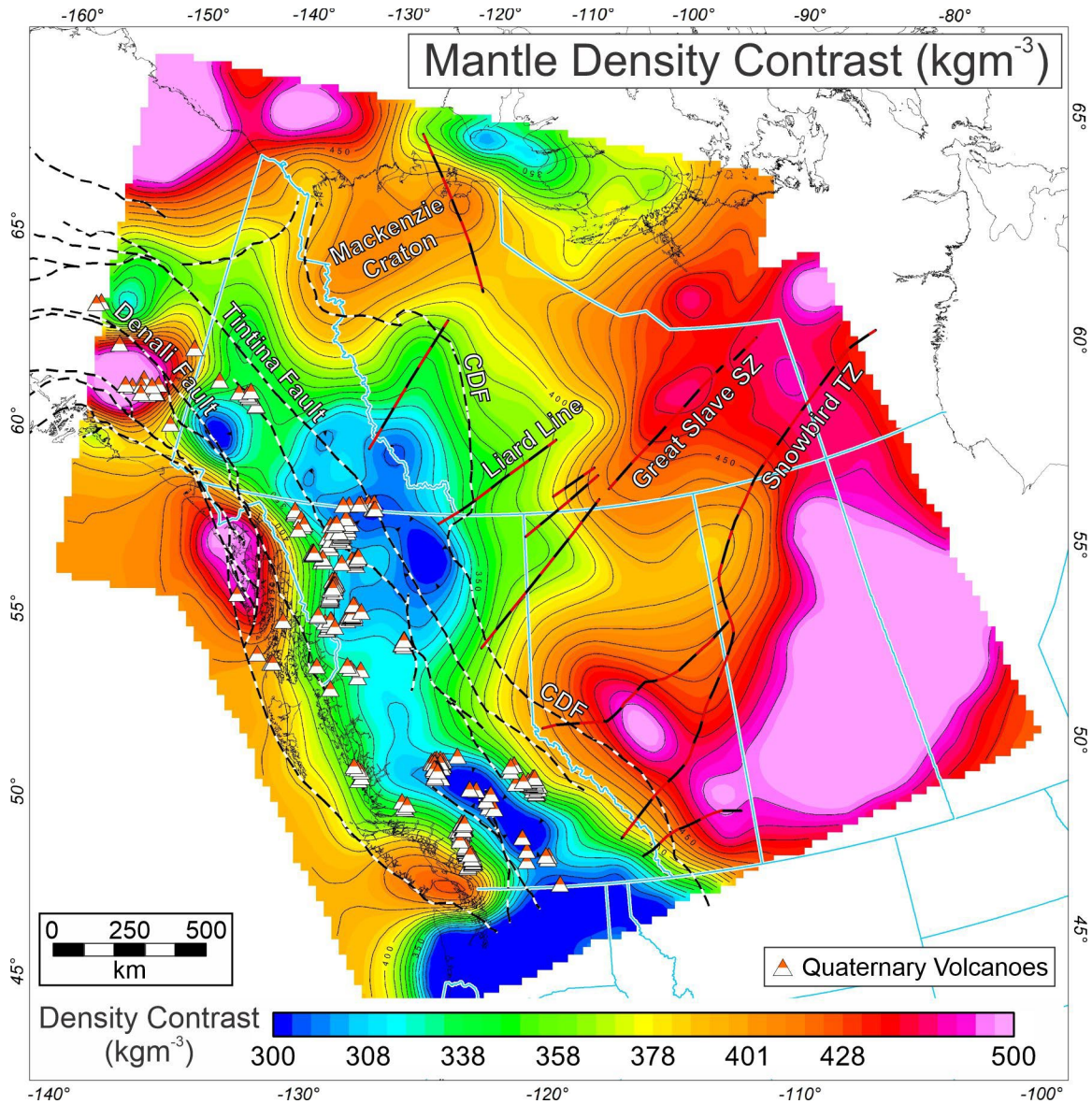
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The thermal state of the lithosphere can exhibit significant control on a region's tectonics. The Canadian Cordillera has experienced a prolonged and complex tectonic development that has significantly altered the character, composition and temperature of the underlying lithospheric mantle, and in stark contrast to that beneath the adjacent Laurentian craton. A new approach to seismically constrained gravity modelling reveals the pattern of density variation within the Cordilleran lithospheric mantle (Fig. 1). Consistent relationships are drawn between the density model and other independent geological and geophysical markers including variations in the depth of the lithosphere-asthenosphere boundary (LAB), the Moho, and the magnetic-based Curie isotherm, the uneven and localised distribution of earthquakes and Pleistocene to Holocene volcanoes, the regional heat flow, and major regional structures. Collectively these data provide a detailed pattern of the current temperature variation beneath the Canadian Cordillera, and reveal causal linkages between the independent observations, informing as to the current structure of the Cordilleran lithosphere and its development. Two regions with the lowest lithospheric mantle density correspond to the hottest regions beneath the Cordillera, associated with extensive and rapid uplift of the past few million years. Areas of low density beneath the Northern Cordillera Volcanic Province (Northern Intermontane belt) and the Cascadia back arc (Southern Intermontane belt), are echoed by shallow Curie isotherm and LAB depths, and sparse seismicity. The lithospheric mantle density low beneath the Southern Intermontane belt also overlaps with continuous lower crustal reflections on seismic reflection profiles, suggesting a relationship to tectonic activity, volcanic related intrusions, fluids or localised lower crustal flow.

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**Figure 1.** Model of the variation in lithospheric mantle density contrast beneath the Canadian Cordillera and adjacent craton. Orange-tipped white triangles show Quaternary volcanoes (*Global Volcanism Program, 2024; Kelman and Wilson, 2024*). Black-white dashed lines show major Cordilleran structures. Red-black dashed lines show cratonic faults and lineaments. Light blue lines show provincial and territorial boundaries. Projection: NAD83 / UTM zone 10N.

## **A review of inverted fault systems and inversion tectonics in the ancestral North American Canadian Cordillera and Foreland Basin**

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Global understanding of tectonic inversion structures and settings has been facilitated by the classic paper of Bally (1984), and subsequent volume edited by Cooper and Williams (1989), that illustrated initial extensional fault geometry and its subsequent compressional reactivation as essential components of an inversion structure. Inverted fault systems and sub-basins are now recognized in most orogenic belts and in other tectonic settings (such as extensional margins and intraplate basins), in large part due to a range of petroleum and/or mineral deposit implications, and especially to improvements in seismic imaging. However, many inversion structures, even in the outer parts of orogenic belts and foreland basins, are still misinterpreted as either thin-skinned thrusts or strike-slip structures. Inversion structures also are commonly difficult to identify and thus overlooked in the interior parts of orogenic belts.

Geoscientists in western Canada have long recognized local examples of thrust faults with earlier extensional histories, yet structural inversion has remained under-recognized and neglected in regional syntheses for several reasons: 1) thick-skinned structures in the foreland basin are subtle, with little or no surface expression, and often difficult to identify on seismic data; 2) the external southern Canadian Rockies are dominated by now-iconic thin-skinned fold-thrust geometries and processes, which have long been the focus of local industry, government and academic study in that portion of the orogen; 3) the complex deformation, metamorphism, igneous activity and lack of subsurface data in the hinterland portion of deformed ancestral North American rocks have made recognition of inversion difficult; 4) there has been limited awareness in the Canadian Cordillera and foreland basin of the criteria for recognizing inversion, and of the stress history that has favoured it in certain areas.

The first part of this presentation includes a review of: criteria for recognizing inversion structures, variations in their geometries and mechanical response to stress change, tectonic settings for inversion, and mineral and petroleum prospectivity and risk implications. Selected global examples illustrate a reference range of structural geometries that can result from inversion (Cooper and Warren, 2010, 2020).

In the second part of this presentation, we discuss several aspects of the tectonic and stress history of the former continental margin, thrust belt and foreland basin that have lead to inversion in the Canadian Cordillera and foreland basin. We offer a variety of examples of inversion structures from western Canada, several with commercial resources directly controlled by one or more components of inversion.

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## Newly proposed regional correlations of Neoproterozoic Windermere Supergroup stratigraphy in the southern Canadian Cordillera

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Rocks of the Neoproterozoic Windermere Supergroup (WSG) in the southern Canadian Cordillera (SCC) were deposited during a pivotal time in Earth history that included the break-up of the supercontinent Rodinia, multiple major marine isotopic excursions, and the advent of multicellular life to name but a few. Nevertheless, despite its geological significance many fundamental questions remain unresolved, which in part can be attributed to the challenges in regional stratigraphic correlation caused by the general absence of biostratigraphic and absolute geochronological control in these mostly siliciclastic rocks. However, recent advances in various geochemical tools and techniques and the study of a number of key outcrops have begun to provide important insight into better constraining the regional lithological and temporal relationships of Windermere Supergroup (WSG) stratigraphy in the SCC.

Based on recent detrital zircon data Hadlari et al. (2021) showed that the WSG in the SCC can be subdivided into two parts based on detrital zircon (DZ) data. The basal part comprises a rift succession dominated by a Grenville-dominated DZ assemblage (1.0-1.5 Ga), in addition to volcanic rocks dated at  $669.6 \pm 6.7$  Ma (Hadlari et al. 2024), which provides a maximum depositional age for the younger overlying part. This upper part comprises a distinctively bimodal Paleoproterozoic (1.75-1.95 Ga) and Archean ( $> 2.5$  Ga) DZ assemblage and represents an areally expansive ( $> 35,000$  km<sup>2</sup>) deep-marine turbidite system composed largely of siliciclastic rocks with few regional lithological markers and almost no absolute geochronological control. These strata are very well exposed in the Cariboo Mountains of east-central B.C. Here, a number of km-scale outcrops composed of steeply dipping strata have provided not only detailed insight into the sedimentological aspects of these strata but also their lithological make up and stratal architecture and arrangement. Combined with the recent geochronological control, these new stratigraphic data provide a better comparison with earlier attempts to correlate WSG strata in the southern Canadian Cordillera, most significantly the compilation of McMechan (2015). Revisions to the work of McMechan are confined mostly to the upper part of the Windermere succession, which is particularly relevant to the positioning of the sub-Cambrian unconformity, and accordingly, the initiation of events leading to development of the Western Canada Sedimentary Basin. In particular, strata included previously in the WSG may in fact be part of a thick succession of mass transport deposits with common decameter-scale blocks of carbonate possibly associated with the earliest stages of the sub-Cambrian unconformity, which then is overlain by a thick succession of carbonates overlain by siliciclastic slate overlain by a succession of mixed and/or interlayered carbonate and siliciclastic strata, and ultimately quartz arenites of the well-known Gog/McNaughton groups. This suggests that the sub-Cambrian unconformity may in fact be older and improperly positioned in many existing correlation schemes, but more profoundly, much more complicated than previously thought, and in fact may represent a single composite surface of discontinuities locally but elsewhere multiple separated disconformable surfaces bounding post Windermere strata.

## **The Okanagan subterrane: a ‘Subduction Initiation Rule’ ophiolite in the Canadian Cordillera**

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The Okanagan subterrane in south-central British Columbia is commonly referred to as the basement to Quesnellia, a composite arc terrane in the Canadian Cordillera. Distinct geochemical, lithologic, and structural characteristics allow for interpretation of the Okanagan subterrane as a forearc ophiolite formed over a long-lived west-dipping subduction zone initiating in western Panthalassa. The forearc ophiolite model has significant impacts on existing Cordilleran models which focus on a North American origin for this terrane. The Okanagan subterrane is comprised of harzburgites, gabbros, basaltic lavas, and ocean basin sediments. The age of the subterrane spans the Middle Devonian through the Early Permian. New stratigraphic, structural, and whole rock geochemical data are presented together with a synthesis of pre-existing data from regional studies to better constrain the origins and evolution of the Okanagan subterrane. The results indicate a transition from quiet shallow ocean basin deposition to the initiation of subduction and construction of a new forearc crustal sequence and mantle wedge. The earliest crustal sequences were formed from the eruption of basalts geochemically similar to those produced at oceanic spreading centres in the Late Devonian to earliest Mississippian. A chemostratigraphic magmatic progression through the Early and Middle Mississippian resulted in lavas becoming increasingly island arc-like in composition. Uplift and erosion dominated through the Pennsylvanian and Permian, punctuated by periods of carbonate deposition and capped by a regional Permo-Triassic unconformity and a Mesozoic volcanic arc. The Okanagan subterrane was affected by two main compressional deformation events, both interpreted as products of ophiolite obduction. The first, in the Permo-Triassic, resulted in tight to isoclinal folding, uplift, and erosion yielding the Permo-Triassic unconformity and the obduction of the Okanagan subterrane onto an extinct island arc within the lower plate. The second, in the Middle Jurassic, resulted in a southwest-verging fold and thrust belt which likely records the subsequent accretion to pericratonic terranes of western Laurentia. Comparing this ophiolite to other supra-subduction zone ophiolites worldwide allows for an interpretation of the Okanagan subterrane as a forearc ophiolite constructed during Late Devonian intra-oceanic subduction initiation.

## **Cretaceous to Miocene exhumation of the Purcell Mountains, southeastern British Columbia**

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Much of the presently-exposed Omineca belt within the southeastern Canadian Cordillera was exhumed to 9-14 km depths by the middle-Cretaceous or Paleocene, followed by a transition to regional extension. The timing and spatial pattern of this last phase of extension and exhumation remains enigmatic, however recent work has shown that parts of the region have been active as recently as the Miocene (e.g. Damant et al., 2023). The Purcell Mountains of southeastern British Columbia form part of the Omineca belt and are bounded by west-dipping extensional structures previously assumed to be of Eocene age. This study examines the post-Cretaceous exhumation across this tectonic domain by combining metamorphic petrology and mid to low temperature thermochronology. First, we examine the emplacement depths of the Paleocene (66-60 Ma) Fry Creek batholith and middle-Cretaceous (~100-96 Ma) White Creek batholith, two voluminous intrusions that span the width of the central Purcell Mountains. Detailed study of the contact aureoles revealed a west to east transition from higher pressure staurolite + garnet + andalusite-bearing mineral assemblages in the western Fry Creek batholith to lower pressure cordierite + andalusite-bearing mineral assemblages in the eastern White Creek batholith. Comparison of these mineral assemblages to thermodynamic forward models indicate emplacement depths of 12 -14 km in the western Fry Creek batholith, 10.5 - 12 km in the western White Creek and Eastern Fry Creek batholiths, and 9.5 - 11km in the eastern White Creek batholith.

Next, the cooling history of these rocks following pluton emplacement is investigated using zircon (U-Th)/He (~160-200°C), apatite fission track (~80-120°C), and apatite (U-Th)/He (~40-60°C) thermochronology from six samples collected across the Purcell Mountains and western Rocky Mountains. Zircon (U-Th)/He ages range from 56 - 29 Ma, apatite fission track ages range from 69 - 16 Ma, and apatite (U-Th)/He ages range from 36 - 24 Ma. After combining these results with existing mica Ar/Ar data, cooling ages fall into three groups: Paleocene to Early Eocene (56-48 Ma), Late Eocene (38-29 Ma), and Early to Middle Miocene (24-16 Ma). Inverse thermal history modeling of these data indicates accelerated Eocene (~40-29 Ma) cooling in the central and eastern portions of the Purcell Mountains, and accelerated Miocene (~16 Ma) cooling in the western Purcell Mountains. When combined with the emplacement depths of the Fry and White Creek batholiths, these results suggest heterogeneous exhumation of the region during Paleocene to Miocene extension.

## **Contact-metamorphosed to regionally-metamorphosed pelites: the natural record**

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The geoscience community relies on metamorphic petrology/petrologists to determine the formation conditions of metamorphic rocks (how hot and how deep). Thermodynamically calculated phase diagrams underpin our ability to make these determinations. A minimum requirement of such modelling is the reproduction of repeated patterns of natural mineral assemblages and mineral compositions. This presentation focuses on a worldwide natural database of metapelites metamorphosed over a range of grade from contact-metamorphosed to regionally-metamorphosed pelites (365 localities; 3,293 samples; 12,429 mineral analyses). First, consistent prograde mineral assemblage sequences as a function of pressure are identified. Second, mineral compositional variations (intra-mineral and inter-mineral) are examined. Third, the results of popular thermodynamic models are assessed against the natural record, showing that new thermodynamic models are required.

## **Two-Phase Delamination Magmatism and Exhumation: Refined Chronostratigraphy of the Challis-Kamloops Group and the Early Eocene Tectonic Evolution of the Pacific Northwest**

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The Challis-Kamloops group (CKG) is the supracrustal record of Early Eocene crustal collapse in the retro-arc region of the Pacific Northwest Cordillera. It comprises volcanic and non-marine sedimentary deposits in basins formed in the upper plates of developing metamorphic core complexes (MCCs) and peripheral terrain along a vast linear belt from the Yukon Territory to Montana.

Nineteen new tandem LA-ICP-MS/CA-TIMS zircon ages help to redefine the legacy stratigraphic framework, revealing that the CKG comprised two magmatic phases separated by a magmatic lull. The 1st phase (~52.7 Ma to ~51.5 Ma) was coincident with lower crustal flow and high-rate ductile exhumation (~16 mm/yr), forming MCCs. The onset of magmatism was oldest in the central Republic and Toroda Creek grabens and propagated outward in a radial pattern, consistent with strain indicators in the lower plates of the MCCs and the regional magnitudes of extension. The 1st phase was followed by a magmatic lull (~51.5-49 Ma) characterized by regional erosion, with minor felsic volcanism and sedimentation in basins along detachment faults bounding the highly extended region. The 2nd phase (~49-45 Ma) comprised mainly felsic volcanic flows and plugs, and accompanied brittle extension with a lower exhumation rate (~3 mm/yr).

A similar shoshonitic, calc-alkaline, arc-like magmatic sequence occurs in each CKG basin. This common sequence is time-transgressive. It is oldest in the center of, and youngs toward the margins of the highly extended region, suggesting that a common tectonomagmatic process propagated across the entire highly extended region within ~1.13 My, coupled with rapid lower crustal exhumation.

The pattern of onset ages appears to be less consistent with slab rollback or slab breakoff than with delamination of mantle lithosphere/lower crust, as was previously inferred from geophysics, but both mechanisms may have contributed. CKG geochemistry, magma sources and radiogenic isotopes are generally consistent with a delamination origin. The very short duration of the 1st phase (1.13 My) is in line with numerical models of delamination events. The propagation rate of CKG 1st phase magmatic onset, which we interpret as tracking delamination, varied from ~170 km/My along axis to ~130 km/My axis-perpendicular. Which geotectonic processes contributed to triggering delamination is still under study.

The two CKG magmatic phases correspond to two periods of plate boundary reorganization in the Pacific basin, to the timing of Siletzia terrane accretion and to tectonic events in the Washington Cascades orogen.

**Late Triassic Kamloops picrites, southwestern British Columbia: Degassing-driven ascent and explosive eruption of picritic slurries in arc settings**

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Primitive arc magmas are inherently oxidized and rich in H<sub>2</sub>O and other volatile species, such as CO<sub>2</sub>, SO<sub>2</sub>, and H<sub>2</sub>S. These volatiles drive the buoyant ascent of arc magmas through the mantle and into the crust, but eventually reach saturation leading to degassing and supersaturation of near-liquidus minerals olivine and Cr-spinel. Restricted escape of magmatic volatiles further propels the ascent of crystal-rich slurries, and in rare cases, these slurries may be erupted as olivine-rich picritic (MgO >12 wt.%) tuffs and volcanic piles, recognized in several localities across the globe [1,2,3], including near Kamloops, BC, where picritic rocks comprise a small, but important, part of the Late Triassic Nicola Group [4, 5]. The Fo-Ni-Mn-Ca systematics of olivine (Fo =90-93.5) from the Kamloops picrite delineate two broad populations; one characterized by high Fo and Ni, but low Mn and Ca, and another with lower Fo and Ni, but high Mn and Ca. Similar olivine systematics are also characteristic of crystal-rich arc picrite suites from Kamchatka [1] and Solomon Islands [2]. The bimodal population distribution is interpreted to record initial crystallization of low-Ca olivine (~400 ppm) from a relatively oxidized water-rich (~9 wt.%; [6]) near-primary magma followed by rapid, degassing-driven ascent, during which Ca contents in olivine reached >2700 ppm. The concomitant changes in Mn content and Fe/Mn ratios of olivine suggest that degassing also resulted in significant oxidation of the melt, possibly through SO<sub>2</sub> degassing. Unravelling the complexities related to degassing and magma ascent is critical to understanding the composition and nature of the primary, mantle-sourced melts and, by extension, the composition and thermal structure of the sub-arc mantle. Understanding these variables is important because picritic magmas may be potent carriers of metals from the mantle and play a fundamental role in the metallogenic endowment of arcs, as suggested by the spatial and temporal association between picrites and prolific porphyry Cu mineralization in the Canadian Cordillera [7].

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**Porphyry copper formation driven by water-fluxed crustal melting during flat-slab subduction: Insights from the Laramide Belt, SW USA**

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The prevailing view of the formation of porphyry copper deposits along convergent plate boundaries involves deep crustal differentiation of metal-bearing juvenile magmas derived from the mantle wedge above a subduction zone. However, many major porphyry districts formed during periods of flat-slab subduction when the mantle wedge would have been reduced or absent, leaving the source of the ore-forming magmas unclear. Here we use geochronology and thermobarometry to investigate deep crustal processes during the genesis of the Late Cretaceous–Palaeocene Laramide Porphyry Province in Arizona, which formed during flat-slab subduction of the Farallon Plate beneath North America. We show that the isotopic signatures of Laramide granitic rocks are consistent with a Proterozoic crustal source that was potentially pre-enriched in copper. This source underwent water-fluxed melting between 73 and 60 Ma, coincident with the peak of granitic magmatism (78–50 Ma), porphyry genesis (73–56 Ma) and flat-slab subduction (70–40 Ma). To explain the formation of the Laramide Porphyry Province, we propose that volatiles derived from the leading edge of the Farallon flat slab promoted melting of both mafic and felsic pre-enriched lower crust, without requiring extensive magmatic or metallogenic input from the mantle wedge. This also caused a time-transgressive thermal and mechanical evolution of the North American lithosphere involving: (1) pre-mineral shortening, volcanism and ore-barren magmatism associated with steep subduction that did not sufficiently hydrate the lower crust, (2) syn-mineral water-fluxed anatexis, relaxation of compressional stress, crustal derived magmatism and porphyry copper formation related to the arrival of the leading edge of the flat-slab, which hydrated the lower crust under elevated thermal conditions, and (3) post-mineral ore-barren peraluminous magmatism, cooling and tectonic and magmatic quiescence associated with continual underthrusting of the flat-slab. Other convergent plate boundaries with flat-slab regimes may undergo a similar mechanism of volatile-mediated lower-crustal melting.

## **The Upper Crust of the Southwestern North American Cordillera was Eroded in Response to Laramide Flat-Slab Subduction**

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Upper crustal responses to Late Cretaceous–Eocene flat-slab subduction in the southwestern North American Cordillera remain poorly understood and contentious. The ~137–70 Ma McCoy basin near the southern California–Arizona border provides a unique record of extreme (> 7 km) subsidence, immediately prior to the underplating of trench fill (Orocopia schist) beneath the region during very shallow flat-slab subduction at ~70 Ma. Detrital zircon (U-Th)/He (ZHe) dates from the entire McCoy basin were completely reset by burial and reveal rapid cooling (10 °C/Myr) beginning at ca. 70 Ma. This requires basin heating (burial) to >200 °C after ~70 Ma and subsequent rapid cooling immediately (within ca. 1–? Ma) after deposition ended. ZHe and <sup>40</sup>Ar/<sup>39</sup>Ar data from the Maria Fold-Thrust Belt and Mule Mountains Thrust– north and south of the McCoy basin –also indicate comparable and coeval (~70–50 Ma) cooling. Given that shortening along these thrust systems ceased by ~ 70 Ma and large magnitude metamorphic core complex extension did not begin until the Miocene, cooling cannot be ascribed to upper crustal deformation. Instead, the abrupt ~ 70 Ma transition from basin burial to erosional exhumation coincides with passage of the flat slab and underplating of Orocopia Schist beneath the McCoy basin region. We argue that flat-slab subduction enhanced rock uplift and caused regional removal of > 6 km of the upper crust, which in turn helps explain the absence of any brittle manifestations of the ductile Maria fold-thrust belt. Contemporaneous erosion-driven exhumation in the Arizona transition zone indicates that the wave of exhumation moved through the region at plate subduction rates, further supporting flat slab subduction as a primary driver of regional upper plate exhumation.

## Taking the Pulse of Cenomanian-Turonian Cordilleran Magmatism using West Texas research cores with over 275 bentonites

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During parts of the Cenomanian and Turonian Stages (89-97 Ma), cyclic limestones-marlstones of the Eagle Ford Group (EF) were deposited in a distal, sediment-starved cratonic basin, mostly below storm-wave base where the seafloor had frequent episodes of suboxia and anoxia. The area was part of a retroarc foreland basin located at the southern end of the Cretaceous Western Interior Seaway and the northwestern margin of the Gulf of Mexico Carbonate Shelf (passive margin), in what is now West Texas.

The stratigraphic section analyzed records an 8 Myr long interval within Greenhouse climate and frequent explosive volcanism. It contains two Oceanic Anoxic Events (OAEs) marked by globally recognized positive Carbon Isotope Excursions (CIEs), trace metal anomalies, and over 275 bentonites (altered volcanic ash layers or tephra).

The bentonites are generally homogenous clay-rich beds (av. 5 cm, max. 70 cm) showing sharp contacts and strong yellow-orange mineral fluorescence under UV light. Two research wells drilled behind outcrops (IONA-1 and INNES-1) recovered the entire EF (111 and 60 m thick) and part of the encasing formations. The bentonites form ~5% of the EF thickness and are interpreted as distal pyroclastic fall deposits from large volume (>10-100 km<sup>3</sup>) Plinian eruptions from subduction-related calderas in the Peninsular Ranges and nearby western Cordillera magmatic arc based on their thicknesses (<1-70 cm, average 2 cm in the lower EF, and 5 cm in the upper EF) and lateral extents. Some of the bentonites are correlated for more than 1000 km integrating sedimentology, petrophysics, geochemistry, and biostratigraphy studied in our two cores and previous studies in other key sections along the Western Interior Seaway, including the Cenomanian-Turonian Global Stratotype (GSSP) at Pueblo, CO.

A robust chronostratigraphic framework is built anchoring an astrochronological age model (based on the rhythmic alternations of limestone and marlstone beds) to the bentonites dated with high-precision zircon U/Pb CA-TIMs (absolute ages with 2 sigma errors as low as 0.05 Myr). The abundance and frequency of bentonites decrease with time from 97 to 89 Ma. Peak bentonite abundance occurred in units dated ~95-96 Ma where the frequency of the bentonites thicker than 2 cm is ~20 Kyr. In contrast, in units dated 90-94 Ma, the frequency decreases to ~60-160 Kyr. An <sup>187</sup>Os/<sup>188</sup>Os<sub>i</sub> excursion at 95.0±0.1 Ma occurs in the middle of the OAE2 CIE probably related to the eruptions of one or more Large Igneous Provinces (i.e., Caribbean, High Arctic, Madagascar). The bentonites provided nutrients for marine primary productivity and probably played a role in the generation and preservation of the abundant organic matter in the marlstones (av. 6% Total Organic Carbon, TOC), contributing to the CIEs. In fact, the organic-rich Lower Eagle Ford displays 229 bentonites and 4-7% TOC (94.7-96.8 Ma), whereas the Upper Eagle Ford displays 39 bentonites and 2-3% TOC (90.3-94.7 Ma).

## Forearc depression formation in warm subduction zones

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We propose a model for forearc depression formation in warm subduction settings. Forearc depressions are a type of forearc basin that overlie some ocean-continent subduction zones and form between a forearc high and volcanic arc. We use geophysical data to show how subduction interface shear stress distribution controls the loci of underplating and crustal flexure. Forearc high crests are situated near the down-dip termini of megathrust earthquake rupture zones, and hence, overlie where material within the subduction interface reaches its brittle-ductile transition. Rheological change of subduction interface material causes shear stress to begin decreasing with depth, which triggers underplating. Forearc high uplift through underplating is supported by juxtaposition of forearc high crests with >100 mGal gravity anomalies and km-scale reflectors in seismic reflection sections. Forearc depressions are situated landward of megathrust earthquake rupture zones and tremor epicenters, and are therefore landward of the mantle wedge corner. Forearc depressions are counter-flexural basins that form in response to underplating. Counter-flexure occurs landward of the mantle wedge corner; in that position, the upper plate crust ceases being supported by the flexurally rigid slab and can bend downwards.

# *Poster Abstracts*

*Maurice Colpron with MSc student, Liz Westberg, and Ruby.  
Pelly Mountains, Yukon, July, 2009*

## Uncovering magmatic ages and cryptic tectono-metamorphic history of the Monashee Complex, British Columbia, Canada: Insights from carbonatitic zircon U-Th-Pb data

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Four samples from meta-carbonatite and meta-alkaline rocks in the Monashee complex and Selkirk allochthon in the southeastern Canadian Cordillera were studied to clarify the primary magmatic ages and subsequent metamorphic events through new zircon U-Th-Pb geochronology. The concordant and discordant U-Pb and Th-Pb zircon ages from carbonatites and syenites provide an eruptive or intrusive age of ca. 360 Ma for all four alkaline samples. This establishes a Late Devonian maximum depositional age for an extrusive carbonatite unit in the Monashee cover sequence, the Mt. Grace carbonatite. The Monashee décollement at the base of the structurally overlying Selkirk allochthon involved significant older-over-younger thrusting of Neoproterozoic Horsethief Creek Group strata. New metamorphic ages of 163 Ma and 130 Ma from the Monashee complex indicate resetting of U-Pb systems in zircon, corresponding with accretionary events in the Selkirk allochthon and deformation along the detachment zone (Fig. 1). Mineral lead isotopic analyses from the same four carbonatites and syenites and one sediment-hosted magnetite-rich ore deposit reveal a highly radiogenic linear trend inconsistent with traditional closed-system models, likely indicating mixing between radiogenic lead derived from clastic sedimentary sources and lead in the alkaline bodies. Lead isotopes in accessory phases track the same metamorphic fluid processes observed in zircon U-Pb isotopes, leaching radiogenic lead from older zircon and redistributing it into phases such as pyrite and pyrrhotite in carbonatites and K-feldspar in syenites. Our updated model reveals a more protracted tectonic history in the Monashee complex, with burial beginning as early as the Middle Jurassic in the north and early Cretaceous in the mid-latitude region, along with an additional shear zone above the Monashee cover sequence (Fig. 1). It demonstrates that zircon in alkaline rocks that have undergone complex thermal and deformational histories can be interpreted via CL imaging and combined U-Pb-Th and REE analysis of domains to identify original magmatic and subsequent resetting events.

**Correlating subsurface architecture to the tectonic evolution of the Whatcom Sub-Basin,  
Georgia Basin, British Columbia**

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The Georgia Basin, a Late Cretaceous to Cenozoic forearc basin that transitioned into a forearc depression in the Eocene following uplift of the forearc high, Vancouver Island. Despite their significance in convergent-margin dynamics, forearc basins and forearc depressions remain poorly understood due to limited subsurface data and complex tectonic histories. This study focuses on the Whatcom Sub-Basin, which is the southeastern depocenter of the Georgia Basin, and uses 2D seismic and well data to reconstruct its subsurface architecture. Four key tectono-stratigraphic units are identified: the Lower Nanaimo Group, Upper Nanaimo Group, Huntingdon Formation, and Boundary Bay Formation. These units are separated by regionally extensive unconformities that record episodes of erosion and tectonic reorganization. The Whatcom Sub-Basin exhibits a wedge-shaped geometry and thickens to the south and west; the thickest strata (up to 8,000 m) are located east of the Outer Island Fault in the Strait of Georgia. The structural elements that separate depocenters of the Georgia Basin exhibit displacements up to 2,250 m. The Upper Cretaceous Nanaimo Group records the initial phase of deposition within a forearc basin that, after deposition of the lower Nanaimo Group, deepened to the west. During this phase, most deposition occurred in deep marine settings or turbidite channels and fans. In the Whatcom Sub-Basin the Nanaimo Group is preserved in the deepest parts of the basin and its thickness is controlled by NE-SW- and NW-SE-trending normal faults and the underlying basement topography. The overlying Huntingdon and Boundary Bay formations exhibit more tabular geometries and mark a shift to broader, more uniform subsidence as the basin evolved into a forearc depression and became tectonically more stable. Sedimentation styles also changed with fluvial and terrestrial strata dominating in both the Huntingdon and Boundary Bay formations and paleodrainage towards the south and southwest. By linking tectonic events to stratigraphic architecture, this study provides new insights into the multi-phase evolution of the Georgia Basin and highlights the changes in the basin's structural and depositional history.

### **New insights on the origin of gold mineralization from deformation mechanisms in quartz veins and shear zones, Pogo, Alaska**

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Pogo is a ca. 8-million-ounce gold deposit in the central Yukon Tanana upland of eastern interior Alaska. The deposit is hosted in polydeformed, parautochthonous North American Devonian paragneiss and orthogneiss. Gold is hosted in complex, low and high angle quartz veins that cut host rock foliations at subparallel to steep angles. Predominant quartz veins dip ~ 30-40° WNW, are laterally continuous for up to ~ 1.4 km, and vary in thickness up to ~ 10 m. Since the discovery of Pogo in the 1990s, the origin of gold and the hosting quartz veins has been enigmatic. Proposed origins include low-sulfide orogenic, shear-hosted veins derived from fluids released during metamorphic dewatering, magmatic-hydrothermal veins related to coeval intrusions, or hybrid models. New work presented here focuses on the microstructural characteristics of quartz vein, associated shear zone, and host rock samples collected from underground mine exposures and oriented drill core. These data combined with structural orientation and geochemical data are used to further constrain the nature of Pogo quartz veins and implications for the source of gold.

Although a variety of major quartz vein microstructures exist, the most voluminous, and earliest quartz in our samples shows pervasive subgrain rotation, undulose extinction, deformation lamellae, and moderately bulged grain boundaries, all with an absence of simple shear fabrics indicating the veins are not shear zones themselves. These quartz textures are also compatible with penetrative dynamic recrystallization at upper greenschist to amphibolite facies conditions in the Earth's plastic regime.

In the mine, some of the major veins show evidence of brittle regime shear fabrics restricted to the host rocks at their sharp contacts. These shear fabrics die off quickly and the host rocks themselves are not particularly mylonitic. Sharp shear zone-auriferous quartz vein contacts are also observed in drill cores. In the mine and core there is brittle damage composed of subsidiary veins with a general decrease in intensity away from their contacts. These veins are commonly arsenopyrite ± pyrite ± Au veins, which are late in the paragenetic sequence, and they always cut the crystal plastic vein fabrics. Vein sulfide grains span the range from euhedral crystals to cataclastically "pulverized" textures contained within relatively intact but brecciated quartz as well as in small displacement microfaults and fractures. Bladed calcite associated locally with arsenopyrite and euhedral prismatic quartz that grew into open space, is consistent with boiling late in the paragenetic sequence.

Discrete, ~ meter thick, shear zones marked by foliated cataclasites occur in the mine and in drill core. Cataclasite porphyroclasts are commonly cored by quartz that show the same intracrystalline plastic fabrics as observed in the massive quartz veins. The porphyroclasts are also rimmed by

lower temperature phases including white mica, illite, carbonaceous material, chlorite, sulfides, and bladed calcite. Disseminated gold occurs in the porphyroclasts and within the comminuted matrix otherwise dominated by phyllosilicates and carbonaceous materials. Many clasts and rims show asymmetric tails strung out into the cataclastic flow field providing kinematic information. Some vertically oriented core samples show subhorizontal cataclastic fabrics with down foliation shear sense consistent with low angle extensional kinematics.

The characteristic occurrence of plastically deformed quartz in the major veins is consistent with segregation during regional metamorphism, independent of shear related deformation. Plastically deformed, Au-rich quartz porphyroclasts and matrix found in cataclastic shear zones that locally cut the major quartz veins, as well as sulfide rich damage zones and late bladed calcite, indicate that faulting and sulfide/gold deposition occurred in the brittle regime and post-dated plastic deformation of the host quartz veins. An alternative model at Pogo envisions the quartz veins as mechanical heterogeneities with a large competency contrast compared to paragneissic host rocks. Once in the brittle regime, the veins response to brittle fracture perhaps due to local and coeval pluton emplacement and (or) hydraulic fracturing related to regional extensional deformation could have localized permeability, sulfide and gold deposition.

## Preliminary Structural Analysis and Characterization of the Mount Hinton Property, YT, Canada

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High-grade gold- and silver-bearing veins and breccias are abundant in the Mount Hinton property in central Yukon. Found within the Keno Hills, there has been sporadic hardrock and placer exploration on Mount Hinton property over the last 100 years due to its proximity to the Keno Hill and Eagle mines (Willms and Friend 2023). The property is situated in northwestern Selwyn Basin and lies within the Tombstone Gold Belt, an 800km long region of reduced intrusion related gold system (RIRGS) deposits that spans across central Yukon to Alaska (Hart et al. 2002). These RIRGS are spatially and genetically associated with mid-Cretaceous plutons of the Tombstone and Mayo plutonic suites (Hart 2004; Hart 2007). While there are several intrusion-related deposits nearby such as Dublin Gulch and Scheelite Dome, there does not appear to be any evidence of major plutonism on the Mount Hinton property that would fit the RIRGS model. However, preliminary geochemical results on Mount Hinton and recent studies at the adjacent Keno Hill mine area suggests that the mineralization at both are related and in the distal zones of a RIRGS deposit model (Hantelmann 2013; Willms and Friend 2023).

There is a strong structural control on the mineralization on the Mount Hinton property as it is hosted in discrete veins and breccias. The property is situated between the Robert Service and Tombstone thrusts within the Tombstone Strain Zone (Gordey and Anderson 1993; Murphy 1997). This results in a complex structural history with abundant ductile and brittle features (Mair et al. 2006). The regional deformation has likely had a strong influence on movement of mineralizing fluids (Stephens et al. 2004). This thesis will focus on characterizing the mineralization at Mount Hinton by identifying how its distribution is structurally controlled. Ultimately, the results from this study will be used to constrain the deposit model and reconcile it with the regional RIRGS model.

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## **Permian intraoceanic arc rocks in the Canadian Cordillera: revisiting the relationship between Yukon-Tanana terrane the Klinkit Group**

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The Klinkit Group, situated along the eastern margin of the Yukon-Tanana terrane (YTT) in Yukon and northern British Columbia, comprises a volcanic, volcanoclastic, and sedimentary sequence with distinctive geological attributes. Traditionally interpreted as a Pennsylvanian to Early Permian volcanic cycle associated with the Yukon-Tanana arc, the Klinkit Group displays characteristics indicative of a unique tectonic history. It is notably less deformed and metamorphosed compared to Mississippian YTT arc rocks, suggesting a different tectonic setting during collisional events. The volcanic rocks are reportedly juvenile, and the mature, continentally-derived sediments in the upper sections do not resemble detritus from the existing YTT, raising questions about the proximity of YTT during deposition.

Field observations of the Klinkit Group in the Dorsey Lake region reveal a consistent south-southwest dip of the stratigraphy, with a homoclinal sequence depicted in cross-section. Its lower section is dominated by mafic-intermediate volcanic flows and volcanoclastic beds, transitioning to thin units of submarine, intermediate to felsic volcanics and volcanoclastics in the upper section. Petrological analysis highlights pervasive alteration, varied volcanic textures, and the presence of mature sandstones with well-rounded quartz grains.

Mafic to intermediate volcanic rocks in lower sections are aphanitic to porphyritic with sub-trachytic textures, suggesting eruption and deposition as flows. Autoclastic brecciation in coarse volcanic rocks includes clasts of varying composition, indicating a degree of explosive eruption. The presence of felsic volcanic rocks in the upper sections, restricted to thin layers, may indicate a transition in the volcanic setting upsection. Felsic volcanoclastic material, including lapilli and bombs, is commonly found in siltstones of the middle to upper sections, suggesting deposition while hot with subsequent flattening.

Zircon U-Pb geochronology indicates that volcanism in the studied Klinkit Group is Permian (ca. 270 Ma), with a crosscutting dyke constraining upper-section sedimentation to older than ca. 263 Ma. The lowest stratigraphic levels produced 333 Ma ages, potentially indicating an unconformable or structural contact. Geochemical discrimination shows that Klinkit Group volcanic rocks are consistent with an oceanic arc signature, and the closest regional analog may be Permian suprasubduction ophiolitic/extensional arc fragments.

Mature sandstones in the middle to upper sections are characterized by well-rounded quartz grains with sub-angular lithic components including common feldspar and occasional volcanic fragments. However, analyzed detrital zircon age distributions detected no late Paleozoic age components similar to the determined ages of volcanism or the Devonian-Mississippian YTT Finlayson arc cycle. The presence of considerable Mesoproterozoic age components is consistent with derivation from a likely recycled Laurentian margin source but is dissimilar to regional YTT

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metasedimentary substrate age distributions which are Paleoproterozoic and older. These characteristics of the Klinkit Group suggest a lack of proximity to YTT during deposition. This study of the Klinkit Group depicts it as a likely juvenile Permian arc that was built in proximity to eroding Laurentian margin-derived sedimentary rocks and was subsequently obducted, or accreted, onto either YTT or the Laurentian margin in a collisional event later than ca. 263 Ma.

## **Four new U-Pb zircon ages from Mesozoic intrusions in Southeast BC, Canada. Insights into timing of regional deformation and faulting along the Slocan Lake Fault**

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Four new U-Pb zircon ages from Mesozoic intrusions north of the Valhalla Complex produce Late Jurassic and Late Cretaceous ages, therefore providing insights into the timing of regional deformation and faulting along the Slocan Lake Fault.

The Valhalla Complex is a metamorphic core complex situated between Nakusp and Trail in Southeast British Columbia, Canada. It is bound by the ~60 Ma ductile Valkyr Shear Zone (VSZ) on its southern, western, and northern margins and by the ~50 Ma brittle-ductile Slocan Lake Fault (SLF) on its eastern margin. These two faults separate the high-grade metamorphic rocks within the complex from the structurally overlying, lesser metamorphosed strata.

Two intrusions yielded Late Jurassic ages, namely the East Caribou Stock and the Shannon Lake Stock. They are located in the northern hanging wall of the VSZ and west of the SLF in its footwall. The East Caribou Stock is a foliated biotite hornblende (monzo-) granite that yielded a weighted mean age of  $157.66 \pm 1.66$  Ma. The Shannon Lake Stock is a foliated biotite hornblende (syeno-) granite that contains elongated mafic-rich xenoliths that are also foliated and oriented parallel to the main foliation. Where it is intruded into low-grade metamorphic rocks the Shannon Lake Stock formed a contact aureole consisting of andalusite  $\pm$  staurolite  $\pm$  sillimanite assemblages. Zircon grains from the intrusion yielded a weighted mean age of  $156.16 \pm 5.57$  Ma.

The intrusions of Late Cretaceous age are the East Wragge Creek Stock and the Wragge Creek Stock. The East Wragge Creek Stock lies in the hangingwall on the east side of the SLF. It is a biotite (monzo-) granite that yielded a weighted mean age of  $75.29 \pm 1.37$  Ma. The Wragge Creek Stock is located on the opposite side of the SLF in its footwall and is in contact with the Shannon Lake and East Caribou Stocks. It is a biotite granodiorite that yielded a weighted mean age of  $75.4 \pm 1.3$  Ma. Both Cretaceous intrusions are not foliated but are intensely fractured where in proximity of the SLF. Contact metamorphic assemblages containing cordierite and andalusite that overprint an earlier foliation are found around both of these intrusions. Possible overlapping contact aureoles at the contact between the Wragge Creek and Shannon Lake Stocks complicate the metamorphic relationships.

The observation that only the Jurassic intrusions contain a penetrative deformation fabric, whereas the Cretaceous bodies do not, brackets the timing of regional deformation between the Late Jurassic and Late Cretaceous. Further, different mineral assemblages found in the contact aureoles of the Jurassic Shannon Lake Stock and the two Cretaceous Wragge Creek intrusions reflect different pressures of contact metamorphism. This elucidates that at the Shannon Lake Stock a deeper part of the aureole has been exhumed compared to the Wragge Creek Intrusions. This suggests that the older Shannon Lake Stock experienced a few km of uplift before the Wragge Creek Intrusions were emplaced in the Late Cretaceous.

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Similar ages and compositions for the two bodies of the Wragge Creek Stock to the west and east of the SLF confirms that these form one continuous intrusion. Intense brittle fracturing near the fault indicates that the intrusions had been cut by the SLF. Additionally, same contact metamorphic assemblages in the aureoles of the Wragge Creek Stocks on either side of the SLF suggests little movement along the fault at the latitude of the northern end of the stocks. A few km to the south however, the contrast of regional metamorphic grade across the fault suggests vertical displacement of about 15 km. This implies a rapid southward increase of displacement along the Slovan Lake Fault where it merges with the older Valkyr Shear Zone.

## **Drainage patterns of the Cadomin Conglomerate in the Crowsnest Pass: insights from 3D photogrammetric outcrop models**

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Conglomerates are sedimentary rocks composed of gravel, pebbles, or cobbles that are cemented together by finer sand, silt, or clay. The clasts provide clues about the source region and the tectonic setting during deposition. The Late Cretaceous Cadomin Conglomerate is one of the most distinctive and continuous stratigraphic units along the western margin of the Western Canada Sedimentary Basin. It sits immediately above the sub-Cretaceous unconformity implying that deposition was coeval with the onset of the Columbian/Sevier Orogeny. This study focuses on the Cadomin outcrops exposed in the Crowsnest Pass, southern Alberta, Canada. Dip directions of cross-stratification and higher-order bounding surfaces in the conglomerate were collected from 3D photogrammetric outcrop models. Based on these data, the dip relationships of bedding planes are interpreted as the accretion patterns and drainage direction during deposition of the conglomeratic strata. The results reveal: (1) The clasts consist of sedimentary lithologies, mostly chert, and lack igneous or metamorphic components; (2) the Cadomin Formation consists of 2D and 3D compound dunes within a gravel-bed braided river system; and, (3) the dip direction of cross-stratification is primarily south to the south-southwest, indicating that sediment transport responsible for the deposition of the Cadomin Conglomerate was directed toward the south-southwest. These results indicate that the exhumed source terrane was situated to the northeast, where the Cadomin clasts were derived through weathering of Paleozoic strata within the Western Canada Sedimentary Basin.

## **Geological Implications of a Mid-Triassic Assembly: Revisiting the Structure and Evolution of the Intermontane Terranes**

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The Intermontane Superterrane is a vast region within the North American Cordillera, composed of several terranes associated with oceanic and arc-related environments. These terranes have been amalgamated into a complex structural arrangement through multiple tectonic events. The timing and mechanisms of their assembly remain controversial.

At the core of the Intermontane region lies the Cache Creek Terrane, a major belt consisting of carbonate platform facies, oceanic crustal rocks, and marine sediments that extend discontinuously from southern Yukon to northern Washington State. Structurally, this terrane is interpreted to occupy the lowest position within the Intermontane belt and is surrounded—and partly tectonically overlain—by two paleo-volcanic arcs: Stikinia to the west and Quesnellia to the east.

The collision between these terranes was widely assumed to have occurred in the mid-Jurassic, leading to a clear distinction between pre-collisional and overlap assemblages in the sedimentary units forming the upper stratigraphic layers of Cache Creek. However, recent discoveries challenge this long-held view, suggesting that the Intermontane Superterrane assembled in the mid-Triassic. This revised interpretation suggests that the oceanic arc and ophiolite crust represents a separate terrane—the Atlin Terrane—which formed as a Permian-to-Triassic arc-backarc system between Paleozoic Stikinia and the Cache Creek carbonate platform. If a mid-Triassic assembly is correct, then the current framework for distinguishing pre-collisional from overlap assemblages must be entirely re-evaluated.

This study presents a preliminary reclassification of the volcanic and sedimentary units within Cache Creek and adjacent portions of Stikine and Quesnel, based on a proposed mid-Triassic collision between Cache Creek and Stikine. As part of this compilation, existing geological units from central to southern British Columbia—available through the "Map Place 2" portal—have been reassessed using published data on geochemical affinity, age, and structural context.

Our preliminary results suggest that several clastic units within Cache Creek, including the Sowchea Succession, portions of the Stikine Assemblage, the Cunningham Formation, and the Tezzeron Succession, can be reclassified as overlap assemblages. Similarly, in the surrounding Stikine and Quesnel terranes, several volcano-stratigraphic units—including the Takla, Nicola, and Hazelton Groups—are also reclassified as overlap assemblages. Based on this reassignment, the overall geological framework of the central and southern Intermontane Superterrane appears to be predominantly composed of post-assembly successions.

Future research will focus on refining unit reclassification by integrating additional datasets, including published geochronology, geochemistry, and paleontology data.

## **Tectonic Controls on Marine Terrace Origin and Character in the Lituya Bay Area, Eastern Gulf of Alaska**

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Strongly deformed marine terraces differ in their degree of development and preservation along 65 km of the coast between Fairweather Glacier and Icy Point in the Lituya Bay area of the eastern Gulf of Alaska. From Fairweather Glacier to Lituya Bay one prominent terrace flanks the coastal mountain front, and isolated remnants of a lower, younger terrace occur landward of a wide prograded coastal plain. From Lituya Bay to Crillon River a sequence of five well-developed terraces bevel the coastal foothills. From Finger Glacier to Icy Point four terraces and the possible remnants of a fifth occur. The terraces form an arch with an axis of maximum uplift near La Perouse Glacier. The deformation is progressively greater in the older terraces and shoreline angle relief on the highest terrace is 100 m or more. The terraces are of Pleistocene and Holocene age. The oldest terrace studied is not well dated but the next oldest may have formed during the post-Wisconsin sea level rise. The three Holocene terraces probably formed about 3,500 (3,990–2,960 cal yr BP), 1,000, and 500 years ago. Ongoing uplift and arching of the coastal zone may mark renewal of mid-Pleistocene folding but Holocene uplift has taken place as discrete events that were probably accompanied by earthquakes. At least five uplift events have taken place between Lituya Bay and Icy Point in the past 3,000 to 4,000 years, which imply an average recurrence interval of ~500 years. Because recurrence of events that uplifted the terraces is distinctly longer than the average earthquake recurrence interval for the nearby Fairweather fault, coastal uplift may occur independently. The Finger Glacier fault displaces the Holocene terraces and may be a developing link between the onshore and offshore segments of the Fairweather fault.

This poster is based on ADGGS Report of Investigation 2022-4 ... published and downloadable at [Publications - Search | Alaska Division of Geological & Geophysical Surveys](#)

## Potential petrologic, tectonic, and economic implications of hydrated ultramafic rocks in southwestern British Columbia, Canada

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There is an urgent need to reduce atmospheric carbon dioxide emissions to limit the impacts of global climate change. This has resulted in a major upswing in research and development of carbon capture and storage solutions. The potential for rapid, permanent carbon capture through carbon mineralization within reactive, hydrated ultramafic rocks (*e.g.* serpentinite), has created a push to identify areas hosting these rocks and characterize their lithological properties. In addition to their carbon capture potential, ultramafic rocks are known hosts to Ni-Cr-Cu-PGE mineral deposits, which are critical metals for green energy solutions. Thus, ultramafic rocks potentially host major economic and climatic benefits.

Oceanic-related terranes of the western North American Cordillera (*e.g.* Atlin (formerly part of Cache Creek), Bridge River, Slide Mountain terranes) host significant volumes of variably hydrated peridotites. Recent petrologic and tectonic studies in the northern Cordillera (*e.g.* McGoldrick et al., 2017; van Staal et al., 2018; Cleven et al., 2018; Milidragovic and Grundy, 2019; Zagorevski et al., 2021) have interpreted these ultramafic rocks as being generated through hydrothermal alteration of supra-subduction zone lithospheric mantle and tectonically emplaced onto the paleo-western North American margin (*i.e.* supra-subduction zone ophiolites). Since the formation of supra-subduction zone ophiolites implies generation of ophiolitic rocks in the upper plate of a subduction zone, these interpretations have significant implications for the paleo-tectonic settings of Cordilleran oceanic-related terranes and accretion and obduction models.

This PhD study will interrogate multiple areas proximal to the Bridge River terrane in southwestern British Columbia, Canada (eastern Harrison Lake; Coquihalla serpentinite belt; Shulaps complex) that host significant volumes of variably hydrated ultramafic rocks. The study will utilize field mapping, structural, whole-rock and mineral geochemical (major-, trace-element and isotopes), and geochronological analyses of ultramafic-mafic complexes and surrounding rocks of the Bridge River, Cadwallader, and Methow terranes. This information will be used to better understand the petrogenesis, emplacement mechanisms, paleo-tectonic settings, and deformation and alteration of the ultramafic-mafic rocks. These results will provide the necessary geological context to ongoing carbon mineralization potential studies in the Cordillera and globally. Furthermore, a more complete understanding of the tectonic setting of hydrated ultramafic rocks in southern British Columbia will help to better understand tectonic relationships between the Bridge River, Cadwallader, and Methow terranes, and in turn, help evolve the Cordilleran tectonic framework.

**Bedrock Geology of the Howard's Pass District, Yukon and Northwest Territories – new insights into the Cordilleran deformation of world-class sediment-hosted massive sulfide Zn-Pb deposits**

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The Howard's Pass sediment-hosted massive sulfide (SHMS) deposits, located in the siliciclastic Selwyn basin on the border of the Yukon and Northwest Territories, are one of the largest undeveloped global reserves of zinc and lead. The district comprises 15 Silurian-age deposits that were subsequently deformed during their incorporation into the Selwyn Mountains Fold-and-Thrust (SFAT) Belt during the Cretaceous Cordilleran Orogeny. The SFAT Belt lies between the carbonate-dominated Mackenzie Mountains Fold-and-Thrust Belt to the NE and displaced allochthonous terranes to the SW.

Detailed mapping focused on the XY cluster of zinc-lead deposits at Howard's Pass was first conducted in the 1970s by Placer Development and Morganti (1979). The structure and stratigraphy of the larger 105I Nahanni Map Sheet were mapped and compiled at 1:50,000 and 1:250,000 in the 1980s and published by Gordey and Anderson (1993). More recently, Martel et al. (2015) and Martel (2017) proposed a new structural model for the district. These workers hypothesize that the Howard's Pass district has been incorporated into a Cordilleran-age duplex structure, in which thrust faults control the structural geometry of the district instead of folding. This interpretation is a radical departure from the geometry outlined by Gordey and Anderson (1993). On the maps presented by Martel (2017), contacts are all tectonic, and stratigraphy has been disrupted by complex thrust imbrication.

Here, we present the results of a detailed structural study of the geometry and kinematic history of the Howard's Pass district with two detailed structural and lithostratigraphic maps for the areas surrounding the XY and OP zinc-lead deposits mapped at 1:10,000. Two new cross-sections portray the effect of Cordilleran shortening on the stratigraphic sequence at Howard's Pass. Accompanying the detailed maps is an updated bedrock geology map compiled at 1:50,000. The map was completed using new structural data, internal data from Selwyn-Chihong Ltd., and legacy maps from the Geological Survey of Canada and the Yukon Geology Survey. The completed geologic maps differ from the duplex model of Martel et al. (2015) and Martel (2017) and are similar to the previous Gordey and Anderson (1993) interpretation, with folding exerting a primary control on the geometry of the district and the SHMS deposits.

During incorporation into the SFAT Belt, the zinc-lead deposits and their host strata were folded into a series of regional gently NW plunging folds. This folding event ( $F_1$ ) formed a pervasive axial planar cleavage ( $S_1$ ) in the less competent lithostratigraphic units (e.g., mudstones, siltstones, and limestones).  $S_1$  appears as a slaty to spaced cleavage, comprising penetrative dissolution seam, sub-parallel to  $F_1$  axial planes, and dipping steeply NE. In more competent units, such as the Devonian Earn Group's sandstones and conglomerates, shortening has been accommodated by large-scale parallel folds without forming an axial planar cleavage. Parallel folding of the competent strata plays a key role in shaping the structural geometry of the district by controlling the wavelength of regional folds. The enveloping wavelength of folded incompetent strata and the SHMS orebodies broadly conform to that of the parallel folds in the overlying units.

**Controls on Critical Metal Department in the Macmillan and Cirque SHMS Deposits***Zoe Lynn<sup>1</sup>, Foteini Drakou<sup>1</sup>, Kenneth Hickey<sup>1</sup>, Shaun Barker<sup>1</sup>, Dominique Weis<sup>1</sup>, Joel Saylor<sup>1</sup>*<sup>1</sup> University of British Columbia

Sediment-hosted massive sulphide (SHMS) deposits account for ~25% of global production of Pb and Zn, with potential economic value in their critical metal by-products, including In, Ge, and Sb. However, the distribution and enrichment mechanisms of these critical metals on a deposit and mineral scale are poorly understood. This study investigates how hydrothermal and post-mineralization metamorphic processes affect the department of critical metals in sphalerite, the main ore mineral for zinc in SHMS. The study will draw comparison between deposits in the Yukon/NWT, including the Devonian Earn Group hosted Macmillan and Cirque deposits. These deposits underwent deformation during the Cretaceous Cordilleran orogeny and experienced low-grade metamorphism, reaching greenschist facies. Through whole-rock geochemistry, high-resolution XRF mapping and laser ablation ICP-MS analysis, the aim is to a) quantify critical metal concentrations between deposits and b) identify their mineral hosts. Preliminary micro-X-ray fluorescence ( $\mu$ -XRF) mapping of samples from the Cirque deposit, provided by Teck Resources Limited, has revealed bladed barite mineralization and significant fine-grained sphalerite endowment. These samples will be prepared for thin section before performing LA-ICP-MS analysis to identify their critical metal host and abundance i.e., sphalerite, pyrite. The main goal of the study is to generate new genetic models for critical metal enrichment within SHMS deposits. This has direct implications for mineral exploration strategies and processing optimization at facilities like the Trail Smelter at Red Dog, Alaska.

## **Constraining the Timing of Deformation of the Spokane Dome Mylonite Zone, Priest River Complex, Idaho: Implications for Basal Décollement Continuity across Basement Structures**

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In the Himalayan orogenic system, basement structures in the underthrust Indian plate have been interpreted to directly influence the geometry of the orogenic basal décollement thrust and the resulting evolution of the overriding metamorphic core. In conjunction with our research in the Himalaya, our Cordilleran research seeks to test if the basement structures of the underthrust Laurentian plate experienced reactivation during Cordilleran shortening, thus causing diachronous movement on the basal décollement. Geophysical imaging of the Laurentian basement of southern Alberta highlights basement structures that are oriented at high angles to the Cordilleran front. One such feature is the Vulcan Low basement structure, which has been proposed to have influenced the structural evolution of the Foreland fold-thrust belt and continue westwards beneath the Omineca Belt. The Vulcan Low basement structure is traced between the metamorphic core complexes of the Monashee Complex in southern British Columbia and the Priest River Complex of northern Idaho. The base of the Priest River Complex is marked by the Spokane Dome Mylonite Zone, which been broadly correlated with the Late Cretaceous to Early Tertiary basal décollement of the southern Canadian Cordillera. The absence of age constraints for the Spokane Dome Mylonite Zone and regional integration with other basal décollements in core complexes elsewhere within the Omineca Belt undermines this correlation. Our research seeks to (1) constrain the age of thrust-sense deformation along the Spokane Dome Mylonite Zone and (2) compare it with age data along the Monashee décollement. Ultimately, such comparisons will be used to assess the possible continuity or segmentation of the basal décollement on either side of the Vulcan Low during Cordilleran evolution.

Preliminary results from detailed field work and petrographic analysis reveal a dominant top-to-the-east-northeast shear sense within the Spokane Dome Mylonite Zone, consistent with Cordilleran shortening. The main garnet-biotite-sillimanite-K-feldspar paragneiss unit within the mylonite zone contains foliation-parallel deformed leucosome boudins, and both lithological units are crosscut by undeformed dykes. To bracket the age of deformation within the Spokane Dome Mylonite Zone, the two different melt populations will be dated using accessory mineral geochronology, such as monazite and zircon. Additionally, we will date accessory minerals within the paragneiss host that are deformed and/or in important microstructural locations, such as within micro-shear bands. The age correlation and regional integration of the Omineca Belt basal décollement will contribute towards our understanding of how basement structures influence the evolution of the overlying orogen in different orogenic systems through time.

## **Preliminary Tectonic Framework Interpretations of Aeromagnetic Data in the Yukon-Tanana Upland, Alaska**

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The Yukon-Tanana upland (YTU) in eastern Alaska is thought to host undiscovered deposits of critical minerals. The geologic framework and mineral systems of the YTU have been mapped using geologic and geochemical methods with mixed success due to poor bedrock exposure. Airborne geophysical data are effective at mapping poorly exposed areas like the YTU, but existing data were too coarse for mapping mineral systems components. We present a modern aeromagnetic merge of the YTU with the addition of new data. Leveraging higher-resolution data than previously available allows us to better establish terrane boundaries and identify characteristics of mineral systems unique to each terrane.

The YTU consists primarily of the allochthonous Yukon-Tanana Terrane (YTT) and the parautochthonous North American basement (NAb). The YTT is a crustal fragment that rifted from North America in the Late Devonian, forming an ocean basin now represented by the Seventymile – Slide Mountain Terrane (SSMT). The YTT was subsequently accreted to, and eventually thrust over the NAb in the Jurassic. Cretaceous extension then exhumed underlying NAb rocks, emplacing granitoids thereafter. Mineral deposits are thought to be related to Mesozoic tectonomagmatic events where differences in crustal composition and structure likely contributed to variations in mineral deposits within each terrane.

The YTT-NAb boundary is interpreted to be a low-angle extensional detachment and the juxtaposed rocks have similar lithologies that are difficult to distinguish aeromagnetically. However, plutonic suites unique to each terrane can help define their boundaries and better understand their associated mineral systems. Our initial interpretations suggest that Triassic and Jurassic intrusive bodies are generally strongly magnetized compared to the weakly magnetized metamorphic rocks of the YTT. The metamorphic rocks within the NAb are invariably weakly magnetized, and highly magnetized rocks within the NAb appear to consist of Cretaceous plutonic and younger volcanic rocks. Magnetic lineaments are consistent with high-angle, post-detachment faults associated with movement between the Tintina and Denali faults that bound the YTU. By refining our understanding of the geologic framework, our work paves the way for more targeted exploration efforts of undiscovered critical mineral deposits in the YTU.

## A new and comprehensive restoration of the Denali fault, Yukon and Alaska

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The Border Ranges, Denali and Tintina faults are three first-order manifestations of the intra-continental response to the Paleogene transition from orogen-normal convergence between the North American plate and the plates underlying the Pacific Ocean to orogen-parallel transform faulting within and along the northwestern North American continental margin (Fig. 1).

The Denali fault and second-order splays form a fault system that extends for over 2,000 km from western Alaska to southern British Columbia. For much of its strike-length in British Columbia and southern Yukon, the fault is a single strand lying within the structural corridor between the Insular superterrane and inboard terranes which together formed the Jura-Cretaceous continental margin to which the Insular terrane accreted (eastern Denali fault and part of Coast Shear Zone in BC and southeastern Alaska). At its northern end, however, the fault trace leaves this corridor and cuts into the continental margin. This observation suggests that the continental margin was oroclinally bent before the fault initiated. Furthermore, along-fault discrepancies in separation observed near the hinge of the Alaska oroclinal embayment suggest that bending continued during fault displacement and forced the fault to develop new traces along a network of second-order structures (Hurricane-Mulchatna fault, Talkeetna-Mulchatna transpressional relay, and McKinley-Farewell fault; Murphy, 2019). Neogene (and younger) displacement on the Totschunda and Chatham Strait faults fed/feeds into post-ca. 37 Ma displacement on the eastern Denali-McKinley-Farewell fault although some displacement is partitioned into transpressional shortening on structures on both sides of the fault system (Waldien et al., 2021 and references therein).

Eocene and younger dextral displacement on Denali fault system sliced up key features of pre-Eocene interactions between the Insular superterrane and the Jura-Cretaceous continental margin, largely obscuring that history. In this poster I present a backward kinematic model for the post-ca. 50 Ma evolution of the Denali fault system which successfully restores all assemblages cut by the Denali fault and honours all constraints on timing and displacement along individual splays and related zones of shortening (Figs. 2, 3). This comprehensive restoration of the Denali fault illuminates key relationships that permit greater understanding of the pre-ca. 50 Ma evolution of the northwestern Cordillera, including the accretion of the Insular superterrane and Jura-Cretaceous and late Early Cretaceous sinistral strike-slip along the Jura-Cretaceous continental margin.

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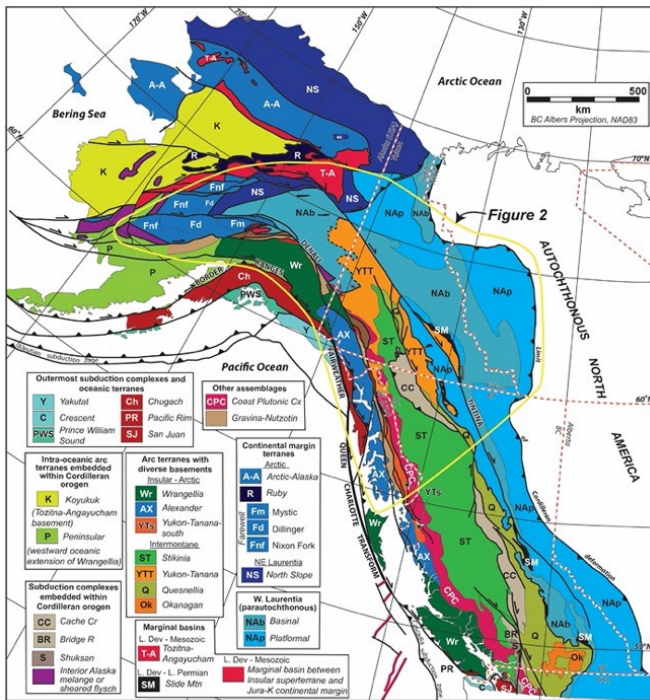


Figure 1

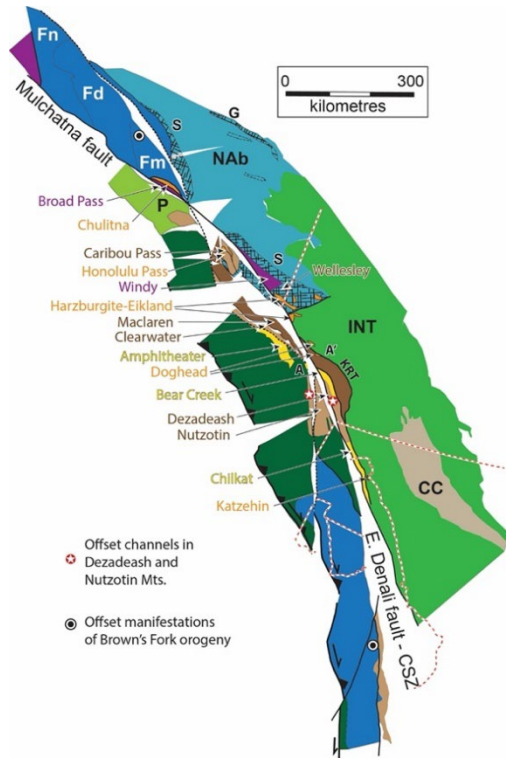


Figure 3

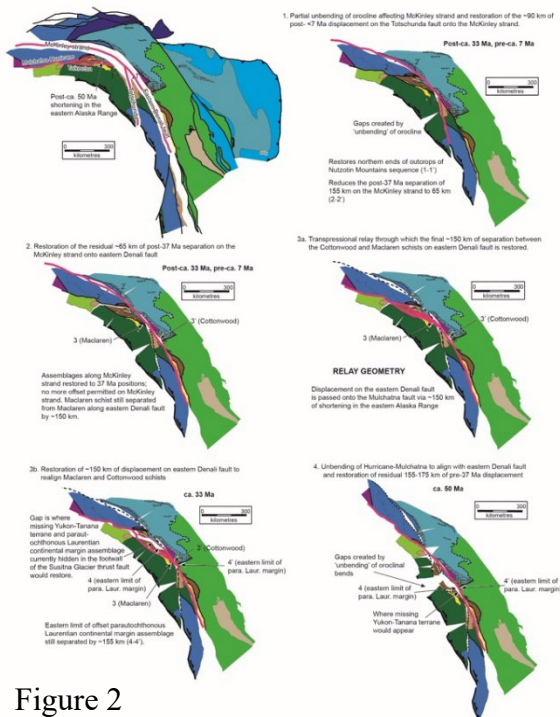


Figure 2

## Early Cretaceous accretion of the Insular superterrane, Yukon and Alaska

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In this poster, we present a new model for the accretion of the Insular superterrane to the composite Jura-Cretaceous continental margin in the northern Cordillera of Yukon and Alaska (Fig. 1). The model is based on an analysis of new data on assemblages and structures in the structural corridor between the superterrane and the continental margin, made possible by a new restoration of the Denali fault system (Fig. 2). The restoration is a ca. 50 Ma (pre-Denali fault) paleogeological reconstruction from which we can draw a cross-section from the inboard margin of the Insular superterrane to the outboard margin of the composite Jura-Cretaceous continental margin (Fig. 3).

At the latitude of the cross-section, the continental margin is composed primarily of parautochthonous North America at the deepest levels structurally overlain by Yukon-Tanana terrane along the Middle Jurassic Inconnu thrust. At the highest structural levels, klippen of Paleozoic to Late Triassic oceanic assemblages overlie all components of the continental margin; these locally include Jura-Cretaceous clastic rocks of the Insular-superterrane-derived southern Kahiltna assemblage. The klippen root outboard of the Jura-Cretaceous continental margin and represent the inboard part of the marginal basin separating the continental margin and the Insular superterrane. The inboard margin of the Insular superterrane passed laterally to the east into an ocean basin floored by the Triassic Bear Creek assemblage and correlative rocks and covered by Jura-Cretaceous clastic rocks of the Dezadeash Formation, correlative with the Kahiltna assemblage.

By analyzing the evolution of the structures along which the various assemblages were juxtaposed, we conclude that the marginal ocean basin between the continental margin and the Insular superterrane fully inverted in the Early Cretaceous (Albian, before ca. 106 Ma), by its thrusting onto the continental margin (Fig. 4). The thrust-fault-suture represents shortening within the suprasubduction zone wedge above the Chugach subduction complex, not east-facing subduction of the marginal basin beneath the Insular superterrane. Following the closure of this basin and suturing of the Insular superterrane to the continental margin, arc magmatism migrated from its Late Jurassic-Early Cretaceous location in the Insular superterrane (pre-obduction ca. 160 Ma to ca. 135 Ma Chitina-St. Elias and syn-obduction ca. 125 Ma to ca. 115 Ma Chisana-Nutzotin arcs) across the suture into the continental margin, starting with the ca. 110 Ma to ca. 95 Ma Whitehorse-Coffee Creek plutonic suite and lasting until ca. 57 Ma (Ruby Range batholith).

During the Late Cretaceous, the original suture was overlapped by early Late Cretaceous sedimentation (Kluane schist) and deformed by Late Cretaceous-Paleogene west-vergent syn-metamorphic and syn-intrusive deformation. Although widely considered to represent the terminal suturing of the Insular superterrane to the continental margin (Waldien et al., 2021; McKenzie et al., 2024; Regan et al., 2024), this phase of deformation was superimposed on the original suture and like the obduction of the marginal basin, represents intra-arc, intra-plate shortening of a continental margin/suprasubduction zone wedge.

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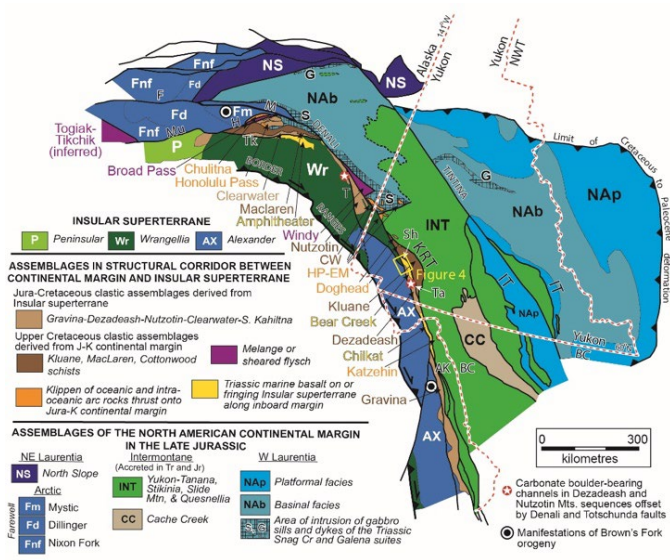


Figure 1

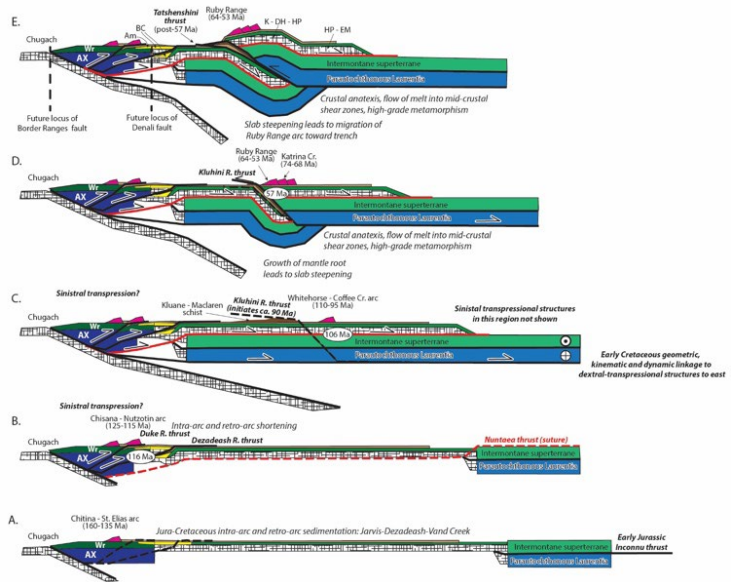


Figure 2

### **Insights from fault gouge geochronology: deciphering the (re)activation history of the Llewellyn Fault and its links to regional tectonics and mineralization**

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The Llewellyn Fault (LF) is a long-lived, regional-scale, southeast-striking, steeply dipping, brittle-plastic, dextral strike-slip structure extending over 100 km in the northwestern Canadian Cordillera. It locally overprints earlier ductile deformation along the Tally-Ho shear zone, situated at the boundary between Stikinia and the Yukon-Tanana terrane. The LF corridor includes a complex fault network that is associated with hydrothermal gold deposits, sulphide-rich skarns, and critical minerals, that was previously determined to have formed during two main stages, at c. 75 Ma and 50-55 Ma. Despite its regional and economic significance, the timing of LF activity remains poorly constrained. Most age data come from the intrusions at c. 74-76 Ma, that postdate the ductile deformation within the Tally-Ho shear zone and are later crosscut by the LF. Other age data are associated with the skarn formation and ore deposits dated at 50-55 Ma. Directly dating the fault's activity will provide insights into discrete deformation events, linking them not only to mineralization and fluid circulation but also to the broad tectonic context. This includes understanding the LF's role relative to other major Cretaceous and Cenozoic strike-slip structures, such as the Teslin, Tintina and Denali faults, and the Coast shear zone within the framework of accretionary tectonics.

To investigate the LF's deformation history, we focused on clay-rich fault gouges and integrated field observations with mineralogical and geochronological analyses. Samples were collected from key localities along the LF's trace, including Moon Lake, Klondike Highway, underground at the historic New Polaris mine and from core at Core Assets's Laverdiere property. At these locations the LF crosscuts granodiorite to quartz-rich metavolcanic rocks along multiple brittle fault strands, with damage zones ranging in thickness from centimeters to several meters. Fault segments strike approximately N350° to N045° and dip steeply. To date the timing of fault slip, gouge samples were subdivided into grain-size fractions (63–10 µm, 10–6 µm, 6–2 µm, 2–0.6 µm, 0.6–0.2 µm, and <0.2 µm) using gentle sample disaggregation methods and high-speed centrifugation. This method allows for distinguishing different authigenic illite generations that formed during discrete faulting events, following the hypothesis that finer fractions reflect the most

recent crystallization events. X-ray powder diffraction (XRD) was used to quantify clay mineralogy, and illite and chlorite crystallinity were measured to assess the temperature conditions under which the clay fraction formed. Results show that discrete illite generations formed under epizonal to diagenetic temperature regimes, with a generally decreasing metamorphic grade from coarser to finer fractions.

$^{40}\text{K}$ - $^{40}\text{Ar}$  dating of the clay fractions, has revealed multiple recrystallization episodes along different strike segments of the fault, with ages progressively younging from ~70 to ~40 Ma from coarser to finer fractions within each segment. At Moon Lake, where the damage zone exceeds several meters, isotopic ages decrease from the fault margins toward the core.  $^{87}\text{Rb}$ - $^{87}\text{Sr}$  geochronology on the same specimens does not have the precision to delineate different dates for each fraction size, however, a composite isochron date overlaps the  $^{40}\text{K}$ - $^{40}\text{Ar}$  results. To enhance our understanding of fluid pathways and fault-fluid interactions, future work will focus on geochemical and stable isotope analyses that assess fluid composition and partitioning during faulting. These investigations will contribute to answering unresolved questions regarding the LF's connections with other regional faults, its (re)activation history, and its role in hydrothermal ore formation in the Canadian Cordillera.

**Timing, source, and tectonic setting of primitive arc magmatism in the Canadian Cordillera: U-Pb geochronology and Hf isotope geochemistry of zircon in the Polaris Alaskan-type intrusion, north-central British Columbia**

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Establishing the age, duration, and source of primitive (high-MgO) arc magmatism is important for evaluating the evolution of subduction cycles under western North America and related magmatic Ni-Cu-PGE mineralization. The Early Jurassic Polaris ultramafic-mafic Alaskan-type intrusion, an exceptionally exposed composite sill-like intrusion, consists of peridotitic to gabbroic rocks that were emplaced at upper crustal levels ( $\leq 14-17$  km) into late Paleozoic arc-derived volcanosedimentary rocks of the Lay Range assemblage (Quesnel arc terrane). U-Pb zircon dating by LA-ICP-MS ( $n = 27$  samples) yields a range of ages from 182 to 190 Ma for the Polaris intrusion and identifies a previously undocumented suite of earlier Permian gabbros at ca. 255 Ma. Single-grain CA-ID-TIMS results ( $n = 10$  samples) refine this apparently protracted Early Jurassic magmatic episode into two distinct phases over a more restricted interval of time at ca. 187.5 Ma in the east and ca. 186 Ma in the west. High-precision solution MC-ICP-MS Hf isotope compositions of zircon vary between the older and younger phases ( $\epsilon\text{Hf}_{(t)} = +12.5$  and  $+11$  to  $+9$ , respectively) and are consistent with a juvenile mantle-derived magma source for Polaris parent magmas where the lower values potentially signify minor contributions from Lay Range crust. The 186-187 Ma crystallization age of the Polaris Alaskan-type intrusion coincides with the Early Jurassic accretion of the Quesnel arc to the pericratonic margin of Laurentia. This study highlights the importance of combining field relationships, geochronology, and Hf isotopic geochemistry to constraining the tectonomagmatic setting of primitive arc magmatism in the northern Cordillera.

## Geomorphic evidence of an active fault in the Mackenzie Mountains

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The Mackenzie Mountains in the Northern Canadian Cordillera are actively deforming despite being located nearly ~1000 km east of the plate boundary. Historic seismicity and GPS data indicate a generally NE-SW compressive stress regime throughout much of the Mackenzie Mountains that transitions to transpressive dextral strike-slip displacement in the north. The Mackenzie Mountains are a Mesozoic to early Cenozoic fold-and-thrust belt comprising Neoproterozoic to Devonian platform and basinal strata. Questions remain regarding what role pre-existing structures play in the distribution and accommodation of present-day deformation. Addressing this requires understanding which of the many mapped faults are active today. To identify active faults, we used a suite of areal and catchment-scale geomorphometric indicators across the entire Mackenzie Mountains and Plain (~300,000 km<sup>2</sup>). These metrics are sensitive to geomorphic processes that develop over 10<sup>2</sup>–10<sup>5</sup> years and therefore link deformation documented by geophysical data (decades) with the more distant geologic past (10<sup>6</sup> years).

We used the coincidence of river knickpoints, areal hypsometry, and topographic lineaments as indicators of potentially active faults. Our results identified one clear area where all three parameters coincide. This area, located in the Nahanni region in the southern Mackenzie Mountains, parallels the Battlement fault, a ~west-dipping thrust fault that strikes ~N-S with a mapped length of ~100 km and thrusts Middle Devonian limestone and dolomite over Upper Devonian shale and sandstone. These observations suggest that the Battlement fault is active.

To confirm Quaternary activity on this structure and explore its growth history, we investigated relative uplift rates along-strike of the Battlement fault using the morphology of 41 catchments that drain the hanging wall. We characterized catchment morphology using a suite of catchment-scale geomorphic indices: hypsometry (index and curves), catchment elongation ratio, catchment volume-to-area ratio, valley floor width-to-height ratio, and surface roughness. We interpret along-strike trends in multiple indices to reflect three zones along the fault with different relative uplift rates. The northern zone shows a high relative uplift rate, the central zone shows a low relative uplift rate, and the southern zone shows a moderate relative uplift rate. Differences in relative uplift rate along the fault may indicate fault growth by recent segment linkage.

The surface trace of the Battlement fault is located ~25 km east of the epicenters of the two M > 6 Nahanni earthquakes in 1985. Focal mechanisms for these earthquakes indicate that rupture occurred along a ~N-S-striking fault. It is probable that displacement during these events was accommodated along the Battlement fault. Our characterization of relative uplift rates along the Battlement fault suggests that this fault has been active since at least the Pleistocene.

## **Did the Cordilleran orogeny influence the thermal histories of the Canadian Shield and overlying basin in the Northwest Territories?**

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Ancient basement structures promote rifting during continental break-up, accommodate subsidence during basin development, and allow uplift during orogenic events. The Canadian Shield in the southwestern Northwest Territories comprises Precambrian terranes and orogens (e.g., Wopmay orogen, Slave craton) characterised by a conjugate array of NE-SW and NW-SE striking structures. Some of these are lithospheric-scale weaknesses (e.g., Great Slave Shear Zone) that follow the trend of the Precambrian orogens and were reactivated during Neoproterozoic–Cambrian rifting. However, Paleozoic and younger fault reactivation, particularly due to Cordilleran orogeny, is poorly constrained because the basement is mostly covered by the sedimentary rocks of the Western Canada Sedimentary Basin. These comprise Cambrian–Triassic passive margin strata and Jurassic–Paleogene foreland basin deposits.

This study aims to constrain the long thermal history of the Canadian Shield at its transition to the modern WCSB. We use low-temperature thermochronology to constrain heating associated with burial and cooling associated with exhumation. The methods used are apatite and zircon (U-Th)/He (AHe and ZHe, respectively) and apatite fission track dating (AFT), which have temperature sensitivity windows of ~55–85°C, ~140–200°C, and ~60–120°C, respectively. We analyzed 10 basement and 8 Cambrian–Devonian strata samples collected from outcrops and boreholes in the Great Slave Lake area.

Our results show that the Precambrian basement samples underneath the WCSB yield mostly Mesozoic AHe and AFT dates, suggesting experience of temperatures of at least 120°C since the basin formation. In contrast, samples from the exposed basement yield predominantly Paleozoic AHe and AFT dates, and Paleozoic–Precambrian ZHe dates, indicating heating to temperatures between 160–200°C. Samples from the overlying Cambrian–Devonian strata yield Mesozoic AHe and Precambrian ZHe dates, suggesting that these rocks have experienced post-depositional temperatures between 85–200°C.

To better constrain the thermal history of these rocks, we have performed thermal history modeling. Our models reveal two thermal history scenarios for different regions of the basement and overlying strata: (1) Devonian–Carboniferous burial followed by slow cooling, and (2) Devonian–Early Cretaceous burial and steady-state at >85°C followed by Late Cretaceous cooling. The slow cooling scenario (#1) occurs in samples within the Slave Craton and the Taltson-Thelon orogen, which have a dominance of NW-SE striking faults. In contrast, the Late Cretaceous cooling scenario (#2) occurs in areas where both the NW-SE and NE-SW striking faults overlap, such as the Wopmay orogen and the Great Slave Shear Zone. These findings suggest that the complex pattern of basement structures were reactivated during Cordilleran orogeny.

## **Preservation of Toodoggone District mineral deposits: the role of the Jura-Cretaceous Bowser Lake Group and the Cretaceous Sustut Group**

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The Toodoggone District in northern BC hosts numerous epithermal and porphyry-Cu deposits hosted within Late Triassic Takla Group and Early Jurassic Hazelton Group volcanic rocks. A north-south division exists, with epithermal deposits exposed in the north and porphyry-Cu deposits in the south, suggesting increasing post-Early Jurassic exhumation southward. Globally, epithermal deposits are most commonly of geologically young age, rarely older than Cenozoic, owing to their shallow origin and susceptibility to exhumation and subsequent erosion. However, within the Toodoggone District, numerous Early Jurassic epithermal deposits are preserved within Lower Jurassic volcanic rocks of the Toodoggone Formation. Burial by Jura-Cretaceous Bowser Lake Group and Cretaceous Sustut Group strata have been suggested mechanisms of preservation. Sustut Group strata occur along the western margin of the district and likely extended further east prior to erosion, while Bowser Lake Group strata are absent in the district. Consequently, the mechanisms that led to preservation of epithermal deposits in the district during Mesozoic Cordilleran orogenesis remains unclear.

Seven samples, comprising three intrusive rocks from the Late Triassic to Early Jurassic Black Lake plutonic suite, three volcanic rocks from the Early Jurassic Toodoggone Formation, and one sedimentary rock from the Early to Late Cretaceous Sustut Group were collected at surface from across the Toodoggone District for apatite (U-Th)/He, apatite fission track (AFT), and zircon (U-Th)/He analysis. The samples were collected from different parts of the district to determine if there was any differential exhumation/cooling and/or heating/burial. The low-temperature thermochronology data was input into the HeFTy software program to inverse model time-temperature (t-T) paths to determine plausible thermal history models for the district.

The Toodoggone District's geological history reveals two key phases of heating/burial and subsequent cooling/exhumation, as indicated by new AFT analyses, (U-Th)/He dating, thermal history modeling, and regional geological data. Burial beneath Bowser Lake Group strata resulted in the first phase of reheating in the Early to Middle Jurassic. This was followed by a significant cooling/exhumation period from the Early to late Early Cretaceous, potentially driven by uplift and erosion related to the development of the Skeena fold and thrust belt. Subsequent burial under Sustut Group strata led to a second major reheating phase during the late Early to Late Cretaceous. Since the onset of the Cenozoic, the district has undergone slow exhumation as the Sustut strata were eroded away. Preservation of the Toodoggone district's epithermal deposits is a product of post-mineralization burial, a phenomenon also observed in other older epithermal deposits globally.

## **Developing a laboratory method to assess post-depositional heating in sediments from the Alberta basin**

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Thermochronology uses radiometric dating to understand the thermal history of minerals. Apatite (U-Th-Sm)/He (AHe) is a low-temperature thermochronometer that records the cooling of apatite grains through the 50 to 80°C temperature window. Conventionally, AHe analysis uses whole apatite grains that are picked, packed and analysed. However, the method requires a strict grain selection for analysis, such as unbroken, inclusion-free, euhedral crystals with >80 µm width. It also requires grains to be digested in acid, limiting the possibility for multi-method analysis on top of the costly and time-consuming preparation. This limits the use of AHe dating to study sedimentary rocks, where grains are commonly imperfect, and analysis requires tens to hundreds of grains.

However, the extraction of helium from apatite by laser ablation offers a solution to the limitations of the whole-grain method. Laser ablation apatite (U-Th-Sm)/He analysis (LA-AHe) analyzes only a small portion of the grain core, which means that requirements for LA-AHe dating are less strict than for the conventional method, reducing selection bias. It also allows for the analysis of a large number of grains per sample at a high cost and time efficiency, making it particularly powerful for analyzing sediment and sedimentary rocks. On top of obtaining an AHe age, other data can be acquired from the same grain. Thus, the LA-AHe method not only increases sample throughput, but also allows multi-method analysis to obtain geologically important information.

In this study, we build on the novel LA-AHe dating procedure developed in the Geo- and Thermochronology Lab at the University of Calgary and apply it to a series of Cretaceous–Paleocene sandstones from the Alberta Foreland Basin. These samples experienced different degrees of post-depositional burial and heating. We compare our LA-AHe results to: 1) the whole-grain AHe data of the same sample, 2) the zircon (U-Th)/He (ZHe) and apatite fission track (AFT) data of the same sample, sensitive to higher temperatures of 160–200°C and 60–120°C, respectively, and 3) LA-AHe data between samples representing different degrees of thermal resetting post deposition.

Preliminary results from three samples suggest that the LA-AHe method is more effective than the whole-grain AHe method at identifying the resetting of sedimentary samples. The large number of LA-AHe grain dates allows to further constrain the degree of resetting that the samples experienced and derive the timing of cooling after maximum heating due to basin inversion

### Contrasting geological domains in the 30 Mile Range, Teslin area, southeast Yukon

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The nature of individual terranes, relationships between terranes, and the timing of major accretion and orogenic collision events remain debated in the northern Cordillera of Yukon, British Columbia and Alaska. The area of the 30 Mile Range in southeast Yukon encompasses units that may span a multiply reactivated suture zone, considering that the accretion of the Yukon Tanana terrane (YTT) to the North American (NA) margin must have involved subduction tectonics, and multiple collisional/orogenic events. Our mapping has deciphered a fold and thrust belt, wherein we interpret supracrustal rocks on the eastern side of the YTT (Finlayson and Klinkit assemblages) are structurally juxtaposed with a small panel of Cassiar terrane (a sliver of the ancestral NA margin), with Slide Mountain terrane (SMT) units in the region as potential suprasubduction ophiolite slivers, and with units of eclogitic rocks of the St. Cyr assemblage; along a terrane boundary that is possibly a suture zone with bonafide Cassiar terrane to the east. The presence of these diverse units, and their steep metamorphic gradient, are indications that the study area is suitable to examine collisional tectonic and accretionary processes and effects.

Bedrock geology exposure varies considerably across the area of the 30 Mile Range, from well-exposed ridge and mountain tops, to large lowland regions with essentially no exposed bedrock. We rely heavily on geophysical data to help extrapolate from our direct geological observations, and examination and analysis of archived samples from previous mapping projects. Deciphering the geology of the 30 Mile area is made difficult by “look alike” units, particularly the common presence of chert in all domains, and the general sparsity of direct dating opportunities of stratigraphy. The western part of the map area is underlain mainly by a domain of Finlayson assemblage units of fine-grained metasedimentary rocks, with lesser biotite +/- garnet and staurolite porphyroblastic metavolcanic rocks. These rocks have a trace element geochemical signature consistent with an oceanic volcanic arc. Finlayson assemblage rocks are overlain by Klinkit assemblage fossiliferous limestone (with local crinoidal debris) and marble and calcareous schist. The YTT rocks are intruded by Jurassic plutons of the Lokken suite, and record dominantly Early Jurassic Ar<sup>40</sup>-Ar<sup>39</sup> cooling ages ranging from ca. 198 to 190 Ma, with a single age as old as 213 Ma. A geological domain to the east of the YTT units are rocks we interpret as being part of Earn Group and older rocks of the Cassiar terrane, apparently structurally overriding YTT. The lower part of this stratigraphy is dominated by (meta)chert and lithic arenite interlayered with phyllite. These lithologies are intruded by foliated tonalite with a crystallization age of 362 Ma (a typical age of Earn Group magmatism). This domain also hosts sparse, thin layers of mafic metavolcanic rocks, with ocean island basalt (OIB) geochemical affinity. Stratigraphically above is fine siliciclastic sedimentary rocks (feldspar lithic quartz arenite, distinctive mauve coloured siliceous siltstone, charcoal grey phyllite and phyllitic argillite), all weakly metamorphosed. These appear to be unconformably overlain by a distinct near-monomictic chert pebble conglomerate

(multiple colours of chert clasts) with a silt matrix. The Earn Group rocks are intruded by middle Cretaceous plutons, but not Early Jurassic ones. Due to the low grade of metamorphism in the Cassiar rocks, we only determined a single  $\text{Ar}^{40}\text{-Ar}^{39}$  cooling age of 93 Ma. Cretaceous cooling ages are characteristic of the North American parautochthon elsewhere in Yukon. Structurally below the Earn Group rocks in the southern part of the map area, the deep valleys are underlain by featureless coarse-grained marble of un-determined affinity (ie. Unknown if it is part of Cassiar terrane, or YTT).

The eastern side of the map is underlain by the poorly exposed Red River assemblage, which dominantly comprises metasedimentary rocks of garnet-plagioclase-quartz muscovite schist and quartzofeldspathic schist (+/- garnet), with strong  $S_2$  transposition foliation overprinting an  $S_1$  foliation. A crucially distinctive characteristic of the domain is its mainly Permian  $\text{Ar}^{40}\text{-Ar}^{39}$  cooling ages that range mainly from ca. 278 to 263 Ma; with local resetting at ca. 245 Ma. The western edge of the domain which shows the prominent  $S_2$  crenulation fabric shows late Triassic overprinting in cooling ages between ca 220 and 210 Ma; an uncommon age of cooling in Yukon. Like the Earn Group rocks west of it, it is intruded by a foliated tonalite dated at 362 Ma (typical age of Earn Group magmatism). It shares a unique Neoproterozoic-Cambrian detrital zircon age component with Earn Group, making both distinct from YTT units. The St. Cyr assemblage occurs in the northeast extremity of the area. It comprises prominent amphibolite and eclogite lozenges (which have Devonian and Mississippian igneous protoliths) in undifferentiated quartzofeldspathic schist derived from strongly metamorphosed sedimentary and igneous rocks. The St. Cyr assemblage is characterized by Permian metamorphism and cooling ages, similar to those in the Red River assemblage.

The YTT rocks in the west part of the map area are strongly affected by west-directed folding and thrusting. The Cassiar rocks in the south-central domain are much less deformed, but appear to override a shallowly east dipping thrust. Structural vergence within the Red River domain is more complex, but the domain does appear to be separated from the YTT and Cassiar domain rocks along a steeply east dipping structure. Because the metamorphic cooling ages in the Red River domain are Permian, versus Early Jurassic in the YTT domain, the bounding structure must be Early Jurassic or younger. The St. Cyr domain shares a metamorphic and cooling history with the Red River domain, indicating they may have exhumed and cooled together, after experiencing subduction zone metamorphism. Resolution of a robust model for explaining how and when the distinct domains in the area were assembled, as well as with Bonafide North American rocks to the east of the map area, is ongoing.

## **Collapse of the Cordilleran Orogen in the Pacific Northwest: Evidence from High-resolution Geochronology of the Early Eocene Challis-Kamloops Group**

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The Challis-Kamloops group (CKG) is the supracrustal record of Early Eocene crustal collapse in the retro-arc region of the Pacific Northwest Cordillera. It comprises two phases of volcanic and non-marine sedimentary deposits separated by a magmatic lull, that were laid down in basins that formed in the upper plate of evolving metamorphic core complexes and highly extended terrain along a vast linear belt that spans from the Yukon Territory to Wyoming and Montana. Prior to orogenic collapse, the crust was up to 62 km thick, and likely comprised a broad, high-elevation plateau region within the hinterland of the compressional orogen.

Sixteen new tandem LA-ICP-MS/CA-TIMS zircon ages refine the legacy stratigraphic framework, revealing continuous tectonism comprised of two phases of magmatism separated by a magmatic lull. The volcanism-dominated 1st phase accompanied lithospheric delamination and rapid southwestward migration of the onset of magmatism. Mid-crustal rocks were exhumed to upper crustal levels at high rates by ductile lower crustal flow, which was accommodated by low angle, high offset detachment shear zones. A magmatic lull followed, during which regional erosion accompanied clastic and volcanoclastic deposition in supradetachment basins. The 2nd phase of magmatism was primarily felsic, and accompanied brittle exhumation of a similar magnitude to the 1st phase, but over a longer time and thus lower rate. Major brittle faults developed sub-parallel to the ductile detachments. The endpoint of CKG magmatism is not yet well-defined.

The key to this advance in understanding, gained through the application of the high-resolution geochronology, is the recognition that a similar but time-transgressive magmatic sequence propagated across the region as delamination occurred. This finding obviates the previous lithostratigraphic correlations of the CKG. The onset age of magmatism coincides with when the lithosphere delaminated beneath the region, following which the lower crust was heated by inflowing asthenosphere and simultaneously decompressed, which led to partial melting. The detached mantle lithosphere and lower crust may have also melted as they sank into the asthenosphere and contributed to CKG magmatism.

The pattern of onset ages indicates a southwestward propagation of delamination magmatism at very rapid (~130-170 km/My) rates. This is roughly twice the rate of well-documented slab-rollback related magmatism in the US Cordillera (~81 km/My), and more consistent with rates derived from numerical modeling of lithospheric delamination. The very short interval of ductile exhumation (~1.1 My) is also consistent with modeling of lower crustal flow and delamination rates.

The high-resolution geochronology of the CKG reveals a good correlation of the two phases to regional and megaregional tectonics in the Pacific Northwest and the Pacific Basin. Onset of delamination and 1st phase magmatism corresponds to a change in North America-Farallon convergence caused by the initiation of the Izu-Bonin-Marianas-Tonga subduction in the western

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Pacific basin, which resulted in a sudden decrease of the convergence rate. The magmatic lull is coincident with a regional unconformity in the Pacific Northwest that can be attributed to Siletzia LIP collision and accretion. The 2nd phase is coincident with the Hawaii-Emperor bend and the change of Pacific plate motion at ~49-47 Ma. Why delamination occurred, the style of delamination, and whether there were one or two delamination events is currently under study.

## Reconstructing Thermal Histories in the Intermontane Belt of the Southern Canadian Cordillera

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The Intermontane Belt, one of the five NW–SE striking morphogeological belts of the Canadian Cordillera, is situated in central British Columbia (BC). This belt features low-relief highlands positioned between the high-relief and mountainous Coast Belt to the west and the Omineca Belt to the east. The Intermontane Belt consists of an amalgamation of island arc terranes, including Stikine, Cache Creek, Quesnel, and Slide Mountain, composed of sub-greenschist to greenschist facies late Paleozoic to Mesozoic volcanic and sedimentary rocks, overlain by Neogene to recent basalts. In contrast, the adjacent belts comprise high-grade metamorphic and plutonic rocks exhumed from mid- to lower-crustal depths. This study aims to investigate the preservation history of upper-crustal rocks in the Intermontane Belt. Specifically, we analyze the thermal histories of basement rocks exposed in the Intermontane Belt and compare them with those of the Coast and Omineca belts. Our study region is located at the latitude of Williams Lake, BC (approximately 52°N), spanning east to west from the Columbia to the Coast mountains. We use apatite (U-Th)/He (AHe), apatite fission track (AFT), and zircon (U-Th)/He (ZHe) thermochronometry to analyze cooling through the temperature sensitivity windows of 45–70 °C, 60–120 °C, and 140–200 °C, respectively. This temperature-time information corresponds to the rock's history within the upper 2–8 km of the crust. We report AHe ages from 13 samples, yielding mean ages ranging from 9 to 65 Ma, AFT ages from 11 samples ranging from 29 to 56 Ma, and ZHe ages from 10 samples ranging from 34 to 155 Ma. We compare our new data with published data from adjacent regions.

Overall, we find that cooling below the AHe and AFT systems (120–45°C) occurred mostly during the Paleocene-Eocene in the Intermontane Belt, suggesting minimal erosion (<4 km) since then. This contrasts with the mountainous belts to the east and west, where ages are mostly Miocene and mid-Miocene–Pliocene, respectively, suggesting more recent and rapid exhumation. Many of our samples yield AFT and AHe ages that are similar within their uncertainties or inverted, indicating a more complex thermal history. The ZHe ages are generally much older in the Intermontane Belt (Cretaceous) and become younger towards the Coast Mountains. Our thermal history modeling reveals three distinct cooling phases: (1) a steady-state period (>150–60 Ma) preserved only in the Intermontane Belt, (2) an accelerated cooling phase between 60–40 Ma, which is the dominant phase across the study area, and (3) a localized accelerated cooling around 20 Ma. The 60–40 Ma cooling phase indicates significant regional exhumation, while the 20 Ma event is more limited in extent. Some samples exhibit a combination of these phases, suggesting spatial variations in exhumation and possible tectonic reactivation.

## Assembly and evolution of St. Cyr klippe, Yukon as informed by multi-chronometer geochronology and phase equilibrium modelling

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The St Cyr klippe (SCK) in southern Yukon is one of four localities in the northern Cordillera that preserves Permian-age eclogite. Previous work concluded that the SCK is comprised of rocks correlated to the Yukon-Tanana terrane (YTT) which were thrust onto North America or the YTT (depending on the study). The presence of eclogite and the SCKs location near or on the eastern margin of the accreted YTT make it critical for studying subduction processes and terrane accretion in the northern Cordillera.

Previous work has found the SCK comprises three main rock units: 1) intercalated eclogite and quartzofeldspathic host rocks metamorphosed and subsequently cooled in the Permian (referred to as St. Cyr assemblage here), 2) amphibolite facies garnet-plagioclase-white mica schists metamorphosed and cooled through the  $^{40}\text{Ar}/^{39}\text{Ar}$  closure temperature for white mica in the Permian (referred to as Red River assemblage here), and 3) amphibolite facies metasedimentary rocks that record metamorphism and cooling in the early Jurassic (referred to as Finlayson assemblage here). Previous limited data from the SCK has led to ambiguity in interpreting its tectonic evolution. It has been proposed that the St. Cyr assemblage eclogites and quartzofeldspathic host rocks were intercalated pre-metamorphism, metamorphosed and rapidly exhumed as a coherent tectonic slice before juxtaposition against the Red River assemblage and cooling during the Permian. Subsequent structural association with the Finlayson assemblage post-Jurassic resulted in the current configuration. This interpretation is based on mapped lithological differences, U-Pb zircon geochronology from a limited number of eclogites, Ar-Ar muscovite and/or biotite dates restricted to the Red River and St. Cyr assemblages, and pressure (P)- temperature (T) conditions derived from disparate eclogite and quartzofeldspathic rock.

To build upon the existing data and refine the tectonic model for eastern YTT and the northern Cordillera during the Permian, we carried out phase equilibrium modelling and multi-chronometer geochronology on specimens collected along transect through all three SCK units. Phase equilibria modelling with garnet-based thermobarometry of two eclogites from different structural levels within the St. Cyr assemblage have similar isothermal P-T paths with peak conditions of 3.4 GPa at 600 °C. Si-in-phengite geobarometry on the host rock for the structurally higher eclogite indicates eclogitic peak pressure of ~3.0-3.2 GPa prior to a final matrix equilibrium at amphibolite conditions of 0.9 GPa at 725 °C. Within the Red River assemblage, Si-in-phengite geobarometry also indicates an eclogitic peak pressure of ~2.7-2.9 GPa. Multi-fraction garnet Lu-Hf geochronology for the two mafic eclogites investigated using phase equilibria modelling in the St. Cyr assemblage yield dates of  $266 \pm 1$  Ma (MSWD=1.7) for the structurally highest eclogite specimen and  $250 \pm 1$  Ma (MSWD=2.1) for the structurally lowest specimen. *In situ* Rb-Sr geochronology on biotite and phengite in the quartzofeldspathic host rocks from specimens near the structurally highest eclogite specimen yield a variety of

dates:  $267 \pm 3$  Ma,  $251 \pm 23$  Ma,  $250 \pm 2$  Ma, and  $234 \pm 1$  Ma. Garnet Lu-Hf geochronology on a specimen from the Red River assemblage defines an isochron at  $280 \pm 4$  Ma (MSWD=0.33), whereas *in situ* Rb-Sr on phengite and biotite from the same structural level yield a date of  $243 \pm 2$  Ma. Phengite-only isochrons from two other nearby specimens yield low-precision dates of  $301 \pm 30$  Ma and  $260 \pm 23$  Ma.  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology on phengite from a slightly higher structural level than the Lu-Hf dated specimen gives a date of  $269 \pm 1.6$  Ma. *In situ* Rb-Sr geochronology on muscovite from a specimen collected from the structurally highest level in the Finlayson assemblage returned a date of  $199 \pm 18$  Ma, while  $^{40}\text{Ar}/^{39}\text{Ar}$  mica dates from three specimens in the highest structural levels are  $195.1 \pm 1.1$  Ma and  $195.3 \pm 1.2$  Ma for muscovite, and  $193.3 \pm 1.1$  Ma for biotite. Two specimens from a structurally lower level within the Finlayson assemblage define Rb-Sr isochrons of  $226 \pm 13$  Ma, and  $232 \pm 10$  Ma

Within the St. Cyr assemblage, the similarity in peak pressures for the eclogite and host rocks indicate that they were juxtaposed prior to peak-pressure metamorphism and subsequently exhumed as a coherent tectonic slice. The Red River assemblage reaching a similar peak pressure to the St. Cyr assemblage further indicates that the Red River garnet schists may be related to the quartzofeldspathic rocks that host the eclogite in the St. Cyr assemblage. The distinct garnet dates within the St. Cyr and Red River assemblages are interpreted to reflect the stepwise assembly and metamorphism of different tectonic slices, perhaps similar to the processes observed in metamorphic soles. *In situ* Rb-Sr dates for the St. Cyr and Red River assemblages are slightly younger than corresponding garnet metamorphic ages for these assemblages indicating that both assemblages were exhumed rapidly after eclogitic grade metamorphism in the Permian. Similar cooling ages in both the St. Cyr and Red River assemblages indicate the tectonic slices that make up these assemblages were potentially juxtaposed during each sequential tectonic slice exhumation. Finally, mica Rb-Sr and  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  geochronology from the Finlayson assemblage outlines areas with differing cooling histories, perhaps also reflecting the assembly of multiple tectonic slices. The difference in cooling ages within the Finlayson assemblage indicates juxtaposition to the Red River assemblage may have occurred as distinct Triassic and Early Jurassic events. These new data facilitate insights into the paleosubduction record of the northern Cordillera.

## **Earth MRI Geologic and Geophysical Mapping of Alaska's Critical Mineral Belts: Working towards an improved regional framework**

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As part of the U.S. Geological Survey's Earth Mapping Resources Initiative (Earth MRI), the Alaska Division of Geological & Geophysical Surveys (DGGS) is working to complete modern and detailed geologic, geophysical, geochemical, and geochronology datasets covering the mineral-rich Yukon-Tanana Upland (YTU), the Kuskokwim River region, and the Seward Peninsula.

The Yukon Tanana Upland of Interior Alaska lies between the Tintina and Denali faults and is underlain by structurally complex metamorphic rocks affiliated with both the allochthonous Yukon-Tanana Terrane and paraautochthonous North America. These rocks experienced post-metamorphic magmatism spanning Permian through Cenozoic time, followed by block faulting and localized sedimentary basin development during the Late Cretaceous through Cenozoic. Mapping and understanding these geologic elements—especially those that impact the YTU's mostly Cretaceous economic mineral systems—is the focus of DGGS's research in the area.

Our understanding of the chronology, chemistry, and spatial distribution of post-metamorphic magmatism has progressively improved during the past 20 years as USGS and DGGS have added new zircon ages and whole-rock analyses to the YTU dataset. Consequently, we are working to define or refine (and ultimately formalize) named plutonic suites using specific age and compositional criteria. Developing this nomenclature is a key part of making more informative geologic maps, regional interpretations, and cross-border geologic reconciliations.

Work in the Kuskokwim River region is presently focused on detailed (400-m line spacing) aeromagnetic and radiometric geophysical surveys using a fixed-wing or helicopter aircraft, depending on terrain. Opportunistic gravimetry collected by an inertial gravimeter has been added to the survey through collaboration with Lamont Doherty Earth Observatory. DGGS and USGS completed a SkyTEM time-domain electromagnetic survey of the Seward Peninsula in 2024, and will initiate detailed magnetic and radiometric surveying of this area in 2026.

This poster presents an overview of our growing geological and geophysical datasets for the purpose of seeking feedback and discussion from workshop participants.

## **Constructing the chemostratigraphy sequence around Zn-Pb mineralization using pXRF analysis on drill core, Howard's Pass district**

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The Howard's Pass district contains fifteen sediment-hosted massive sulphide Zn-Pb deposits spanning the Yukon-Northwest Territories border. Here, we present lithochemostratigraphic analysis results focused on the structurally complicated Duo Lake Formation in drill cores from Howard's Pass. Our study aims to define the chemostratigraphy through the Duo Lake and investigate the paleoenvironment conditions that accompanied the mineralization formation.

Structural, lithostratigraphic, and portable-XRF geochemical data were collected down selected drill holes from the XYZ, Don and Anniv deposits. The cores were structurally reoriented using a NNE-dipping regional S1 cleavage. The fold geometry was determined from cleavage-bedding asymmetry and integrated with marker units to help determine the completeness of stratigraphic sections in drill holes.

Chemostratigraphy of a complete section of the Duo Lake Formation was constructed. Concentrations of aluminum are the lowest in the mineralized Active Member (ACTM) and increase away from ACTM. Excess silica shows a roughly inverse trend to Al and is the highest at the top of ACTM. Vanadium concentrations remain relatively consistent in Duo Lake, with some concentration peaks. Barium concentrations are mostly low but increase uphole gradually above the ACTM, reaching high concentrations in the Steel Formation.

The geochemistry results suggest that the Zn-Pb mineralization occurs in a biosiliceous sediment deposited during a period of decreased terrigenous deposition. Most of the Duo Lake was deposited under suboxic to euxinic conditions, with two euxinic periods in lower ACTM and below. The environment was increasingly oxic in the upper Duo Lake Formation and became fully oxic in the Steel Formation.

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