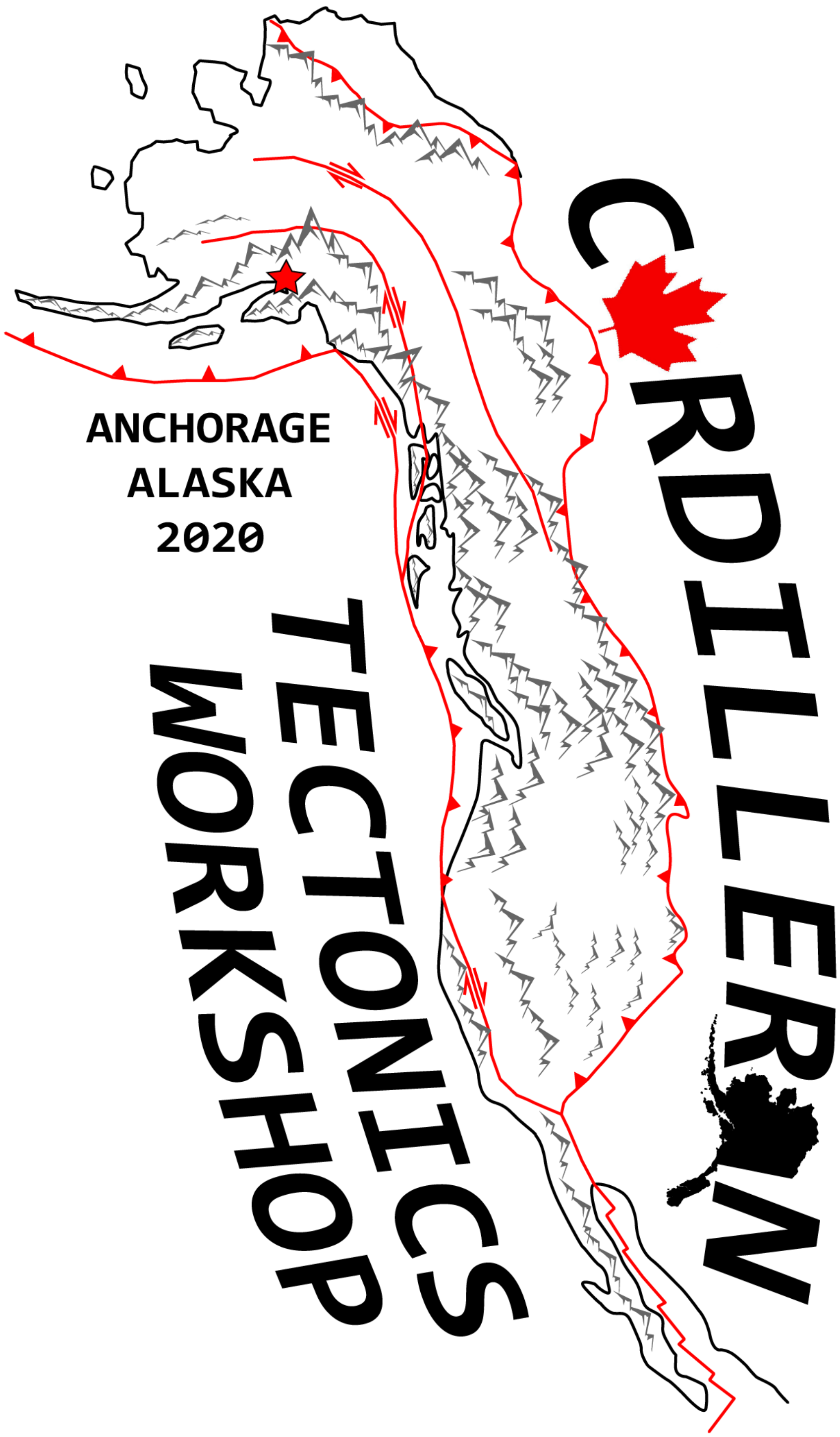


Cordilleran Tectonics Workshop
February 21-23, 2020
Anchorage, Alaska

2020 Cordilleran Tectonics Workshop
Atwood Center Rasmussen Hall, Alaska Pacific University, Anchorage, Alaska

Organizers/hosts: Jamey Jones, USGS Alaska, jvjones@usgs.gov; Doug Kreiner, USGS Alaska, dkreiner@usgs.gov; Jonathan Caine, USGS Denver, jscaine@usgs.gov

Sponsor: GeoSep Services, Paul O'Sullivan, p.osullivan@geoseps.com
GeoSep Services is sponsoring the Saturday evening reception during the poster session and has also contributed to the student travel fund. We are grateful for their support.

GeoSep Services
Quality Mineral Separations and Analytical Services
Moscow, Idaho, USA • geoseps.com

***Quick notes and suggestions*:** The schedule below is subject to change but should be more or less complete. We have tried to organize talks logically while also leaving ample room for breaks and discussion. We also want each poster presenter to take a couple of minutes at the appropriate time (see schedule below) to introduce themselves and the topic of their poster.

We will be catering the Saturday and Sunday sessions ourselves, so coffee, tea, and snacks will be available as needed throughout the day. If you need something specific, please feel free to ask one of the organizers. If possible, bring a reusable mug for hot drinks. We will provide a reusable cup for water or other cold beverages.

The Friday night Icebreaker reception will be in downtown Anchorage in the Heritage Theater at the 49th State Brewing Company. The theater is just inside the brewery to the right. The Saturday and Sunday sessions will be on the Alaska Pacific University campus in midtown Anchorage. See the map at the end of the program for directions to the Atwood Center. Rasmussen Hall is inside on the second floor. Parking is free on the APU campus.

The optional group dinner on Saturday night is at Charlou restaurant in midtown Anchorage. The menu will be simple but delicious and will accommodate any/all dietary restrictions (vegetarian, vegan, gluten free, etc.). It should also be fairly affordable by Anchorage standards, and we'll ask everyone to pay their own way since there will be options and no set cost.

We will try to coordinate shared rides between downtown and midtown to the extent possible for those who do not have transportation in town.

ALASKA PACIFIC UNIVERSITY

Welcome to Alaska Pacific University!

We are dedicated to making your event while visiting our campus a complete success. Whether you are a first-time renter or a long-term affiliate, we are pleased to welcome you to Alaska Pacific University's campus. It is our goal to ensure we accommodate your needs for the duration of your stay on campus.

Please feel free to contact the Conference and Events department at any time with rental, catering, technology, equipment, or other conferencing and event needs. Below you will find information to help make your time at APU more productive and comfortable.

The Conferencing and Events office is located in room 225 on the second floor of the Carr Gottstein building. Office hours are generally Monday-Friday from 8:00AM-5:00PM.

Contact

Conference and Events is your point of contact for the duration of your event and should be used for all non-emergency incidents. Campus safety may respond to incidents at the discretion of the Conference and Events department, but should not be treated as a priority contact for non-emergency incidents (e.g., lockouts). Campus safety's information is provided as a resource in the event of non-life-threatening emergency and for approval to host controlled bonfires at approved housing units.

Conference and Events	907-312-9425 (24-hour number) 907-564-8323 (office)
Campus Safety	907-564-8888 (24-hour number)

Any group or participant in a situation that includes elements of immediate, acute and/or potentially life-threatening situations should notify emergency responders. **If there is a risk to personal safety or life-threatening emergency, please call 911 immediately.**

Regards,

Christopher Pavadore

Chris Pavadore, MBA, SSGBC, PM-LPC, EMC
Executive Director of Auxiliary Services
Alaska Pacific University
p: (907) 564-8323 e: conferencing@alaskapacific.edu

MOVE

Policy and Procedure Overview

The following information is a basic guideline of policies to consider and adhere to while renting University spaces. Your contract will include more detailed descriptions of these basic guidelines as necessary. Additionally, your contract will include *all* policies of rentals and acceptable use agreements. Failure to adhere to University policies is subject to additional fees, suspension, and/or cancellation of your event.

1. **Parking**
    a. Parking is available free of charge in two locations: directly across from Grant Hall or adjacent to the Atwood and Carr Gottstein Academic Centers.
    b. Parking is **NOT** permitted in designated loading areas, except with the sole purpose of loading and unloading.
    c. Parking is **NOT** permitted in designated snow removal or no parking areas. Please remind your participants to avoid parking in the Glenn Olds, Gould, and Grace Hall parking lots, as well as the Moseley Sports Center parking lot.

2. **Accidents & Injuries**
    a. If an accident or injury of any event participant should occur at any time while visiting or renting the Alaska Pacific University Campus or remote, university-owned assets, an incident report must be completed and submitted immediately to the Conference and Events department.

3. **Emergency Exits**
    a. Please review all emergency exits with your participants. Building-specific emergency exit plans can be found in the rooms around campus and near each exit of each building.

4. **Prohibited and Unauthorized Areas**
    a. All University gardens and landscaped areas are off-limits *at all times*.
    b. Unauthorized access to unreserved or uncontracted space at Alaska Pacific University is prohibited *at all times*. Knowingly or negligently utilizing University spaces without prior approval is subject to additional fees, suspension, and/or cancellation of your event.
    c. Damages incurred in prohibited and unauthorized spaces shall be assessed at the expense of the Renter.
        i. Damages may be assessed *after* the event date.

5. **Chaperones**
    a. For groups with youth aged eighteen or under, proper chaperoning is required. A minimum of one chaperone per ten youth is recommended.

6. **Keys**
    a. Keys are checked in and out by the Conference and Events department.
    b. Keys are checked out to the event host or on-site coordinator *only*.
    c. Keys may **NOT** be transferred to other person(s) without prior approval from Conference and Events.
        i. Keys lent to unaffiliated groups or unauthorized persons is a violation of your contract and subject to additional fees, suspension, and/or cancellation of your event.
    d. Failure to return keys will result in additional fees including, but not limited to, key replacements, door lock replacements, and door rekeying in *all* spaces the missing key(s) can access.

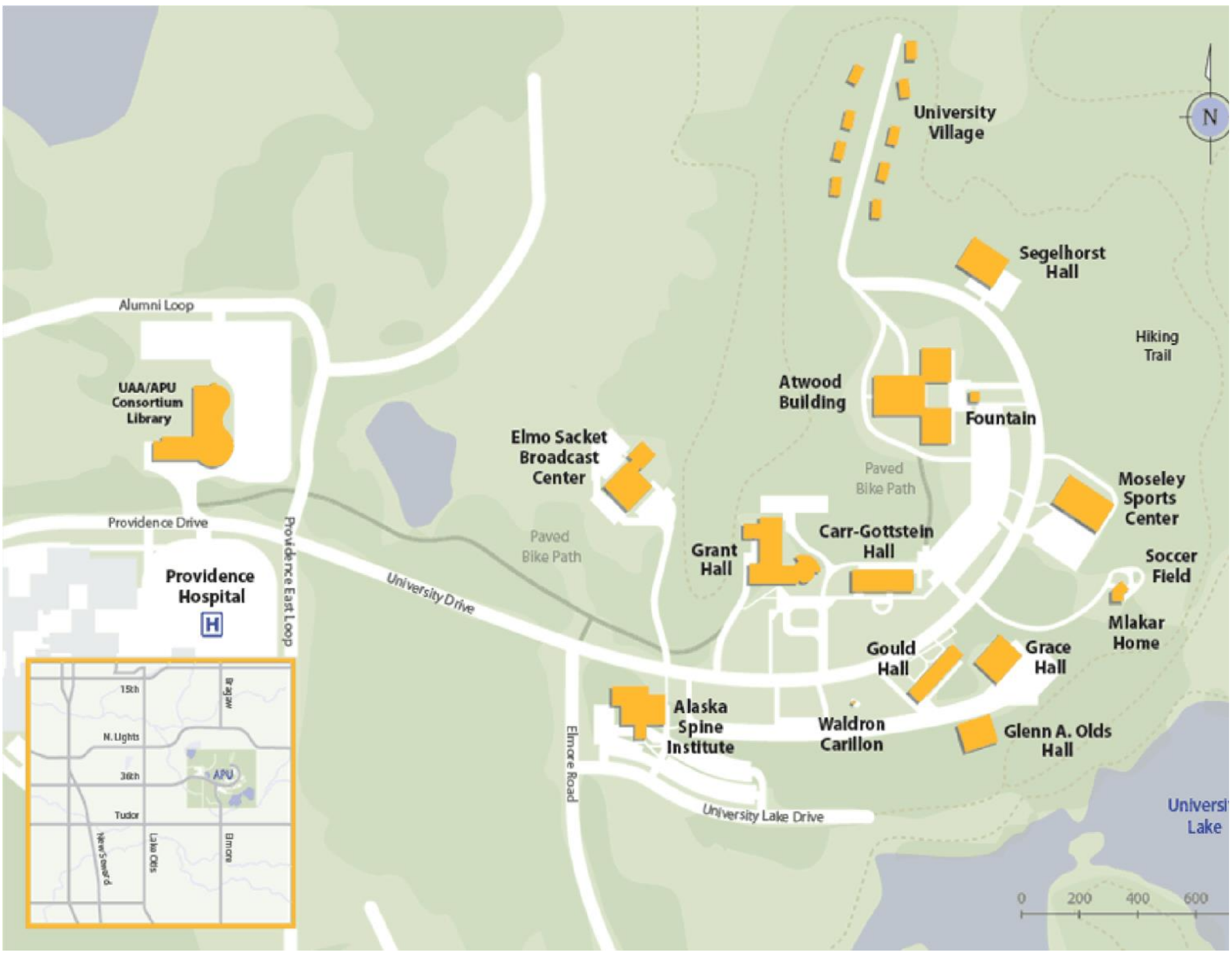
7. Personal Property

a. Alaska Pacific University is **NOT** responsible for damages to or theft of personal property and valuables. All personal items are the responsibility of the renter and event participants. For your own protection, do not leave any valuables or personal property unattended.

8. Other

a. All other university policies applicable to your event will be provided in your contract prior to your event date.

Campus Map



2020 Cordilleran Tectonics Workshop

Atwood Center Rasmussen Hall, Alaska Pacific University, Anchorage, Alaska

Schedule of events

Friday, February 21, 2020

5:30 – 9:00 pm	**Icebreaker and registration** *49th State Brewing Company Heritage Theater, downtown Anchorage* Come down to the 49th State brewery Friday evening to pick up your nametag, have a drink and a bite to eat, and say hello to everyone. If you haven't registered for the workshop yet, we will have the ability to take care of that. We will also have a laptop available to upload the presentations for Saturday morning's session. We'll have maps up for discussion on the walls, but do not bring your workshop posters until Saturday morning.

Saturday, February 22, 2020

8:00-9:00 am	Coffee, pastries, registration, and poster setup
9:00 am	Opening remarks
9:10-10:30 am	Oral session
10:30-11:00 am	Discussion and break
11:00-12:00 pm	Oral session
12:00-1:30 pm	Discussion and lunch
1:30-2:30 pm	Oral session
2:30-2:50 pm	Discussion and break
2:50-4:20 pm	Oral session
4:30-6:30 pm	Poster session and reception sponsored by GeoSep Services
7:00-9:00 pm	Optional group dinner at Charlou, midtown Anchorage

Sunday, February 23, 2020

8:00-9:00 am	Coffee, pastries, and posters
9:00-10:00 am	Oral session
10:00-10:20 am	Discussion and break
10:20-11:30 am	Oral session and wrap-up
11:30 am	Poster session, lunch, takedown

Saturday, February 22

800-900 Setup/coffee			
900	Introduction/overview		
910	Julie Dumoulin	USGS	Triassic Phosphatic Rocks of Northern Alaska: Spatial and Temporal Depositional Patterns on a High-latitude, Low-angle Ramp, Northwest Laurentian Margin
930	Elizabeth Miller	Stanford	Geology of the Schist belt: A 600 km long zone of high strain along the southern flank of the Brooks Range, Alaska
950	Karol Faehnrich	Dartmouth	Stratigraphic architecture of the Porcupine shear zone, Yukon and Alaska and its significance in the evolution of northern Laurentia
1010	Poster Introductions I		Moore, Niglio, Trembath, B. Miller, Wilson, Roeske
1030-1100 Break			
1100	Rosie Cobbett	Memorial	Extensional tectonism recorded by Late Ordovician volcanism near Castle Mountain, north-central Yukon
1120	Emma Kroeger	U Iowa	Detrital zircon U/Pb & εHf signature of the Yukon-Tanana terrane in Yukon, Canada
1140	Alec Wildland	UAF	Shear zone formation and juxtaposition of allochthonous Yukon-Tanana terrane with pericratonic North America, eastern Alaska
1200-130 Lunch			
130	Adam Wiest	Memorial	Unraveling the Upper Triassic to Lower Jurassic stratigraphy of the Faro Peak formation, southern Tay River map area, central Yukon
150	David Moynihan	YGS	SW-vergent deformation and metamorphism of the Hyland River area, southeastern Yukon
210	Poster introductions II		Caine, Naibert, Regan, Twelker, Wypych, Ambrose, Sack

230-250 Break			
250	Dan Gibson	Simon Fraser	Late Jurassic to Early Cretaceous evolution of the Blanchard River and Vand Creek assemblages, southwest Yukon; implications for Jura-Cretaceous basin development and Mesozoic accretionary processes in the northwestern Cordillera
310	Trevor Waldien	UC Davis	Late Cretaceous underplating of the Kluane-Cottonwood-Maclaren schist beneath the northern Coast Mountains Arc, Yukon and Alaska and implications for Cenozoic displacement on the Denali fault
340	Doug Kreiner	USGS	Pre-cursor tectonic and magmatic influences of the Yukon-Tanana terrane on Late Cretaceous porphyry mineralization
400	Poster introductions III		Allan, Keogh, McKenzie, Lease
430-630 Poster session and reception			
700-900 Group dinner at Charlou			

Sunday, February 23

830-900 Setup/coffee			
900	Poster introductions IV		Karl, Case, Nadin, Bowie, Li, Haeussler
920	Trystan Herriott	DGGS	Exploring the law of detrital zircon in Alaska's Cook Inlet: LA-ICPMS and CA-TIMS geochronology of Jurassic forearc strata
940	Erin Todd	USGS	Comparing Middle Crust formed in Continental Margins Versus Island Arcs in the Alaska Range
1000-1020 Break			

1020	Anastasia Ogloff	Simon Fraser	The Murray dyke swarm, southwest British Columbia, records the decline of an Early Cretaceous continental arc during the onset of the mid-Cretaceous magmatic and orogenic culmination of the Canadian Cordillera
1040	Don Murphy	YGS	Some thoughts on Cordilleran accretion history arising from the restoration of Paleogene fault systems
1100	Adrian Bender	USGS	Late-Cenozoic Yukon River capture, climate change, and consequences on the Yukon-Tanana upland landscape (Alaska and Yukon, Canada)
1120	Wrap-up and where next		
1130	Poster session		
1230	Lunch, takedown		

Poster presentations (listed alphabetically by presenting author)

Author	Affiliation	Title
Allen, Wai	Purdue University	Cenozoic basin development and strike-slip displacement along the Denali fault system, eastern Alaska Range, Alaska: A provenance approach
Ambrose, Tyler	YGS	Preliminary bedrock geology of the Rackla River area, Wernecke Mountains, Yukon.
Bowie, Sarah	Simon Fraser University	P–T–*t* conditions of high-temperature metamorphism and deformation in the Shuswap Metamorphic Complex, British Columbia
Caine, Jonathan	USGS	Exploring Regional Scale Metamorphic fabrics in the Yukon Tanana Terrane and environs Using Quantitative Domain Analyses
Case, George	USGS Alaska	Geologic characteristics and ^{187}Re-^{187}Os age constraints on porphyry-style Mo and newly identified porphyry-style Au mineralization revealed by ice retreat in the Taku River corridor, SE Alaska
Haeussler, Peter	USGS Alaska	Age and evolution of mid-Cenozoic stepover basins in southeastern Alaska

Karl, Sue	USGS Alaska	New mapping in the Taku River corridor, southeast Alaska: observations and implications for geologic framework and mineralization in the southern Yukon Tanana terrane and Coast batholith
Keough, Brandon	Purdue University	Tectonic Evolution of the Northern Cordilleran Continental Margin: A Re-evaluation of Upper Paleozoic-Cretaceous Stratigraphy, Denali National Park and Preserve, Alaska
Lease, Richard	USGS Alaska	Progressive exhumation of the Yukon-Tanana upland during Paleocene-middle Eocene Tintina fault strike-slip
Li, Zhiyang	UAA	Dynamic Subsidence and Uplift in the Late Cretaceous Cordilleran Foreland Basin
McKenzie, Will	Simon Fraser University	Unravelling the thermo-tectonic history of the Jura-Cretaceous Kluane Schist, Northern Canadian Cordillera
Miller, Becca	Dartmouth	Compilation of bedrock geology along the Alaska–Yukon border from the Arctic Ocean to the Yukon River
Moore, Tom	USGS	Transition from Foreland Fold Thrust Belt to Metamorphic Hinterland in the Arc-Continent Collisional Brooks Range Orogen, Northern Alaska
Nadin, Elisabeth	UAF	Strength of a Ductile-to-Brittle Fault in the Cretaceous Southern Alaska Accretionary Complex
Naibert, Travis	DGGS	Refining tectonic events in the Fortymile River assemblage using $^{40}Ar/^{39}Ar$ thermochonology and correlating lithotectonic units in eastern Alaska
Niglio, Lou	BOEM	Detrital zircon LA-ICPMS U-Pb geochronology of Arctic Alaska Basin sedimentary rocks
Regan, Sean	UAF	Zircon evolution during shear zone development and progressive grain size reduction: insights from an isochemical strain gradient in eastern Alaska
Roeske, Sarah	UC Davis	Comparison of Alaska Depth to Moho Map with Geologic and Active Tectonic Features

Sack, Patrick	YGS	Late Cretaceous (ca. 80 to 66 Ma) intrusion-related mineralization: A new project to examine the most prolific Cu-Au-Mo epoch in Yukon
Trembath, Matthew	University of Iowa	Structural Characterization of the Porcupine Shear Zone in Arctic Alaska
Twelker, Evan	ADGGS	New bedrock mapping highlights the importance of brittle and ductile structure in the tectonics and metallogeny of the eastern Yukon-Tanana Upland, Alaska
Wilson, Ric	USGS Alaska	Building geologic map databases for tectonic and resource analysis
Wypych, Alicja	ADGGS	Geologic Map of the Northeastern Tanacross Quadrangle, Alaska

Presentation abstracts (listed alphabetically by presenting author)

Cenozoic basin development and strike-slip displacement along the Denali fault system, eastern Alaska Range, Alaska: A provenance approach

Allen, Wai, Purdue University, allen242@purdue.edu
Ridgway, Kenneth, Purdue University,
Benowitz, Jeffrey, University of Alaska – Fairbanks,
Fitzgerald, Paul, Syracuse University,

Analysis of Eocene (?) - Pliocene sedimentary and volcanic strata exposed along and within the McCallum-Slate Creek fault system provides new insight into basin development and strike-slip displacement along the Denali fault system (DFS). These strata are exposed in distinct thrust sheets that are part of an active regional south-verging transpressional thrust belt located on the south side of the DFS. Our dataset consists of measured stratigraphic sections, paleocurrent data, clast compositional data, and U-Pb zircon and $^{40}Ar/^{39}Ar$ geochronology on bedrock and detrital samples.

Eocene or younger strata consist of highly deformed alluvial fan strata with a minimum thickness of 366 m and are exposed in a thrust sheet proximal to the DFS. The age of the strata in this thrust sheet is uncertain. Detrital zircon (n = 1533) results indicate that the maximum depositional age (MDA) of these strata is 49 Ma, but limited palynological data suggest that these strata are as young as Oligocene. Sediment sources for these strata had dominant ages of 58, 102, and 158 Ma based on detrital zircon results. Oligocene and early Miocene strata characterize a medial thrust sheet and consist of lacustrine and alluvial fan strata with a minimum thickness of 549 m. The MDA for these strata is ~21 Ma and is consistent with a $^{40}Ar/^{39}Ar$ tephra age of ~20 Ma. Detrital zircon (n = 2151) results indicate sediment sources for these strata had dominant ages of 26, 124, 204, 297, and 312 Ma. Upper Miocene-Pliocene strata characterize the more distal thrust sheet and consist of lacustrine and alluvial fan strata with a minimum thickness of 564 m. $^{40}Ar/^{39}Ar$ tephra ages from these strata range from ~6 to ~4 Ma. Detrital zircon (n = 2667) results indicate sediment sources for these strata had dominant ages of 5, 26, 89, 92, 98, 101, 123, 156, 166, and 294 Ma.

Our working hypothesis is that the Eocene (?) - Pliocene strata record distinct stages of basin formation, sediment provenance, and deformation along the DFS and related structures. In addition, low-temperature thermochronology on basement rock along the DFS indicate that stages of basin formation are correlative with periods of rapid cooling (Fitzgerald et al. 2019). We present reconstructions of each stage of basin development and use provenance data to interpret the locations of the strata prior to displacement on these major strike-slip faults. Our findings suggest large-scale, strike-slip displacement since the Eocene (?) with potential unique sediment sources identified at ~250 km and ~400 km to the east of the present location of the exposed strata.

Preliminary bedrock geology of the Rackla River area, Wernecke Mountains, Yukon.

Ambrose, Tyler, Yukon Geological Survey, tyler.ambrose@gov.yk.ca

The Rackla River area is underlain by normal faulted and gently folded sedimentary strata of the Paleoproterozoic Wernecke Supergroup, Mesoproterozoic Pinguicula Group, Neoproterozoic Hematite Creek Group and Windermere Supergroup, and Paleozoic Bouvette Formation. Gabbro dikes and sills that are likely age equivalent to the ca. 1380 Ma Hart River Sills cut the Wernecke Supergroup rocks. The presence of a mafic volcaniclastic horizon within the Bouvette allows its informal subdivision into a lower and upper member. These volcaniclastic rocks may the distal equivalent to volcanic rocks near the Tiger deposit, located ~20 km to the southwest. Three major angular unconformities are documented in the map area: at the base of the Rapitan Group, the base of the lower Bouvette, and the base of the upper Bouvette Formation.

Late-Cenozoic Yukon River capture, climate change, and consequences on the Yukon-Tanana upland landscape (Alaska and Yukon, Canada)

Bender, Adrian[1], R. Lease[1], L. Corbett[2], P. Bierman[2], T. Rittenour[3], D. Kreiner[1], J. Jones[1]*
[1]*U.S. Geological Survey Alaska Science Center*
[2]*University of Vermont and National Science Foundation Community Cosmogenic Facility*
[3]*Utah State University Luminescence Lab*

New mapping shows three distinct river terrace levels along the Fortymile River that may correlate with three well-documented Klondike River terrace levels. A Pliocene Yukon River drainage divide is hypothesized to have separated the Fortymile and Klondike Rivers into paleo-drainages that previously flowed to the Bering Sea and the Gulf of Alaska, respectively. The Klondike terraces represent a primary line of evidence for Plio-Pleistocene divide capture, re-routing the Yukon River in totality to the Bering Sea, and have long been interpreted to reflect (a) early-Pliocene (~5.3 Ma) bedrock erosion and late-Pliocene gravel deposition terminated abruptly by rapid, Yukon River capture-triggered incision at ~2.6 Ma, (b) a terrace-forming incisional hiatus ending with incision at the mid-Pleistocene climate transition at ~1 Ma, and (c) Holocene alluvium deposition on a low-level terrace within 20 m of the active channel elevation across the region.

Here, new cosmogenic $^{26}Al/^{10}Be$ and luminescence depositional ages of Fortymile River deposits on three terrace levels track development of the ancient Fortymile River concurrent with the paleo-drainage network preserved in the Klondike terraces. Cosmogenic ages of the base (~4.8 Ma) and top (~2.4 Ma) of a thick (~25 m) gravel on the deeply incised (≤260 m) high terrace near the Fortymile River outlet date the early Pliocene onset of aggradation and subsequent early Pleistocene terrace abandonment via Yukon River capture. Ages of the top 2-3 m of high terrace gravel decrease upstream to ~2.1 Ma at the river midpoint and ~1.8 Ma in the North and West Fork Fortymile River headwaters, demonstrating progressive terrace abandonment by channel incision that propagated headward at a rate of ~270 m/ka. Isochron ages of the uniformly-incised (30-40 m) intermediate terrace gravel (≤8 m thick) are ~0.8 Ma near the outlet, ~1.1 Ma at the midpoint, and ~1.0 Ma in the West Fork headwaters. We interpret these ages to represent the end of a depositional interval from ~1.8 Ma until terrace abandonment during the ~1.2-0.8 Ma mid-Pleistocene global climate transition. Luminescence ages of sand on the minimally incised (<5 m) floodplain terrace range from ~5.0 to 2.4 ka and document late Holocene terrace formation. Our results show Pliocene accumulation of the Fortymile River high terrace gravel coeval with deposition of the White Channel Gravel in the Klondike basin. Plio-Pleistocene Yukon River capture lowered tributary base-levels and triggered the abandonment of high terraces in both the Fortymile and Klondike River basins; subsequent incision (≤200 m into bedrock) appears paced by changes in the amplitude and period of global climate cycles.

These observations are consistent with hypotheses of climate-forced changes in rates of global erosion and are corroborated by offshore records of sediment accumulation and provenance downstream in the Bering Sea. Ongoing fieldwork and remote mapping identify similar terraces in Yukon River tributaries draining the Yukon-Tanana upland over 300 km west of the Fortymile River, and imply widespread landscape reconfiguration triggered by Yukon River capture and modulated by late-Cenozoic climate change.

P–T–t **conditions of high-temperature metamorphism and deformation in the Shuswap Metamorphic Complex, British Columbia**

Bowie, Sarah, Simon Fraser University, sarah_bowie@sfu.ca
Gibson, H. Daniel, Simon Fraser University
Dyck, Brendan, Simon Fraser University

The Shuswap Metamorphic Complex (SMC) in south-central British Columbia is a domal structure that exposes high-grade metamorphic rocks. It is flanked by two extensional shear zones – the west dipping Okanagan Valley fault system and the east dipping Columbia River fault. Previous work suggests that the SMC may have been confined beneath a Cretaceous plateau for up to 100 Myr before exhumation during extensional collapse across the southern Canadian Cordillera in the Eocene. However, ambiguity remains concerning the pressure, temperature, and timing of metamorphism, deformation and exhumation in the SMC.
This project aims to use state-of-the-art techniques to define a series of *Pressure–Temperature–time–deformation* paths across the SMC from Revelstoke to Sicamous, British Columbia (50° 50’ N. Lat.), which provides a complete cross-strike transect of the SMC from east (lowest structural level) to west (highest structural level). Key questions to be addressed include: 1) what were the peak metamorphic conditions reached within the SMC and were they uniform across the complex; 2) what is the relationship between metamorphic recrystallization and deformation;

3) what type of deformational fabrics are present across the Revelstoke–Sicamous transect and when did they develop; and 4) what does the relationship between the timing of fabric development, metamorphic recrystallization, and structural position of these features tell us about the processes of tectonic thickening and exhumation related to the development of the SMC?

Thus far, we have constrained the pressure and temperature conditions within the SMC using *Theriak-Domino* metamorphic phase modeling on two metapelitic samples collected from opposite ends of the Revelstoke–Sicamous transect. Preliminary results and petrography indicate that these rocks reached granulite-facies conditions, with peak temperatures of ~790–850°C and pressures of ~1.0–1.3 GPa. These temperatures, and especially pressures, are higher than previous estimates of ~700–825°C and ~0.6–1.0 GPa acquired at similar locations and structural levels using conventional thermobarometry and petrographic observations.

Future work will focus on refining the timing constraints for metamorphic recrystallization and deformational fabric development within these samples. This will involve linking the deformation fabrics and modeled *P–T* paths with dates obtained through *in situ* U–Th–Pb isotopic analysis of monazite and zircon. Existing ^{40}Ar–^{39}Ar cooling ages from hornblende and micas collected across the same transect will be used as a complement to the high temperature data. Further, quartz microstructural data will aid in defining the kinematics of flow and differentiating between pure and simple shear within the SMC.

Exploring Regional Scale Metamorphic Fabrics in the Yukon Tanana Terrane and Environs Using Quantitative Domain Analyses

Caine, Jonathan Saul, U.S. Geological Survey, Denver, CO, jscaine@usgs.gov
Jones, James V., III, U.S. Geological Survey, Anchorage, AK

Metamorphic rock fabrics such as foliations and lineations provide a rock record of numerous deformational characteristics in the Earth's crust. When spatial information is combined with fabric data collected at points on geologic maps, the nature and consistency of metamorphic fabrics can be explored through structural domain analysis. This is particularly useful in large regions where there is not well-established stratigraphy and where bedrock exposures are limited. Domains that contain distinctive orientations and patterns of fabrics can be constructed on the basis of several different parameters, but in folded, polydeformational regions cylindricity can be particularly useful. Distinct domains of cylindrical folding can sometimes be determined where poles to foliations show characteristic patterns on equal-area projections and lie perpendicular to a single axis in space. Additionally, the patterns of elements such as fold axes and mineral lineations can be used in conjunction with foliation data to refine domains and confirm parameters such as coaxiality.

In the Yukon Tanana upland (YTu) of eastern Alaska and west-central Yukon, we have explored and modeled a rich legacy of federal, state, and provincial structural data from geologic mapping spanning more than seven decades. Digital capture of map-based, georeferenced fabric elements allows for computerized, semi-quantitative domain analysis at the regional scale. Over 6,800 planar features and 1,800 linear features of a variety of types and generations are in the 512 km by 332 km focus region. These data were sorted and subsetted to begin exploration of the most basic fabric elements including the 'dominant' foliation, *S* or *S1*, and fold axes (including crenulations), lumped together as *Fx*.

The domain analyses approach used here utilizes eigenvalue methods implemented in the computer program Orient© (Vollmer, 1990, 2015). Orient© allows plotting options for fabric data on georectified maps including eigenfoliations and eigenlineations in grid cells of specified sizes. All data in each cell are thus represented by a single symbol capturing the best fit foliations or lineations. This facilitates visual inspection of the fabric data, and domain patterns can be iteratively drawn based on the geologic maps, field observations and experience, and other quantitative and qualitative parameters. Fabric data from each domain can be simultaneously plotted on equal-area projections and contoured with eigenmaxima and eigenminima (referred to as maxima and minima). Eigenvector statistical confidence cones facilitate determination of appropriate data patterns (e.g., girdles for folds and point clusters for fold axes) and provide a measure of fit that can be compared from one domain to another, aided by independent geological knowledge. Domains can be further characterized quantitatively based on the distribution of fabrics in each domain indexed by Point, Random, Girdle (PGR), or Cylindrical (C) functions (Vollmer, 2015). Index values are based on their orientation eigenvector matrices and can be graphically depicted on a triangular plot in PGR space where P, G, and R range from 0 to 1 such that P + G + R = 1 and C = P + G.

Results for the YTu *S-S1* data (n=4,489) show highly complex and co-located fabrics. However, several remarkable consistencies are revealed. Eigenfoliation map patterns show regional to local scale domains with high (~ >0.7) cylindricity indices dominated by ~NW-SE and ~WNW-ESE striking fabrics with generally low dip angles. Less dominant fabric orientations in domains strike ~NNE-SSW and NNW-SSE with intervening and co-located W-E and SW-NE fabrics, all with generally low dip angles. Most of the domains share nearly vertical maxima and associated minima distributed about the primitive, interpreted to reflect the regional-scale, upright and open folding observable in the field throughout the region. The dominant fabric is subparallel to the key structural boundaries marking the edge of the Yukon Tanana terrane, lithotectonic boundaries separating different rock assemblages, elongated Cretaceous plutonic suites, and a "belt" of three Late Cretaceous mineralized porphyry bodies. Domains, and fabrics within them, along the northeast margin of the map area trend parallel to portions of the NW-SE striking Tintina and Teslin shear zones suggesting they may have been active during fabric development. Some of the less dominant domains have foliation orientations approximately coaxial with the strike of the dominant domains, but their eigenmaxima plunge at moderate angles suggesting possible refolding. The less dominant domains, associated fabric patterns and orientation gradients also show general correspondence with some major faults, shear zones, and structurally juxtaposed terrane components. For example, a NE-SW trending domain with strong but mixed components of NW-SE and NE-SW striking foliations is located near a region where NE-striking brittle faults, associated aeromagnetic lineaments (e.g., Sánchez et al., 2014), and modern seismicity have been documented in western Tanacross and Eagle map areas. Another fabric gradient and E-W domain near the Tanacross-Eagle boundary may generally correspond to a major detachment fault (e.g., Hansen and Dusel-Bacon, 1998). Domains that share similar patterns, particularly foliation maxima and minima, are present in different locations throughout the region, suggesting heterogeneous response to deformation and(or) possible changes in orientations of major fault-bounded blocks.

Fold-axis data density is much lower (*Fx*, n=843) than *S/S1* data, and many regions have no data. Domains primarily show elongated point distributions in equal-area plots with moderate

Point indices (~0.5) reflecting their diffuse nature in any given domain. Although there is not one-to-one correspondence between *S/S1* and *Fx* in domain locations and geometries, *Fx* maxima and minima show similar patterns of opposite polarity compared to *S/S1* with near-vertical minima and associated maxima distributed about the primitive. This is interpreted to reflect generally subhorizontal fold axes and general coaxiality with the dominant (SW, ENE, and N trends; NE is also present but is convolved within some domains) and less dominant fold sets (moderately plunging, ~N-S trending) reflecting refolding.

Although the analytical results are nonunique, the largely Paleozoic to Mesozoic regional metamorphic fabrics found in the YTu show intriguing patterns, domains, and domain gradients that suggest possible influences on and tracking of late Mesozoic to early Cenozoic deformation, magmatism, and mineral deposit formation. Further exploration of other fabrics such as secondary and tertiary fold generations, mineral stretching lineations, competency contrasts, and kinematics will be required to refine hypotheses and assess rheological controls in the structural and metamorphic evolution of the YTu through its geological history.

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Geologic characteristics and ^{187}Re-^{187}Os age constraints on porphyry-style Mo and newly identified porphyry-style Au mineralization revealed by ice retreat in the Taku River corridor, SE Alaska

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Targeted field work was undertaken in summer 2019 to improve understanding of the framework geology and metallogeny of the Taku River area of the Coast Mountains, southeast Alaska. The Taku drainage has not been mapped extensively since the USGS-led efforts of the 1970s-80s. Ice retreat since that time has exposed new outcrops, including multiple containing porphyry-style? mineralization. We describe the newly identified Wright Glacier Au-rich porphyry-style occurrence ~ 5.5 km west of Mt. Ogden and report a ^{187}Re-^{187}Os -molybdenite age from the Boundary Creek 1 porphyry-Mo-W occurrence (ARDF TR002). The Wright Glacier occurrence is characterized by a swarm of more than 10 quartz trachyte porphyry dikes intruding quartz-biotite gneiss of the Yukon-Tanana terrane (Fig. 1A). The dikes are ~10-20 m wide and extend more than 2 km northeast to the other side of the Wright Glacier proper, where they cut the gneiss and lower-grade schist of the Stikine terrane. The dikes and country rocks exhibit pervasive sericite-pyrite alteration and are cut by quartz-pyrite vein stockworks (Fig. 1B). Two grab samples of the stockwork veins assayed ~0.3 ppm Au and 10 ppm Ag.

The Boundary Creek 1 occurrence is characterized by a seriate, peraluminous and alkaline, biotite granite stock intruding migmatitic gneiss which is cut by leucogranite, aplite, and miarolitic pegmatite dikes (Fig. 1C). Hydrothermal alteration is typified by quartz-pyrite veins and disseminated pyrite in the granite and disseminated pyrite ± chlorite ± epidote alteration of the gneiss. Molybdenite is present as coarse disseminations in all dike phases and in quartz-feldspar veins cutting the gneiss (Fig. 1D). Three ^{187}Re-^{187}Os ages from two molybdenite samples are in excellent agreement with a weighted mean model age of 78.74 ± 0.63 Ma (analytical errors only). These Late Cretaceous Re-Os ages preclude affinity with the much younger Eocene-Miocene intrusive suites and porphyry systems (e.g. Quartz Hill) that dominate the Coast Mountains. Instead, it suggests an association with the alkaline, Mo-bearing, ~80 Ma Surprise Lake suite exposed along strike in Canada. These data suggest more episodes of porphyry-Mo mineralization in the Coast Batholith than previously recognized, and that potential for Mo- or Au-rich porphyry-style mineralization in this region may be underestimated.

Figure 1: A) Wright Glacier dike swarm. Red arrow shows location of samples and quartz-pyrite vein stockworks shown in (B). C) Boundary Creek 1 site. Blue arrows in (D) point to molybdenite in quartz-feldspar veins sampled for ^{187}Re-^{187}Os ages from this occurrence.

Extensional tectonism recorded by Late Ordovician volcanism near Castle Mountain, north-central Yukon

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Carbonate strata of the Cambrian to Devonian Bouvette Formation underlies the Castle Mountain area in north-central Yukon. Volcanic and volcaniclastic rocks interstratified with calcareous and fossiliferous clastic rocks occur locally within the Bouvette Formation and provide information about local uplift and subsidence patterns and volcanism during the Late Ordovician to Early Devonian time. Preliminary fossil ages and TIMS zircon dates from a volcaniclastic horizon indicate the volcanic and clastic rock succession ranges from Late Ordovician to Early Devonian. Extensional tectonism provides an explanation for the temporary disruption in carbonate platform development and associated volcanic activity. Thermal uplift, related to underplating (and subsequent eruption) of igneous bodies, provides a mechanism for subaerial exposure, and subsequent erosion of chert, carbonate and volcanic rocks. Basins and slopes (areas between thermally uplifted blocks and adjacent subsiding areas) collected material eroding from exposed strata and volcanic rocks deposited during eruptions. The exact temporal and spatial relationship between uplift and subsidence, and the source and magmatic evolution of the igneous rocks, remains the focus of future work in this area.

Triassic Phosphatic Rocks of Northern Alaska: Spatial and Temporal Depositional Patterns on a High-latitude, Low-angle Ramp, Northwest Laurentian Margin

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The Shublik Fm. (northern Alaska) was deposited on a high-latitude (~45-60°N), gently sloping ramp on the northwest Laurentian margin, and contains the largest phosphorite accumulation of Triassic age ($5x10^9$ metric tons; Cathcart, 1991). New stratigraphic, sedimentologic, and geochemical data from the Shublik in 33 wells and 23 outcrop localities provide insights into the nature and origin of these strata. Phosphate accumulated from the late Early to Late Triassic (Smithian-late Norian), but highly phosphatic strata (HPS, 10-33% P_2O_5) formed chiefly during the late Middle (Ladinian) and middle Late (early-middle Norian) Triassic. Geographic foci of HPS deposition shifted with time.

Ladinian HPS constitute a petrographically distinct interval up to 7 m thick recognized across 80 km of outcrop in the northeast Brooks Range and in several wells 110 km to the northwest. Beds are parallel- and cross-laminated and contain transported, sand-sized phosphatic clasts—mainly simple peloids and phosphate-coated quartz grains and flat clam fragments—cemented by silica, phosphate, and/or calcite. Phosphate content and grain packing decrease upward within the interval and carbonate content increases. These strata formed on the middle ramp during transgressive and early regressive parts of a single 2^{nd} or 3^{rd} order depositional cycle.

Norian HPS are more widely distributed and heterogeneous than those of Ladinian age. The Norian HPS occur through an ~80 by 180 km outcrop area, and in numerous wells on the eastern North Slope. Phosphate in these strata is both transported and in situ and is chiefly cm-scale nodules and sand-sized peloids. It is most abundant in intervals ≤ 2 m thick at the tops of regressive limestone parasequences that were deposited on the middle to inner ramp.

HPS of other ages are less common. Smithian-Anisian HPS include phosphate ± chert clast conglomerates in a few west and central North Slope wells and phosphatic nodule horizons that top siltstone parasequences in some northeast Brooks Range outcrops. Carnian HPS that contain concentrations of phosphatic nodules and peloids occur mainly in 2 central North Slope wells.

Uranium is elevated in most, but not all, Shublik HPS, resulting in pronounced gamma ray responses in well logs. Values are generally highest (up to 111 ppm) near the base of the Ladinian HPS interval.

The Shublik Fm. represents part of a worldwide shift of phosphorite formation into higher latitudes during the Triassic and is part of a belt of phosphatic organic-rich shale deposited across northwest Laurentia. If, as previously suggested, HPS in the Shublik formed in response to a marine upwelling system, our data show that the effects of this system varied through space and time, with most extensive HPS development in the Ladinian and Norian. Phosphate in the Shublik is more abundant and was deposited through a longer time span than in other Laurentian Triassic sections (e.g., western Canada, Sverdrup Basin, Grasby et al., 2016).

Stratigraphic architecture of the Porcupine shear zone, Yukon and Alaska and its significance in the evolution of northern Laurentia

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The Porcupine shear zone (PSZ) separates the North Slope subterrane of Arctic Alaska from the northwestern margin of Laurentia (Yukon block). Tectonic reconstructions of the displacement history of this fault zone have been hindered by a lack of age constraints on strata exposed along the fault trace. Here, we present new field observations from Yukon and east-central Alaska, along with new detrital zircon U-Pb geochronology and stable isotope geochemistry, to elucidate the stratigraphic architecture of rocks exposed along the PSZ. The oldest strata in the study area consist of interbedded quartz arenite and shale overlain by a thick package of white cross-stratified quartz arenite. Detrital zircon U-Pb data from these sandstones yield ca. 1050-1250, 1350-1450, 1600-1650, and 2500-2800 Ma (n = 1100) age populations, which closely resemble that of age-equivalent strata deposited in the Tatonduk inlier and Amundsen and Mackenzie basins of autochthonous Laurentia, but differ from the equivalent Mount Weller Group of the North Slope subterrane. This clastic succession is overlain by chert-bearing doloboundstone with molar-tooth structures and vase-shaped microfossils, which are interbedded with and overlain

by black fetid limestone that yield an average $^{87}Sr/^{86}Sr$ isotopic value of 0.7064. Together, these data suggest this entire succession is early Neoproterozoic (late Tonian) in age. These strata are locally intruded by mafic dikes and Late Devonian (Famennian) felsic plutons and unconformably overlain by Devonian(?) matrix-supported conglomerate with detrital zircon populations ranging from ca. 420–620 Ma. The mafic dikes have previously been assumed to be ca. 720 Ma, however a strongly deformed dike within the PSZ yielded an age of 379.6 ± 3.6 Ma. This magmatic history and provenance signature of the PSZ succession distinguishes it from the Yukon block. As a result, we propose Neoproterozoic strata of the PSZ comprise a peri-Laurentian crustal fragment that was derived from basinal assemblages on the northern Laurentian margin and differs in some aspects from the more far travelled peri-Laurentian components of North Slope subterrane north of the PSZ. The presence of deformed Devonian dikes within the PSZ demonstrates that the presence of poorly exposed, internally undeformed Devonian plutons do not limit the timing of PSZ displacement.

Age and evolution of mid-Cenozoic stepover basins in southeastern Alaska

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The Paleocene-Oligocene Kootznahoo Formation in southeastern Alaska provides a glimpse of sedimentation and transform tectonics during the transition from subduction to a transform margin. The Kootznahoo Formation is a distinctive fluvial deposit consisting dominantly of cross bedded sandstone, gravel and conglomerate with a maximum thickness of a few hundred meters. We examined exposures of the Kootznahoo Formation across southeastern Alaska, measured paleocurrent directions, analyzed provenance, and utilized fossil ages and radiometric dating to constrain the timing of deposition. Paleocurrent indicators consistently indicate paleoflow to the southwest, indicating that the sediment source was mainly the high topography of the Coast Mountains, consistent with provenance studies. Although there are about a dozen small Kootznahoo Formation depocenters along a 475 km length of southeastern Alaska, it has two larger depocenters, which we refer to as the Angoon and Kake basins. Both of these basins (1) have strata that dip to the southeast, (2) are equidimensional and about 10-15 km across, and (3) have strata that extend from late Paleocene to late Oligocene time, although the Kake basin is dominantly Paleocene and the Kake basin is dominantly Oligocene. The basins are asymmetric, with wedge-shaped stratigraphy that thickens to the southeast and are consistent with being ‘trap door’ or stepover basins within a larger, nascent, right-lateral fault system. We infer the presence of northwest-striking right-lateral strike-slip faults along the basin margins, with one or more northeast-striking normal faults connecting them in the stepover region. Faulting created accommodation for deposition as fluvial drainages transported sediment sourced from the Coast Mountains. As the northwest-striking dextral faults are truncated by the Chatham Strait fault, we infer these faults were active prior to Neogene activity on the Chatham Strait – eastern Denali fault systems. After cessation of Kootznahoo deposition, subsequent late Oligocene-Miocene volcanism and magmatism of the Tkope-Portland Peninsula belt was focused along the inferred basin-bounding dextral faults, suggesting that the faults acted as conduits for the magmas.

The Kootznahoo basins and dextral faulting at their margins, were active both before and after the end of Coast Mountains batholith magmatism, as well as before and after the ridge subduction/slab window episode around ~50 Ma. Deposition and the basin bounding faults must have been active as the Yakutat terrane passed by to the west on the proto-Queen Charlotte fault system. Some Kootznahoo deposition and faulting was coeval with deposition of Eocene-Oligocene sediments in basins along the Denali fault in the Yukon and central interior Alaska, indicating these basins are part of a larger framework of distributed dextral faulting paralleling the continental margin over ~1400 km. The cessation of Kootznahoo deposition is coincident with the onset of the rise of the Alaska Range and the indentation of the Yakutat terrane in southern Alaska. We infer a large-scale reorientation of crustal stresses related to Yakutat collision as dextral faulting became focused on the modern Queen Charlotte-Fairweather fault.

Exploring the law of detrital zircon in Alaska's Cook Inlet: LA-ICPMS and CA-TIMS geochronology of Jurassic forearc strata

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A sedimentary rock cannot be older than its youngest zircon. This premise—the law of detrital zircon—permits maximum depositional age (MDA) determinations, but geochronologic dates are complicated by uncertainty. We conducted U–Pb laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) and chemical abrasion-thermal ionization mass spectrometry (CA-TIMS) of detrital zircon in forearc basin strata of southern Alaska to assess the accuracy of several MDA approaches. Six samples from Middle–Upper Jurassic units are generally replete with youthful (i.e., near stratal age) zircon and underwent three rounds of analysis: 1) LA-ICPMS of ~115 grains, with one date per zircon; 2) LA-ICPMS of the ~15 youngest grains identified in round 1, acquiring two additional dates per zircon; and 3) CA-TIMS of the ~5 youngest grains identified by LA-ICPMS.

Youngest single-grain LA-ICPMS dates are all younger than—and rarely overlap at 2σ uncertainty with—the CA-TIMS MDAs, indicating that random statistical fluctuations during analysis and subtle Pb-loss render these youngest LA-ICPMS dates poorly suited to characterizing the age of the densely sampled youthful populations. Youngest kernel density estimation modes are typically several m.y. older than the CA-TIMS MDAs, with the full probability distributions incorporating truly older dates. Weighted means of round 1 dates that define youngest statistical populations are our preferred LA-ICPMS constraints, as this high-*n* approach extracts a normally distributed sub-sample from the youngest tail of each full density estimation—thus tying these determinations to statistical fluctuations during analysis—and yields the best overall coincidence with the CA-TIMS MDAs (Fig. 1).

CA-TIMS dating of the youngest detrital zircon grains identified by LA-ICPMS is indispensable for critical chronostratigraphic applications, eliminating laser-induced matrix effects, mitigating and evaluating Pb-loss, and resolving complexities of interpreting lower precision, normally distributed LA-ICPMS dates. Finally, numerous CA-TIMS MDAs in this study are younger than Bathonian(?)–Callovian and Oxfordian faunal correlations suggest and underscore the need for additional high-precision radioisotopic constraints to refine the Middle–Late Jurassic geologic time scale.

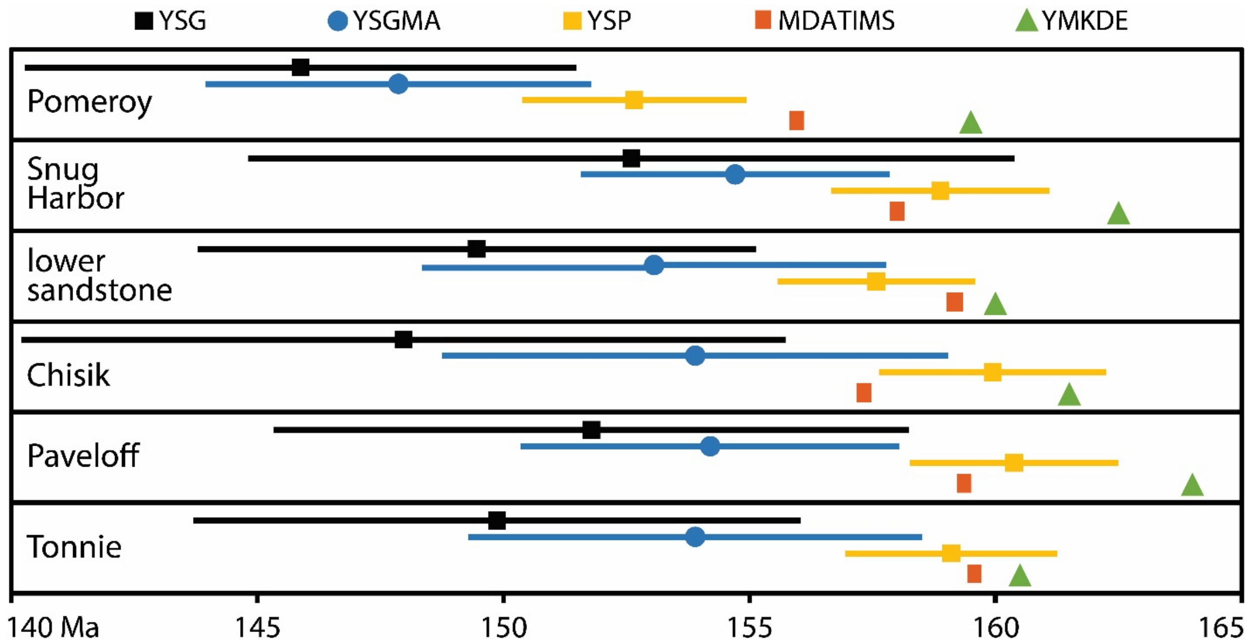

Figure 1. Comparison of maximum depositional dates and ages in this study. Small vertical offsets within each stacked box are for clarity only. Abbreviations: MDATIMS—maximum depositional age determined with CA-TIMS (symbol widths are scaled to include uncertainties); YMKDE—youngest kernel density estimation mode (LA-ICPMS); YSG—youngest single grain (LA-ICPMS); YSGMA—youngest single grain with multiple analyses (LA-ICPMS); YSP—youngest statistical population (LA-ICPMS). See https://doi.org/10.1130/G46312.1 for further information, including explanation of stratigraphic units, discussion of maximum depositional date/age methods, and propagation of systematic uncertainties.

New mapping in the Taku River corridor, southeast Alaska: observations and implications for geologic framework and mineralization in the southern Yukon Tanana terrane and Coast batholith

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New mapping in the Taku River corridor transects the northwest-trending Coast batholith, delineating the distribution of igneous phases and their host rock units and terranes. In southeast Alaska rocks of the Alexander, Wrangellia, Taku, Yukon Tanana, and Stikine terranes host the Coast batholith. The batholith consists mainly of calc-alkaline intrusive rocks of perhaps several magmatic arcs that formed in accreted pericontinental terranes on the west margin of the North American craton in the Jurassic to early Tertiary. The arcs formed above eastward-subducting oceanic crust before and after mid-Cretaceous accretion of exotic oceanic arc terranes. The Coast batholith also includes Eocene to Holocene alkaline igneous rocks attributed to Eocene subduction of Kula-Resurrection spreading-center segments, Oligocene to Miocene subduction of Pacific-Farallon spreading-center segments, and Pliocene to Holocene subduction of Pacific-Explorer-Juan de Fuca spreading-center segments beneath southeast Alaska and coastal British Columbia.

In the Taku River corridor, legacy dating is limited to prominent Late Cretaceous to Eocene calc-alkaline dioritic to granitic phases of the Coast batholith. U-Pb zircon geochronology defines four discrete intrusive events that are sequentially younger northeastward, consisting of 1) the Mount Juneau pluton at ~72 Ma, 2) the Carlson Creek pluton at ~67 Ma, 3) the Annex Lake pluton at ~59 Ma, and 4) the Turner Lake pluton at ~50 Ma. Older intrusive phases are present as orthogneissic inclusions and screens that lack ages in this area but yield Late Jurassic to Early Cretaceous ages elsewhere in the Coast batholith. Undated ubiquitous and common unmetamorphosed, undeformed, pyritic calc-alkaline dacitic dikes and small plugs may correlate with the Eocene Sloko volcanics along strike in British Columbia. Undated alkaline rocks present as bimodal dike swarms, composite volcanic centers, and pyroclastic deposits are similar to rocks that yield Eocene to Holocene ages elsewhere in the Coast batholith.

Host rocks to the Coast batholith in the Taku River area are granulite to greenschist grade metasedimentary and metaigneous rocks. Metasedimentary rocks of a paragneiss unit include biotite and quartz-biotite schist and gneiss, quartzite, and marble that locally contain hornblende, garnet, sillimanite, and calc-silicate minerals. These rocks are similar to rocks assigned to the Tracy Arm assemblage of the Yukon Tanana terrane along strike. Metaigneous rocks range from ultramafic to felsic in composition and include garnet amphibolite and foliated felsite. These rocks are locally mappable but more commonly form meter-scale layers in the paragneiss unit. These rocks occur in screens and as inclusions in km-scale bands of migmatite that are associated with each pluton. An angular boulder on bedrock surrounded by ice at a high elevation, inferred to be locally derived, is an augen gneiss, a signature rock type in the Yukon Tanana terrane. New geochronology is in progress for all igneous and metamorphic rock types.

Near the U.S.-Canada border, greenstone semischist, chloritic, calcareous, carbonaceous, and siliceous schists, and mafic to felsic volcaniclastic rocks contrast sharply in composition and texture with the paragneiss, orthogneiss, amphibolite, and migmatite units to the southwest. These lower grade rocks are similar to rocks assigned to the Stikine terrane along strike. Map patterns suggest a moderately northeast-dipping contact between the medium- and high-grade metamorphic units. Both units are intruded by the youngest granites of the batholith and a bimodal alkaline dike swarm. A northwest-trending steeply dipping shear zone cuts the Yukon Tanana-Stikine contact near the Taku River. A meter-scale mineralized shear zone near the main shear zone cuts the bimodal alkaline dike swarm without significant displacement.

Regionally, mineralization is associated with metamorphic rocks, Jurassic intrusive rocks, and late Tertiary magmatic rocks. In the map area, multiple generations of quartz veins locally contain gold, sulfide minerals, sericite, and (or) epidote. Late quartz veins have cm-scale alteration halos. Initial observations indicate high-grade metamorphic rocks may contain pockets of relict mineralization typical of the Yukon Tanana terrane. Deep levels of exhumation supported by regional pressure-temperature calculations for plutonic rocks in the western part of the batholith signal deep levels of emplacement less likely to have intrusion-associated mineralization. Miarolitic textures and aplitic dikes in Eocene plutons in the Taku River area indicate shallower emplacement and northeastward tilting of the Coast batholith. Potential for mineralization in the area is indicated by molybdenite occurrences associated with these plutons. Prevalent disseminated sulfides associated with late hypabyssal dikes and plugs, and prominent iron-staining associated with crosscutting shear zones suggest the most likely potential for mineralization will be associated with young magmatic rocks and structures.

Tectonic Evolution of the Northern Cordilleran Continental Margin: A Re-evaluation of Upper Paleozoic-Cretaceous Stratigraphy, Denali National Park and Preserve, Alaska

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The Paleozoic-Mesozoic tectonic history of the northern North American Cordillera is comprised of a series of long-lived tectonic configurations including convergent, collisional, and passive margins. Throughout this time, growth of the ancestral continental margin was driven by processes including accretion of arcs and crustal fragments, emplacement of subduction-related complexes, and the incorporation of passive margin sequences during times of convergence. The result of these processes is an assemblage of tectonostratigraphic domains connected by a diverse range of geologic relationships. Reconnaissance-scale geologic mapping provides a first-order framework for deciphering these events, however more detailed structural, stratigraphic, and geochronologic analyses are necessary to demonstrate tectonic connections along the margin.

We present new stratigraphic and geologic mapping data, as well as the first U-Pb detrital zircon ages and Hafnium isotopic data for Pennsylvanian-Upper Cretaceous strata exposed within Denali National Park and Preserve, central Alaska Range. Permian strata include marine siliciclastics with a maximum depositional age (MDA) of 286 Ma; this package is overlain by Upper Triassic basalt. Epsilon Hf values range from -18 to +13. We tentatively interpret these strata as submarine fan deposits similar to the Mystic Assemblage and other strata of the Farewell Terrane exposed in the western Alaska Range. Triassic strata include a package of primarily fine-grained, carbonaceous marine siliciclastic and calcareous beds with a scattered subset of youngest detrital zircons ranging from Pennsylvanian to Mid-Triassic. While our detrital zircon data yield a conservative MDA no younger than Early Triassic, previous biostratigraphic control suggests a Late Triassic depositional age. Epsilon Hf values range from -26 to +8. We tentatively interpret these strata as submarine fan deposits including turbiditic deposition of siliciclastic and calcareous sediments along the ancestral continental margin. An angular unconformity separates these strata and an overlying conglomerate previously mapped as part of the Upper Cretaceous Cantwell Formation is composed primarily of rounded cobble-boulder size quartz clasts. Detrital zircon data are very similar to the previous package with a conservative Permian MDA and single grains as young as latest Triassic. We tentatively interpret this unit as alluvial fan deposits associated with Late Triassic tectonism.

A major unconformity divides these strata and the Upper Cretaceous (Campanian-Maastrichtian) Cantwell Formation. The Cantwell Formation is comprised of a lower and upper member totaling approximately 4 km thick. The lower member is dominated by sheet conglomerate beds and fines upward where conglomerate beds become lenticular and facies are dominated by interbedded sandstone and siltstone. Detrital zircon data from the lower Cantwell Formation include a primary age peak at 200 Ma with subordinate peaks at 100 and 360 Ma and abundant Precambrian grains. We interpret the lower Cantwell Formation as wet alluvial fan and

braided fluvial deposits. The upper Cantwell Formation is comprised of laterally-continuous sandstone and siltstone beds with abundant symmetric ripples, interference ripples, and leaf fossils. Large sandstone bodies cross cut lacustrine deposits locally, though they are not common. These bodies are interpreted as axial trunk channels. Major detrital zircon age peaks occur at 72, 100, and 200 Ma. Subordinate peaks occur at 360 Ma with abundant Precambrian grains. Epsilon Hf values for the upper Cantwell Formation range from -22 to +13. We interpret the upper Cantwell Formation as widespread lacustrine deposits with well-established axial channels and possible nearshore marine environments. The upper and lower members of the Cantwell Formation have similar MDAs of approximately 75 Ma.

We propose an updated stratigraphic framework for upper Paleozoic-Mesozoic strata of the central Alaska Range. We interpret Permian-Early Triassic marine strata as passive margin strata deposited prior to development of an unconformity by the Late Triassic. This unconformity is marked by the juxtaposition of deformed marine strata and cobble-boulder conglomerate, both likely of Mid-Late Triassic age. Upper Jurassic-Early Cretaceous marine strata (map unit KJf of Csejtey et al., 1992) are also exposed in the study interval and have been roughly correlated to the Kahiltna Assemblage. We do not have data from this unit at this time but hope to include new data in our stratigraphic framework over the coming year. However, a significant angular unconformity between these strata and the Upper Cretaceous Cantwell Formation is well documented and suggests significant exhumation prior to development of the Cantwell basin.

We look forward to discussion related to topics and questions including: (1) Regional stratigraphic correlations. (2) The possibility of interaction between the Farewell terrane and the Alexander terrane outboard of the continental margin during the Permian. (3) The timing and nature of accretion of the Farewell terrane to the continental margin. (4) The configuration of the Triassic continental margin prior to accretion of allochthonous terranes including comparisons to other Upper Triassic siliciclastic strata along the margin.

Pre-cursor tectonic and magmatic influences of the Yukon-Tanana terrane on Late Cretaceous porphyry mineralization

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Cretaceous porphyry Cu (±Mo±Au) occurrences are scattered throughout the Yukon-Tanana upland in easternmost interior Alaska. Known occurrences in eastern Alaska are not completely characterized, despite a recent resurgence in exploration. Porphyry deposits in the upland are emplaced into structurally complex packages of metamorphic rocks representing a variety of tectonic environments. The varying compositions and geologic histories of these host rocks appear to produce different and distinct alteration and mineralization assemblages in younger, cross-cutting systems.

The basement hosting the porphyry systems generally consists of metamorphosed siliciclastic rocks, orthogneiss, augen gneiss, and, locally, marble and carbonaceous shale. Tectonically, the basement rocks represent two fundamentally distinct domains. One domain comprises Late Devonian to Early Mississippian augen gneiss, orthogneiss, and metamorphosed siliciclastic units of the parautochthonous North American margin. The other domain consists of Late Devonian to Permian metamorphosed siliciclastic rocks, carbonaceous shale, orthoquartzite, and interbedded carbonate units of the allochthonous Yukon-Tanana terrane (YTT). The allochthonous YTT also contains widespread Triassic and Jurassic magmatic belts that were emplaced prior to accretion, whereas the parautochthonous YTT has been intruded by a large swath of mid-Cretaceous (ca. 110–100 Ma) and younger granitic plutons.

New mapping, drill core logging, petrography, geochemistry, geochronology, and structural analysis provide an updated and improved characterization of the parameters of porphyry systems and identify key linkages to regional tectonic and magmatic events. New sericite $^{40}Ar/^{39}Ar$, $^{187}Re/^{187}Os$, and zircon U/Pb dates constrain porphyry systems to the Late Cretaceous (ca. 71-63 Ma). Late Cretaceous plutons all exhibit zircon trace element signatures showing strong positive Ce anomalies and weak negative Eu anomalies. Zircon Hf-isotope ratios and Ce and Eu concentrations indicate that Late Cretaceous intrusions emplaced into allochthonous YTT basement dominated by Triassic and Jurassic plutons are more isotopically juvenile, reflecting more oxidized conditions. In contrast, those Late Cretaceous plutons emplaced into parautochthonous North American basement dominated by mid-Cretaceous plutons are more reduced and exhibit a geochemical signature indicative of crustal contamination.

Diversity in mineral assemblages in contrasting porphyry systems may reflect emplacement into crustal domains of varying compositions and oxidation states. Those formed within a domain containing more-oxidized Triassic and Jurassic plutons emplaced into the allochthonous YTT are molybdenite-rich and apparently lack gold. In contrast, systems formed within domains dominated by more reduced mid-Cretaceous plutons in the parautochthonous North American basement contain lower-sulfidation state mineral assemblages with reported gold.

Detrital zircon U/Pb & εHf signature of the Yukon-Tanana terrane in Yukon, Canada

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Rocks of the main body of the Yukon-Tanana terrane (YTT) consist of a lower sequence of pre-Devonian metasedimentary rocks and minor amphibolite of the Snowcap assemblage, overlain by three unconformity-bounded sequences of arc-type metavolcanic and metasedimentary rocks of Late Devonian through Permian age. Arc and back-arc sequences in YTT have been divided into the Upper Devonian–Lower Mississippian Finlayson assemblage, Middle Mississippian-Lower Permian Klinkit assemblage, and the mid- to Late Permian Klondike assemblage. The YTT arc rocks formed outboard of coeval oceanic assemblages of the Slide Mountain terrane (SMT). Permian to Triassic clastic rocks of the Simpson Lake and Jones Lake assemblages overlap YTT, SMT and continental margin strata of western Laurentia.

U-Pb geochronologic analyses have been conducted on zircons separated from twenty-eight detrital samples to better constrain the tectonic evolution of the YTT in four main regions of the terrane: Klondike, Glenlyon, Finlayson, and Dorsey Range. Four Snowcap assemblage samples are characterized by Proterozoic and Archean zircons. Finlayson assemblage samples are dominated by mono-peaks between 340-360 Ma with a small percentage of mid-Devonian to Precambrian grains. Klinkit samples yield populations of ca. 350 Ma, 725 Ma, 2.0-1.7 Ga, 2.8-

2.5 Ga, but the proportions of each group are variable. One Klinkit sample is dominated by three young peaks ca. 270, 325, and 360 Ma zircons and a few Proterozoic and Archean ages. Two samples of the Permo-Triassic Simpson Lake assemblage are dominated by Proterozoic and Archean grains with minor but significant populations at 720, 430, 355, and 260 Ma. One Jones Lake sample is dominated by three peaks ca. 267, 330, and 360 Ma with a few Proterozoic and Archean ages.

In the Klondike region, 3 samples of the Klondike schist display prominent peaks at 260 Ma; one of these samples also defines a peak at 245 Ma. Two samples of the Nasina assemblage show vastly different signatures, one with a large peak at 348 Ma, the other with a typical 1.8-1.9 Ga Laurentian signature and a small, but significant population of Upper Ordovician to Lower Devonian ages. Hafnium isotope analyses were also collected on sixteen of the samples showing a trend from 370 to 330 Ma from negative (~-30) to positive (+10) values in the YTT arc signatures

Current interpretations of YTT illustrate a mid to late Paleozoic continental arc/back-arc system recorded by multiple episodes of magmatism that developed upon a metasedimentary basement (Snowcap) inferred to have rifted off the Laurentian margin during opening of the Slide Mountain back-arc ocean. The detrital zircon record of the Devonian-Mississippian sequences is consistent with recycling of western Laurentian detritus, and syn-magmatic deposition indicated by prominent Devonian-Mississippian mono-peaks. Upper Ordovician to Lower Devonian zircons are only significant in Permo-Triassic clastic rocks of the Simpson Lake assemblage in the Finalyson region and in one sample from the Nasina formation in the Dawson region indicating limited interactions between the YTT-proper in Yukon and YTT-south and the Alexander terrane exposed in SE Alaska. A sample collected from rocks mapped as Klondike schist contains Early Triassic zircons that may indicate a younger age for end of Klondike magmatism, suggesting that structural relationships associated with the Permian Klondike orogeny should be carefully re-evaluated.

Progressive exhumation of the Yukon-Tanana upland during Paleocene-middle Eocene Tintina fault strike-slip

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The Tintina fault-Northern Rocky Mountain Trench is a major, orogen-parallel strike-slip fault that extends over 2000 km from central British Columbia into central Alaska. In eastern Alaska, the Tintina fault forms the northern boundary of the Yukon-Tanana upland (YTU). Published studies indicate that 430 to 440 km of right-lateral separation occurred along the fault from ca. 67 to 42 Ma on the basis of several geologic and geophysical piercing points. We document widespread YTU exhumation during the same time period as indicated by detrital and bedrock apatite fission-track (AFT) and apatite (U-Th)/He (AHe) thermochronology.

Detrital AFT data from 9 modern river drainages that span 370 km of the YTU along strike of the Tintina fault are dominated by Early Cretaceous-Paleogene ages that comprise 50% of the age distributions. Age populations are progressively younger from east to west, ranging from ca. 67 Ma to 47 Ma. In addition, bedrock AFT and AHe cooling age-elevation profiles capture the timing of increased exhumation at ca. 60 Ma in the eastern YTU (Taylor Mountain) and ca. 42 Ma in the western YTU (Fort Knox: Murphy & Bakke, 1993, CJES). Furthermore, the match between the ages of increased bedrock exhumation and detrital river cooling age populations in common geographic areas suggests that the detrital ages are a suitable proxy for the timing of exhumation over broad regions where bedrock data is unavailable. Paleocene-middle Eocene YTU exhumation is coeval with a previously identified phase of broad upright folding that warped metamorphic foliation in Paleozoic rocks throughout the YTU and also affected Upper Cretaceous to Paleogene strata in the eastern YTU.

We interpret Paleocene-middle Eocene YTU exhumation to be related to Tintina fault slip given their close spatial and temporal association. Our detrital and bedrock cooling age data suggest that the onset of YTU exhumation propagated from east to west at a rate equivalent to the time-averaged Tintina fault slip rate of 18 km/Myr from ca. 67 to 42 Ma. Coeval eastern Denali fault slip to the south of the YTU occurred at an unknown rate, though published studies have proposed 400 km of post-Paleocene dextral separation. We propose that Paleocene-middle Eocene YTU exhumation occurred in a broad zone of dextral transpression between the Denali and Tintina faults. The demise of spreading between the Kula and Pacific plates at ca. 40 Ma and consequent dramatic drop in northward plate velocity may have led to the cessation of displacement along the Tintina fault and related YTU exhumation. Subsequently, the Queen Charlotte-Fairweather fault transform plate boundary initiated further to the south.

Our findings affirm that the Tintina fault was a major intracontinental strike-slip fault that induced exhumation from 60-110°C crustal temperatures progressively over a broad region of the YTU during the Paleocene-middle Eocene. Furthermore, our results support cessation of major strike-slip deformation along the Tintina fault during the Eocene because regional exhumation of the YTU was completed by this time.

Dynamic Subsidence and Uplift in the Late Cretaceous Cordilleran Foreland Basin

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Dynamic topography refers to the vertical deflection of the Earth's surface generated in response to flow within the mantle. Although dynamic topography has been increasingly invoked to explain the subsidence and migration of depocenters in the Late Cretaceous Cordilleran foreland basin (CFB), it remains a challenging task to discriminate the effects of dynamic topography from other subsidence mechanisms. To unravel the relationship between the distribution of sedimentary systems, accommodation, and subsidence mechanisms of the CFB through time and space, a high-resolution sequence stratigraphic framework was developed for the Cenomanian to Maastrichtian strata based on more than 300 well logs from the Uinta, Piceance, Denver, San Juan, and Raton basins, and Kaiparowits Plateau (study area ca. 900 km × 500 km). The stratigraphic framework divides the Late Cretaceous strata into three chronostratigraphic packages separated by chronostratigraphic surfaces that can be correlated regionally and constrained by ammonite biozones. Regional isopach patterns and shoreline trends constructed for successive time intervals reveal that starting from the late Turonian (ca.

90Ma) to Maastrichtian time, a wave of uplift (300 km × 400 km) swept from southeastern to northeastern Utah. At the same time, the depocenter migrated from central Utah (dominantly flexural subsidence) to north-central Colorado (dominantly dynamic subsidence). After removing the effect of flexural subsidence, the zones of surface uplift and maximum subsidence in the CFB at different times generally coincide with the locations of the trailing part and leading edge of the previously postulated oceanic plateau—the conjugate Shatsky Rise, respectively. Preliminary results from this study further suggests that large-scale (> 400 km × 400 km) dynamic topography (uplift and subsidence) profoundly affected foreland basin-formation, and the position of topography corresponds to the putative Shatsky Conjugate Rise of the Farallon Plate beneath North America. The new stratigraphic framework, regional isopach maps, and depositional system reconstructions provide important constraints for future quantitative models aimed at unraveling other foreland basins such as the North Slope, AK that may have formed by an interplay of crustal and asthenospheric tectonic processes.

Unravelling the thermo-tectonic history of the Jura-Cretaceous Kluane Schist, Northern Canadian Cordillera.

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There is a wealth of information pertaining to the disputed Mesozoic tectonic configuration of the Northern Cordillera preserved within a series of collapsed and metamorphosed Jura-Cretaceous basins. Having formed between the Intermontane and Insular terranes, these basins record the initial deposition of sediment within 'inter-terrane' oceans or seaways as early as 200–180 Ma, as well as metamorphism and deformation associated with basinal collapse and Insular terrane accretion as late as 70 Ma.

The Kluane Schist, southwest Yukon, was deposited in one of these Jura-Cretaceous basins. Comprised of variably metamorphosed and deformed pelitic and psammitic units that were intruded by granodioritic plutons of the Paleogene Ruby Range Batholith (RRB), the Kluane Schist preserves a complex thermal-metamorphic history. Our initial work indicates that the metamorphic assemblages found in the two most extensive map units, a biotite-rich and muscovite-rich schist, can be accounted for by subtle differences in protolith chemistry and are not related to the thermal aureole of the RRB. Growth of prograde garnet, sillimanite and cordierite can be attributed to variations in bulk chemistry during relatively low pressure, high temperature Buchan style regional metamorphism. Whereas, the effects of the RRB thermal aureole are expressed 3–5 km from the intrusive contact as migmatitic and K-feldspar rich gneisses that cannot be accounted for by realistic variation in protolith chemistry alone. Petrological observations indicate the increase in K-feldspar is associated with grain-coarsening, a decrease in prograde biotite, and static growth of fibrolite. Porphyroblasts of staurolite and plagioclase within gneiss units contain similar inclusion patterns to garnet and plagioclase porphyroblasts in the biotite schist, suggesting the units are of similar tectonic affinity. Thermal modelling of the RRB, combined with further metamorphic modelling, petrology, structural analysis and petrochronology will be used to unravel the thermo-tectonic history of the

Kluane Schist. Furthermore, these results will facilitate a more robust interpretation of Kluane Basin evolution, providing new insight into Mesozoic Northern Cordilleran tectonics.

Geology of the Schist belt: A 600 km long zone of high strain along the southern flank of the Brooks Range, Alaska

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The Schist belt of the southern Brooks Range is a structural/metamorphic terrane distinguished by its penetrative deformational fabric and relict blueschist facies minerals that extends along the southern flank of the range for 600 km with counterparts on the Seward Peninsula and possibly Wrangel Island, Russia, another 800 km away. Despite its impressive extent, its age and origin are problematic and highly debated. Deformational fabrics in the Schist belt affect most units of the Brooks Range fold-thrust belt, thus post-date formation of the shortening-related architecture of the belt. It is a broad zone (km's to > 15 km) of deformation, characterized by an intense transposition/crenulation cleavage formed during flattening normal to foliation and N-S stretching, evolving to localized simple shear and brittle faulting along the southernmost flank of the range. Here, fault slivers of structurally higher units of the thrust belt are in normal fault contact with rocks of the Schist belt. The hanging wall of this fault system includes thick sections of the deep water Cretaceous Koyukuk basin. Current exposure of Schist belt rocks and overlying fault systems/basin is the result of folding and uplift during NS shortening in the Cenozoic, revealing parts of an extensional shear system not typically exposed in orogenic belts. For instance, Schist belt fabrics locally develop across (post-date) the bounding normal fault slivers and hanging wall basin deposits. The age of Schist belt fabrics has been difficult to determine as greenschist grade structures are superimposed on older greenschist and blueschist assemblages. Fluid-assisted metamorphic zircon overgrowth on detrital zircon populations in Schist belt rocks, formed at T's of ~450°C, yield ~ 114 ± 5 Ma U-Pb ages from several widely separated localities (Hoiland et al., 2018). On the Seward Peninsula, Ar plateau ages on phengites provide a 116-125 min age for blueschist metamorphism and a max age for the fabrics (Hannula and McWilliams, 1995). On Wrangel Island, flattening during N-S stretching is ~ 100-105 Ma. This remarkably long belt of high strain deformation is spatially and temporally linked to the northern margin of a magmatic belt developed across Arctic Russia and central Alaska between 120-90 Ma and resulted in the extensional fragmentation of the Brookian orogen.

Compilation of bedrock geology along the Alaska–Yukon border from the Arctic Ocean to the Yukon River

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The northern Alaska-Yukon border region exposes the boundary between autochthonous North America and various accreted terranes, as well as profound variation in the orientation and kinematics of the northernmost Cordilleran fold-thrust belt. Despite this, research in this area has largely been hampered by remoteness, relatively large areas of poor bedrock exposure, and a fundamental lack of detailed geological maps along the border of Alaska and Yukon. Currently, there exists a series of reconnaissance-scale 1:250,000 geologic maps of this region, as well as new and updated state- or territory-wide digital bedrock and surficial map compilations; however, synthesis and correlation using the existing maps is remarkably difficult across the border region due to inconsistent nomenclature, structural interpretations, level of observation, etc. In addition, newer datasets from the Brooks Range of Alaska and North Slope of Yukon have yet to be integrated across the border region. Here, we aim to generate a revised bedrock compilation map of the international border region from the Arctic Ocean to the Yukon River. This map will not only serve as a tool for future geologists planning field work along the border region, but also highlight areas where further work is needed to investigate the complexity of the northernmost Cordilleran fold-thrust belt. Beyond applications for geologic research, this map will also be useful for resource management, sustainable development planning, and management of geohazards for the surrounding areas.

Transition from Foreland Fold Thrust Belt to Metamorphic Hinterland in the Arc-Continent Collisional Brooks Range Orogen, Northern Alaska

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The most enigmatic structural contact in the north-vergent Brooks Range orogen is the boundary between the foreland fold-thrust belt that deforms the Devonian to Early Cretaceous sedimentary strata of the Endicott Mountains allochthon (EMA) and the Devonian and older phyllites and schists composing the Central Belt (CB) to the south. In contrast to the EMA, the CB displays inhomogenous metamorphic fabrics with locally relict sedimentary features and an uncertain stratigraphy. The boundary lies south of the crest of the range and commonly is placed in the lower part of the Late Devonian (Frasnian) Hunt Fork Shale. The Hunt Fork contains the lowest known structural detachment of the EMA, although some map authors have reported the Hunt Fork lies depositionally on older rocks in the CB, suggesting the boundary may be a gradational metamorphic contact.

We report here on recent stratigraphic and detrital zircon (DZ) investigations in the Chandalar D6 quadrangle along the Dalton Highway south of Atigun Pass. This area spans the northeast plunging crest of a large Cenozoic Mt. Doonerak antiform , which exposes in its core the parautochthonous rocks that underlies the EMA on the north and the CB on the south. The rocks in our study area in the CB are structurally complex low-grade metaclastic and metavolcanic rocks with thin to thick units of metacarbonate rocks. Conodonts from the metacarbonate rocks indicate they compose Cambrian to Ordovician and Silurian to Early Devonian parts of a thick lower Paleozoic carbonate platform succession that has been duplexed above and below an internal unit of Ordovician phyllite. Strata in the lower duplex consist of a thick unit of Middle Cambrian coarse-grained metaclastic rocks that yield DZ distributions featuring major peaks between 550-650 Ma, interpreted as indicating derivation from the Timanian orogen in northern

Baltica. Metaclastic strata stratigraphically above the Silurian-Early Devonian upper metacarbonate duplex consist of several units, including fine-grained locally micaceous metagraywacke, purple and green volcaniclastic phyllite, and metadacitic volcanic rocks. The clastic rocks yield DZ spectra with important peaks at 1600, 900, 500-650, and 475 Ma interpreted as indicating a mixed Timanian, Baltican and Ordovician (Caledonian?) provenance, whereas the volcanogenic strata display a single dominant peak at 375-390 Ma interpreted to be the age of volcanism. The base of phyllitic Hunt Fork Shale (Dietrich River phyllite) is locally marked by thin limestone units with abundant Frasnian (Late Devonian) fossil assemblages or by lenticular units of quartz-chert lithic sandstone. The sandstone, along with phyllitic sandstone higher in the Hunt Fork, yield DZ peaks at ~400 Ma and a range of smaller peaks between 1 and 2 Ga and 2.4-2.8 Ga that are similar to those of the Late Devonian-Early Mississippian Kanayut Conglomerate of the EMA. This suggests the progradational Hunt Fork to Kanayut depositional sequence (i.e., Endicott Group) has a Caledonian provenance. Across the study area, the various lithologic units of the Hunt Fork rest on the Lower Paleozoic carbonate platform sequence as well as the Cambrian metaclastic strata below and Devonian metaclastic deposits above, indicating the Hunt Fork lies in angular unconformity on older rocks of the CB.

Implications of these observations:

1. The stratigraphy of the CB in the central Brooks Range consists of a Lower Paleozoic carbonate platform sequence underlain by metaclastic rocks having a Timanian provenance and overlain by metaclastic deposits having a mixed provenance from Baltican and lesser Timanian sources. These units are overlain by Late Devonian units of the EMA that were derived from Caledonian sources.
2. The inferred sub-Hunt Fork unconformity is angular, indicating the CB was deformed in the Middle(?) Devonian prior to deposition of the Late Devonian-Early Cretaceous passive margin deposits of the EMA. Moore et al (1997, JGR) previously suggested the CB experienced extensional deformation related to opening of the Angayucham Ocean on the basis of geochemistry of Devonian mafic volcanic rocks in the CB and the Hunt Fork.
3. The sub-Hunt Fork unconformity in the CB may correlate with the widespread sub-Mississippian unconformity in the North Slope autochthon. Transgression following erosion began in the Frasnian in the CB and continued through the Early Mississippian northward across the parautochthon.
4. The unconformity beneath the Hunt Fork indicates that the CB comprises the stratigraphically older, structurally more complex, and metamorphically higher grade part of the EMA. Relations suggest the north-directed ramp thrust fault forming the southern (hindward) boundary of the EMA truncated and removed progressively older deposits toward the rear of the allochthon. The EMA-CB boundary is explained here as a gradational metamorphic boundary developed across the sub-Hunt Fork angular unconformity when the EMA was imbricated by accretionary processes in the frontal part of the Early Cretaceous Brookian subduction zone.

SW-vergent deformation and metamorphism of the Hyland River area, southeastern Yukon

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The Selwyn-Mackenzie fold-thrust belt of the northern Canadian Cordillera underlies a large arcuate region east of the Tintina trench in eastern Yukon and N.W.T. The arcuate geometry of the belt reflects the presence of an embayment in the ancestral Laurentian margin, which has been attributed to along-strike variations in rift styles. The fold-thrust belt overprints three main Lower Paleozoic paleogeographic domains: from southwest to northeast, these are the McEvoy platform, Selwyn basin and the Mackenzie/Ogilvie platform. All three regions are underlain by Neoproterozoic-Terreneuvian rocks of the Windermere Supergroup (the Rackla, Hyland, and Ingenika groups).

The Selwyn fold belt, which forms the inner part of this region, experienced a polyphase Jura-Cretaceous structural history. Early deformation (late Jurassic-Early Cretaceous) was restricted to the SW part of the belt (McEvoy platform and western Selwyn basin areas) and was characterised by NE-vergent structures. This was followed by a reversal in vergence, which led to "backthrusting" of the Selwyn basin region over the McEvoy platform to the southwest. This southwest-vergent deformation is best characterized in the Hyland River area of southeastern Yukon, where it produced high-amplitude nappe-style folds and was accompanied by amphibolite-facies metamorphism. Metamorphic grade ranges from chlorite zone on the flanks of the Hyland structural culmination to sillimanite + K-feldspar in its core. New U-Pb data indicate this deformation and metamorphism was ongoing during the interval 112-107 Ma, and ceased immediately prior to the intrusion of voluminous batholiths of the Hyland River suite (107-105.5 Ma). Southwest-vergent deformation was followed by dextral strike-slip faulting ca. 98 Ma. Subsequent to, or accompanying, dextral strike-slip faulting there was a return to northeast-vergent thrusting and folding, as southwestern parts of the fold belt were carried cratonward on deeper structures. Northeastward propagation of the thrust belt during the late Cretaceous-Paleocene led to incorporation of carbonate successions of the Ogilvie and Mackenzie platform, which underlie the mountainous regions in frontal regions of the fold-thrust belt.

Some thoughts on Cordilleran accretion history arising from the restoration of Paleogene fault systems

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A new kinematic model for the tectonic evolution of the northern North American Cordillera during the Paleogene and Neogene (Murphy, 2018) provides the opportunity to gain insights into its Mesozoic accretionary history. In this presentation I focus on the terrane configuration of the northern Cordillera when 440 km and 370 km of dextral offset are restored on the Tintina and Denali faults, respectively (Figs 1 and 2).

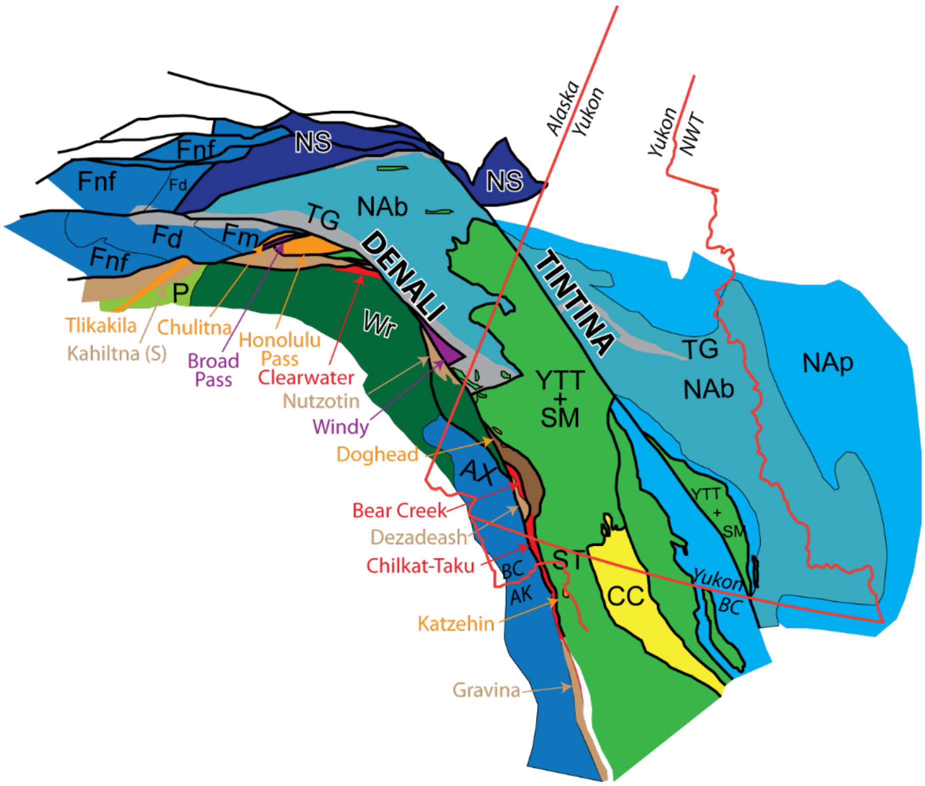

Figure 1. Terrane map of part of the northern North American Cordillera. Terranes: AX, Alexander; CC, Cache Creek; Fd, Farewll, Dillinger assemblage; Fm, Farewell, Mystic assemblage; Fnf, Farewell, Nixon Fork assemblage; Nab, North American continental margin, Paleozoic basinal assemblage; Nap, North American continental margin, platformal assemblage, including Cassiar McEvoy platform outboard of the basinal assemblage; NS, North Slope; P, Peninsular; ST, Stikinia; Wr, Wrangellia; YTT+SM, Yukon-Tanana and Slide Mountain terranes, undifferentiated. Other: TG, Galena suite of 232-226 Ma old gabbro sills and basaltic volcanic rocks (Tasina River volcanics in Alaska) intruding rocks of the North American basinal assemblage to as far west as the Denali fault, and intruding/overlying rocks of Farewell terrane on both sides of Denali fault. Assemblages named in orange are Late Triassic intra-oceanic island arc assemblages. Assemblages named in red are late Triassic ocean basin basalt and associated sedimentary rocks. Assemblages named in brown are Jura-Cretaceous clastic and volcanic rocks of the Gravina-Dezadeash-Nutzotin Mountains-Kahiltna south assemblage.Assemblages named in purple are Cretaceous mélange with debris derived from Farewell terrane (Silurian and Devonian limestone).

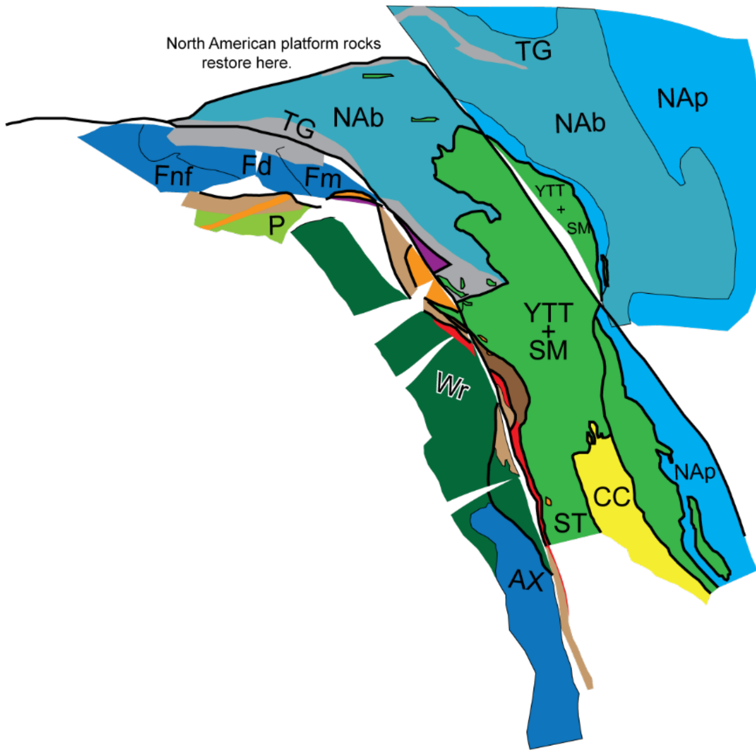

Figure 2. Distribution of Northern Cordilleran terranes at ca. 57 Ma with Late Cretaceous-Cenozoic displacement on the Tintina and Denali faults along the least curved segments of these fault in order to minimize the effects of the oroclines that folded the faults. No attempt was made to restore the splays of the Tintina fault although the net effect is to restore NA platformal rocks of western Yukon to a position north of their basinal equivalents in the Yukon-Tanana uplands. Some minor attempt has been made to deal with the bending strain along the Denali fault. Abbreviations and colours are as in Figure 1.

North of the Tintina fault, the post-Late Triassic, pre-mid-Cretaceous Inconnu thrust and the Permo-Triassic North America-Slide Mountain (sensu-stricto)/Yukon-Tanana terrane suture (which the Inconnu thrust carries in its hanging wall) intersects the Tintina fault in two places, northwest of Faro, YT and north of Watson Lake, YT. Restoration of ~440 km of offset on the Tintina fault brings the northwestern intersection near Faro, YT into continuity with its offset equivalent near Eagle, Alaska. The thrust and suture zone, modified by Jurassic and mid-Cretaceous structures, can be traced around and across the Yukon-Tanana Uplands south to just north of the Denali fault, near Beaver Creek, YT. Thus defined, the Inconnu thrust sheet overlaps rocks of the outer part of the North American continental margin by a minimum of ~320 km. The Inconnu thrust and Permo-Triassic suture zone north of the Denali fault strike westwardly into mélange of the Windy terrane in Nabesna map area, Alaska. The Windy mélange, cut on its south side by the Denali fault, is composed of sheared Cretaceous flysch, bodies of various sizes of Silurian to Middle Devonian limestone, and less commonly slivers of ultramafic rocks, basalt, tuff and chert, all of largely unknown age although Late Devonian radiolarians and conodonts have been extracted from highly deformed cherty siliciclastic rocks. Therefore, the Slide Mountain ocean basin, which in Yukon closed in the Permo-Triassic, remained open outboard of the rocks of the North American continental margin westward into Alaska until some point in the Cretaceous.

What happens to these features south of the Denali fault? Restoration of the post-57 Ma dextral offset of 370 km on the Denali fault restores the Yukon-Tanana terrane, the northern end of the Ruby Range batholith (which intrudes Yukon-Tanana terrane), and Kluane schist (a Cretaceous siliciclastic deposit whose younger parts received detritus from Yukon-Tanana terrane) to the Maclaren metamorphic complex in eastern Alaska (Forbes et al., 1973a,b; 1974; Turner et al., 1974). It also restores the Windy mélange into continuity with identical mélange at Broad Pass, Alaska. The combined Windy-Broad Pass mélange lies between the Yukon-Tanana terrane rocks in the northern part of the Maclaren metamorphic complex and the Chulitna terrane, an enigmatic Late Triassic arc sequence built upon a Paleozoic oceanic basement south of the Farewell terrane. The occurrence of Windy mélange between Yukon-Tanana and Chulitna-Farewell terranes extends the portion of the Slide Mountain ocean basin that remained open into the Cretaceous to as far south as the northern margin of Wrangellia and Peninsular terranes.

Several assemblages fringe Yukon-Tanana terrane on its southwestern side, between it and the Denali fault. Klippe of a Late Triassic intra-oceanic arc terrane structurally overlie Yukon-Tanana terrane along a pre-mid-Cretaceous northeast-vergent thrust fault in a discontinuous belt from the Kotzehin 'ophiolite' in southeastern Alaska east of Skagway (Brew et al., 2009) to near the Denali fault northwest of Kluane Lake, Yukon where they are referred to as the Doghead assemblage (Israel et al., 2011). Rocks of the Doghead assemblage also structurally overlie rocks of the Kluane schist along the Late Cretaceous southwest-vergent Kluhini River thrust (Israel et al., 2011). The Kluane schist, Yukon-Tanana terrane, Late Cretaceous plutons are thrust to the west over Late Triassic or older ocean basin metabasalt and associated metasedimentary rocks (Bear Creek and Jarvis River assemblages (Israel et al., 2015) and correlative(?) Chilkat basalt and Perseverance formation of Taku terrane?) and overlying Jura-Cretaceous clastic rocks of the Dezadeash Formation, the local component of the Gravina-Nutzotin Mountains assemblage along the Tatsenshini shear zone (Lowey, 2000). The Gravina-Nutzotin Mountains assemblage unconformably overlies and received detritus from the Insular superterrane (McClelland and Gehrels, 1992)).

The restoration of displacement on the Denali fault re-establishes continuity of these terranes with their counterparts south of the fault. The counterpart of the Doghead-Kotzehin arc rocks across the Denali fault is the Late Triassic Honolulu Pass formation (Hampton et al., 2007) which is inferred to overlie rocks of Yukon-Tanana terrane west of the Maclaren metamorphic complex. The counterpart of the Kluane schist lies in the immediate footwall of the Meteor Peak fault (Hults et al., 2013) within the Maclaren metamorphic complex. The counterparts of the Bear Creek assemblage are comparable rocks in the Clearwater Mountains (Clearwater terrane of Nokleberg et al., 1992). The Dezadeash Formation aligns with the Nutzotin Mountains flysch (e.g. Lowey, 1998)

The Denali and Tintina restorations establish continuous belts of oceanic rocks of Mesozoic age that lay between Yukon-Tanana terrane and the Mesozoic continental margin, which included both the North American continental margin as well as Farewell terrane of Arctic-Insular affinity. The Windy 'ocean' is the part of the Slide Mountain ocean that remained open into the Cretaceous after its partial closure where Yukon-Tanana terrane sutured with the North American continental margin in the Permo-Triassic. The Windy 'ocean' joined to the south with the Honolulu Pass-Doghead-Kotzehin-Bear Creek-Chilkat-Taku ocean between the Insular superterrane and the side of Yukon-Tanana and Stikinia terranes that faced the Slide-Mountain-Windy ocean basin after their re-orientation with respect to Quesnellia and Cache Creek terranes in the Early Jurassic. A failed third arm of the ocean likely existed in the Late Triassic as intra-continental rift basalts and sills characterize both the North American continental margin and Farewell sides (Dumoulin et al., 2018) and as the contact between the North American margin and Farewell terrane is locally marked by mélange. The Honolulu Pass-Doghead-Kotzehin-Bear Creek-Chilkat-Taku ocean extended westward into the Angayucham ocean.

The evolution of these basins in the Mesozoic occurred within the backarc region of the numerous Pacific-facing arcs associated with the Chugach subduction complex. This evolution included Cordillera-long sinistral strike-slip faulting during sedimentation of the Gravina-Dezadeash-Nutzotin Mountains-Kahiltna (south) assemblage (Anderson, 2015 and references therein) evidence for which has largely been masked by structures associated with the ultimate mid- and Late Cretaceous sinistral-transpressional closure (McClelland and Gehrels, 1992; Monger and Gibson, 2019 and references therein) and Late Cretaceous-Cenozoic dextral strike-slip faulting on the Denali and Chatham Strait faults.

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Strength of a Ductile-to-Brittle Fault in the Cretaceous Southern Alaska Accretionary Complex

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Ductile-to-brittle fault zones reveal mineralogical processes that are thought to be responsible for the mechanical behavior of faults. We examined a pervasively cataclasized zone within the Jurassic to Cretaceous accretionary complex of southern Alaska that preserves hydrothermal alteration, dissolution precipitation, carbonaceous material (CM), clay minerals, and intracrystalline plasticity, all of which influence the strength of a fault. We characterized microstructures by SEM and EBSD, determined compositions by XRD, XRF, and Raman spectroscopy for one carbon-rich sample, and dated whole rock, rotated K-feldspar, and metamorphic muscovite by $^{40}Ar/^{39}Ar$ thermochronology to constrain the timing and conditions of accretion, uplift, and deformation recorded by this fault zone.

We interpret the specific mineralogy and complex network of deformation microstructures as a result of multiple deformation events. Highest-temperature deformation recorded within the shear zone is lower greenschist facies (400–450°C). Quartz-rich clasts preserve deformation lamellae, grain bulges, sweeping undulose extinction, pressure solution, and brittle fractures characteristic of low grade (300–400°C) at the brittle–ductile transition. Brittle overprint is expressed by fractures cross-cutting the stretched quartz phacoids, and black fault rock that has entrained stretched quartz grains. Raman spectroscopy places precipitation of the CM at ~300˚C. We therefore associate the fault-rock fabrics with progressive down-temperature deformation as the fault was exhumed. We suggest that pressure solution and mineral alteration in all fault-zone samples, as well as quartz and phyllosilicate preferred orientation in a subset of the samples, indicate aseismic slip. Growth of clay and precipitation of CM reduced the friction coefficient, lowering the frictional strength and influencing the dynamic behavior of this fault zone. These faulted rocks are similar in appearance to black fault rocks from the SAFOD core, and to fault rocks described elsewhere in southern Alaska as fluidized cataclasite. Recognizing the processes influencing the geomechanical behavior and strength evolution of such exhumed faults is critical to understand hazard potential in active faults in similar tectonic settings.

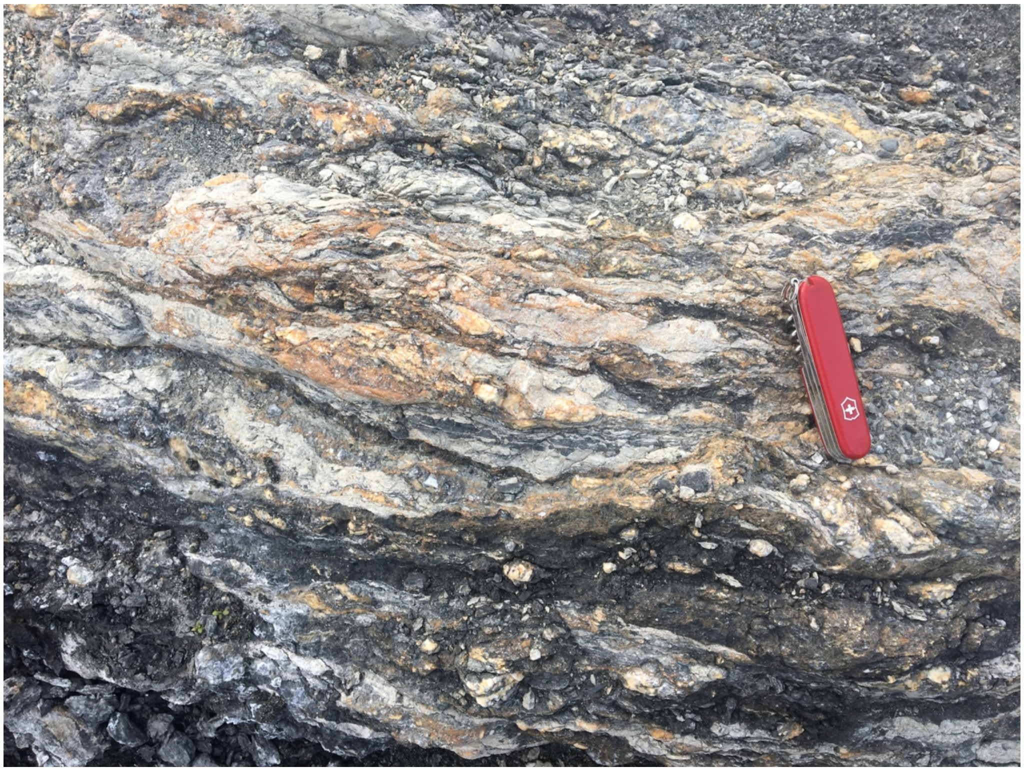

Figure 1. Field photo showing sheared quartzo-feldspathic clasts in a matrix of black carbonaceous material.

Refining tectonic events in the Fortymile River assemblage using $^{40}Ar/^{39}Ar$ thermochonology and correlating lithotectonic units in eastern Alaska

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Thrusting of allochthonous Fortymile River assemblage over parautochthonous Lake George assemblage rocks in eastern Alaska has been attributed to an Early Jurassic contractional event in the Yukon Tanana Terrane (YTT) and pericratonic North America. This event is recorded by 191 to 185 Ma $^{40}Ar/^{39}Ar$ ages in both plutonic and metamorphic rocks. New muscovite $^{40}Ar/^{39}Ar$ metamorphic cooling ages from Fortymile River assemblage rocks collected in the northeastern Tanacross Quadrangle range from 163.9 to 149.2 Ma (this study). Two previously reported mica cooling ages for the Fortymile River assemblage in the same area are 165.6 Ma and 146 Ma (Jones and others, 2017). These ages are 20-40 million years younger than 191 to 185 Ma $^{40}Ar/^{39}Ar$ mica cooling ages reported for the Fortymile River assemblage farther north along the Taylor Highway in the Eagle Quadrangle (Dusel-Bacon and others, 2002). Along the Taylor Highway, hornblende $^{40}Ar/^{39}Ar$ cooling ages are within 2 m.y. of mica cooling ages, but hornblende and mica $^{40}Ar/^{39}Ar$ cooling ages differ by over 17 m.y. closer to the Fortymile River-Lake George fault contact. These marked differences imply much slower cooling rates, as well as later cooling ages in the Fortymile River assemblage in the northeast Tanacross Quadrangle compared to along the Taylor Highway in the Eagle Quadrangle. If the entire Fortymile River assemblage was thrust over North America in the Early Jurassic, this suggests the Fortymile River assemblage exposed in the northeast Tanacross Quadrangle could represent a significantly lower structural level within the allochthon that underwent protracted cooling after thrusting. Alternatively, a later thermal event related to plutonism or mid-Cretaceous extension may have reset mica cooling ages in the lower Fortymile River assemblage, but evidence for such an event is not apparent in the argon step-heating data.

Metamorphic hornblende from east of McElfish Creek along the Alaska-Yukon border yielded a $^{40}Ar/^{39}Ar$ age of 167.1 Ma. It is unclear whether this age represents metamorphic cooling or retrograde greenschist-facies metamorphism, as both hornblende and actinolite were observed in thin section. The age does indicate that this area of the Tanacross Quadrangle is part of the Yukon Tanana Terrane (YTT) and not the Lake George assemblage as previously mapped. The age is similar to ages in the structurally lower part of the Fortymile River assemblage described above.

Correlating units in the YTT and pericratonic North America in eastern Alaska and western Yukon is complicated by the presence of upper greenschist to amphibolite grade units with similar protoliths in both the allochthonous YTT and parautochthonous North America. Recent field work in the Tanacross Quadrangle has resulted in a better understanding of the location of the ductile boundary separating the YTT and the underlying North American margin, as well as further characterization of metamorphic rocks in the allochthonous Fortymile River assemblage, Klondike Schist, and Ladue River unit, and the parautochthonous Lake George assemblage. The timing of metamorphic and tectonic events, such as the north to south variation in cooling ages in the Fortymile River assemblage, should be used to correlate regional tectonostratigraphic units across eastern Alaska and western Yukon and could lead to more complete tectonic models.

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Detrital zircon LA-ICPMS U-Pb geochronology of Arctic Alaska Basin sedimentary rocks

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New detrital zircon U-Pb ages were determined by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) for several quartz-rich horizons from cores and cuttings from boreholes across Arctic Alaska. Results are presented here for rocks in the Chukchi Sea, National Petroleum Reserve Alaska (NPRA), and central North Slope. The samples are from middle Paleozoic basement and the Middle Mississippian to Upper Jurassic-Lower Cretaceous Ellesmerian and Beaufortian (Rift) mega-sequences (Holm-Denoma, 2017).

Our results suggest two sources for pre-Mississippian age basement detrital zircon age populations: a northern Laurentia type 1 signature (Hadlari et al., 2012), and a Caledonian signature, implying a linkage between the Caledonian orogeny and the Arctic during the Early Paleozoic (Miller et al., 2017). Laurentian and Caledonian type basement rocks on the western North Slope are similar to detrital zircon age spectra of pre-Mississippian rocks found in the Northeast Brooks Range platformal and basinal successions (Strauss et al., 2019). Reflection seismic and potential field data in the Northeast Chukchi Basin and western NPRA show platformal pre-Mississippian rocks that were possibly peri-cratonal, outboard of the Cambrian shelf edge of North America (Sherwood, 1992). These platformal rocks were progressively drowned due to tectonic loading during Caledonian orogenesis and then covered by Ordovician-Silurian forearc rocks (Bjornerud, 1992).

Ellesemerian and Beaufortian detrital zircon U-Pb age populations, including samples from boreholes in the Chukchi Sea, are remarkably similar and span the Mesoarchean to Devonian. Age populations include major peaks between ~500-390 Ma, a broad spread of ages between ~1900-950 Ma, and a minor peak between ~2800-2400 Ma. The observed western Arctic Alaska Precambrian detrital zircon age spectra are largely consistent with lineages from Neoproterozoic to early Paleozoic sedimentary rocks of the northwestern Laurentian passive margin; specifically these age spectra are similar to hybrid or mixed populations of cratonal and marginal sequences (e.g., Adams Argillite, Lane and Gehrels, 2014). Samples from rocks above the pre-Mississippian basement inherited basement age spectra, indicating a local source of sedimentation during Mississippian-Pennsylvanian rifting following the Ellesmerian orogeny. In addition, the overall detrital zircon age spectra of Arctic Alaska samples are remarkably similar to rocks of the Devonian clastic wedge in Arctic Canada and the Yukon (Gottlieb et al., 2014 and references therein; Holm-Denoma, 2017).

Our results suggest consistent Devonian clastic wedge sourcing of zircons and widespread, well mixed, sediment dispersal in post-Mississippian Ellesmerian and Beaufortian (rift) sequence marine rocks. Similarities between detrital zircon age spectra from Chukchi wells and other Laurentian-sourced Arctic Alaska samples suggest that areas west of the Hanna Trough axis in the Chukchi Sea contain Devonian clastic wedge-derived sediments (Holm-Denoma, 2017).

Restoration of western Arctic Alaska against the margin of the Canadian Arctic Islands using a simple rotation model generally aligns the Hanna Trough axis in the Chukchi Sea to the Sverdrup Basin axis (Embry, 1990; Sherwood, 1992). Triassic clastic strata from the westernmost tip of Arctic Alaska contain <300 Ma zircon, which is postulated to have been derived syndepositionally from eastern Arctic Russia (e.g. Miller et al., 2006; Midwinter et al., 2016). The absence of <380 Ma zircon in Berriasian-Valanginian sandstone samples deposited just west of the Hanna Trough axis implies that sediment derived from eastern Arctic Russia during the Triassic may not have been deposited in this location, in contrast to the Sverdrup Basin. It is possible that deposits with Triassic-derived detritus are present over the Chukchi Platform further to the west of the Hanna Trough.

The Murray dyke swarm, southwest British Columbia, records the decline of an Early Cretaceous continental arc during the onset of the mid-Cretaceous magmatic and orogenic culmination of the Canadian Cordillera

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The Murray dyke swarm is located west of the town of Spences Bridge and is exposed in prominent 1100 m-high cliffs. The swarm likely fed a major volcanic centre of the Spences Bridge Group, a succession of 105-102 Ma volcanic rocks that overlap the western margin of the Intermontane terranes. The dykes strike to the north in a parallel, sheeted morphology that indicates a previously unrecognized extensional stress field within the evolving arc. Mingling textures within dykes together with the overall sheeted morphology of the dyke swarm is consistent with rapid emplacement in a regime of crustal extension. U-Pb zircon dating yielded an igneous crystallization age of 103.660 ± 0.029 Ma for a Murray dyke, and 104.111 ± 0.031 Ma for the youngest host rock. $^{40}Ar/^{39}Ar$ plateau ages on hornblende and phenocryst-free groundmass indicates the swarm cooled within <2 million years.

Swarm emplacement records the invasion of a calc-alkalic magma reservoir by intraplate-composition melts, a transition that heralded the end of Spences Bridge volcanism. Dyke compositions range from mafic to felsic and are dominated by three distinct petrological groups: basalt, basaltic trachyandesite, and andesite. These petrological groups are derived from different sources and are not related through closed-system fractional crystallization. Whole-rock initial isotopic values of Sr and Nd are consistent with juvenile mantle sources. Taken together, the andesites were derived from a hydrated mantle and were closely related to continental arc volcanism, whereas the intraplate-composition rocks were derived from drier mantle and represent slab tear that led to subsequent post-subduction magmatism.

Field relations demonstrate a structural evolution from sinistral translation to compressional deformation between 102 and 90 Ma. After termination of Spences Bridge volcanism at ~102 Ma, the dyke swarm was cross-cut by a fault with 7-10 km of sinistral displacement. This fault was likely part of the previously-recognized Cretaceous sinistral tectonic regime that was active in the southwest Canadian Cordillera until ~ 96 Ma. At the beginning of the Late Cretaceous (~100 Ma), the Spences Bridge Group was folded, and subsequently a conglomerate was deposited with angular unconformity at ~90 Ma. The conglomerate is correlative to the upper Pasayten Group, a sedimentary overlap assemblage deposited during the inversion of the Methow-Tyaughton basin, the forearc basin to the Spences Bridge Group, and sourced from the basin's basement, the oceanic Bridge River terrane.

The Spences Bridge Group occupies a 215 km-long segment of a nearly continuous belt of Early Cretaceous subduction-related igneous units that overlap the western margin of the Intermontane terranes. A similar geological evolution to that observed near Spences Bridge is present in this belt of Early Cretaceous igneous units, and together reflects onset of the mid-Cretaceous orogenic and magmatic culmination. These Early Cretaceous calc-alkalic rocks suggest the Intermontane terranes hosted a continental arc and formed the leading edge of North

America. The transition to intraplate magmatism with syn-volcanic extension at ~104 Ma and subsequent termination of magmatism in these units suggests that subduction under the Early Cretaceous arc ended. The ensuing compressional deformation of the Early Cretaceous arc and its forearc (at ~102-90 Ma) suggests that the subduction ended due to accretion. This evolution is best explained by mid-Cretaceous accretion of the Insular terranes. Indeed, this sequence of tectonic events appears to be diachronous, starting ~13 million years earlier in the northern Cordillera, at ~117 Ma. Subsequent magmatism (after ~100 Ma in the southern Canadian Cordillera) along the western edge of North America must have been related to a) post-subduction magmatism pertaining to the Early Cretaceous continental arc, and b) renewed arc volcanism associated with subduction under the new western margin of North America, then occupied by the Insular terranes.

Zircon evolution during shear zone development and progressive grain size reduction: insights from an isochemical strain gradient in eastern Alaska

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Zircon is a ubiquitous accessory mineral and the most widely used U-Pb geochronometer owing to its resistance to physical and chemical alteration processes. Despite its broad utility in geochronology, the potential of zircon as a petrochronometer remains relatively underutilized. To explore the effect of progressive deformation on zircon, a strain gradient located near the top of the Lake George subterrane (para autochthonous North America) ranging from completely unstrained coarse granite to mylonite over the structural distance of ca. 3 meters was sampled at varying degrees of apparent macroscopic strain. Oriented thin sections were cut from the XZ plane and subjected to petrographic, in-situ EPMA, and fabric analysis via EllipseFit. All samples contain evidence for consistent top to the southeast vergence defined by σ- and δ-clast asymmetry. EPMA full thin section scans were acquired to find all zircon crystals, and to relate them to the overall structure preserved within the thin section. Submicron-scale zircon grain maps were obtained, with one spectrometer set to collect a cathodoluminscence image. At lower finite strain, fluid-mediated coupled dissolution reprecipitation reactions appear to consistently disturb igneous zircon. With increasing grain size reduction, zircon crystals begin to develop thin metamorphic rims of varying composition, ultimately leading to partial to complete recrystallization of existing zircon. Within the mylonitic sample, two types of zircon are preserved: fine-grained fragments of pre existing zircon, with truncated oscillatory zoning, and inclusion-rich, fractured, and complexly zoned crystals aligned within the plane of the foliation. To explain these data, we suggest that the following processes occur in sequence with increasing

finite strain: 1) metamorphic fluids aid in the recrystallization of coarse igneous crystals, 2) zircon crystals begin to fracture, 3) continued recrystallization of existing zircon accompanied by new zircon growth, and 4) grain size reduction and complete fluid-mediated recrystallization of zircon grains. These data have important implications for the chemical and isotopic behavior of zircon during high-temperature fabric formation and mylonitization. Further investigation into the U-Pb isotopic and trace element geochemistry of these samples is in progress.

Comparison of Alaska Depth to Moho Map with Geologic and Active Tectonic Features

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The Earthscope TA full deployment in AK produced an unprecedented view of the crustal thickness of the whole region, as determined in this presentation by P-wave receiver functions. The map view of hand-picked individual stations' depth to Moho reveals an irregular Moho surface across the whole region, both the previously known N-S variations but also significant changes in depth from E to W. The boundaries between different crustal thicknesses are sharp in some areas and gradual in others. This presentation focuses on a comparison of these boundaries with recent (2017-2018) seismicity, terrane boundaries, known faults, and other geologic and active tectonic characteristics.

Some of the more striking Moho features include a significant region of thick (> 40 km) crust in SW Alaska and variable but overall relatively thick crust (35-45 km) in the Koyukuk basin. Some of the abrupt changes in Moho depth are across known strike-slip faults that have not been active in 10s of millions of years, suggesting that "relict" or inherited crustal features can remain well-preserved. In other regions where the Moho changes depth over relatively short distances the late Cenozoic structures accommodate crustal shortening; this may indicate that high-angle crustal boundaries are being reactivated as thrust or reverse faults. The lack of a smooth Moho in any part of the state and the coincidence of steps in the Moho across active strike-slip faults does not support a décollement or slip transfer surface within any crustal layer as a way to transfer strain far inboard from the Pacific margin.

Late Cretaceous (ca. 80 to 66 Ma) intrusion-related mineralization: A new project to examine the most prolific Cu-Au-Mo epoch in Yukon

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The Late Cretaceous (ca. 80 to 66 Ma) is the most prolific epoch of Cu-Au-Mo mineralization in Yukon. Mineralization was primarily related to oxidized Cu-Au-Mo porphyry systems (porphyry, epithermal and skarn deposits) emplaced within Yukon-Tanana rocks in the Dawson Range, southwestern Yukon. Yukon-Tanana country rocks in the Dawson Range have been the locus for prolonged (>150 m.y.), largely subduction-related magmatism with magmatic pulses in the Late Triassic to Jurassic, mid-Cretaceous, Late Cretaceous and Paleogene. Early Jurassic plutons host metamorphosed Late Triassic porphyry Cu-Au deposits such as those at Minto and there are small deposits associated with mid-Cretaceous and Paleogene magmatism such as the Whitehorse Copper belt skarn deposits and Mount Skukum epithermal deposits, respectively. The largest deposits however, are associated with Late Cretaceous porphyry systems and contain >25 Moz Au, >10 Blbs Cu and >2 Blbs Mo; mostly within the giant Casino deposit (18 Moz Au, 8 Blbs Cu and 1.1 Blbs Mo) though there are other significant (>1 Moz Au) deposits in the Mt. Freegold and Nansen camps. This poster outlines a new multi-year Yukon Geological Survey research project that will examine Late Cretaceous magmatic rocks and associated porphyry systems.

Previous workers have recognized early (ca. 80 to 72 Ma) and late (ca. 72 to 66 Ma) Late Cretaceous magmatic pulses, both associated with significant porphyry systems in the Dawson Range. Early Late Cretaceous magmatic rocks comprise the calc-alkaline Casino suite and are thought to be economically more significant as this suite includes the causative plutons at the Casino, Nucleus and Revenue deposits. Older intrusions of the Casino suite are coeval, but not coincident, with intermediate to mafic volcanic rocks of the Tlansanlin and Windy-Table formations making a genetic connection unclear. More recently recognized are late Late Cretaceous magmatic rocks that include the causative intrusions at the Klaza epithermal deposit and porphyry occurrences such as Cyprus, X-man and Mt. Cockfield. These intrusive rocks comprise the alkalic Prospector Mountain suite. The alkali-basalt dominated Carmacks Group is also late Late Cretaceous (ca. 70 Ma) but any genetic connection to the Prospector Mountain suite has not been established; given the alkalic nature of both, such a connection seems probable. Coeval with the Prospector Mountain suite, but intruded into ancestral North America rocks in western Yukon, are plutons of the Katrina Creek suite and spatially associated intermediate to mafic volcanic rocks of the Donjek formation.

Despite the economic importance of Late Cretaceous deposits in Yukon, rocks of this age are not clearly and consistently documented. In addition, previous work has given rise to a new set of questions with direct implications for mineral deposits. For example:

1. What is the relationship between the Prospector Mountain suite and the Carmacks Group basalt? Based on the poorly constrained coeval timing and alkalic chemistry of both, it is reasonable to look for a genetic link. However, the Prospector Mountain suite is subduction related whereas the Carmacks Group basalts have been suggested to be hot spot related.
2. Are Katrina suite and Donjek volcanic rocks direct equivalents to Prospector Mountain and Carmacks Group rocks? If so, these may also be attractive exploration targets.
3. What is the relative importance of early vs. late Late Cretaceous mineralization? The age of mineralization in many deposits is not well-constrained making interpretation of the relative importance of one suite over another difficult.
4. What is the relationship between Casino and Prospector Mountain suites? Recent studies indicate the Klaza deposit has both early and late Late Cretaceous mineralization suggesting the relationship between Casino and Prospector Mountain suites is more complicated than previously thought.
5. Is there a significance to the prolonged (~150 m.y.) magmatism within the Dawson Range? For example, does repeated intrusion somehow enhance the ‘fertility’ of the district?

6. How do the broadly coeval (ca. 83 to 78 Ma) Rancheria suite and Open Creek volcanic rocks farther east which host the Red Mountain molybdenum porphyry deposit relate to the Casino and Tlansanlin/Windy-Table rocks?

Late Cretaceous porphyry systems are attractive exploration targets making them important to industry, academia and government. To increase understanding of deposits associated with these systems, the 'Late Cretaceous porphyry systems in Yukon' project will:

1. Produce a new bedrock geology map for the Mount Nansen camp extending detailed mapping south from the Mount Freegold camp.
2. Document composition and age of Late Cretaceous plutons and volcanic rocks with the goal of producing an 'Atlas' for these rocks in Yukon (Similar to that done for the Late Triassic to Jurassic plutons in Yukon; YGS Open File 2020-1).
3. Document and date mineralization in intrusion-related deposits within the Dawson Range.
4. Test all plutonic suites as potential drivers and/or metal sources for magmatic-hydrothermal mineralization.
5. Compile and simplify plutonic suites and volcanic stratigraphy for Late Cretaceous rocks throughout southwestern Yukon.

Structural Characterization of the Porcupine Shear Zone in Arctic Alaska

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Tectonic models for large-scale terrane translation along the northern Laurentian margin during the evolution of the circum-Arctic region require the presence of large-scale shear zones. The Porcupine shear zone (PSZ) in northeastern Alaska and Yukon juxtaposes the Arctic Alaska terrane with autochthonous rocks of Laurentia and is a prime candidate for such a structure. However, beyond a recent study of relationships at several sites across the 10-km-wide deformation zone in Yukon (von Gosen et al., 2019), little is known of the style of deformation and kinematic history of the PSZ. Structural relationships within the PSZ were examined along strike for an 80-km stretch of the Porcupine River in Alaska. Lithologic units along the river are divided here into discrete blocks of Neoproterozoic carbonate, quartzite and shale, Silurian limestone and shale, Devonian limestone and Mississippian limestone and shale, Permian limestone, conglomerate and shale, and Triassic siliciclastic and mafic rocks. Individual blocks are separated by NNE-striking, NW-dipping thrust faults or poorly exposed NE-striking zones characterized by strong brecciation and veining.

Internal deformation in the blocks varies by lithology, but is dominantly brittle. Neoproterozoic rocks immediately west of the international border are broken into several panels separated by NW-dipping thrust faults striking 030° and marked by 0.5-m-thick gouge zones. Smaller scale faults define a complex array dominated by conjugate, E-W-striking reverse faults, NNW-striking strike-slip faults, and lesser NNE-striking normal faults. Neoproterozoic shale units commonly define large (tens of m amplitude) overturned folds. Paleozoic strata are characterized by a similarly complex array of NNW-striking normal faults, E-W-striking normal and reverse faults, and NE-striking strike-slip faults. Paleozoic shale units locally display abundant isoclinal folds with subhorizontal hinge planes. Where Devonian limestone is thrust on

Mississippian shale, the younger units define SE-vergent isoclinal folds that are gently refolded about NW-plunging hinge lines. In contrast, deformation in Triassic rocks along the PSZ appears less pronounced, with Triassic strata occurring as a gently folded homoclinal panel with a relatively simple array of NS-striking normal faults, EW-striking reverse faults, and NE-striking strike-slip faults.

Although the kinematics are uncertain, a strike-slip displacement history for the PSZ is consistent with the abundance of steep, NE-striking faults with subhorizontal striae in most lithologic blocks, coupled with the presence of NE-trending zones of brecciation and veining at their boundaries. The fault arrays within individual stratigraphically defined blocks are consistent with secondary structures associated with strike-slip faults, but their geometry and observed kinematics do not define a simple or consistent displacement history. The difference in deformation observed in Mesozoic and older units suggests a protracted history of displacement on the PSZ, but the presence of a significant NE-striking strike-slip deformation zone along the Laurentian margin in Yukon and Alaska supports tectonic models for large-scale terrane translation. Additional field and analytical work are required to refine the timing and detailed kinematic history of the PSZ.

References

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Comparing Middle Crust formed in Continental Margins Versus Island Arcs in the Alaska Range

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The Alaska-Aleutian Range batholith (ARB) records long-lived and spatially overlapping plutonism from ca. 210 to 25 Ma, with at least three distinct stages of pluton emplacement separated by magmatic lulls. The oldest stage includes rocks from the Jurassic Talkeetna arc, considered a type example of an intra-oceanic arc (IO). Arc volcanic rocks and coeval plutons from this stage (210-150 Ma) make up the eastern portion of the ARB and are key components of the Peninsular terrane of southern Alaska. The second ARB stage lasted from ca. 110 Ma to 55 Ma, coeval with progressive Talkeetna arc accretion to the southern Alaska margin. Arc accretion and associated deformation are thought to have been completed by ca. 80 Ma, but intrusive magmatism during this continental margin (CM) stage persisted for ca. 25 My after "docking" of the Talkeetna arc. Volcanic rocks from these two older stages are absent or only locally preserved. The youngest ARB stage, from ca. 44 to 25 Ma, is represented by volcanic deposits locally intruded by cogenetic plutons. Here we focus on middle crustal plutons associated with the two older stages.

Similarities and differences in the chemistry of ARB magmatic stages have important implications for mechanisms and timing of middle crust formation in different tectonic settings and suggest constraints on the production of new continental crust. Zircon U-Pb ages from both IO and CM stages are represented by periods of ca. 50 My of continuous crystallization and both stages feature the onset of high Dy/Yb, Sr/Y, and Nb/Y compositions after ca. 25 My. However, CM rocks are always higher in Nb/Y, and are more alkaline (less-calcic) at similar degrees of differentiation relative to IO rocks. Average CM trace element composition resembles global estimates of average continental middle crust, whereas IO rocks do not. Both stages indicate an increasing role for partial melting of lower crust over time. However, thickened continental margin crust (relative to a juvenile oceanic arc) at the early stage of collision, and progressive crustal shortening and thickening through terminal "docking" stages, may yield a greater fraction of amphibole-rich lower crustal melt, which, under modern geothermal conditions, may be required to form new middle crust with a "continental" trace element endowment.

New bedrock mapping highlights the importance of brittle and ductile structure in the tectonics and metallogeny of the eastern Yukon-Tanana Upland, Alaska

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The Alaska Division of Geological & Geophysical Surveys (DGGS) presents new draft bedrock geologic mapping for a 4,800 km^2 (1,900 mi^2) portion of the Yukon-Tanana Uplands lying between Tok, Alaska and the Alaska-Yukon border. The area is of exploration interest for its potential mineral resources, including porphyry copper-molybdenum-gold, orogenic- and intrusion-related gold, volcanogenic massive sulfides, and rare-earth-elements. The area is of interest to Cordilleran tectonics because it presents complex (though poorly exposed) rocks reflecting the tectonic assembly and subsequent dismemberment of the Yukon-Tanana Uplands metamorphic province, as well as the emplacement of multiple magmatic arcs during mid-Paleozoic through Paleogene time.

Mid-Paleozoic amphibolite-facies gneiss and amphibolite of the Lake George assemblage, part of parautochthonous North America, occupy the lowest structural level in the map area. The Ladue unit (a component of the allochthonous Yukon Tanana Terrane and possibly the along-strike equivalent of the Fortymile River assemblage) is a partially retrograded amphibolite-facies assemblage dominated by Devonian to Mississippian felsic orthogneiss, which overlies the Lake George assemblage on a low angle mylonitic shear zone. A chlorite schist-dominated unit contains felsic metavolcanic rocks with Permian zircon ages; this greenschist facies unit is the apparent continuation of the allochthonous Klondike schist across the border in Yukon.

The area is intruded by voluminous mid-Cretaceous plutons of granodiorite to granite composition. Plutonic rocks locally preserve weak foliation, suggesting emplacement during the waning stages of deformation. Multiple generations of hypabyssal dikes (mostly felsic) of mid-Cretaceous to Paleocene age intrude the plutonic and metamorphic rocks. Coarse-grained plutonic rocks of latest Cretaceous age occur at Mount Fairplay and apparently also within strands of the Sixtymile-Pika fault system.

Middle Cretaceous to Paleocene volcanic rocks and local volcanic-rich sedimentary rocks unconformably overlie the metamorphic and plutonic rocks, mainly in the northern half of the map area. Where mappable, the unconformity and measured bedding surfaces dip moderately, suggesting significant post-Paleocene tilting related to Cenozoic high angle faulting. This faulting may also help explain the juxtaposition of coeval volcanic and plutonic rocks within the map area.

Late Jurassic to Early Cretaceous evolution of the Blanchard River and Vand Creek assemblages, southwest Yukon; implications for Jura-Cretaceous basin development and Mesozoic accretionary processes in the northwestern Cordillera

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Within the Canadian-Alaskan Cordillera a series of Jura-Cretaceous basinal assemblages are juxtaposed between Insular and Intermontane terranes, preserving information that speaks to the Mesozoic-Paleocene evolution of the western edge of the northern Cordillera. Throughout BC and Alaska these basins include the Methow-Tyaughton, Gravina, Nutzotin and Kahiltna assemblages. In southwest Yukon they include the Late Jurassic Dezadeash Formation, early Late Cretaceous Kluane schist, and the newly identified Blanchard River and Vand Creek assemblages. New U-Pb detrital zircon results from the Blanchard River assemblage indicate primary sediment sourcing from the Yukon-Tanana terrane and plutons within it and minor sourcing from Insular terrane arc intrusions. These results suggest proximity of Insular terranes to the western margin during Blanchard River assemblage deposition. The latest Jurassic Vand Creek assemblage beneath the Blanchard River assemblage also contains detrital zircon signatures indicating both Intermontane and Insular terrane sources.

We compare detrital zircon signatures from this study to Jura-Cretaceous assemblages throughout southwest Yukon, BC and Alaska to propose a tectonic reconstruction that depicts the Late Jurassic to latest Cretaceous interactions between the Insular and Intermontane terranes (Figure 1). Our reconstruction supports tectonic models allowing for proximity of Insular and Intermontane terranes as early as Late Jurassic, and sediment deposition within pull apart basins formed during sinistral transtension along the boundary between the Insular and Intermontane terranes. In mid- to Late Cretaceous time post-dating deposition of the Blanchard River assemblage, a tectonic transition to dextral transpression caused northeastward movement of the Insular terranes and the Late Cretaceous collapse of these basins.

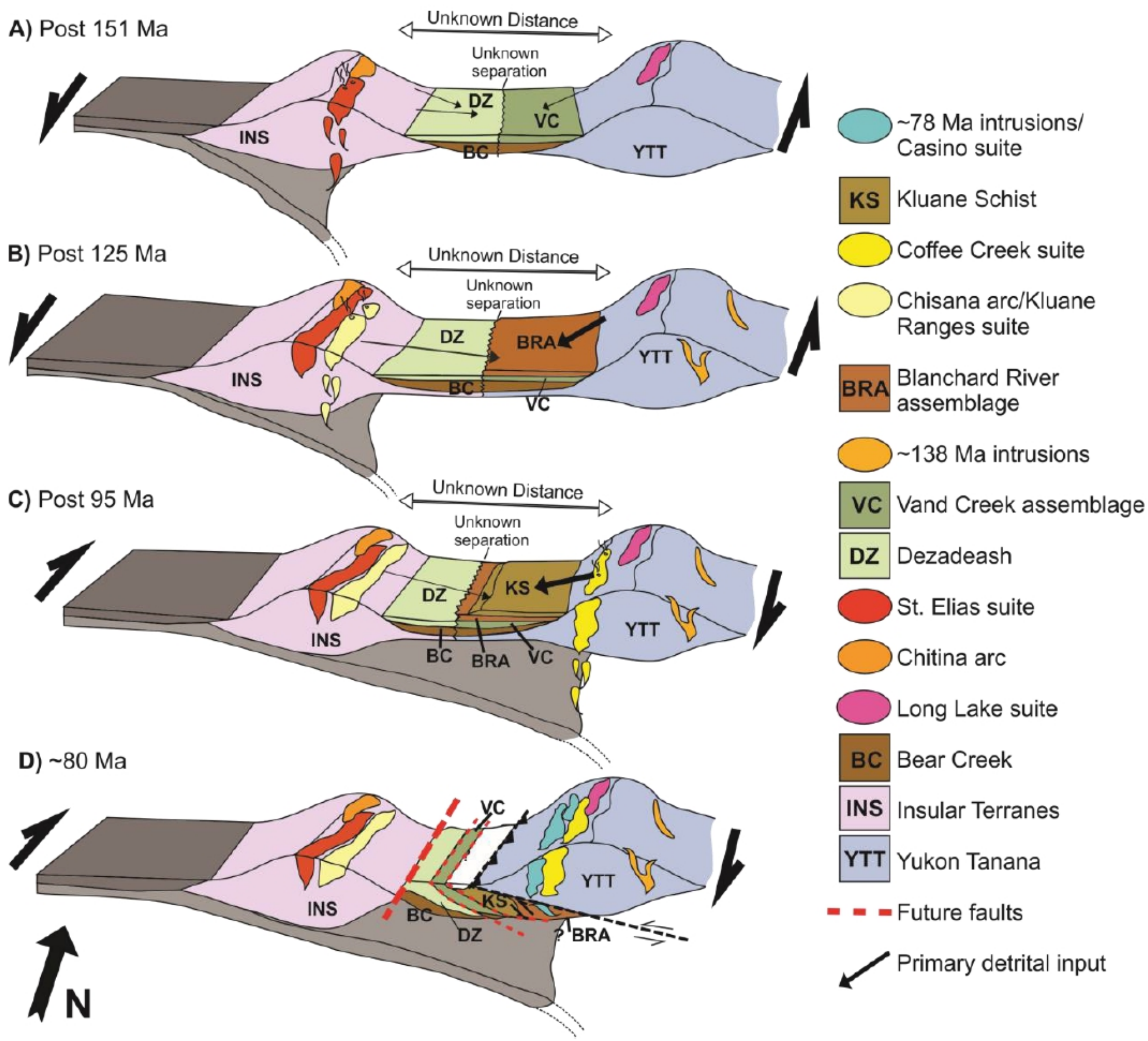

Figure 1. Schematic cross sections depicting the Late Jurassic to Late Cretaceous deposition and collapse of Jura-Cretaceous basinal assemblages observed in southwest Yukon.

Late Cretaceous underplating of the Kluane-Cottonwood-Maclaren schist beneath the northern Coast Mountains Arc, Yukon and Alaska and implications for Cenozoic displacement on the Denali fault

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The timing and structural vergence of the Wrangellia terrane collision with North America have resurfaced as controversial topics in Cordilleran tectonics. The controversy appears to stem from an incomplete understanding of the ages and deformation characteristics of metasedimentary rocks in the suture. We present a synthesis of our recent work elucidating the protolith age, metamorphic path, and deformation history of the Kluane-Cottonwood-Maclaren (KCM) schist belt at the inboard margin of the Wrangellia terrane. Because these rocks are used to estimate total slip on the Denali fault, our results also bear on the displacement history of the Denali fault.

The KCM belt is a package of amphibolite facies metapelitic and quartzofeldspathic schist and gneiss, which is dismembered by the Denali fault in southern Alaska and southwestern Yukon. New and published detrital zircon age spectra from the KCM schist belt give maximum depositional ages of ca. 90-100 Ma for the sedimentary protolith. A strong correlation between age populations of Mesozoic detrital zircon grains from the KCM belt and periods of high magmatic flux in the Coast Mountains arc suggests that the sedimentary protolith of the KCM belt was sourced primarily from the Coast Mountains arc. Lesser Paleozoic and Proterozoic grains record input from Yukon Tanana terrane igneous rocks and peri-Laurentian strata. Syn-kinematic intrusions (Valdez Creek tonalite) and metamorphic zircon ages in the Maclaren schist (Alaska) record prograde metamorphism and thrust burial of the schist belt from ca. 75-65 Ma. The prograde shear zones dip toward the continent and are interpreted as primary collisional structures. Ca. 57-50 Ma intrusions throughout the KCM belt predate dissection by the modern Denali fault and ca. 40-32 Ma syn-kinematic intrusions in the Maclaren and Cottonwood schists (Alaska) were emplaced into a dextral shear regime along the modern Denali fault.

Restoring the KCM belt to its original late Cretaceous geometry reveals a suite of correlative rock packages that have been offset by the Denali fault. The correlative rock packages are: Maclaren schist (AK)-Kluane schist (YT); Valdez Creek tonalite (AK)-ca. 75-65 Ma phase of the Ruby Range batholith (YT); ca. 57-50 Ma felsic intrusions (AK)-Hayden Lake intrusive suite (YT); Clearwater metasediment (AK)-Dezadeash formation (YT); ultramafic cumulate bodies intruding the Clearwater metasediment (AK)-Shorty Creek pyroxenite (YT). Restoring each of these correlative rock package results in at least 450 km of post ca. 50 Ma dextral slip on the Denali fault. Accounting for the newly recognized ~80 km of Neogene dextral slip on the Totschunda fault further implies that the widely cited ~370 km of separation recorded by correlation of the Dezadeash and Nutzotin formations underestimates the Cenozoic slip budget.

On the basis of our integrated dataset, we interpret that the protolith of the KCM belt was deposited into a contractional forearc basin to the west of the northern Coast Mountains arc (Northern B.C. and YT) at ca. 100-90 Ma. Collapse of the basin between ca. 90 and 75 Ma caused the KCM belt to be underplated beneath the arc along east-dipping thrust shear zones. Eocene intrusions seal the collisional structures. Our analysis of the KCM belt supports a model of diachronous (generally south to north) early-to-late Cretaceous accretion of the Wrangellia terrane along west-vergent structures. After collision, the KCM belt, adjacent thrust panels, and associated intrusions were cut obliquely by the Denali fault. Reconstructing all major components of the Denali fault results in >450 km of dextral slip since ca. 50 Ma.

Unraveling the Upper Triassic to Lower Jurassic stratigraphy of the Faro Peak formation, southern Tay River map area, central Yukon

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The Late Triassic to Early Jurassic was a time of changing tectonics along the northwestern margin of North America. Regional plate convergence, accretion, outward stepping of the continental margin, new arc development, and crustal thickening and exhumation of the northern Intermontane terranes resulted in the deposition of multiple syn- and post-orogenic sedimentary successions from eastern Alaska to northern British Columbia. Middle to Upper Triassic overlap assemblages were deposited across the Yukon-Tanana terrane, Slide Mountain terrane, and North American margin following late Permian closure of a marginal back-arc ocean basin. Latest Triassic to Early Jurassic crustal thickening occurred contemporaneous with, or immediately prior to, rapid exhumation of Yukon-Tanana and Stikinia basement units and deposition of Lower to Middle Jurassic synorogenic strata of the Laberge Group in the Whitehorse trough. The purpose of this research project is to examine potentially correlative Upper Triassic to Lower Jurassic clastic units of the Faro Peak formation and determine their physical stratigraphy, provenance, and significance to the tectonic evolution of the Canadian Cordillera.

The Faro Peak formation is exposed along a northwest-trending belt that parallels the Tintina Trench in the southern Tay River map area near Faro, Yukon. This area restores near the town of Eagle, Alaska, after ~430 km of post-Cretaceous dextral displacement on the Tintina fault. The Faro Peak formation has historically been mapped with a lower and upper member and unconformably overlies the exposed basement (Snowcap assemblage) of the Yukon-Tanana terrane and is in faulted contact with Slide Mountain terrane along the Vangorda fault, a northern equivalent to the Jules Creek fault in the Finlayson Lake area. Local bedrock mapping and stratigraphic studies during the 2018 and 2019 field seasons suggest the two members have unconformable lower and upper contacts, are lithologically distinct, and of mappable extent, and therefore should be separated into two new formations. These field data are supported by detrital zircon U-Pb-Hf isotope results that show contrasting provenance between the lower and upper members.

The lower member of the Faro Peak formation is ~650 m-thick and consists of a basal conglomerate and overlying argillite, limestone, basalt, and lithic feldspathic wacke to arenite units that unconformably overlie Snowcap assemblage metasedimentary rocks. The lower member contains normally graded, tabular, and convolute bedding characteristics that are consistent with turbulent, concentrated density flows. Detrital zircon grains from two lower member samples exhibit unimodal, 260-250 Ma age peaks with 95% subchondritic εHf (-17 to +7) values. The upper member of the Faro Peak formation unconformably overlies both the Snowcap assemblage and lower member units. The upper member is interpreted to be >800 m-thick and is mostly composed of massive conglomerate and channelized pebbly sandstone. Clasts in upper member conglomerate facies include schist, quartzite, limestone, chert, basalt, and felsic volcanic to plutonic igneous rocks. Detrital zircon grains from four upper member samples show 200-190 Ma age peaks with mostly superchondritic εHf (-1 to +10) values.

Based on the available detrital zircon and stratigraphic data, the lower member of the Faro Peak formation is most likely correlative with regionally extensive Upper Triassic overlap assemblages that are in depositional or faulted contact with the Slide Mountain terrane in the Finlayson Lake and Quiet Lake map areas. The upper member of the Faro Peak formation is coeval with Laberge Group strata in central Yukon, however, differing clast types and geographic position suggests the Whitehorse trough and Faro Peak basin(s) were probably not connected.

Shear zone formation and juxtaposition of allochthonous Yukon-Tanana terrane with pericratonic North America, eastern Alaska

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The relationship of accreted terranes with pericratonic North America is not well constrained, but critical for unraveling the complex, polydeformational history of the North American Cordillera. The Yukon-Tanana Terrane (YTT) is an extensive and heterogeneous accreted terrane in the North American Cordillera. The boundary separating the YTT from pericratonic North America is largely obscured by large orogen-parallel Cenozoic strike slip faults. However, rocks within the eastern Tanacross quadrangle expose this fundamental suture zone of the northwestern Cordillera, where it is defined by a ductile shear zone. Historically, the shear zone has been defined by discontinuities in muscovite $^{40}Ar/^{39}Ar$ thermochronology, and in the field area delineates a mappable metamorphic discontinuity. The upper plate metamorphic rocks of the YTT near the Ladue River generally yield Jurassic $^{40}Ar/^{39}Ar$ cooling ages interpreted to represent the timing of thrusting of YTT rocks over the pericratonic North America. The structurally lower package, interpreted as parautochthonous, is dominated by amphibolite-facies orthogneisses with Cretaceous cooling ages (ca. 100-120 Ma), which represents exhumation and juxtaposition of these disparate tectonic units. Clearly, the shear zone juxtaposing these distinctive packages of rock is a fundamental boundary in the northern Cordillera and can help explain these major tectonic discontinuities.

Field observations and preliminary observations from targeted samples suggest that the boundary between the YTT and pericratonic North America is subhorizontal ductile shear zone with local ultramylonitic rocks containing ubiquitous top-to-the-SE kinematic indicators. Both the upper and lower plate packages have experienced multiple phases of deformation, but the timing of lower plate deformation remains enigmatic. Forward petrologic modelling of metamorphic assemblages paired with microstructural analysis of the lower plate rocks within the shear zone, suggest that deformation was synchronous with decompression from amphibolite facies. Evidence for top-to-the-SE deformation is pervasive throughout the augen orthogneisses, even well below the limits of the shear zone. This suggests that localization may have been preceded by a more regionally extensive manifestation of this phase of deformation. Mid-Cretaceous granites sometimes occur in antiformal dome interiors, perhaps emplaced into dilatant sites generated by the shear zone or subsequent doming. Existing $^{40}Ar/^{39}Ar$ thermochronology, relationships with mid-Cretaceous granitoids, and ongoing zircon and monazite petrochronology are consistent with the shear zone having accommodated exhumation of the pericratonic North America adjacent to structurally higher allochthonous units of the YTT during the Cretaceous following peak metamorphic conditions in the footwall. Future work will focus on older deformation and accretionary events, such as the manifestation of Jurassic northwest-directed and margin-parallel contraction within pericratonic North America.

Building geologic map databases for tectonic and resource analysis

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At the U.S. Geological Survey Alaska Science Center, we have created geologic map databases to serve many uses, analysis being one of the most critical. Many individual studies attempting to resolve tectonic or mineral resource questions have been handicapped by map data that are inadequate for extrapolation to broader areas. Designed as a multi-layered tool, the expandable database we have constructed for Alaska (Wilson and others, 2015) allows for queries that enable rapid delineation of rock units and searches based on characteristics of geologic units that meet the user's criteria. These queries rely on a map unit key that ties similar or related units together for compiled source maps ranging in scale from 1:63,360 to 1:500,000. Accompanying the source maps in the Alaska database are radiometric age locations, and a series of relational tables that describe age, lithology, and other information, such as terrane designations or locally, engineering properties. The related tables allow the complete original data for the source maps to be preserved in the database. Output from the database has been published in several different "views" ranging from a simplified and generalized poster for public consumption (Wilson and Labay, 2016), to various levels of detail for bedrock geology, and surficial deposit maps (Wilson, 2015). These products are all derived from the same map database source.

Given that Alaska is only a small part of the northern Cordillera, we tested our database's utility to see if it could effectively capture data for other parts of the northern Cordillera (fig. 1). Originally working from the 2003 version of the Yukon geologic map (Gordey and Makepeace, 2003), we were able to link Yukon with Alaska, eliminating most border issues. With the release of a newer version of the Yukon geologic map (Colpron and others, 2016), we have adapted to that version. We can do our linking without making any modifications to the published Yukon databases. This enabled us, for some types of analysis, to treat Alaska and Yukon as single entity. As Alaska also has significant border with British Columbia, we began an effort to link the British Columbia map (Massey and others, 2005) with Alaska and Yukon. Unfortunately, the database design used for British Columbia was not amenable to a simple linking as was done for Yukon. This required us to reformat the British Columbia data and then build links.

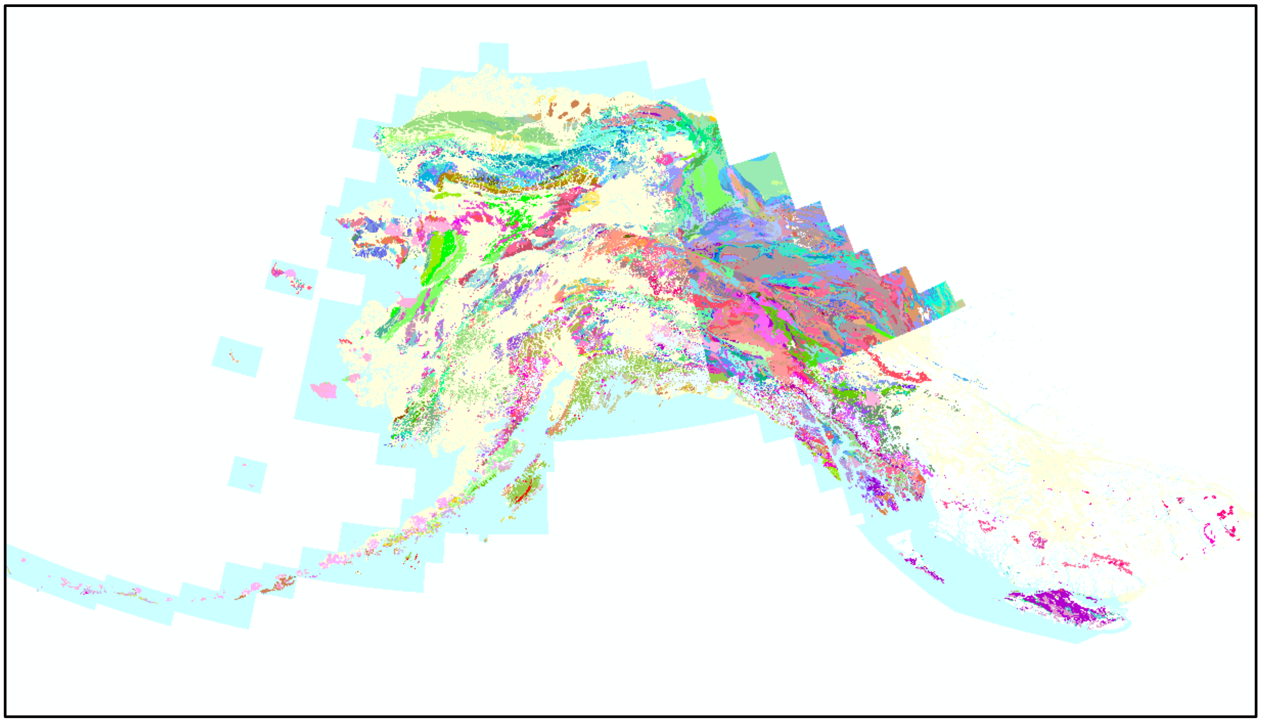

Figure 1. Integrated Alaska, Yukon and partial British Columbia geologic maps

As should be expected, the original map units defined for Alaska, become less applicable with distance from Alaska. We found that we had to define new units for parts of Yukon in order to integrate them in the database. As we work to link British Columbia, differences in the geology will also require new entries based on British Columbia geology. Collaboration with our Canadian colleagues in Yukon and British Columbia to integrate the geology of the northern Cordillera as well as to further test the database design and adapt it as needed, are the challenges before us.

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Geologic Map of the Northeastern Tanacross Quadrangle, Alaska

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During the 2017 and 2018 field seasons, Alaska Division of Geological & Geophysical Surveys (DGGS) geologists conduced helicopter-supported, 1:63,360-scale geologic mapping and sampling in the Tanacross D-1 and parts of the C-1, C-2 and D-2 quadrangles ~15 miles southeast of Chicken, Alaska, adjacent to the Alaska-Canada border.

The Northeastern Tanacross map area contains the Pika, Fishhook, and Baggage mineral occurrences as well as exploration projects at the Taurus and Bluff Cu-Mo-Au porphyry prospects, and multiple placer gold operations on Liberty Creek.

The Northeastern Tanacross project area has a complicated tectonic history highlighted by multiple generations of faulting, reactivation of pre-existing structures, and complexity of the Lake George - Fortymile terrane boundary. The region is underlain by two major amphibolite grade Devonian to Mississippian geologic assemblages: the parautochthonous Lake George assemblage in the south and the overlying allochthonous Fortymile assemblage in the north, as well as minor Devonian to Mississippian Nasina assemblage in the northeastern corner of the map. The Lake George metamorphic assemblage is composed of paragneiss and interlayered quartzite, semischist and augen orthogneiss and minor amphibolite. The Fortymile metamorphic assemblage is characterized by widespread quartzite, schist, paragneiss, orthogneiss and very common amphibolite and garnet-bearing amphibolite. Both metamorphic assemblages are intruded by locally foliated, garnet-bearing, ~110 Ma pegmatites and granitoids, and ~70 to 68 Ma porphyry intrusions overlain by ~68 Ma intermediate to siliceous lava flows and Quaternary basanites (Naibert and others, 2018). A new Cretaceous conglomerate, sandstone, and gravel unit was recognized and mapped unconformably overlying the Fortymile metamorphic assemblage. The zircon population analysis indicate that this unit is an equivalent of Indian River formation recognized in the Yukon. This unit have been mapped in local sedimentary basins formed by northeast trending normal fault.

Multiple types and ages of mineralization are present in the region. The Pika and Fishhook prospects are characterized by mainly structurally controlled mineralization topographically within or immediately overlying intrusions of ~68 Ma age and are geochemically characterized by Ag (Pb-Bi-As) and locally Au. Broadly distributed tourmaline-sericite alteration occurs around both the Pika and Fishhook prospects and the Taurus-Bluff porphyry system. The tourmaline-bearing alteration style in the Taurus-Bluff area carries elevated Ag-Pb-Bi-As. We postulate that this style of mineralization may be related to a suite of intermediate, magnetite-bearing intrusions with ages of ~68 to 70 Ma (Naibert and others, 2018) that are observed in both areas. The slightly older (~70 to 72 Ma) Cu-Mo-Au systems at both Taurus and Bluff are related to potassic- and sericitic-altered quartz feldspar porphyry.

The region is cut by numerous Cenozoic northeast-striking, high-angle, oblique faults with left-lateral movement that offset the older, low-angle detachment between the Lake George and Fortymile assemblages. Less pervasive northwest- and east–west-striking, high-angle minor faults also cut the region.