Canadian Tectonics Group

40th workshop 2020, Virtual

Program with abstracts

Organized by Sean Kelly, Renaud Soucy La Roche, Eric Thiessen

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Cover Photo: Hornblende tonalite dyke (middle) with some syn-kinematic left-lateral shear cuts a gabbroic anorthosite (bottom right). Later garnet coronas developed around ferro-magnesian phases. Photo from the Shawmere anorthosite complex in the Kapuskasing uplift (Abitibi terrane), Ontario. © Eric Thiessen

Program

Friday Nov 20 (EST)

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  - Early concentric and transverse, 'Venus-like' phi structures formed during mantle upwelling preserved in the mid- to deep crust of the W Superior Province: the 'smoking gun' against Archean plate tectonics — Harris, Lyal
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  - Deep structural features in prospectivity mapping for epigenetic gold mineralization in the red lake–stormy lake region, superior province — Adiban, Parham
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  - The Montmorency Fault, St. Lawrence Platform, Quebec: field evidences of strike slip reactivation of a high-angle normal fault — Konstantinovskaya, Elena
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  - Simulating flanking structures from ductile shear zones and its application : A micromechanics based investigation — Bhandari, Ankit
- 19:35 General discussion & closing remarks

Saturday Nov 21 (EST)

- 12:00–12:30
  - Syncing fault rock clocks: Direct comparison of U-Pb carbonate and K-Ar illite fault dating methods — Invited Speaker Mottram, Catherine
- 12:30–12:45
  - Wrangellia Composite Terrane Collisional Timing from Structurally Restoring Subducted Slabs and Mantle Convection Forward Modeling — Fuston, Spencer
- 12:45–12:55

A Canadian Cordilleran perspective of the architecture of subduction zone magma reservoirs: a field and petrochronological investigation of the Early Jurassic Polaris ultramafic-mafic Alaskan-type intrusion, north-central British Columbia — Nott, James

12:55–13:10

The Conicity of Thrust Folds — Langenberg, Willem

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Lithospheric evolution and the thermochronological record. Relationship status: it's complicated — Kellett, Dawn

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Evaluating Trace Element Behaviour in Monazite as a Record of Metamorphic Reactions — Larson, Kyle

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Adding time constraints to polymetamorphism in the Canadian Cordillera with monazite and xenotime petrochronology — Soucy La Roche, Renaud

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No more thumbtacks, no more tracing paper: Old graphical skills in a new world. — Waldron, John

14:10–14:25

Revealing mid-crust lateral flow through aeromagnetic images, quartz c-axis fabrics and U-Pb chronology: inside a ductile shear zone network within the Trans-Hudson Orogen — Vanier, Marc-Antoine

14:25–14:40

Linking shallow seismicity and seafloor structures to understand back-arc basin dynamics — Baxter, Alan

14:40–14:55 Break

14:55–15:10

Interview with a titanite: a petrochronometer's response to deformation — Kavanagh-Lepage, Charles

15:10–15:20

Relict S-Z structures (RSZSs), multi-scale features of major high-strain zones, westernmost Grenville Province — Schwerdtner, Fried

15:20–15:35

Evidence from the Hinchinbrooke gneiss for a circa 1260 Ma granulite facies metamorphic event in the Composite Arc Belt of the Grenville Orogen in Ontario — Easton, Mike

15:35–15:45

Structural characterization of the Saint-François-de-Sales shear zone, Central Grenville Province — Gosselin, Eve

15:45–16:00

Squishy Garnets: Revisiting A Classic Canadian Controversy — Phillips, Noah

16:00 General discussion & closing remarks

Friday November 20 (EST)

17:00–17:15 Chair's message

17:15–17:25

Wind, Water, Ice & Faults: How Erosion Interacts with Tectonics to Shape the Landscape — Schoenbohm, Lindsay

Lindsay M. Schoenbohm[12], Monica Giona Bucci[2], Mitchell McMillan[2], Erin Seagren[2], Alexander Tye[1], Joshua Wolpert[2]

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My research team and I broadly address both constructive (tectonic) and destructive (erosion by wind, water, and ice) forces. On the tectonics side, we consider how deep-seated geodyamic processes are expressed at the Earth's surface, including the dripping or delamination of material from the bottom of the plate, extensional collapse of elevated regions or injection of weak lower crust due to gravitational potential, and plateau uplift. Our research also encompasses neotectonics, which includes measuring fault slip rates and the record of past earthquakes through paleoseismology. On the erosion side, our research examines the action of rivers in the landscape in great detail, including how rivers reorganize as a response to tectonic disruption, how rates of tectonic uplift can be read from the shape of rivers and their catchments, and how erosion rate is controlled by climate, tectonic uplift rate, lithology, and vegetation. We also look at how glacial erosion shapes and is turn shaped by tectonic uplift and climate. Finally, we have begun exploring the remarkable but under-recognized power of wind erosion on Earth, with implications for erosion on other planets, including Mars.

Our team has carried out research in plateau regions around the world, including the Tibetan Plateau (particularly the southeast margin of the plateau in Yunnan, China and the Pamir mountains in western China), the Puna Plateau in NW Argentina, and the Central Anatolian Plateau in Turkey. The reason for this focus is that the margins of plateaus are places of extreme gradients in both tectonic deformation and climate, with steep, structurally-controlled margins producing strong orographic effects – these gradients allow the teasing out of tectonic-climate interactions. The underlying geodynamic processes are also profound and profoundly exciting in plateau regions. Recently however our research has branched into more general questions of how rivers and landscapes respond to tectonic disruption, expanding to study sites in the Nepalese Himalaya and Canada, and we have begun work on paleoseismology and active tectonics in Ontario and Quebec as well.

In this talk I will provide a brief overview of our research and introduce work that team members will share in more detail.

17:25–17:40

Formation of the Salar de Antofalla depression, Puna Plateau, Argentina by transient extension: an effect of mantle lithosphere foundering — Tye, Alex

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Removal of dense mantle lithosphere is hypothesized to be an essential component of compressional orogenesis, yet the effects of such removal and their timing and magnitude are debated; one proposed effect is gravitationally-driven extension. In the southern Puna plateau, late Cenozoic foundering of mantle lithosphere is hypothesized based on tomographic imaging of a dense mass in the asthenosphere beneath the orogen and the spatial distribution and geochemistry of volcanic rocks. New field observations, mapping, and interpretive structural cross sections, together with published mapping and stratigraphic data, suggest that the Salar de Antofalla depression in the southern Puna was formed by a transient episode of tectonic extension that corresponded spatially and temporally with inferred lithosphere foundering.

The Salar de Antofalla depression is a sublinear, ~125 km long, NNE-trending topographic trough, across which topography and stratal ages are asymmetric. The western margin of the depression is a ~1 km tall escarpment that exposes a subhorizontal to gently folded Eocene to Early Miocene sequence. The east side of the depression slopes more gently and exposes Middle/Late Miocene to Pliocene strata at elevations ~1 km below the Early Miocene strata to the west. We observed a tabular, east-dipping body of fault breccia exposed on the western margin of the Antofalla depression. The fault breccia and juxtaposition of stratal ages suggest normal-sense slip on a basin-bounding fault.

Published paleocurrent directions in Cenozoic strata on both sides of the depression and new mapping constrain the age of inferred extension. Paleocurrent directions indicate that the location of the Antofalla depression was occupied by a paleotopographic high during the Oligocene to Early Miocene. In contrast, Late Miocene to Quaternary paleocurrents indicate flow toward the Antofalla depression, suggesting that an extensional basin existed by Late Miocene time. Thrust deformation of Late Miocene to Quaternary strata on the eastern margin of the depression indicates re-establishment of compressional deformation during the Quaternary or earlier. Importantly, Miocene normal slip and subsequent thrusting occurred on faults with similar orientations, implying a tectonic toggling between kinematic states. The temporal correspondence of inferred Antofalla extension with Late Miocene to Quaternary, foundering-related volcanism suggests that inferred extension may have resulted from mantle lithosphere foundering.

17:40–17:55

Insights from a preliminary tectono-geomorphic analysis into the Temiskaming region, Eastern Canada, with implications for future paleoseismic investigation — Giona Bucci, Monica

Monica Giona Bucci[1, 2]**, Lindsay Schoenbohm**[1,2]

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Areas of active deformation are identified in the Temiskaming region, the NW portion of the Western Quebec Seismic Zone (WQSZ), that was hit by a M6.3 earthquake in 1935. We took a three-step approach in this study: i) river profile analysis and identification of knickpoints; ii) identification of high-value clusters of HI (Hypsometric Integral) index, indicating broad, elevated regions; iii) mapping and analysis of linear structural features. A set of knickpoints identified in this study correspond to steps in river profiles that cannot be explained by lithological contacts, anthropic-induced changes, or climatic causes. Most of these knickpoints are located along or near fractures, and fall within areas of higher elevation identified by HI analysis. Although each of these structures requires further investigation with higher resolution data and fieldwork, the results of our study have brought to light structural features that have received little or no attention so far. The strength of the methodology proposed here lies in our synthesis of the results produced by each technique – alone, river profile, HI, and lineament analysis are insufficient to identify important structures. This tectono-geomorphic analysis integrates and corroborates paleoseismic and seismic hazard studies that have been carried in the WQSZ by various research groups. Because it is based on remote sensing and geomatic analysis, our methodology is cost-effective, and therefore this approach could be extended to other sectors of the WQSZ, such as the Ottawa-Bonnechere graben where intense urban development and nuclear facilities are located. Moreover, the methodology here proposed is a successful example of employing geomorphometric techniques in areas with low elevation and gentle topography, not commonly examined in tectonic geomorphic analysis. The final aim of this project is to capture how tectono-geomorphic techniques could identify promising features for classical paleoseismic investigation.

17:55–18:05

Anomalous Low-Relief Surface in Western Nepal and its Potential Link to Himalayan Tectonics — Wolpert, Josh

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In western Nepal, the India-Eurasia collision features the Himalayan fold and thrust belt juxtaposed against the Tibetan Plateau. The resulting topography, which focusses orographic precipitation along narrow strike-parallel bands, can be broadly categorized into three groups (from north to south): 1) low relief (<1000 m) in the Tibetan Plateau; 2) extreme relief (~6000 m) in the Greater Himalaya; and 3) moderate relief (~500-2000 m) in the Lesser Himalaya. However, topographic nuances exist, including numerous low-relief surfaces perched at high elevations and surrounded by rugged terrain. One such surface is the Bhumichula Plateau, an ~250 km^2 patch in the Lesser Himalaya of western Nepal with 300-500 m local relief and elevations ranging between 4100 and 4780 m. Recent mapping places the surface entirely in high grade metamorphic and igneous rocks. The Bhumichula Plateau’s origin is enigmatic and may reflect degradation of a once more expansive Tibetan Plateau, uplift and erosion of a low-elevation surface, various surface processes operating on the catchment scale, or some combination thereof. To test these mechanisms, we will assess the spatial distribution of erosion rates (as measured with cosmogenic ^{10}Be in quartz sand) from within and around the Bhumichula Plateau along with geomorphic indices that reflect surface response to rock uplift rate and catchment divide migration. Collaborators on this project will assess the plateau’s longer-term exhumation history with various thermochronometers, and our combined results may shed light on the history of topography in western Nepal.

18:05–18:15

The era of virtual field trips: An example through the Grenville Province in western Quebec — Lambert, Chris

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Geological conferences and fieldtrips have been an integral part of the geoscience community for more than 180 years. These platforms present the opportunity for geoscientists with similar research interests to network amongst peers and create a forum to share, discuss and ultimately drive new scientific research and publications. Fieldtrips in particular, promote opportunities in a relatively informal, exciting and highly interactive environment, which attracts participants from across the globe. However, due to the novel coronavirus (SARS-CoV-2) global pandemic, conferences and fieldtrips currently require re-imagination into a virtual environment. Recent efforts in creating virtual fieldtrips include the integration of geological sites into the Google Earth online and smartphone platforms. The '*Streetcar2Subduction'* website (https://www.agu.org/learn-and-develop/learn/streetcar2subduction/streetcar2subduction) embodies some of the first field trips to be successfully integrated into the Google Earth format. '*Streetcar2Subduction'* presents a novel series of new and re-imagined existing, field stops from physical fieldtrips in the San Francisco Bay area of the USA, that were developed as part of the American Geophysical Union's Centennial conference in 2019. In this workshop, we present our efforts in creating a similar virtual fieldtrip through part of the Grenville Province in western Quebec, Canada. The Grenville Province is part of the Meso-Neoproterozoic Grenvillian Orogen, equated to the contemporary Himalayan-Tibet Orogen, and as a consequence, is the focus of numerous conceptual, numerical and field based topical studies. Our self-guided tour is the virtual replacement for both the guidebook and physical excursion planned as part of the GSA 2020 conference in Montreal. Our tour presents a series of stops along Highway 117, which forms a near orogen-perpendicular transect through the Grenville Province, that were built off works of previous studies as well our current research. Similar to the format of a guidebook, the trip includes 'pages' for geological context and outcrop descriptions, where each stop can include Google Earth Street View panoramas, data tables, figures and if desired, even video clips. Online discussion sessions can be conducted live or in post-trip virtual meetings. Such virtual trips have the advantages of eliminating the financial costs associated with physical trips and allow for a greater number of participants, broader scientific exposure and even avenues into online teaching. Much like published field guides, these new digital platforms may drive a new format for the publication, not only for fieldtrip guidebooks, but outcrop-focused research manuscripts. Instructions for accessing the tour are available from the corresponding author.

18:15–18:30 Break

18:30–18:45

Early concentric and transverse, 'Venus-like' phi structures formed during mantle upwelling preserved in the mid- to deep crust of the W Superior Province: the 'smoking gun' against Archean plate tectonics — Harris, Lyal

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Long wavelength (deep-source) aeromagnetic, pseudo-gravity and ground gravity data for the W Superior Province highlight:

- NNE- to NNW striking rectilinear extensional fractures and/or faults at high angles to mapped structures and sub-province boundaries which, despite little to no surface expression, localise epigenetic Au and Ni–Cu–PGE–Cr mineralisation.

- Concentric circular to elliptical features, ca. 90-185 km across, along the S boundary of the N Superior proto-craton (Hudson Bay Terrane) intersected by the deep transverse faults. These 'phi (ϕ) structures' are spatially associated with magmatic Ni–Cu–PGE–Cr and Au occurrences. The McFaulds Lake greenstone belt, aka. 'Ring of Fire', constitutes only a small, crescent-shaped belt within one of these concentric features within which 2736-2733 Ma mafic-ultramafic bodies were intruded. The Big Trout Lake igneous complex hosting Cr-Pt-Pd-Rh mineralization W of the Ring of Fire lies within a smaller concentrically ringed feature and the Lingman Lake Au deposit, numerous Au occurrences, and minor Ni showings are also located on concentric structures. Preliminary magnetotelluric interpretations suggest concentric structures also have an expression in the subcontinental lithospheric mantle, where linear resistivity anomalies trend N-S as well as parallel to E-W subprovinces.

Intra-crustal decoupling in the W Superior led to the preservation of these early-formed deep structures in strong anhydrous, melt-depleted felsic and mafic granulites. Transverse structures acted as conduits for magma transport and hydrothermal fluid flow into the overlying crust during their reactivation as dilatational antithetic sinistral (R') shears during dextral transpression and extensional fractures during N-S shortening.

Elliptical structures are similar in size and geometry to coronae on Venus formed above mantle upwellings, e.g. Fatua Corona, which is intersected by a graben-fissure system that extends for ca. 1,700 km. Emplacement of mafic-ultramafic bodies hosting Ni-Cr-PGE mineralization along these ring-like structures at their intersection with coeval deep transverse faults and their location along the margin to the N Superior proto-craton, are consistent with secondary mantle upwellings portrayed in numerical models of a mantle plume beneath a craton with a deep lithospheric keel within a regional N-S compressional regime.

Results provide an important new dataset for regional prospectively mapping and furnish evidence for parautochthonous Neoarchean development of the S Superior Province during plume-related rifting; they cannot be explained by conventional subduction and arc-accretion models.

18:45–19:00

Deep structural features in prospectivity mapping for epigenetic gold mineralization in the red lake–stormy lake region, superior province — Adiban, Parham

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Orogenic gold deposits are linked to geological structures at different crustal that act as conduits for hydrothermal fluids. The western Superior Province in Canada hosts world-class Au deposits such as the Red Lake camp. In this study, deep regional structures at high angles to general mapped lithological and structural trends identified from enhanced aeromagnetic, pseudogravity and ground gravity data. Machine learning algorithms (notably the XGBoost and Random Forest algorithms) were trained using a compilation of the geophysical datasets and engineered datasets from buffer analysis to produce a statistical model that defines the spatial relationship between the regional shear structures and epigenetic gold deposits. The XGBoost model recovered 69% of known deposits in the region with a precision of 52%. Evaluation of the model using Shapley Additive Explanations (SHAP) ranked deep structures at a high angle to the regional trend higher than the deep structures parallel to the regional trend. There was a positive correlation between the deep structures at a high angle to the regional trend and known gold deposits. This project was funded through NRCan’s TGI mineral exploration program "Increasing Deep Exploration Effectiveness" and NSERC.

19:00–19:10

Sources for the History of Tectonics in Canada — Orenstein, David

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My research into the History of Tectonics in Canada focuses on the primary sources, with a special emphasis on the holdings of the University of Toronto Libraries (UTL) and a concentration on the ramifications of Tectonics at the 1913 Toronto International Geological Congress (IGC) and the 1972 Montreal IGC.

Both IGCs published extensive *Proceedings* with the 1972 *Proceedings* having one of its many volumes totally dedicated to Tectonics. As expected, both IGCs had many associated field trips, promoted through an extensive array of excursion booklets and summarised in the Proceedings. Most dealt with tectonics and related issues in structural geology, stratigraphy and paleontology. All of these are to be found on the open shelves and may be borrowed.

These trips were often covered by local newspapers, as compiled in J. B. Tyrrell's a massive scrapbook of the 1913 IGC. Tyrrell's papers also include such gems as his Geological Survey of Canada (GSC) field notebooks, correspondence, and photos of geological events and sites.

While the Tyrrell collection is located in the Thomas Fisher Rare Books Library, the J. Tuzo Wilson Fonds is in the Archives. The Canadian father of Plate Tectonics was the prime mover of the 1957 International Geophysical Year (IGY) Congress, held at U. of T. and was the Co-Convener, with R. J. W. Douglas, of Tectonics - Section 3 - at the Montreal IGC.

There is a virtual museum of the University of Toronto Scientific Instrument Collection (UTSIC), with a storeroom you can visit by appointment. There, for example, you can find apparatus from three different geochronology laboratories.

However, during the pandemic, none of these are accessible. So what is to be done? There are electronic substitutes, but more of the earlier than the more recent material has been digitised. My home library contains such gems as the GSC's *1897 Annual Report*, including a report by J.B. Tyrrell; the 1970 *Geology and Economic Minerals of Canada*, edited by R.J.W. Douglas; and the *Program* of the 1972 Montreal IGC. Oral history is also possible, and participation in the CTG lecture series has been invaluable in finding informants.

19:10–19:20

The Montmorency Fault, St. Lawrence Platform, Quebec: field evidences of strike slip reactivation of a high-angle normal fault — Konstantinovskaya, Elena

Elena Konstantinovskaya[1] and Michel Malo[2]

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The Montmorency Fault is one of the major basin-bounding faults at the northern border of the Paleozoic sedimentary basin of St. Lawrence Platform. The fault strikes N53°E and dips at ~60° to the SE. The eroded footwall of the fault is composed of metamorphic rocks of the Grenvillian basement overlain by thin eroded sub-horizontal limestone beds of the Trenton Group. The exposed hanging wall consists of Trenton limestone overlain by the Utica shales and Lorraine siliciclastic rocks dipping at ~45° to the SE. The apparent vertical offset across the Montmorency fault is ~180 m, probably > 300-400 m taking into account data from neighboring wells.

The fault core zone is composed of smears of calcareous shales 15-20 cm thick containing extended limestone boudins. A system of fractures and gneiss cataclastic breccia of ~30-40 cm thick are exposed in the footwall damage zone. Multiple open and calcite-filled fractures affect shale and limestone beds in the hanging-wall damage zone. The calcite-filled fractures indicate normal-fault displacement. Normal-fault grooves on the fault surface plunge to the SE indicating dip-slip along the fault. At the same time, extensive horizontal striations on the gneiss footwall indicate strike-slip displacement that likely overprinted the dip-slip movement. The rotated domino structures occurring in boudinated limestone layers along the fault plane are consistent with the horizontal striations and indicate dextral strike-slip displacement along the fault. A system of oblique open fractures cutting through the horizontal striations in the gneiss footwall is compatible with dextral strike-slip movement.

The observed outcrop indicators of normal and strike slip displacements along the Montmorency Fault likely reflect subsequent stages in the fault kinematic history. The initial normal faulting most probably resulted from the NW-SE extension of the Grenvillian margin. The NW-verging thrusts and anticline folds in the Lorraine Group observed to the SE from the Montmorency Fault indicate the phase of shortening associated with the NW-directed emplacement of the Appalachian thrusts during the Taconian orogeny. The subsequent fault reactivation as the dextral strike-slip displacement likely occurred as a result of paleostress field rotation during the Late Cretaceous – Early Tertiary, when maximum principal stress was oriented SW-NE, similar to the present-day maximum horizontal stress orientation.

Structural analysis of exposed basin-bounding faults of the St. Lawrence Platform contributes for better understanding of subsurface faults evolution and hydraulic behaviour that is relevant for the assessment projects of CO_2 storage and deep geothermal energy potential in the sedimentary basin.

19:20–19:35

Simulating flanking structures from ductile shear zones and its application : A micromechanics based investigation — Bhandari, Ankit

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Flanking structures are deflections in linear or planar fabric elements around any cross-cutting element such as a fracture, vein or dyke. They are potential tools to infer flow kinematics of ductile shear zones. Previous numerical modeling investigations are limited to situations where the cutting element is either a frictionless free slipping surface, or a rigid material. Works with more variable cutting element's rheology are limited to low finite strains, cutting element's high aspect ratios, limited cases of cutting element's initial orientations and 2-D geometry. In natural setting, the rheological properties of the cutting element mainly its strength, shape and orientation can be highly variable. Common examples include flanking structures associated with a cross-cutting dyke or a mineral inclusion. Here, we use Eshelby formalism to simulate flanking structures around a cutting element of varying rheological properties, shape and orientation. Specifically, we regard a cutting element as a 3D Eshelby inclusion embedded in a viscous medium. The numerical exterior Eshelby solutions provide velocity fields in the vicinity around the element. These velocity fields are then used to simulate the deflection of marker elements surrounding the cutting element, under a macroscale general plane strain flow ranging from simple to pure shear. We reproduced all observed flanking structure types recognized from natural shear zones. In contrast to the previous models, our modeling results show that all three types of flanking structures with antithetic (a-type), no- (n-type) and synthetic (s-type) displacement along the cutting element can be formed around any cutting element rheologically stronger than the embedding medium such as a dyke or a strong mineral inclusion. The a-type flanking structure may transition into an s-type depending on cutting element's viscosity and macroscale finite strain. We have developed a reverse-dynamic modelling tool that can provide a quantitative estimate of flow vorticity, finite strain and cutting element's viscosity relative to the embedding medium from an observed natural flanking structure.

19:35 General discussion & closing remarks

Saturday November 21 (EST)

12:00–12:30

Syncing fault rock clocks: Direct comparison of U-Pb carbonate and K-Ar illite fault dating methods — Invited Speaker Mottram, Catherine

Catherine Mottram[1], Dawn Kellet[2]
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The timing of slip on brittle faults in the Earth's upper crust is difficult to constrain and is commonly found by either indirect methods or by dating fault-generated materials using radiometric dating. Both methods often yield results that can be difficult to interpret. Here we make the first direct comparison between K-Ar dating of fault gouge clay (authigenic illite) and U-Pb dating of carbonate slickenfibres and veins from the same fault, the Big Creek fault, a NW-striking, dextral strike-slip fault system in Yukon Territory, Canadian Cordillera. Both methods yielded dates at ~73 Ma and ~60–57 Ma, representing at least two periods of fault slip which form part of a complex fault and fluid-flow history. The Cretaceous result lies within indirect estimates for major slip on the fault. The Paleocene-Eocene result coincides with the estimated timing of slip of the nearby Denali and Tintina faults, large-scale, NW-striking dextral faults, indicating Big Creek fault reactivation during regional faulting. The coincidence of periods of carbonate-crystallizing fracturing and fluid flow with intervals of seismic, gouge-generating slip supports the fault valve model where fault strength is mediated by fluid pressures, and fluid emplacement requires seismic pumping in otherwise impermeable aseismic fault zones. The reproducibility of slip periods for different fault-generated materials using distinct decay systems indicates that these methods provide complimentary results and can be reliably applied to date brittle fault slip, opening new opportunities for investigating fault conditions with associated mineralizing fluid events.

12:30–12:45

Wrangellia Composite Terrane Collisional Timing from Structurally Restoring Subducted Slabs and Mantle Convection Forward Modeling — Fuston, Spencer

Spencer Fuston[1], Lorenzo Colli[1], Jonny Wu[1]
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Wrangellia composite terrane collisional timing and history is debated, leading to uncertainty regarding its influence on regional orogenesis. Possible times of collision range from Early Jurassic to Late Cretaceous and vary between closure of a single open-ocean back-arc basin to two back-arc basins of differing sizes. We test the timing of this collision by unfolding (i.e., structurally restoring) the upper mantle Cascadia slab below the western US, imaged by mantle tomography, back to Earth's surface. When reconstructed within a global mantle reference frame, the unfolded Cascadia slab accounts for at least ~75 Ma of Farallon subduction below southern California. This suggests a major slab breakoff event during Late Cretaceous time, that we interpret as a possible time of WCT collision. To test this interpretation, we performed 3D numerical mantle convection forward modeling with imposed surface velocities derived from kinematic plate motion models. We considered several classes of WCT collisional models: (1) a "Conventional" model involving an Early Jurassic initial collision followed by the opening of a small back-arc basin prior to final suturing in Early Cretaceous time, (2) a "Late Collision" model constrained by our slab-unfolding results involving the Late Cretaceous closure of a single open-ocean basin, and (3) a "Western Corrected" model identical to the "Conventional" model but with a more western position of Pangea to assess the sensitivity of model outputs to absolute mantle reference frame. Our modeling results demonstrate that the "Conventional" model reproduces the east-dipping "Mezcalera" lower mantle slab below the North American east coast but fails to reproduce the sub-vertical "Deep Cascadia" slab present at similar depths below the western US. Crucially, the "Late Collision" model succeeds in reproducing both lower mantle slabs, supporting a Late Cretaceous WCT collision. In this scenario, the Mezcalera slab is linked to east-dipping subduction below western North America. Linking the WCT with the Deep Cascadia slab has profound implications for western North American plate reconstructions including constraining paleo-latitude and longitude for the WCT as well as suggesting that WCT collision may overlap spatiotemporally with the enigmatic Laramide orogeny.

12:45–12:55

A Canadian Cordilleran perspective of the architecture of subduction zone magma reservoirs: a field and petrochronological investigation of the Early Jurassic Polaris ultramafic-mafic Alaskan-type intrusion, north-central British Columbia — Nott, James

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The c. 186 Ma Polaris Alaskan-type intrusion in north-central British Columbia belongs to a class of convergent margin ultramafic-mafic intrusions that are gaining global importance as potential hosts to Ni-Cu-PGE mineralization. These intrusions typically exhibit a zonal distribution of lithologies ranging from dunite in the core to clinopyroxenite, hornblendite, or gabbro at the margin and they are characterized by a distinct lack of orthopyroxene. The Polaris intrusion is one of the best exposed Alaskan-type intrusions in the Canadian Cordillera. It is an elongate sill-like body, 14 km long by 3 km across, that exhibits an asymmetric distribution of lithologies with dunite in the east and gabbro-diorite to hornblende clinopyroxenite in the west.

Detailed mapping (1:15,000 scale), including preparation of a new geological map and intersecting cross sections, integrated with the results of a recent aeromagnetic survey have allowed for establishment of contact relationships and the 3D architecture of the Polaris intrusion. Key observations include: the variable nature of lithological contacts, complex dike and sill emplacement mechanisms, evidence for magmatic disruption, and eastward-directed thrusting of the intrusion atop contact aureole rocks in the east. Contacts between olivine clinopyroxenite, wehrlite, and dunite can be sharp, gradational, or diffuse, and there are localized chaotically mixed zones that incorporate all these lithologies. Remobilization of cumulates is recorded in disrupted chromitite seams contained primarily in dunite that occur as schlieren with both planar and folded chromite layers present.

Current research at UBC involves U-Pb geochronology and trace element characterization of accessory minerals (zircon, titanite) to constrain petrological processes and to develop an emplacement framework for the Polaris intrusion. In addition, geochemical and isotopic analysis (Pb-Sr-Nd-Hf) of minerals and whole rocks will provide an opportunity to evaluate the evolution of arc magmatism and the role of mid-crustal magmatic systems through comparison with lesser exposed intrusions throughout the North American Cordillera (Alaska to California) and globally (e.g. Urals). As the Early Jurassic Polaris intrusion coincides with the breakup of the Pangea supercontinent and the concurrent initiation of terrain accretion in the Cordillera, this research will have implications for our understanding of Cordilleran tectonics in the Early Jurassic and the evolution of subduction zone magmatism in this region.

12:55–13:10

The Conicity of Thrust Folds — Langenberg, Willem

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Two contrasting styles of deformation and related fold-thrust interaction can be distinguished in the thin-skinned fold and thrust belt forming the central Alberta Foothills and Front Ranges. Paleozoic carbonates form thick competent beams, which are cut by east verging thrust faults with stair-case trajectories (ramps and flats). In contrast, the overlying Mesozoic and Cenozoic strata show much more folding above detachment zones (detachment folds).

These two contrasting styles of deformation can be reconciled by the notion that thrust-ramps in competent units (such as the Paleozoic carbonates) are localized by a buckling instability in the layered succession in an early stage of buckle-folding. Thrust faults in the overlying Mesozoic and Cenozoic units form in a later stage of the buckle-folding process, whereby these faults ramp through the fore-limbs of tight folds (described as fault-propagation folds or as thrust folds). Consequently, the prominent process in these layered strata is buckling, whereby thrust faults initiate at buckling instabilities. Buckle folds can be modified by fault-bending at a later stage, after thrust faults formed.

A sequence of events is suggested, whereby detachment buckle folds are formed first. Subsequently, this process would allow for modification of the folds by propagating thrust faults, which are termed Thrust Folds.

Modeling by Liu and Dixon (1990) showed that the threefold fold classification of Jamison (1989) is part of a continuum. I propose a twofold classification of fault related folds consisting of Detachment Folds and Thrust Folds. Fault-bend Folds and Fault-Propagation Folds are varieties of these folds.

These folds are generally cylindrical, but they do not continue indefinitely along the trend. At the terminations they are conical periclines (Kelker and Langenberg, 1988). A statistical procedure allows the classification of these structures and predicts changes in expected unexposed geometry.

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13:10–13:20

Lithospheric evolution and the thermochronological record. Relationship status: it's complicated — Kellett, Dawn

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Thermochronological ages are points in time along a rock's cooling path. Our ability to interpret these ages is influenced by how well we understand both intrinsic and extrinsic factors that affect the thermochronological systems that we use. Grain geometry, crystallinity, and parent isotope concentration and distribution are all examples of intrinsic properties that influence thermochronological ages. Erosion patterns and rates, the crustal thermal field, rock translations via structures and rock thermophysical properties (all of which may be dynamic in time) are all examples of extrinsic factors that influence thermochronological ages. Consequently, unlike geochronology, simple relationships between thermochronological ages and geological processes are rare. However, the value in thermochronological data lies in being able to explore past geological conditions – because of how those conditions have affected the thermal history of the analyzed mineral and resulting age data.

Major regional changes in lithosphere evolution, for example slab break-off, sub-continental lithospheric mantle delamination or slab windows caused by ridge subduction, could induce high heat flow in the crust as asthenosphere comes into contact with the base of the crust. It is reasonable to assume that the thermochronological record could capture such thermal perturbations, and past studies have made associations between thermochronological datasets and lithospheric removal events. Our current work focuses on using forward 1D thermal models of mantle delamination linked to thermochronological age prediction algorithms to quantify the effects of this process and hence determine the conditions under which thermochronological data can be definitively linked to past lithospheric evolution.

13:20–13:35 Break

13:35–13:45

Evaluating Trace Element Behaviour in Monazite as a Record of Metamorphic Reactions — Larson, Kyle

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Quantifying the geological history of phase reactions in rocks has been paramount in understanding tectonic processes. In metamorphic rocks, changes in phase and/or mineral chemistries in response to changing pressure-temperature (P-T) conditions provide an opportunity to quantify the absolute value of those conditions. While P-T data are critical for understanding the history of a metamorphic rock, the other main unknown that must be determined is time. Advancements in geochronology now allow near-routine *in situ* investigation of geochronometers such as monazite. Moreover, many recent geochronological studies also analyse trace element concentrations from the same ablated material used for isotopic characterization. This influx of “time-stamped” or petrochronological data has allowed researchers to make informed correlations between the geochemistry of a chronometer and the metamorphic reactions occurring within rocks specimens.

Some of the early work that linked geochronometer chemistry to bulk-rock reactions included qualitative and quantitative *in situ* and separated monazite chemical investigations paired with different types of geochronological data. This work identified linked age + chemical zonation of monazite, particularly in heavy rare earth elements (HREE), commonly generalized through Y content. These early studies have gone on to become classic works that have informed prevailing thought on how changes in monazite trace element chemistry are linked to phase reactions. In particular, the linking of the HREE/Y budget of monazite to the stability of garnet in metapelites has become commonplace. While such interpretations have been employed in many studies, recent work has demonstrated that partitioning of HREE within monazite may not be quite so simple. Work on amphibolite facies metapelites with textural and spatial characteristics that indicates monazite and garnet grew together do not appear to reproduce derived HREE partitioning coefficients and that the coefficients themselves are temperature dependent. These studies demonstrate that our understanding of HREE incorporation into monazite is incomplete and as such, the simplistic view of HREE budgeting that has been implemented in many recent works may not be representative.

Herein we examine three specimens used in some of the original studies that informed current thought on monazite, garnet and HREE partitioning using high spatial density *in situ* petrochronological analyses, garnet trace element mapping, and metamorphic phase equilibria modelling to develop detailed P-T-time histories. The results provide information on HREE partitioning between garnet, monazite, xenotime and apatite and, as such, the means to assess the basic interpretations around Y zoning in monazite that have propagated from the original work.

13:45–14:00

Adding time constraints to polymetamorphism in the Canadian Cordillera with monazite and xenotime petrochronology — Soucy La Roche, Renaud

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The Yukon-Tanana terrane of the Canadian Cordillera is characterized by a polymetamorphic evolution that results from its complex tectonic interactions with the Laurentian margin and other adjacent micro-continents, arc-back arc systems and oceanic domains. This complex evolution can be deciphered with careful petrography combined with petrochronology on accessory minerals associated with each metamorphic phase. In particular, Al_2SiO_5 polymorphs (andalusite, kyanite and sillimanite) – which are common in aluminous metamorphic rocks, are easily identifiable, and crystallize at distinct pressure (P) and temperature (T) conditions – provide first-order constraints on the metamorphic grade and facies series. The metastable coexistence of all three Al_2SiO_5 polymorphs in the Florence Range metamorphic suite in northwestern British-Columbia provides an excellent opportunity to reconstruct the polyphase metamorphic evolution of the Yukon-Tanana terrane. We used in-situ laser-ablation split-stream petrochronology to target monazite and xenotime associated with specific metamorphic index minerals. These data reveal a complex P–T–t path, requiring at least three P–T loops, and passing through the kyanite, sillimanite and andalusite stability fields over 150 Myr from the Permian to the Early Cretaceous. The earliest preserved metamorphic event reached the kyanite stability field (>600 °C, >0.6 GPa) at ca. 270–240 Ma and was followed by retrograde metamorphism at ca. 240–215 Ma. Renewed garnet growth occurred during a second prograde metamorphic event at ca. 195–185 Ma. Garnet breakdown, probably linked to decompression in the suprasolidus stability field of sillimanite and K-feldspar (>700 °C, <0.7 GPa) occurred at ca. 185–170 Ma. Finally, a third P–T loop is characterized by the growth of andalusite, then cordierite, and reached >600 °C below 0.3–0.4 GPa after ca. 120 Ma. This study illustrates the importance of analyzing petrochronometers in their textural context, especially inclusions in porphyroblasts, and the complementary P–T–t information that can be extracted from monazite and xenotime. Our new data are compatible with two separate collisions between the Yukon-Tanana terrane and adjacent terranes during the Permian–Triassic and Late Triassic to early Jurassic, followed by contact metamorphism during Cretaceous magmatism.

14:00–14:10

No more thumbtacks, no more tracing paper: Old graphical skills in a new world. — Waldron, John

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Spherical projection is a widely used tool for representing structures in three-dimensions (3D) on two-dimensional media, including paper and computer screens. Traditionally, projection has been taught in both introductory mineralogy and structural geology classes using a stereographic or equal-area *net* as a template for drawing points or curves on the *projection*, which is constructed on tracing paper. The traditional method imposes a significant perceptual challenge. Ideally, the projection, which represents a flattened version of the 3D world, would be held stationary, with north at the top, while the net, functioning as a 3D protractor, would be rotated to make measurements and constructions. However, this procedure is physically difficult because the net is below the projection, so most workflows call for the projection to be rotated, typically using a thumb-tack as a pivot, over a fixed net. This challenge of spatial awareness is compounded by poor labelling practices, in which the projection is sometimes referred to as a net, and the net is sometimes labelled with cardinal compass points, even though it has no fixed orientation in space. In addition, students may simultaneously be taught upper-hemisphere projection (in mineralogy) and lower-hemisphere projection (in structural geology). These practices cause perceptual difficulties for students.

To overcome these difficulties, students may be encouraged to use a set of learned rules for plotting, or may use computer software. Although these methods enable them to produce correct plots, they do not give the students the depth of understanding necessary to solve new and unexpected problems on the projection.

In response to the Covid-19 crisis, a new method was devised, using readily accessible office software to replicate the traditional process of plotting lines and planes. In contrast to tracing-paper methods, the projection can be kept fixed to the page with north at the top while the net is easily rotated underneath it. Preliminary responses indicate that this method of computer-assisted hand plotting avoids some perceptual problems of traditional techniques, while retaining the hands-on characteristics necessary for engaged learning and problem solving. It is unlikely that we will return to tracing paper and thumb-tacks.

Tutorials are availalable at www.youtube.ca/c/JohnWaldronEarthScience

14:10–14:25

Revealing mid-crust lateral flow through aeromagnetic images, quartz *c*-axis fabrics and U-Pb chronology: inside a ductile shear zone network within the Trans-Hudson Orogen — Vanier, Marc-Antoine

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The southeastern Churchill Province (SECP) represents a lateral segment of the Paleoproterozoic Trans-Hudson Orogen. Oblique convergence is actually proposed to explain the structural and metamorphic architecture of the SECP. The main focus of this presentation is the Core zone, which occupies the centre of the SECP and is composed of a mixture of Archean and Paleoproterozoic reworked crust compressed between convergent cratons and divided by major shear zones. Past investigation demonstrating protracted high grade metamorphic conditions suggest it is part of a hot orogens. This type of orogens often shows complex system of anastomosing shear zones. The understanding of such system necessitates investigations of the regional geometry, kinematics, finite strain, temperature of deformation and geochronology. The interpretation of aeromagnetic survey, structural analysis, petrofabrics and geochrology are combined to achieve this.

The main characteristics of the shear zones are: i) subvertical foliation and subhorizontal stretching lineation, ii) dextral kinematics along N-S shear zones, iii) sinistral kinematics along WNW-ESE shear zones, and iv) L to LS tectonites. The obtuse angle of 116° between the George River (GRSZ) and Moonbase shear zones supports that they form a set of conjugate ductile shear zones. Quartz *c*-axis opening angle thermometry outlines representative deformation temperatures that range from 575 (±50) °C to 685 (±50) °C in the GRSZ and from 670 (±50) °C to 805 (±50) °C in the lac Tudor shear zone. Microstructures support those deformation temperatures and indicate a variable degree of static recrystallization in the GRSZ. Most of the deformation in the GRSZ occurred prior to 1812 ± 5 Ma. Generalized high deformation temperatures in the SECP has favored penetrative deformation resulting in the development of a shear zone network. The geometry and kinematics of the shear zone network indicates that the eastern portion of the SECP accommodated near coaxial bulk strain during ~NE-SW

shortening, which was accommodated by ductile lateral flow of the mid-crust towards the unconfined SSE. This tectonic model provides an explanation for the lack of a trans-hudsonian metamorphic footprint in the Mistinibi-Raude Block and the Orma Domain. The GRSZ is therefore interpreted to be related to lateral flow in the mid-crust during close to orthogonal collision rather than to oblique collision caused by northward displacement of the Superior Craton.

14:25–14:40

Linking shallow seismicity and seafloor structures to understand back-arc basin dynamics — Baxter, Alan

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Back-arc basins open in response to subduction processes, such as slab rollback, which induce extension in the upper plate, usually along trench-parallel spreading centers. Over time, far- and near-field tectonic perturbations destabilize the back-arc region and the dominantly extensional stress regime fragments into different stress domains. For example, global seismic data reveal that most of the seismic events in the Lau Basin, SW Pacific, occur along transcurrent (strike-slip), rather than extensional faults. To better understand active deformation in the Lau Basin, we compared focal planes from centroid moment tensors (CMTs), calculated for large, shallow seismic events between 1976 and 2017, with over 4000 seafloor lineaments mapped throughout the back-arc basin. The lineament map was constructed using satellite altimetry, ship-based multibeam and vertical gravity gradient (VGG) data. The orientations of the lineaments were compared with the two possible focal planes of the CMTs, and the most likely focal planes were selected to classify the faults. We identified ten stress domains in the basin, by grouping similarly classified faults, according to their location and proximity to known tectonic features, such as microplate boundaries. The results show that the stress regime of the Lau Basin is dominated by: (i) left-lateral and right-lateral strike-slip faults, (ii) large-scale transcurrent motion along rigid crustal-scale fault zones, and (iii) non-rigid diffuse deformation, while extension is mainly restricted to the tips of propagating rifts and spreading centers. By classifying many of the faults in the Lau Basin, the study addresses a number of questions concerning basin-scale stress regimes and microplate formation and provides a more complete picture of the complexities of back-arc basin dynamics.

14:40–14:55 Break

14:55–15:10

Interview with a titanite: a petrochronometer's response to deformation — Kavanagh-Lepage, Charles

Charles Kavanagh-Lepage[1], Félix Gervais[1], Tomas Næraa[2], Abdelali Moukhsil[3]
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In this study, we investigate the Pressure-Temperature-time-deformation path from the Manicouagan Imbricate Zone (MIZ) of the central Grenville Province, known for its Grenvillian eclogitic mafic bodies, in order to better constrain the previously proposed model of ductile extrusion of lower crustal nappes. We report new *in situ* U-Pb, Zr and REE analysis for two samples: (1) an amphibolite gneiss with textures indicative of decompression from eclogite facies collected ~1 kilometer structurally below a normal-sense shear zone; and (2) a mylonitic garnetite with lineation-parallel titanite collected within the shear zone itself. In sample (1), thermodynamic modelling suggests titanite growth during decompression and heating from eclogite facies to high-pressure granulite facies. Zr-in titanite and Zr-in-rutile thermobarometry results for samples (1) and (2) support titanite genesis at 17 kbar-892°C and 17kbar-894°C, respectively. REE profiles and trace element patterns of both samples further suggest that titanite grew at the expense of allanite and rutile, whereas the influence of garnet was minimal. *In situ* LA-ICP-MS U-Pb geochronology yields single populations ages at 1034 ± 7 (2s; MSWD = 1.3) Ma and at 950 ± 24.0 (2s; MSWD: 1.1) Ma for samples 1 and 2, respectively. The age of the former is contemporary to the age of the sole regional metamorphic peak documented at ca. 1030-1050 Ma, whereas the latter age is 40 myrs younger than the end of ductile extrusion most recently constrained at ca. 990 Ma (Labat et al., 2020, *JSG*).

Thus, to account for: the similar REE and trace element signatures, a single peak-T petrogenetic event and the difference in ages between the samples, we infer that titanite grains of sample (2) were effectively reset during localized deformation associated with a normal-sense shear zone at ~950 Ma. This implies that trace element and REE composition of titanite is somewhat resilient, whereas the U-Pb system remains sensitive to deformation and recrystallization. In agreement with a growing number of studies, we interpret these results to be evidence for decoupling of the U-Pb system from other trace elements and REE in titanite grains during localised deformation.

15:10–15:20

Relict S-Z structures (RSZSs), multi-scale features of major high-strain zones, westernmost Grenville Province — Schwerdtner, Fried

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Detailed analysis of well exposed, heterogeneously strained, metamorphic rocks at Cap de Creus (NW Spain) has provided insight into the kinematics, rheologic conditions and episodic tectonic evolution of km-scale shear zones. Specifically, Carreras and co-workers have drawn attention to the significance of m-scale amphibolite inclusions, boudin-like segments of asymmetrically buckled layers contained within ductile metasedimentary schists. In the western Grenville Province, similar m-scale mafic and felsic inclusions, provisionally called relict S-Z structures (RSZSs), abound in high-strain zones developed in variably retrogressed granulite-facies banded orthogneiss, and km-scale counterparts, informally termed mega-RSZSs, occur along the southeastern boundary of the Grenville Front Tectonic Zone and at the sheared interface between two allochthonous litho-structural subdomains (relict thrust sheets). Trains of tight to isoclinal, asymmetrical folds (TIAFs), with a geometric style similar to that of model folds formed under conditions of protracted simple shear, occur at the transitional margins of some banded gneiss zones and appear to be the forerunners of RSZSs. Characterized by thick short limbs, thin long limbs and hinge-parallel stretching lineations, TIAFs probably qualify as rotated 'oblique folds' reported from many Phanerozoic shear zones.

In well-exposed banded gneiss zones, we have documented the strain-induced transformation of trains of TIAFs into series of linked RSZSs, due to preservation of the short fold limbs and pinch-out of the long fold limbs. On exposure surfaces parallel to hinge lines, neighbouring mesoscopic RSZSs are connected by thin necks or separated by regular gaps, indicating the total finite strain is triaxial. Although additional study is required, these results suggest that many zones of retrogressed banded gneiss are the sites of intense episodic non-coaxial deformation during crustal thickening and subsequent horizontal extension.

15:20–15:35

Evidence from the Hinchinbrooke gneiss for a circa 1260 Ma granulite facies metamorphic event in the Composite Arc Belt of the Grenville Orogen in Ontario — Easton, Mike

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The origin of the domal, Hinchinbrooke enderbite complex, which underlies ~400 km^2 of the southern Sharbot Lake domain (SLD) has long been enigmatic. Is it an Elzevir Suite tonalite (circa 1270-1250 Ma) affected by Frontenac terrane granulite facies metamorphism at circa 1168 Ma? Or is it basement to the SLDn supracrustal rocks, as suggested by Wynne-Edwards? A prior attempt to resolve this question by U-Pb geochronology was inclusive, with a 3-point discordia line yielding an age between 1250 and 1290 Ma. In order to better constrain the age of the Hinchinbrooke complex, and to compare it with the domal Pakenham structure in the northern SLD which contains granodioritic and tonalitic rocks emplaced at 1263, 1299 and 1378 Ma, a new sample was collected in July 2019 for U-Pb CA-ID-TIMS geochronology. The rock is a grey, leucocratic, homogeneous, gneissic tonalite consisting of ~40% quartz, 40% oligoclase (An_{30-35}), 10-15% hypersthene and minor biotite, magnetite and fluorapatite. Locally the hypersthene is replaced by green amphibole.

Zircon grains have primary cores with growth zonation surrounded by overgrowths. Three tips are concordant and yield a mean age of 1258.4±1.4 Ma, interpreted as the age of peak metamorphism, which apparently was concurrent with initial emplacement. The mean age of three whole grains with tips removed and one tip is circa 1247 Ma, suggesting some possible lead loss after 1258 Ma or protracted heating. Similar relationships have been documented from Paleoproterozoic enderbites in Lapland, where magma generation at ~1000°C and 8Kbar was followed by high-grade metamorphism which decompressed rapidly to 750°C and 4 kbar, the whole processes taking 1 to 3 million years.

The new ages indicate that the hypersthene in the Hinchinbrooke complex is not the result of Frontenac terrane granulite facies metamorphism, and in fact, there is a much older emplacement and metamorphic history for the complex. The age of circa 1260 Ma is similar to that of the youngest intrusive events in the Pakenham structure. No Geon 13 events have been found in the southern SLD, but such history might be preserved in layered mafic and quartzofeldspathic gneisses present along the northern margin of the Hinchinbrooke complex west of Parham.

The relationship of the Pakenham and Hinchinbrooke gneiss complexes to carbonate-hosted zinc mines and occurrences (Long Lake, Hopetown) in the SLD remains to be ascertained, however the clean marbles that host zinc mineralization were deposited prior to circa 1266 Ma, in a silicate-sediment-starved basin.

15:35–15:45

Structural characterization of the Saint-François-de-Sales shear zone, Central Grenville Province — Gosselin, Eve

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Late- to post-collision shear zones are responsible for lateral spreading of orogenic belts, the structural reorganization of orogenic architecture, and the overall reduction surface elevation. In the Grenville Province, such structures are common and are associated with an orogenic collapse phase during the late Ottawan (ca. 1060 to 1020 Ma). We investigate the Saint-François-de-Sales shear zone recently identified by the Ministère de l'Énergie et des Ressources Naturelles du Québec south of the Lac Saint-Jean in Quebec to characterize its influence on the Grenville orogen evolution. The shear zone forms a N-S striking, 6-14 km wide anastomosing deformation corridor over 56 km long. It deforms the 1076 ± 8 Ma Travers suite, the 1044 ± 7 Ma Lachance Mangerite, and the undated Belley plutonic suite. These magmatic units contain a weakly to moderately developed NE-striking metamorphic foliation cross-cut by the main shear fabric characterized by abundant protomylonitic to ultramylonitic bands with a generally sub-horizontal lineation. Ultramylonitic bands are millimeter to decimeter thick, while protomylonites and mylonites are up to several hundred meters thick. The sense of shear is dominantly sinistral, but rare NE-striking dextral mylonitic bands cross-cut and are cross-cut by the sinistral mylonites, suggesting that strain was partly accommodated by a conjugate shear system. Future work includes a detailed microstructural characterization of the country rocks and protomylonitic to ultramylonitic bands with crystallographic <c>-axis preferred orientation (CPO) analyses to identify potential differences in slip direction and temperature of deformation. U-Pb geochronology on zircon from deformed and undeformed dykes is expected to bracket the age of the structural fabrics. These data will then be used to evaluate the impacts of the Saint-François-de-Sales shear zone in the tectonic evolution of the Grenville Province.

15:45–16:00

Squishy Garnets: Revisiting A Classic Canadian Controversy — Phillips, Noah

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Garnet is a common mineral at elevated pressures, and how it deforms plays an important role in the strength of lower crustal shear zones, subduction thrusts, and the mantle. Strong shape preferred orientations in garnet at elevated temperatures and pressures attest to its ability to deform through ductile mechanisms; however, how individual garnets deformed is frequently ambiguous or disputed. Garnet microstructures from the Morin shear zone and the Sulu ultra-high pressure terrane are revisited using fine-scale electron backscattered diffraction and wavelength dispersive spectroscopy mapping. The dominant deformation mechanism at each site is re-interpreted, and we show that garnet deformed through dissolution-precipitation creep at Sulu and through dislocation-assisted creep (where diffusion rates were high) at Morin. These observations are integrated into a compilation of ductile deformation microstructures for garnet which reveals domains where dissolution-precipitation creep, dislocation creep through subgrain rotation, and dislocation assisted creep dominate in P-T space. Garnet may deform through ductile deformation at temperatures as low as ~500 °C and deforms under low differential stresses in both eclogite and granulite facies conditions. The efficacy of deformation indicates that 1) garnet may not be the strongest phase in these environments, and 2) that at elevated temperatures, inclusion barometry may be affected by garnets inability to maintain high differential stress.

16:00 General discussion & closing remarks