2021 Canadian Tectonic Group – CTG – workshop

Wednesday – September 29th

18h00 (Eastern Time) – Introduction

18h05 – Shelby Brandt, et al. – Structural Analysis of the Central Glennie Domain, Reindeer Zone, Saskatchewan, Canada

18h25 – Ève Gosselin, et al. – New insights from titanite geochronology on shear zone deformation timing during Grenvillian orogeny

18h45 – Walfried Schwerdtner et al. – Clustering and coalescence of asymmetrical incipient megaboudins in the southeastern detachment zone of the Ottawa River Gneiss Complex, Grenville Province of Ontario

19h05 – Daniela Garcia Ramos, et al. – Long-term exhumation history of the Frontenac Arch in southeastern Ontario, Canada: Constraints from low temperature thermochronology

19h15 – Pause

19h25 – Lyal Harris, and Haakon Fossen. – The Patos-Pernambuco ductile shear system of NE Brazil — structures at different depths from aeromagnetic data

19h45 – Renaud Soucy La Roche, et al. – Paleozoic evolution of the Yukon-Tanana terrane in northwest British Columbia

20h05 – Willem Langenberg. – Cylindrical, Conical and Elliptical Conical Folds and their relation to Thrusting

20h25 – Taylor Rae Morrell, et al. – Thermo-Kinematic Study of the Himalayan Metamorphic Core in Far West Nepal: Implications for Along-Strike Tectonometamorphic Variations in Active Orogens

20h35 – conclusion of talks and key information for field trip – Friday to Sunday, see you there !

Structural Analysis of the Central Glennie Domain, Reindeer Zone, Saskatchewan, Canada

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Currently, the only producing gold mine in Saskatchewan is SSR Mining's Santoy Mine situated within the Pine Lake Greenstone Belt in the central Glennie Domain. This is a structurally controlled, Paleoproterozoic, orogenic gold deposit situated along the Santoy splay of the Tabbernor fault. While the Tabbernor fault appears to have acted as a conduit for auriferous fluids to flow, it is remains unclear how polyphase folding in units surrounding this fault influenced mineralization. This thesis aims to better define the structural controls on mineralization of the Gap Hanging Wall deposit at Santoy mine and evaluate how the deposit formed in relation to the complex structural evolution of the Glennie Domain. The thesis comprises two main components: a broad-scale analysis of the structural geology of the central Glennie Domain, coupled with detailed mapping and 3D modelling of the Gap Hanging Wall deposit. The former (regional analysis) will be discussed in this talk.

Regional-scale analysis covered three distinct map areas including: 1) Lewry 1977's map area in the center, 2) the 2017-2019 map areas of Ralf Maxeiner and Samantha Van Der Kerckhove of the Saskatchewan Geological Survey to the West, and 3) the SSR Mining property to the East. The region was separated into 32 sub-cylindrical, uniform structural domains which isolate individual fold interference patterns. Structural measurements from each domain were plotted on individual stereonets in which the fold axis and axial plane of each visible folding event were quantified.

This talk will discuss the orientations of F_3 and F_4, how and why they change across the area, and what this means for structurally controlled gold mineralization in the Glennie domain. It will also discuss how these orientations can be predicted using remote sensing techniques/methods.

New insights from titanite geochronology on shear zone deformation timing during Grenvillian orogeny

Eve Gosselin[1], Renaud Soucy La Roche[1], Kyle Larson[2], Abdelali Moukhsil[3], Mhamed El Bourki[3]

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Late- to post-collisional shear zones in the Grenville Province are commonly associated with an episode of orogenic collapse during the late Ottawan phase (ca. 1060 to 1020 Ma). In this study, we investigate the Saint-François-de-Sales shear zone (Lac Saint-Jean region, Quebec) to understand its role in the tectonic evolution of the Grenvillian orogeny. This >12 km wide, up to 65 km anastomosing deformation corridor is characterized by abundant NNW-striking protomylonite to ultramylonite that record sinistral shear and rare coeval NE-striking dextral mylonite. Quartz recrystallization microstructures indicate that deformation occurred at temperatures of 400-500 °C. The shear zone crosscuts the 1076 ± 8 Ma Travers magmatic suite, which contains a weakly to moderately developed high-temperature (>500-630 °C) NE-striking foliation, and the unstrained 1044 ± 7 Ma Lachance Mangerite, which provides a maximum age on shearing.

To better quantify the timing of movement within the shear zone, we dated titanite with laser-ablation U-Pb geochronology in three samples containing ultramylonite bands (Fig. 1A). In the low-strain portions of these samples, titanite occurs as rare, equant and lobate grains that rim ilmenite and magnetite. In the ultramylonite bands, titanite is more abundant, generally larger, and elongate parallel to the mylonitic foliation. In one sample, titanite grains in the ultramylonite commonly display sigmoidal shapes, asymmetric magnetite wings, polysynthetic twins, and intracrystalline distortion (Fig. 1B, C, D). These characteristics indicate a relationship between shearing and titanite (re-) crystallisation. U-Pb data from the titanite define a single age population at 1015 ± 6 Ma, which is interpreted to represent the timing of shearing. Similar and older age populations were acquired in the two other samples, but the spread in dates hinders straightforward interpretations. This heterogeneity could reflect the presence of primary igneous titanite and/or metamorphic titanite, or the partial or protracted (re-) crystallisation of titanite during deformation. Our results indicate that the Saint-François-de-Sales shear zone is, at least in part, younger than other N-S late-Ottawan shear zones in Central Quebec such as the ca. 1064 Ma Eastern Taureau and ca. 1065-1035 Ma Tawachiche shear zones to the south. It is potentially coeval with NE-SW thrust-dextral-oblique and N-S sinistral shear of the ≤1008 Ma Saint-Fulgence shear zone to the east. These data point to a transition from exhumation to strike-slip and/or thrust tectonics at the end of the Ottawan phase of the Grenvillian orogeny in Central Quebec.

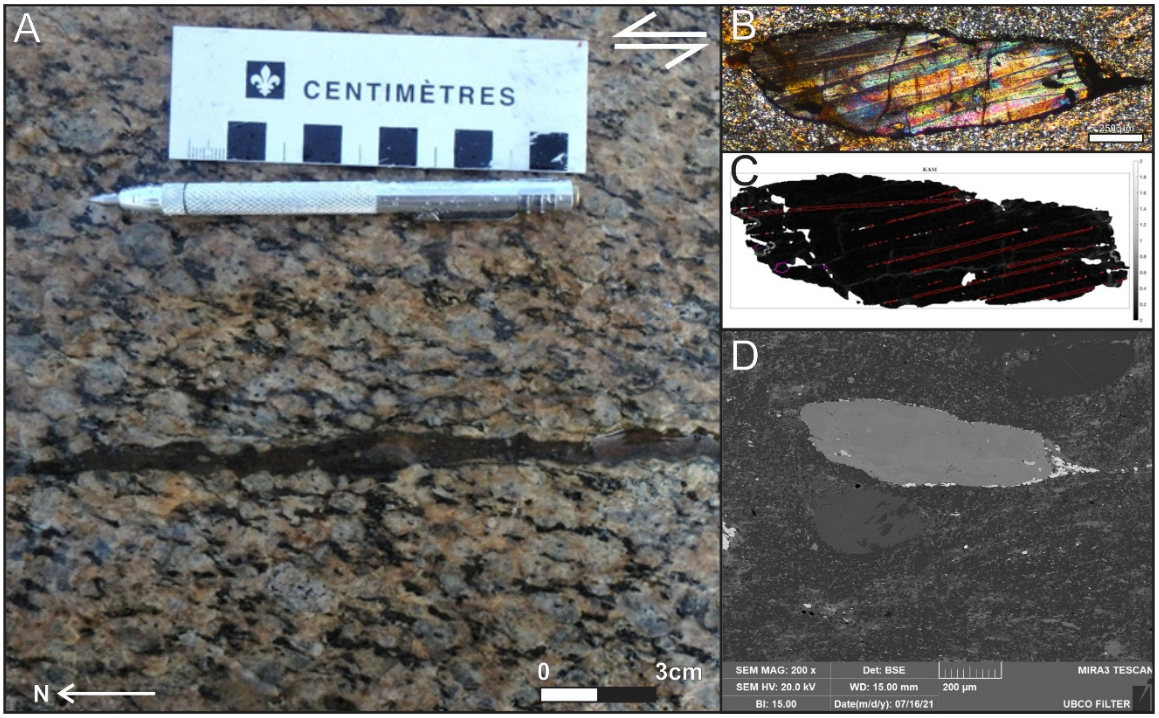

Fig. 1A. Sinistral ultramylonite band that crosscuts a weakly deformed mangerite of the Travers Suite and contains syn-shearing titanite.
B. Photomicrograph in cross-polarized light of an asymmetric titanite grain with polysynthetic twins in the ultramylonite band.
C. Kernel average missorientation map from the same titanite grain as in B.
D. Back-scattered electron image from the same titanite grain as B and C with an asymmetric magnetite wings on the bottom right.

Clustering and coalescence of asymmetrical incipient megaboudins in the southeastern detachment zone of the Ottawa River Gneiss Complex, Grenville Province of Ontario

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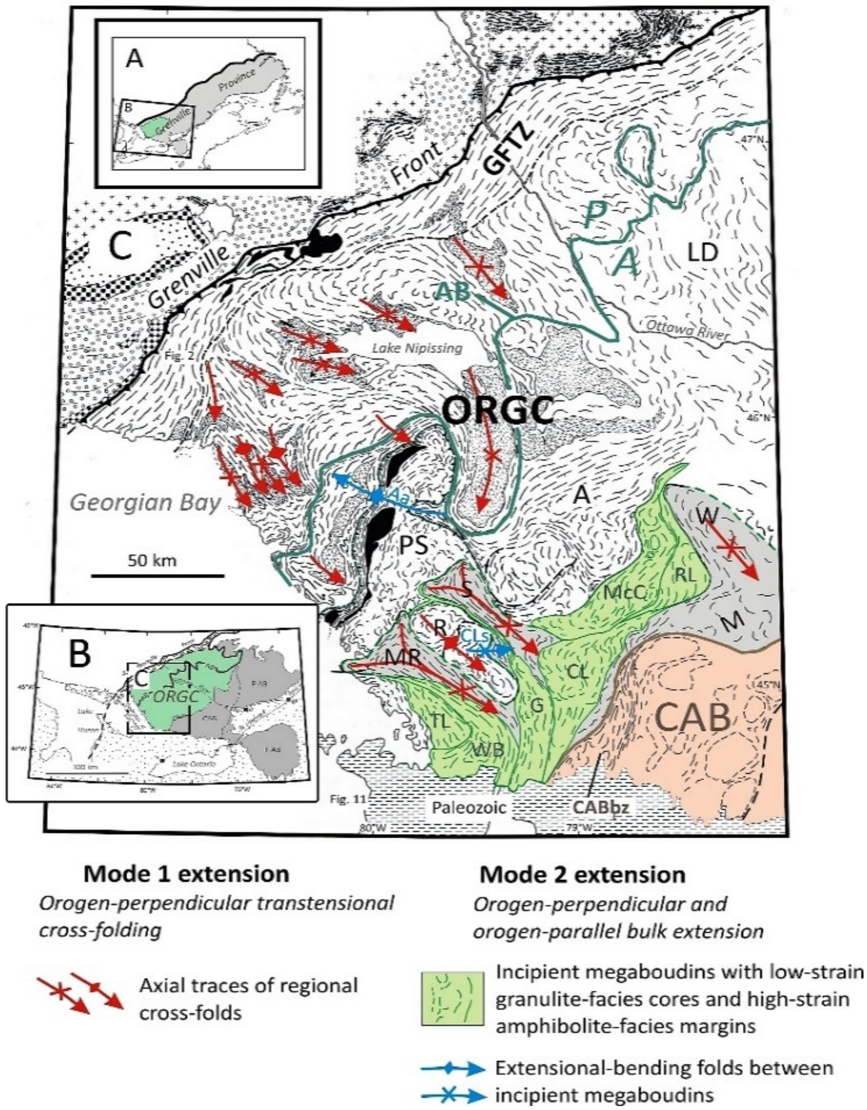
The late-Ottawan (1050 – 1010 Ma) Ottawa River Gneiss Complex, western Grenville Province, represents the cross-folded metamorphic core and southeastern extensional detachment zone of a large metamorphic core complex. The detachment zone, known in Ontario as the Muskoka domain, exhibits 10 – 50 km long major lenticular structures, the first of which were identified in the early eighties, but their extensional nature was not fully recognized until 2012. We now interpret these large features, which are characterized by weakly strained cores of partly retrogressed charnockite or other granulite-facies metamorphic rocks and highly strained amphibolite-facies margins and tails, as coalescent noncylindrical asymmetric incipient megaboudins (NAIMs). In this contribution, we document the clustering and configuration of NAIMs and compare them with those of apparent mesoscopic counterparts.

Developed during retrogression and extensional orogenic collapse of the early-Ottawan (ca. 1090 – 1060 Ma) mid-crustal thrust-sheet stack, the NAIMs define a 100-km long NE-SW-trending belt covering much of the Muskoka domain and its northeastern vicinity. Mesoscopic structural counterparts of this first-order belt occur in the footwall of the Mill Lake shear zone, an inverted mid-crustal thrust in western Parry Sound domain, where families of miniature anastomosing thrusts were similarly inverted and stretched during the subsequent orogenic collapse.



(A, B) Location of the Ottawa River gneiss complex (ORGC) in the western Grenville Province; (C) Structural map of the southwestern ORGC (modified from Davidson, 1984) showing cross-folds (red arrows; mode 1 extension; extensional-bending folds (blue arrows: Aa – Ahmic antiform, CLs – Camel Lake synform), and megaboudins (light green: CL - Clear Lake, G - Germania, McC - McClintock, RL - Rockaway Lake, TL - Tea Lake, WB - West Bay), both mode 2 extension. Muskoka domain is light grey; grey stipple - granitoid bodies; black - anorthosite bodies. Megaboudins are situated in the Muskoka domain and the top of the underlying Algonquin domain and Go Home subdomain. Green lines mark high-strain boundaries between contiguous megaboudins. Domains and sub-domains: A - Algonquin, LD - Lac Dumoine, M - Muskoka, MR - Moon River, PS - Parry Sound, R - Rosseau. CAB is the structurally overlying Composite Arc Belt; AB - Allochthon boundary separating parautochthonous (*P*) from allochthonous (*A*) crust; GFTZ - Grenville Front tectonic zone (modified from Rivers and Schwerdtner, 2015).

Long-term exhumation history of the Frontenac Arch in southeastern Ontario, Canada: Constraints from low temperature thermochronology

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The Frontenac Arch is an enigmatic low-relief ridge (< 200 m) of Precambrian 'basement' rocks that connects the southeastern Ontario part of the Canadian shield with the Adirondack Massif of northern New York State. The NW-SE trending Frontenac Arch is oriented perpendicular to the major tectonic fabric of the Grenville, Appalachian, and St Lawrence rift systems.

Recent studies in the Adirondack Massif in New York State and along the St. Lawrence rift system in southern Quebec suggest that differential vertical rock displacements along pre-existing orogen-perpendicular fault systems played an important role in the postorogenic unroofing history of exhumed Precambrian rocks. Alternatively, the passage of northeastern Laurentia over the Great Meteor hotspot could have triggered significant surface uplift and extension during the mid-Cretaceous. In order to test these models, apatite fission track (AFT) and (U-Th/He) dating will be used to quantify the timing of the exhumation of this basement topography.

Our results will be compared to previous studies to test the hypothesis that the Frontenac arch is a horst-like structure bounded by NW-trending faults, orthogonal to the St. Lawrence rift-system, and was likely a prominent physiographic element and tectonically active during the early deposition of the Lower Ordovician siliciclastic and carbonate strata that unconformably overlie metamorphic and igneous rocks of the Proterozoic Grenville Province. Knowledge of the nature, extent and distribution of possibly reactivated structures has implications in our understanding of basement fault interaction with regional seismicity in the intraplate setting of southeastern Canada.

The Patos-Pernambuco ductile shear system of NE Brazil —structures at different depths from aeromagnetic data

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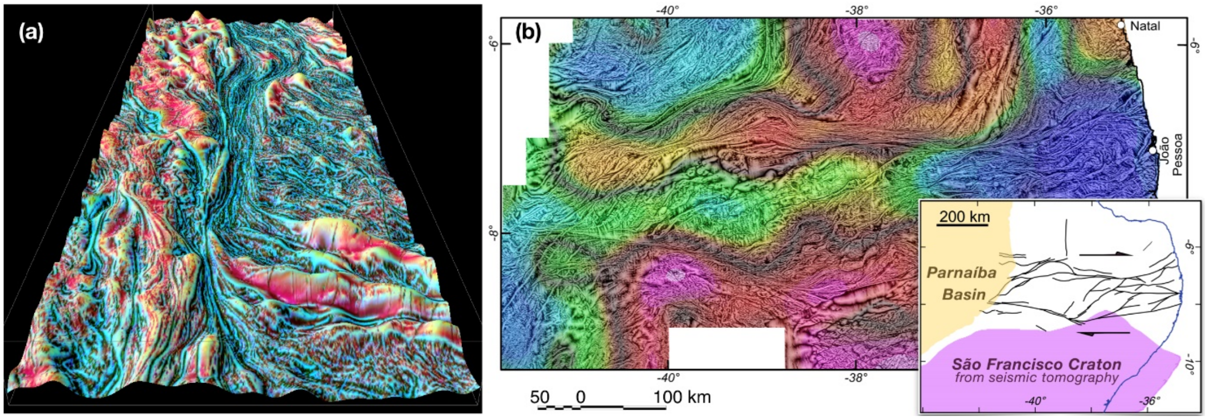
The Neoproterozoic to Cambrian 'Brasiliano' Patos-Pernambuco shear system on the N margin of the São Francisco Craton deforms Archaean to Neoproterozoic rocks, including high-grade gneiss, migmatite, and syntectonic granitoid plutons, in the Borborema province of NE Brazil. In tectonic reconstructions, the shear system continues into Africa on the N margin of the Congo Craton, making its total length over 2,000 km. Brazilian geological survey (CPRM) aeromagnetic data were enhanced to study structures within the sub-parallel Patos and Pernambuco dextral ductile shear zones and their margins and in the Central (*a.k.a*. Transverse) Domain between them, and to establish mid- and deep-crustal controls on shear zone localisation. This study provides an excellent example of how structural information at different depths can be extracted from aeromagnetic data, providing information not possible from field surface mapping alone.

Aeromagnetic data were converted to pseudo-gravity to better define deeper tectono-stratigraphic domain margins and different depth slices were extracted for both based on the slope of the radially averaged power spectrum and visual inspection during frequency domain filtering. Tilt, theta angle, and ternary gradient images (Fig. a) were used to enhance contacts and structures for interpretation. Pseudo-gravity 'worms' at different depth intervals highlight main structures and provide their dip. A regional transposed foliation axial planar to regional folds N of the Patos Shear Zone (hitherto unrecognised, and only apparent in pseudo-gravity) and minor fold axial traces curve into parallelism with shear zones in an S/C relationship consistent with dextral displacement on ca. E-W structures. Isoclinal folds are often refolded during progressive deformation in and between shears. Synthetic C' shears at the regional scale are associated with the bounding shear zones. NE-SW sinistral (± reverse) shear zones in the Central Domain developed both as antithetic shears and due to slip on margins to rotated lithological packages containing conjugate shears (*viz.* strain partitioning). Folds with axial traces at high angles to shear zones also formed due to local shortening at the intersection of synthetic and antithetic shears. Overlaying images and interpretations of shear zones in the upper crust on enhanced long wavelength pseudo-gravity images (Fig. b) shows the shear zone system to be localised by preserved basement rift margins. High temperatures from preceding rifting also explain migmatization/anatexis and pluton emplacement during transcurrent shearing.



(a) 3D representation of a ternary gradient image of short wavelength (near surface) aeromagnetic data looking W along the dextral Patos shear zone. Width = ca. 150 km. Felsic rocks = orange-red. **(b)** The gray tilt angle image of short wavelength aeromagnetic data draped on long wavelength pseudo-gravity in colour show rift margins localise shearing.

Paleozoic evolution of the Yukon-Tanana terrane in northwest British Columbia

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Proper characterization of terranes, i.e. the tectonic building blocks of convergent orogens, is fundamental for understanding of active continental margin evolution. Trace element geochemistry can be used to identify protoliths and assess their tectonic setting where metamorphism and deformation have destroyed primary textures and contacts. We collected new geochemical and U–Pb zircon geochronology data on medium- to high-grade metamorphic rocks in northwest British Columbia that were previously correlated to the Yukon-Tanana terrane of the Canadian Cordillera. The Florence Range, Boundary Ranges and Whitewater suites are separated by shear zones and faults and appear to have formed in distinct tectonic settings. The Florence Range suite is composed of Late Devonian or older continentally derived metasedimentary rocks intruded by latest Devonian (360 ± 4 Ma) calc-alkaline plutonic rocks and earliest Carboniferous (357 ± 4 Ma) rocks with oceanic island basalt composition, compatible with a continental rift setting possibly preceded by a continental volcanic arc. The Boundary Ranges suite is composed of Late Devonian or older metasedimentary rocks that formed in proximity to a mafic source, and Late Devonian (367 ± 7 Ma) calc-alkaline plutonic rocks compatible with continental volcanic arc or continental rift settings. The Whitewater suite is composed of interlayered manganiferous meta-chert, graphite-rich metapelite and amphibolite with back-arc basin basalt composition (ages unconstrained). Although strikingly different, these metamorphic suites may have formed in adjacent and genetically related tectonic settings similar to the Japan arc (Boundary Ranges suite) – Sea of Japan back-arc basin (Whitewater suite) and Korean Peninsula (Florence Range suite) system. Alternatively, they may have formed in entirely unrelated tectonic settings. Intra-terrane shear zones and Jurassic high grade metamorphic overprint within the Yukon-Tanana terrane added a lot of complexity to the distribution of rocks formed in originally distinct tectonic settings, and a detailed characterization of protoliths is necessary to decipher the origin of this composite terrane.

Cylindrical, Conical and Elliptical Conical Folds and their relation to Thrusting

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In Fold and Thrust belts, 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, resulting in Thrust Folds.

Modeling by Liu and Dixon (1990) showed that the threefold fold classification of Jamison (1989) is part of a continuum. A twofold classification of fault related folds consisting of Detachment Folds and Thrust Folds is possible, although Butler et al. (2021) indicated that natural folds display various geometries that reflect a range of relationships between folds and thrusts that do not conform to idealized models. Fault-bend Folds and Fault-Propagation Folds are considered varieties of Thrust Folds.

These Thrust 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.

Examples from the Canadian Rockies, Swiss Alps and Belgian Ardennes will be given, analyzed by Fred Vollmer's Orient software (http://docvsoft.com/orient/index.html). Thrust Folds can localize on pre-existing structures, showing structural inheritance.

References

Butler, R.W.H., Bond, C.E., Cooper, M.A., and Watkins, H. (2018): Interpreting structural geometry in fold-thrust belts: Why style matters; Journal of Structural Geology, v.114, pp.251-273.

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Thermo-Kinematic Study of the Himalayan Metamorphic Core in Far WestNepal: Implications for Along-Strike Tectonometamorphic Variations in Active Orogens

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The influence of pre-orogen (inherited) basement crustal features in orogenic systems is emerging as a key process in understanding along-strike variations of mountain belts. The active Himalayan orogen is the result of the Cenozoic continental collision between the Asian and Indian plates, both exhibiting long geological histories prior to the collision. The geometry and structure of the Indian lithosphere is interpreted to have affected the evolution of the Himalayan orogen along its length, but to what degree and on what time span is not fully understood. In particular, how do the documented Precambrian Indian basement cross-strike faults influence the pressure-temperature-time-deformation (P-T-t-D) evolution of the ductile middle crust in the Himalaya?

The proposed research focuses on the Himalayan metamorphic core in far western Nepal, along the Seti Khola in the hinterland, and in the Dadeldhura klippe in the foreland. The P-T-t-D conditions of the Himalayan metamorphic core in far western Nepal will be constrained using quartz crystallographic preferred orientation analysis, monazite and allanite petrochronology, and phase equilibrium modelling. Preliminary microstructural results indicate that along the SetiKhola, the strain gradient associated with the Main Central Thrust zone at the base of the Himalayan metamorphic core extends approximately 4 km south and 400 m structurally lower than previously mapped. Quartz crystallographic preferred orientation fabrics along the Seti Khola indicate a typical increase in deformation temperature structurally upwards through the Himalayan metamorphic core from 325-425°C to 650-750°C just below the South Tibetan detachment system.

Integration of monazite and allanite petrochronology and analysis of their reaction textures, combined with pressure-temperature modelling of metamorphic conditions, will allow the formulation of a thermo-kinematic model for the Himalayan metamorphic core in far western Nepal Himalaya. Our results will then be compared to previously published research using the same methodology along adjacent transects of laterally equivalent lithotectonic units in westernNepal and northern India. The along-strike comparison of P-T-t-D conditions will test the existence of basement structures that may have influenced the deformation and subsequent exhumation of the Himalayan metamorphic core.

October 2nd

2021 Canadian Tectonic Group – CTG – workshop

-Normand Goulet – Tectonic and stratigraphic comparison between the western and the eastern zone of the Archean basin, Opinaca subprovince, Superior Province: a new potential area for gold deposit.

-Benoît-Michel Saumur, and Johnston, S.T. – Mappin' Baffin: New insights on the structure of the NE Trans-Hudson Orogen and the metallogeny of the Mary River greenstone belts

-Carl-Philippe Folkesson, Benoit M. Saumur, Joshua Davies, Jon Hey, Luke Howitt. – Stratigraphy, structure and geochronology of the Eqe Bay greenstone belt, north Baffin Island, Nunavut: implications for mineral exploration in the Mary River group – 5 min

-Jérémie Langlois, Stéphane De Souza, Patrick Mercier-Langevin, Marjorie Simard – Defining the controls on vein formation in the Paleoproterozoic Tiriganiaq orogenic gold deposit, Meliadine district, Nunavut, Canada

-Carol-Anne Généreux., Tinkham, D.K. and Lafrance, B. Shock melting, anatexis and breccia formation: southern Sudbury impact structure – 5 min

-Mark Coleman, David Schneider, Bernhard Grasemann, Konstantinos Soukis – The evolution and timing of a multi-plane detachment system: from ductile to brittle (Cyclades, Greece)

-Adina Bogatu, Sauvé, G., Tremblay, A., Meshi, A., Bédard, J and Davies, J – Western- and Eastern-type ultramafic massifs of the Mirdita ophiolite, Albania: a Jurassic example of oceanic core complex and its possible links to VMS mineralisation

Tectonic and stratigraphic comparison between the western and the eastern zone of the Archean basin, Opinaca subprovince, Superior Province: a new potential area for gold deposit

Normand Goulet, Professeur associé, UQAM, Michel Boily PGeo

The contact zone between the La Grande and Opinaca subprovinces in the western part of the James Bay area has been the focus for gold exploration, especially since the discovery of the Eleonore mine in 2004. The contact zone is often represented by highly deformed rocks and/or is coincident with a significant metamorphic gradient. The La Grande subprovince is composed of a tonalitic gneissic basement (older than 3.3 Ga), volcano - sedimentary sequences and ultramafic intrusive rocks (2.82-2.72 Ma) and were probably emplaced during continental rifting. Unconformably overlying the basement rocks, the Apple Formation is composed by a monomictic quartz pebble conglomerates or quartzite developed on a passive margin basin. The Opinaca Subprovince is represent by an east - west elongate sedimentary basin (2710–2672 Ma) with a complex tectonometamorphic history. Many gold deposits occur along the highly deformed northern, southern and western contact zone like La Pointe and Serpent deposits.

The recent discovery of a unit composed of quartz-pebble conglomerate, quartz arenite, green fuchsitic quartzite, iron formation, calcsilicate rocks, similar to those of the Apple Formation, and located around 600 Km east of the original description, could represent a marker horizon, indicating a similar basin setting, forming the base of the Opinaca subprovince. In the discovery area, the Courcy gold deposit, located about 70 km west of the town Wabush, is associate with ultramafic rocks, mafic volcanics, monomictic and polygenic conglomerate with orogenic auriferous quartz veins. The area is highly deformed with thrust faults affected by folds overturned toward the south-east. As a reminder, the Witwatersrand, on the Kaapvaal craton, has about the same age, rock type, dimension but less deformed with more gold found as a placer or hydrothermal type deposit model.

Mappin' Baffin: New insights on the structure of the NE Trans-Hudson Orogen and the metallogeny of the Mary River greenstone belts

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Northern Baffin Island is dominated by Mesoarchean felsic orthogneiss and Neoarchean monzogranitic to granodioritic plutons. Meso-Neoarchean greenstone belts of the Mary River Group are preserved as strongly deformed 1-50 km-scale panels bounded by the plutonic and gneissic units, and are less extensive than implied by previous reconnaissance-scale maps. Structural analysis of greenstone belts within the crustal-scale Paleoproterozoic Isortoq shear zone provides new insights on the involvement of the Rae Craton in the broader ~1.8 Ga Trans-Hudson Orogen. The Isortoq Shear Zone and two associated greenstone belts (Isortoq and Eqe Bay) form part of a SSE-verging nappe reminiscent of the S-verging Rinkian nappes in West Greenland. The NE-striking, moderately SE-dipping Isortoq belt is structurally-thinned, metamorphosed, sheared and overturned, whereas the ENE-striking, steeply-dipping Eqe Bay belt is structurally thickened, less metamorphosed, less sheared, and shows right-way-up polarity. Both greenstone belts are folded around a hinge zone to the SW, forming an asymmetric synformal anticline.

Evidence of the Isortoq Nappe can be detected in regional airborne gravity data, up to 200-km to the NW, in the vicinity of the high-grade, high-tonnage Mary River Fe-deposit hosted within highly deformed and metasomatised Algoma-type banded iron formation. Deposit-scale folding, which likely contributed to the locii of Mary River ore zones, produced E-plunging folds interpreted to be co-genetic with the nappe. The apparent 50km-scale repetition of these folds along ESE-the Central Borden fault zone could be attributed to bookshelf normal faulting along NNW-trending structures.

Our findings imply that S-verging tectonics – opposed to and pre-dating the dominantly N-verging nappes of the Foxe Fold Belt on central Baffin Island – are greater in spatial extent than previously considered, and emphasize the importance of horizontal transport via nappe tectonics during assembly of the Nuna Supercontinent.

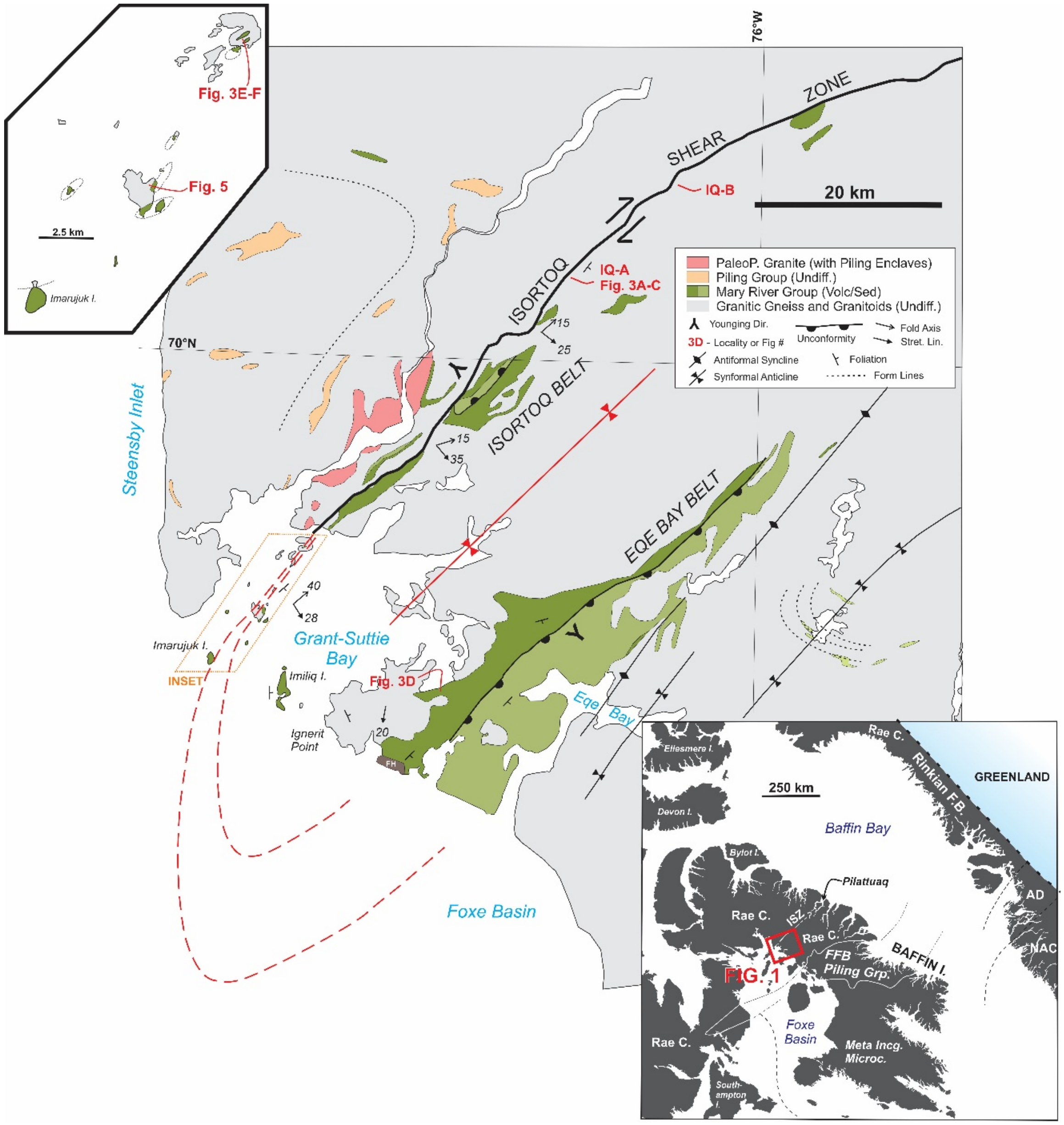

Figure 1: Geology of the Eqe Bay – Isortoq area, Northern Baffin Island. The two belts define a regional scale fold attributed to a S-verging nappe.

Stratigraphy, structure and geochronology of the Eqe Bay greenstone belt, north Baffin Island, Nunavut: implications for mineral exploration in the Mary River group

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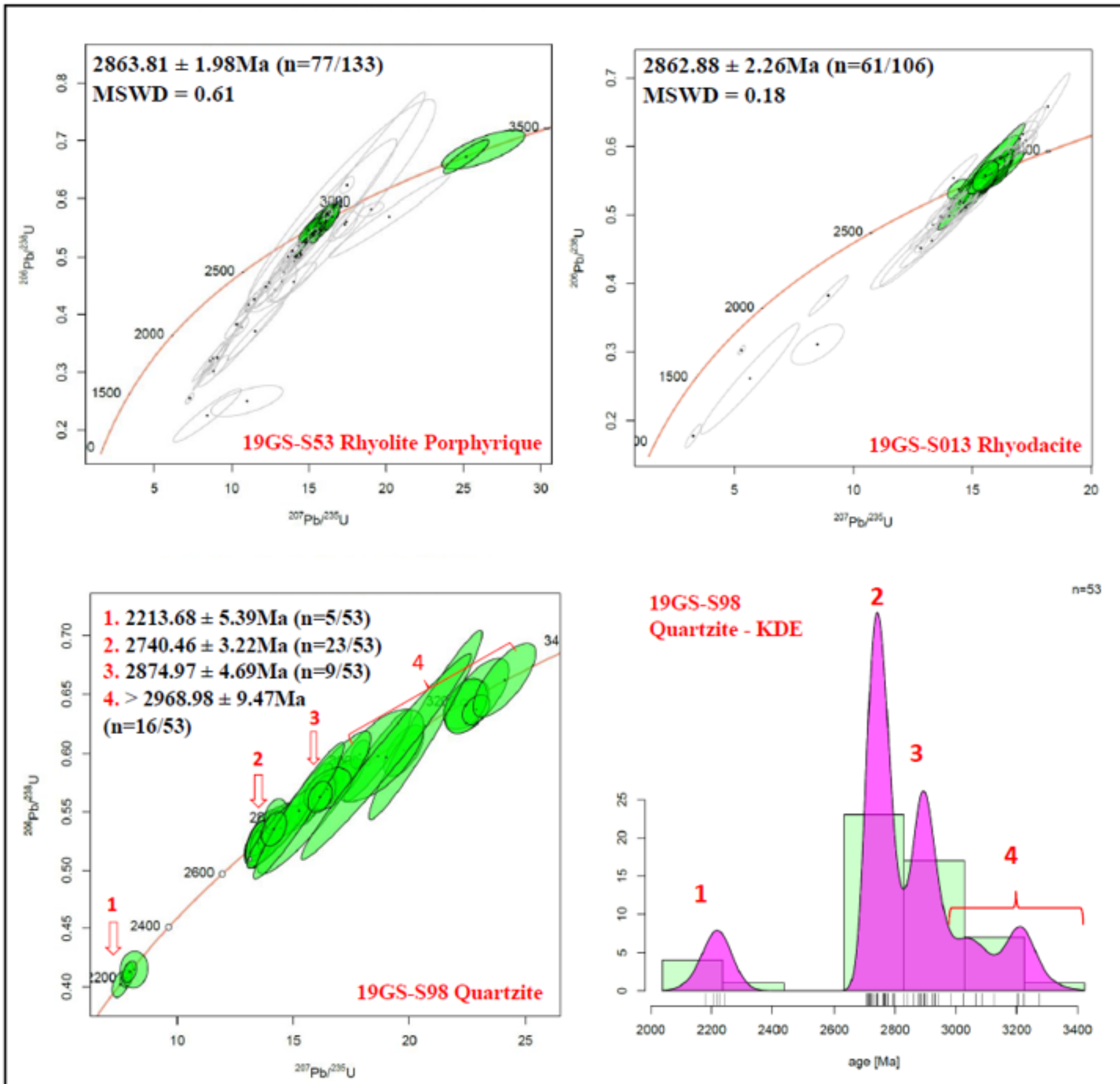
Exposed in remote areas of northern Baffin Island, the Archean greenstone belts of the Mary River Group (2865-2706 Ma), or MRG, remain poorly understood in terms of structure, stratigraphy and metallogeny. The MRG hosts the world-class high-grade iron ore Mary River deposit and has a high potential for a variety of other metals such as copper, silver, and gold. The greenstone belt of Eqe Bay represents the least deformed and metamorphosed exposure of supracrustal rocks from the MRG across Baffin Island. The purpose of this study is to update the stratigraphy and structure of the Eqe Bay metasedimentary belt using field observations and data, as well as geochronological, to better understand the age, provenance, and mode of formation of these metasedimentary rocks. The upper sequence of the Eqe Bay belt consists mainly of a large turbiditic formation overlaying unconformably the lower sequence of volcanic and volcaniclastic rocks. Four primary units make up the Eqe Bay metasedimentary formation: (U1) a jointed polygenic conglomerate with a varying thickness between 100 and 250m, stratigraphically overlying the volcanic domain and coinciding with the main unconformity; (U2) an overturned turbiditic formation with a maximum thickness of 6.5km consisting mainly of wackes and graywackes including siltstone, argillites and meter-scale beds of granular polygenic conglomerate interbedded with sandstone; (U2.1) distinctive 5 to 10m thick quartzite unit among the turbiditic sequence; (U2.2) thin unit of iron formation interbedded with phyllite and garnet-rich schist. The unconformity occurs as a major NE-SW trending shear zone, which introduces a mylonitic zone along the length of the Eqe Bay belt and coincides with, but not exclusive to, the basal conglomeratic unit (U1). We distinguish three deformation events affecting the metasedimentary belt: the first deformation represented by a penetrative foliation parallel to bedding (S1), the second (S2) records an oblique foliation to the first resulting in local isoclinal folding (F2), the third is recorded in strongly deformed areas as a shallowly dipping crenulation cleavage (S3). U-Pb geochronological work on magmatic and detrital zircons provide an update on the stratigraphy and formation age of the greenstone belt as well as for the entire MRG. Within the underlying volcanic sequence, two rhyolite samples were dated at 2865 Ma pushing back the age of volcanism in the MRG and acts as control for different populations in the detrital zircon analyses whose maximum depositional age is 2706 ± 20 Ma. This stratigraphic and structural study is applicable to all mineral exploration projects in the Mary River Group by helping to better target associated units with economic potential in a still poorly understood greenstone belt.



Résumé des travaux d'analyses géochronologiques sur 3 échantillons, 2 roches volcaniques felsiques et 1 quartzite

Defining the controls on vein formation in the Paleoproterozoic Tiriganiaq orogenic gold deposit, Meliadine district, Nunavut, Canada

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ABSTRACT

The Tiriganiaq gold deposit (4.07 Moz at 6.1 g/t Au in probable and proven reserves in 2020 (Agnico Eagle Mines ltd.) is part of the Meliadine district, which comprises Paleoproterozoic orogenic gold deposits hosted in supracrustal rocks of the Neoarchean Rankin Inlet greenstone belt (>2.66 Ga). The deposits are spatially associated with the Pyke fault, a first-order structure along the northern margin of the Hearne Craton.

A significant portion of the ore at Tiriganiaq is hosted in steeply dipping, dm- to m-thick Qz-Ak shear veins along the W-trending, N-dipping Lower Fault, a local splay of the Pyke fault. Shallowly S dipping Qz-Ak extensional veins are also mineralized and cut tightly folded iron formations that plunge shallowly to the W. The mineralized vein system at Tiriganiaq is compatible with N-S shortening during D3, in agreement with previous work. However, about a quarter of the gold at Tiriganiaq is hosted in zones with a high density of Qz-Ak veins informally referred to as the "*Interveining lodes*" that locally form hydrothermal breccia bodies with steeply NW-dipping extensional veins oriented N255. The geometry of these veins and breccia zones present challenges in terms of modeling and mining. This study aims to better document the *Interveining lodes* and to define the controls on their formation within the context of the local deformation history.

The *Interveining lodes* differ from the other lodes at Tiriganiaq. Preliminary results indicate that the *Interveining lodes*-style breccia bodies are associated with inflexions across the Lower Fault acting as local dilatational jogs. Extensional veins in the *Interveining lode*s are boudinaged and may have been verticalized during progressive deformation. Furthermore, they are crosscut by D3 coaxial extensional veins. Overall, the new observations suggest a more complex and protracted history of auriferous mineralisation at Tiriganiaq than previously documented.

Shock melting, anatexis and breccia formation: southern Sudbury impact structure

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At the Crean Hill mine along the southwestern contact of Sudbury Igneous Complex (SIC), breccias formed as melts with contact-parallel flow textures defined by elongate wispy clasts. The presence of melts in the footwall of large impact melt sheets may be due to shock melting during propagation of the shock wave, frictional melting along superfaults during modification of the crater, injections from the impact melt sheet, or anatexis during cooling of the impact melt sheet. The absence of nearby superfaults at Crean Hill precludes the formation of the breccia by frictional melting. Modeling of partial melt compositions during contact metamorphism produces chemical melts that are generally enriched in Zr and more felsic than the breccia matrices, negating the possibility of their formation by anatexis during cooling of the melt sheet. The breccia matrices also have significantly lower SiO_2 and higher TiO_2 than the SIC original melt composition, thus they could not have formed by the injection of SIC melt into the fractured target rocks. Because the composition of the breccias mirrors that of their host rocks, the breccias are best interpreted as locally-derived shock melts that formed during shock compression, were trapped in the basement rocks until they cooled, and were subsequently modified by contact metamorphism during cooling of the SIC and by later regional metamorphism.

The evolution and timing of a multi-plane detachment system: from ductile to brittle (Cyclades, Greece)

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The Attic-Cycladic Complex (Greece) is characterized by multiple bivergent low-angle detachment systems, crustal-scale structures that accommodate differential extension of bedrock. These detachment systems have been generalized into two cases: 1) a singular detachment plane accommodating ductile-then-brittle deformation and 2) a multi-plane detachment system, wherein plutonism results in deactivation of an initial detachment surface and relocalization of strain along younger detachment horizons at higher structural levels and lower temperatures as indicated by thermochronometry and cross-cutting relationships. New results from field mapping, structural analysis, and thermochronometry of Mt. Hymittos may suggest a new type of Cycladic-style detachment system. Bedrock mapping identified a paired ductile-then-brittle detachment system. The detachments are ~500 m apart and divide the local tectonostratigraphy into three packages: low-grade phyllites and marbles in the uppermost hanging wall package, and high-pressure greenschist-facies schists and marbles in the lower two packages. Ductile mylonites in the footwalls of both detachments grade into brittle-ductile mylonites and finally into cataclastic fault cores. Flanking structures, stepped porphyroclasts, sigmoids, SCC' fabrics, asymmetric boudins and alignment of clasts in cataclasite fault cores indicate consistently top-S senses of shear from ductile to brittle conditions. The consistency of the kinematics and styles of deformation of both detachments indicate the structures accommodated the same extension. Geo- and thermochronometry on samples from the footwalls of both detachments produced late Oligocene to early Miocene white mica $^{40}Ar/^{39}Ar$ ages and mid-to-late Miocene zircon (U-Th)/He ages, suggesting that the activity of the detachments overlapped in time though at different pressure and temperature conditions. Notably there is no evidence of intrusive rocks within the massif. The presence of a paired detachment system without spatially associated intrusions suggests that plutonism is not the only mechanism that leads to a multi-plane detachment geometry. We suggest that the paired detachment morphology is due to the presence of large carbonate blocks within the massif; as extension progressed and the bedrock cooled, these blocks differentially strengthened relative to phyllosilicate-rich schists, leading to localization both above and below the carbonate dominated unit. Thus, multi-plane detachments may occur without the influence of plutonism, and deformation along these detachments may be contemporaneous.

Western- and Eastern-type ultramafic massifs of the Mirdita ophiolite, Albania: a Jurassic example of oceanic core complex and its possible links to VMS mineralisation

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The Jurassic Mirdita ophiolite of Albania contains distinctive Eastern- and Western-type mantle and crustal rocks. Geological mapping of selected sections combined with geochemical and structural analysis suggests that the Western-type Mirdita ultramafic massifs represent a fossilized oceanic core complex (OCC). The relationship between Western and Eastern massifs, their respective crustal covers, and VMS mineralisation is still under debate, as is the position of the spreading center associated with the crustal sequence(s) and the OCC's genesis. In the crustal sequence of Eastern-type massifs, multiple VMS deposits define a north-south trend above the inferred OCC-related detachment. Studies on modern OCCs suggest that a 'locus of hydrothermal discharge' frequently occurs in the hanging wall of OCC-forming detachments (de Martin et al., 2007). Temporally linking VMS mineralisation with OCC genesis in the Mirdita ophiolite would help to clarify the position of the spreading center from which it originated.

Eastern-type massifs are dominantly harzburgites with a thick arc-related IAT intrusive and extrusive crust, late gabbro dykes of boninitic affinity, and display an apparently classical Moho mantle/crust transition. At the Moho, mantle harzburgites grade through a ~2 km wide transition zone dominated by dunitic harzburgite, dunite, and chromititites, which are succeeded by layered peridotites and pyroxenites, and then by layered gabbroic cumulates. Conjugate, moderately to steeply, E-SE dipping normal faults affect both Eastern- and Western-type crustal rocks, consistent with east-west trending extension. Western-type mantle massifs are harzburgitic to lherzolitic, and have a thinner MORB-like crustal sequence of tholeiites and locally prominent isotropic gabbros. The Western-type mantle/crust transition is exposed in the Puka and Krabbi massifs. Here, the upper mantle and the lower crust display zones of lithospheric ductile flow 10s of m wide that are marked by cataclastic breccias and amphibolitized layers of crustal and mantle rocks affected by an intense NNW- to NE-dipping ductile shear fabric. Crustally-derived amphibolites contain possible igneous zircons and syn-detachment titanites. An ongoing U-Pb dating analysis of zircon and titanite should help to establish the temporal association, if any, between VMS mineralisation (Bathonian à Oxfordian) and OCC genesis.

The presence of extension structures at the mantle/crust contact in the Western-type massifs, the west-to-east geochemical variations, and the thickening of the ophiolitic nappe from west to east are consistent with east-over-west emplacement of the Mirdita ophiolite. This is supported by the occurrence of VMS deposits in the hanging wall of the inferred detachment suggesting an easterly spreading center, possibly located in the Vardar zone more than 100 km away.