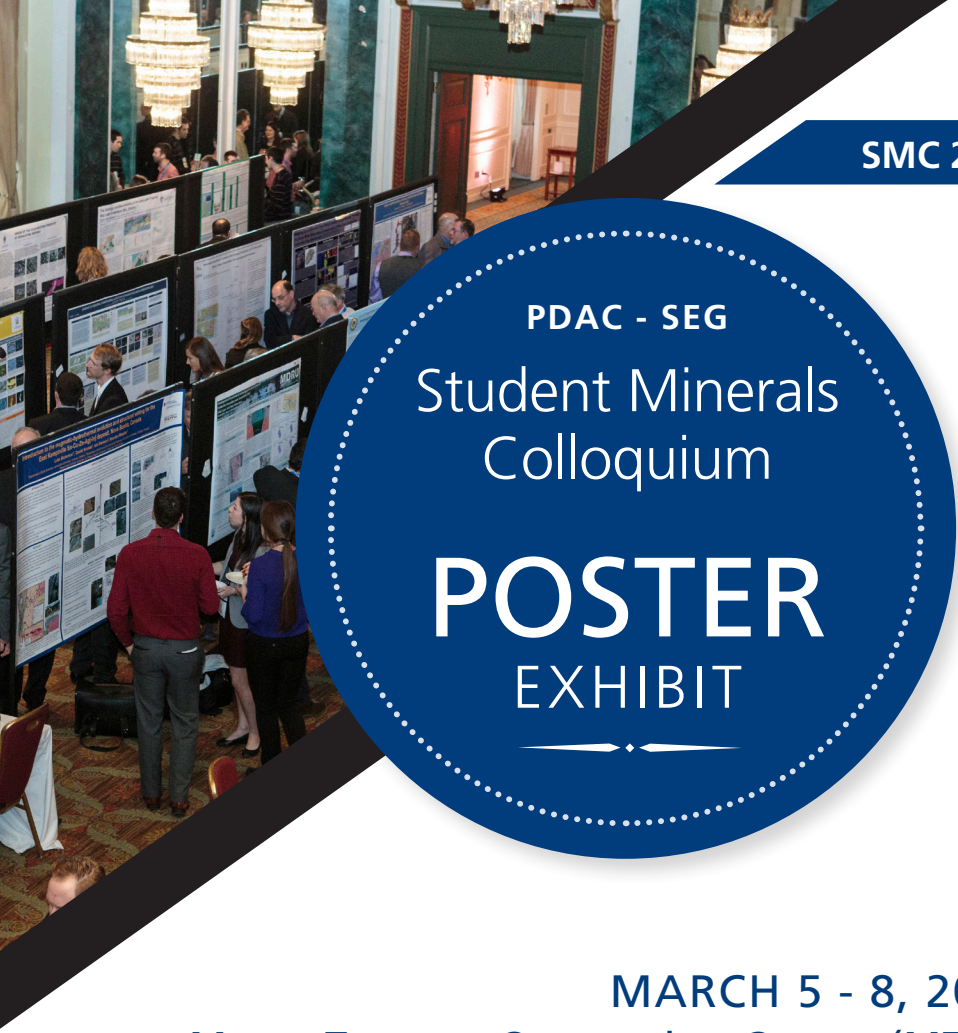


SMC 2023

PDAC - SEG

Student Minerals Colloquium

POSTER EXHIBIT

MARCH 5 - 8, 2023

Metro Toronto Convention Centre (MTCC)

PDAC

PROSPECTORS & DEVELOPERS ASSOCIATION OF CANADA

SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

uOttawa

MERC
Mineral Exploration Research Centre at the HARQUAIL School of Earth Sciences

METAL EARTH

The Student Minerals Colloquium (SMC) brings together geoscience students and industry professionals at the annual Prospectors & Developers Association of Canada convention.

Please join us in celebrating innovative student research in mineral deposits, geophysics, environmental sustainability, and experimental studies from students around the world.

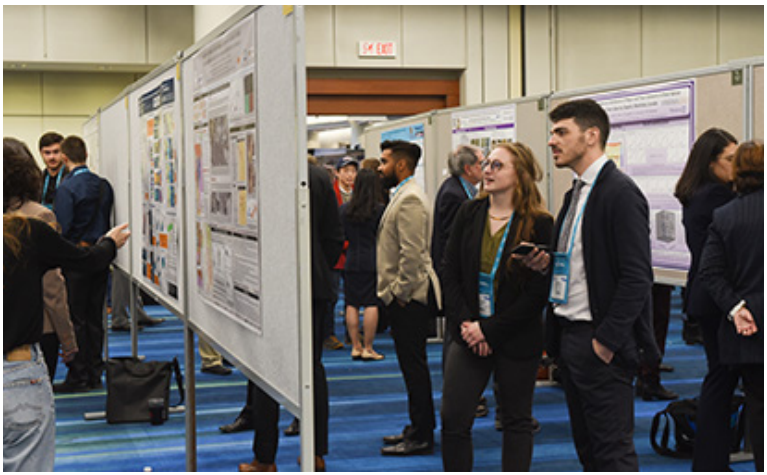
The SMC highlights student research focused on innovative projects essential for the successful evolution of the modern mining industry. Over the years, this event has featured hundreds of poster presentations from BSc, MSc, and PhD students around the world studying mineral deposits and related disciplines, and provides industry professionals with an unparalleled opportunity to discover and support student research related to the mining industry.

This year, we invite you to celebrate the **14th Anniversary** of the SMC.

This year, judges will select nine winners (1st, 2nd and 3rd) from poster presentations at the BSc, MSc, and PhD Levels. We are pleased to showcase 75 participants from 33 universities across 11 countries.

Poster judging for the PDAC-SEG Student Minerals Colloquium will take place from 10:00 am - 12:00 pm on Tuesday, March 7th, followed by an awards ceremony and reception from 3:30 pm - 5:00 pm in Room 713.

For details about this year's event, news and announcements, past winners, and more, visit ***merc.laurentian.ca/seg-smc****.*



Thank you to our partners and sponsors:

PDAC

PROSPECTORS & DEVELOPERS ASSOCIATION OF CANADA

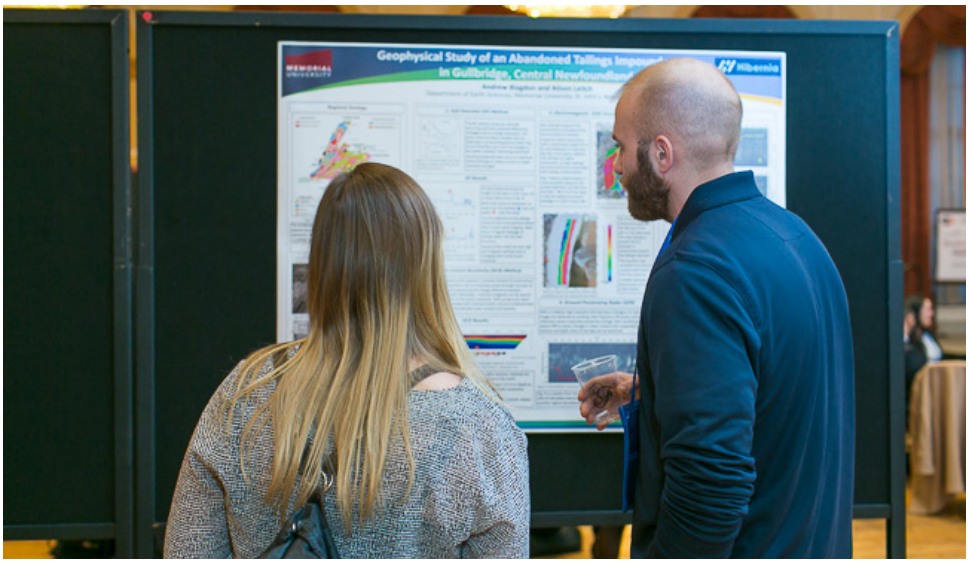
SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

Laurentian University / Université Laurentienne
HARQUAIL School of Earth Sciences / École des sciences de la Terre

MERC
Mineral Exploration Research Centre at the HARQUAIL School of Earth Sciences

METAL EARTH

uOttawa



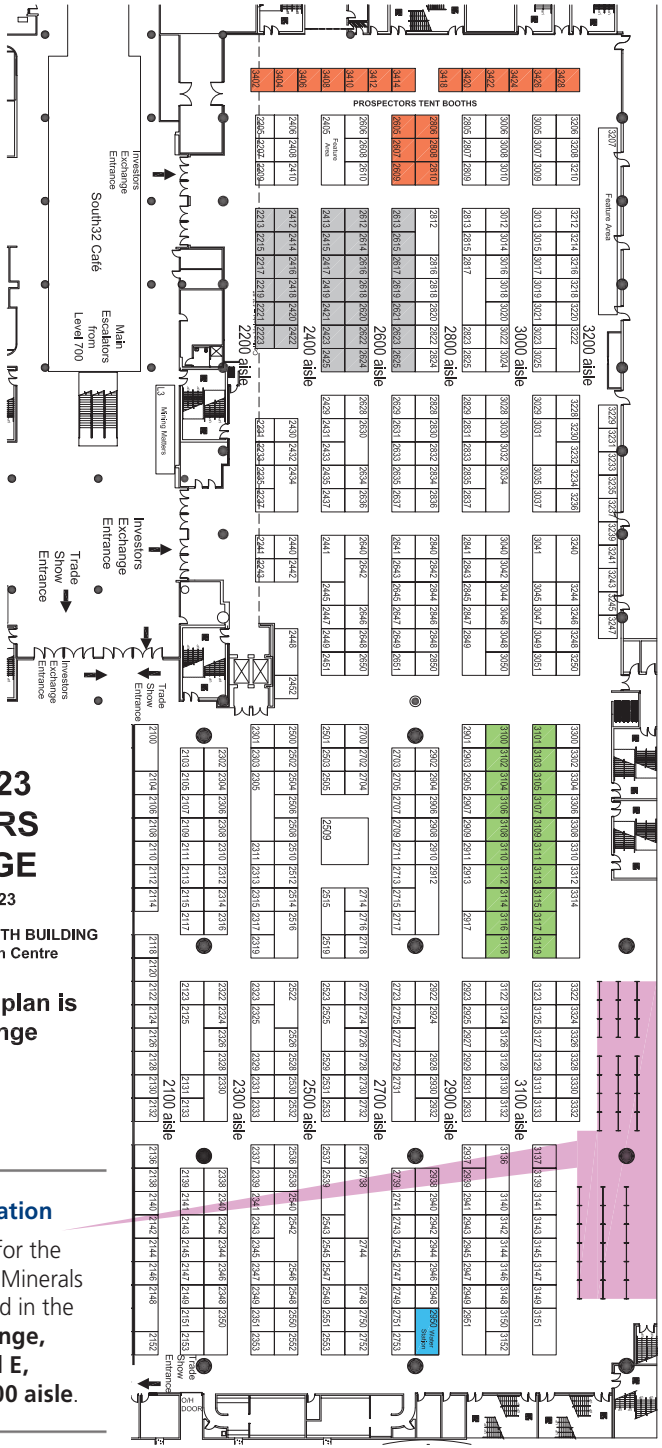
PDAC 2023 INVESTORS EXCHANGE

MARCH 5 - 8, 2023

EXHIBIT HALLS E, F & G - SOUTH BUILDING
Metro Toronto Convention Centre
Toronto, Canada

Please note: Floor plan is subject to change

GES



SMC Exhibit Location

The poster exhibit for the 14th Annual Student Minerals Colloquium is located in the **Investors Exchange, Level 800, Hall E, just behind the 3100 aisle**.

Poster Locations

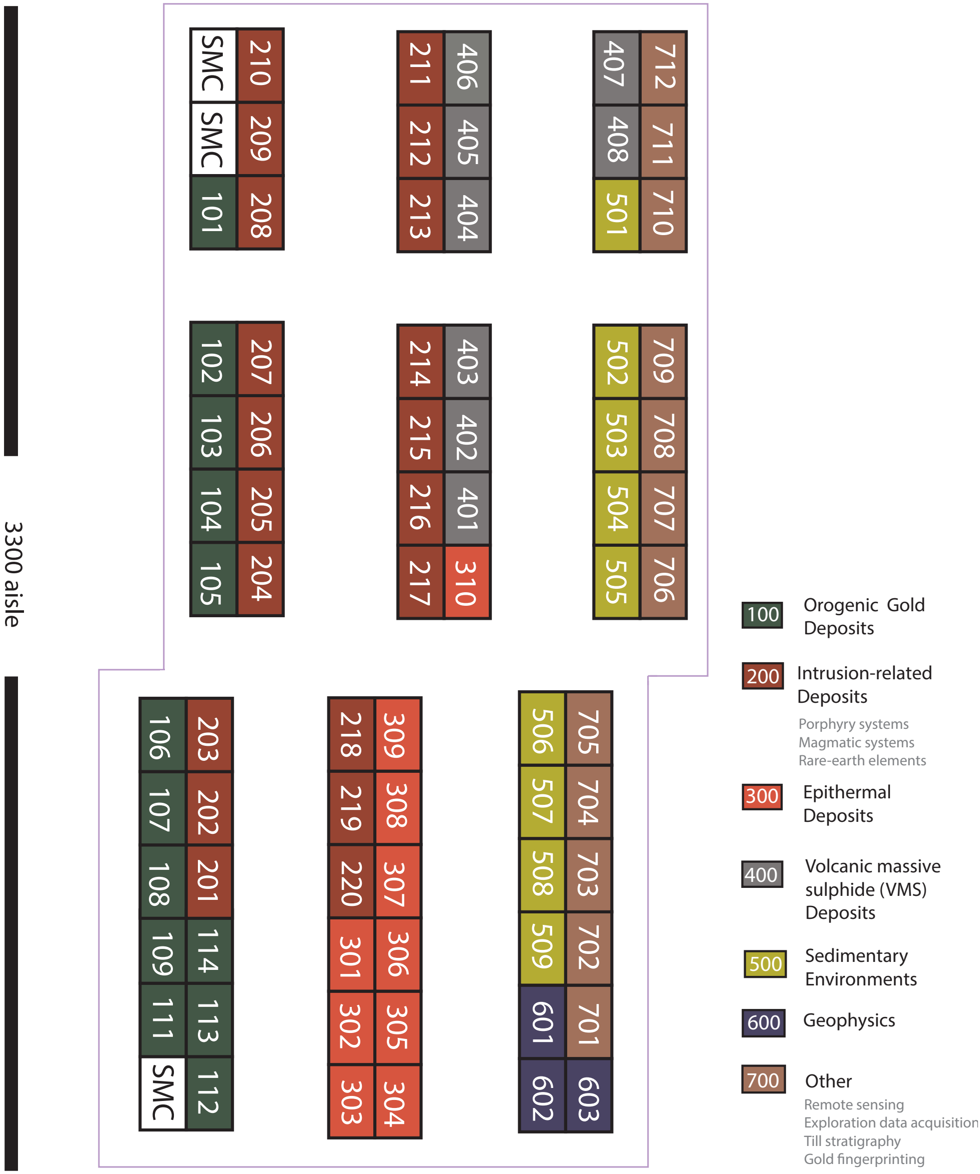


Table of Contents - Abstracts

100 Orogenic Gold Deposits

Table of Contents - Abstracts

200 Intrusion-Related Deposits

Table of Contents - Abstracts

300 Epithermal Deposits

Table of Contents - Abstracts

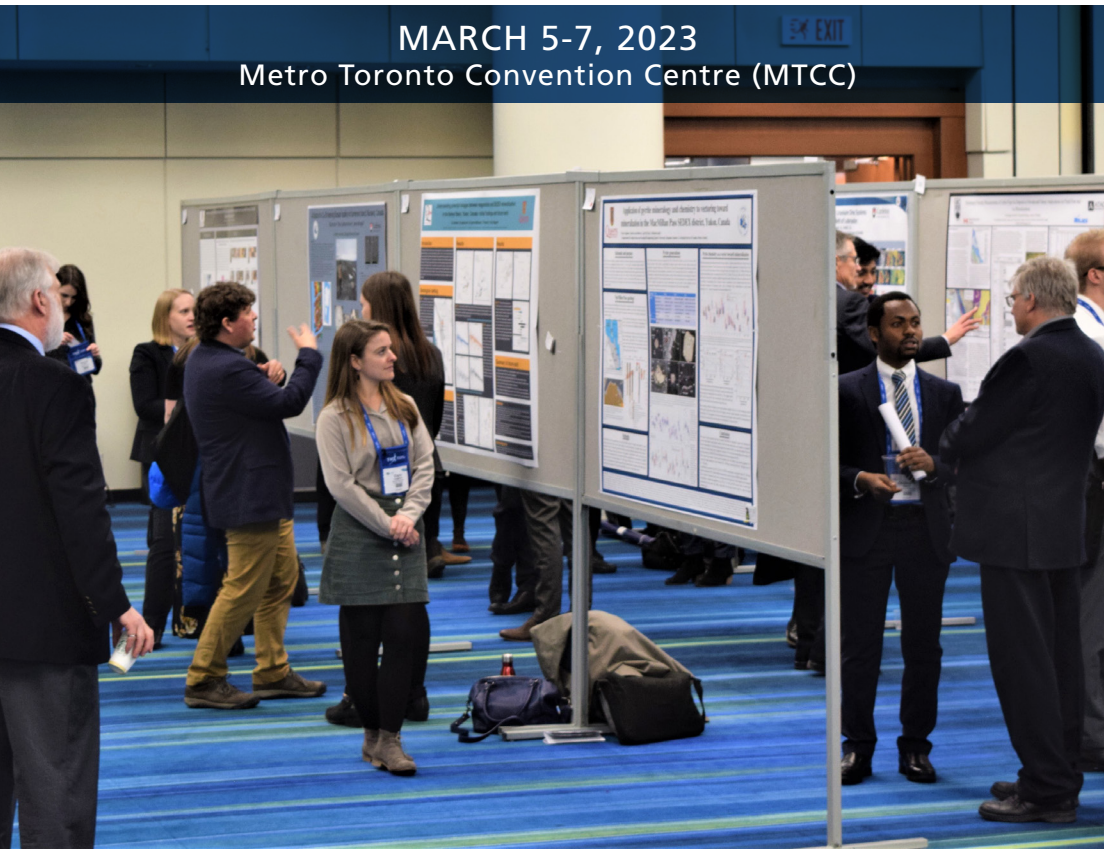
Table of Contents - Abstracts

600 Geophysics

Table of Contents - Abstracts

700 Other

Abstracts



100 Orogenic Gold Deposits

Shalaila Bhalla - MSc
sbhalla@laurentian.ca

Characterization of the Ormaque deposit in Val-d'Or, Quebec (101)

The Ormaque deposit is a new gold discovery by Eldorado Gold Corporation within the renowned Val-d'Or mining camp in the Archean Abitibi greenstone belt, Quebec, with an inferred resource of 839,000 oz of gold at a grade of 11.74 g/t. Ormaque is located 4 km north of the Larder Lake Cadillac Deformation Zone and is in close proximity to the historic Sigma-Lamaque mines, where the fault-valve model for orogenic gold deposits was first proposed. Ormaque differs from other deposits in the camp by its host lithology, relative abundance of extensional veins and fault-fill veins, their orientation and associated alteration. The deposit is hosted in a porphyritic diorite intrusion and consists of E-W flat-lying quartz-tourmaline-carbonate (QTC) extensional veins adjacent to both north and south dipping high-angle ductile reverse shear zones. The QTC veins are surrounded by 2 metre wide, alteration halos of tourmaline, calcite, ripidolite, phengite, pyrite ± chalcopyrite and gold, which are overprinted by 50 cm wide alteration zones of albite, phengite, calcite, ripidolite, pyrite ± chalcopyrite, and gold. Two generations of chlorite are present: an early regional metamorphic chlorite of clinochlore and brunsvigite composition and a late hydrothermal chlorite of ripidolite composition adjacent to the veins. In the tourmaline alteration zone, gold occurs as micro-inclusions within pyrite and as small gold grains in association with telluride minerals such as petzite and tellurobismuthite. In the albite-phengite alteration zone, gold occupies fractures across albite grains. Two generations of pyrite are present within the tourmaline alteration halo: inclusion-rich Py-I in the core of the grains and inclusion-free Py-II in the rim of the grains. Py-I is enriched in Bi, Te, Se, Pb, Co, Ag, and Au both within inclusions and in its crystal lattice, and is interpreted to have precipitated from a fluid rich in those metals. Py-II is depleted in those trace metals and is interpreted to have formed during recrystallization of Py-I or growth of new pyrite around Py-I. The abundance of extensional veins and near absence of fault-fill veins at Ormaque suggest that the reverse shear zones were not reactivated as brittle faults during the restoration of differential stresses and fluid pressures across the shear zones due to intense chlorite alteration which weakened the shear zones and prevented the build-up of high differential stresses. As fluid pressures became buffered by the formation of extensional veins, the shear zones slipped ductilely under the same low-differential stress conditions that resulted in the formation of extensional veins. The results of this study demonstrate the critical mechanical role played by the host rocks in the formation of extensional and fault-fill vein systems in the Val-d'Or camp.

Ian Campos - MSc
icampos@laurentian.ca

Structural controls on gold mineralization, Magino gold mine, Wawa Subprovince, Northern Ontario (102)

The Magino gold mine is located approximately 40 km northeast of the town of Wawa, within the Michipicoten greenstone belt of the Archean Wawa subprovince. It is a past-producing underground mine being redeveloped as a large tonnage open pit gold deposit with proven and probable reserves of 2.4 Moz of gold at a grade of 1.15 g/t Au. Gold mineralization at Magino is primarily hosted in the Webb Lake stock, a steeply-dipping ca. 2724 Ma tabular multi-phase tonalitic intrusion. The Magino deposit underwent three episodes of ductile deformation (regional D2, D3, and D4) and two pre- to syn-tectonic auriferous alteration events (Au1 and Au2; respectively). N-S-directed shortening during the D2 event produced a steeply-dipping WSW-ENE

striking regional cleavage (S2) which overprints the deposit. The D3 event resulted in localized dextral shear zones and reactivation of D2 fabrics, whereas the D4 event produced recumbent F4 folds and associated, axial planar, flat-lying crenulation cleavage (S4). The Au1 event comprises early intrusion-related, disseminated phengite/muscovite-quartz-pyrite alteration and associated sheeted to stockwork-style, molybdenite-bearing sugary quartz (SQ) veins (pre-regional D2 event). The Au2 event comprises N-S-trending orogenic quartz-carbonate-tourmaline (QTC) veins with albite-paragonite-ankerite-pyrite selvages (syn-regional D2 event). The intrusion-related SQ veins are cross-cut by inter-mineral quartz-feldspar-phyric (QFP) dikes, which are both transposed and boudinaged along S2. The orogenic QTC veins were emplaced syn- to late-D2 and are deformed within D2 shear zones, D3 dextral shear zones, and D4 shear zones. These structures are overprinted by metamorphic minerals, suggesting that alteration and mineralization formed prior to peak metamorphism. Late, sinistral E-side-up faulting along Matachewan(?) diabase dikes further modify and offset mineralization. Magino is an excellent example of a paragenetically complex Archean intrusion-related system which has been overprinted by multiple stages of deformation and orogenic-style mineralization.

Andrea Caratsch - BSc
andrea.caratsch@mail.utoronto.ca

Hydrothermal alteration proximal to veins at the Lone Star Deposit, Yukon (103)

The Lonestar deposit is located within the Klondike region of north-western Yukon. Attracting prospectors worldwide this Canadian Territory underwent intensive exploration following the 1896 Gold Rush, which led to the 2009 discovery of the White Gold District and ultimately to the identification of orogenic mineralisation. Underlain by the Permian Klondike Schist Assemblage of the Yukon-Tanana terrane (YTT), west of the Klondike region are meta-plutonic Sulfur Creek orthogneiss which over the span of ~100 km transition eastward into metavolcanic and metasedimentary units.

This study considers the quartz mica schist member – where sulphide mineralization, including visible gold (VG), is typically hosted within discordant quartz veins. Given the properties of the gold mineralization within the deposit, it is interpreted that gold formed from a cooling hydrothermal fluid at a shallow crustal level. This fluid originated from a deeper within the crust and is interpreted to have formed through metamorphic devolatilization. Economic grades of gold have been recorded and associated with disseminated, euhedral pyrite and spotty chlorite-carbonate alteration.

To gain a better understanding of the fluids that formed the deposit, short wavelength infrared spectrometry (SWIR) was used to determine diagnostic changes in sericite and/or chlorite by capturing the chemical variability of samples as we extend from mineralized and unmineralized quartz veins. This paper also seeks to determine whether complete digestion analyses are a useful sampling strategy for the efficient identification of alteration halos.

Alex Copeland - MSc Level
acope075@uottawa.ca

Alteration mineralogy surrounding gold bearing-quartz veins in the Klondike, Yukon (104)

The Klondike Gold Fields are located in West-Central Yukon, Canada just south of the historic town of Dawson. This area was once the site of the massive 1896 gold rush which saw thousands come to the region to seek their fortune in placer gold. The region remains an important placer

and paleoplacer gold district, but there are also ongoing efforts to uncover the bedrock source of the placer gold. This study examines samples drilled from claims owned by Klondike Gold Corp. (KG), a junior gold exploration company working in the Klondike gold district. The claims are hosted in the metaplutonic and metavolcanic rocks of the Klondike assemblage. The main mineralized unit of this assemblage is the Klondike Schist. The aim of this study is to characterize the cryptic alteration mineralogy and trace element chemistry of the quartz-muscovite-chlorite schist that hosts the gold-bearing quartz veins and provide a useable exploration vector for KG.

Samples were selected from KG's historic and recent diamond drill core archives in clusters that aimed to capture both the most altered wall rock directly adjacent to gold-bearing quartz veins and the least altered wall rock up to 50 cm away from these veins. Petrography and energy dispersive X-ray spectroscopy (EDS) were used to examine the mineralogy and trace element geochemistry of the least and most altered vein margins. This was further supported by portable short wave infrared reflectance (SWIR) spectra collected from the various samples. The most altered vein-proximal wall rocks contain chlorite and the Ba-rich potassium feldspar, hyalophane, whereas the less altered vein margins and distal wall rocks contain Ba-rich phengite. The transition from vein-proximal chlorite and feldspar to more distal phengite can also be seen in the SWIR spectra. The abundance of hyalophane in the vein-proximal wall rock is interpreted to be due to a pH increase which may also be linked to gold precipitation. The mineralogical zonation of the vein margins is now being tested as an exploration vectoring tool.

Tavis Enno - MSc
tenno@uwo.ca

Characteristics of ore fluids and mineralization at the Troilus Gold Project, Quebec: Implications for ore transport and exploration (105)

The Troilus Gold Project in Quebec is a low-grade, high-tonnage Au-Cu deposit situated on the Eastern limb of the Frôtet-Evans greenstone belt in the Archaean Opatica Subprovince of Canada's Superior Province. Past production of the deposit totalled 2 million ounces of gold and almost 70,000 tonnes of copper. The Troilus deposit extends along a northeast-southwest striking suite of isoclinally deformed volcano-plutonic rock which dips steeply to the northwest. Mineralization is centered around a dioritic intrusion bordered by intermediate to mafic volcanics and intruded by felsic dikes. Two distinct styles of mineralization have been described at the Troilus deposit; an early disseminated gold-copper event associated with potassic alteration and a later shear-hosted gold episode hosted by quartz ± carbonate veins. Renewed exploration on the property by Troilus Gold Corporation has extended mineralization along the structural corridor. Additionally, several promising regional gold targets have been identified beyond the historic mine site. The Troilus deposit suffers from conflicting genetic models describing it as an Archaean porphyry, mesothermal lode-gold deposit, and/or multi-stage orogenic deposit. Efforts to characterize the deposit have been complicated by metamorphic overprinting, deformation, and remobilization of ore metals. Recent characterization of fluid inclusions within gold-bearing quartz veins have identified a metamorphic fluid source lending support to a multi-stage orogenic model. However, the recognition of multiple superimposed structurally and mineralogically distinct styles of mineralization does not preclude the involvement of a volcanic and/or magmatic component during the development of the ore system. Additionally, mineralization at the Troilus Gold Project has not previously been evaluated in the context of other regional gold targets, preventing a complete understanding of the contribution of regional-scale processes to mineralization. Preliminary examination of samples through optical microscopy and electron probe micro-analysis using energy dispersive and wavelength dispersive spectroscopic

analyses has established textural relationships relating mineralization to penecontemporaneous metamorphism of the region. Fluid inclusion microthermometry is being used to investigate pressure-temperature conditions during mineralization while quantitative fluid inclusion gas analysis is being used to further characterize the source of ore fluids and establish a possible ore transport mechanism in the vapour or liquid phase. The results of this phase of the study will be used to create a global genetic model for the Troilus deposit that describes gold-copper mineralization in the context of local- and regional-scale processes.

Fatma Gumus - MSc
fatmag@mun.ca

Mineral chemistry and Nd isotope geochemistry of apatite in orogenic Au-associated gabbros, Baie Verte, NL (106)

Orogenic Au deposits on the Baie Verte Peninsula, Newfoundland Appalachians, are structurally controlled and primarily hosted by Lower Ordovician volcanic cover sequences (Snooks Arm Group) and ophiolitic rocks. Gabbro-hosted orogenic Au can be found in three locations: the Stog'er Tight and Argyle deposits, and the Animal Pond prospect. All these deposits are located in the hanging wall of the Scrape thrust fault usually within 100s of meters of the surface trace of the fault. Gold mineralization in all three areas is associated with coarse-grained, pegmatoidal gabbros that are variably deformed and were metasomatically altered by orogenic Au-related hydrothermal fluids. The original igneous rocks contain primary apatite that were subsequently partially to fully replaced during hydrothermal alteration to produce secondary hydrothermal zircon, monazite, and xenotime.

All apatite in fresh and altered rocks are subhedral to euhedral and have homogeneous backscattered electron images. In contrast, cathodoluminescence (CL) images for apatite in unaltered rocks displays yellow to yellow-green luminescence, whereas apatite in altered rocks displays a dark green to gray luminescence. Electron microprobe and laser ablation inductively coupled plasma mass spectrometry data for apatite in altered rocks show they are depleted in Mn, Cl, LREEs (low La/YbN, La/SmN), Th, and U, and enriched in S, Sr and Sr/Y compared to apatite in the fresh rocks. This is compatible with the altered apatites having experienced fluid aided REE-Mn-Cl-Th-U remobilization and subsequent growth of hydrothermal monazite and lesser xenotime inclusions. Despite variable elemental concentrations, the Nd isotope signatures of fresh and altered apatite are similar in all apatite grains with $\varepsilon Nd(t) = 2.34\text{-}6.31$ vs. 2.8-6.96, respectively.

This study highlights that the combination of textural studies, CL imaging, and chemical composition of apatite can be modified by hydrothermal fluids during fluid-rock interaction and can be used to determine igneous vs apatite influenced by Au-related hydrothermal alteration.

Evan Hall - MSc
ehall@laurentian.ca

Structural and Stratigraphic Controls on Gold Mineralization, Ulu Project, High Lake Greenstone Belt, Nunavut, Canada (107)

The Ulu gold deposit is the largest gold deposit within the relatively underexplored High Lake greenstone belt (HLGB) in the northwest of the Archean Slave Craton; 45 km north of the Arctic Circle, approximately 523 km north-northeast of Yellowknife. The belt runs roughly north-south and consists of mafic volcanic rocks, and lesser felsic volcanic and sedimentary rocks that range in age from 2705-2612 Ma. The deposit is unusual in that it is hosted in amphibolite facies

meta-volcanics. This obscures many of the alteration and deformation characteristics that are common in deposits hosted by lower metamorphic grade rocks. Renewed exploration in the belt has highlighted a need for better understanding the kinematics of the mineralized system. Detailed structural mapping, microstructure analysis, and whole rock geochemistry provide a framework for structural and chemical controls on gold mineralization within the deposit. Dating of the alteration and examining relationships of crosscutting dykes and structures provide relative and absolute ages on mineralizing events. The Flood zone, which hosts the bulk of the gold mineralization, occurs at the contact between high and low Fe/Ti basalt flows. These volcanics are bound by sediments, which are altered to quartz-biotite ± cordierite schist. Bedding parallel gabbro sills intrude between sediment and volcanic units, and the package is folded into an anticline, interpreted to have formed during a regional NE-SW D2 shortening event. The Flood zone is inferred to be associated with the D2 event, with mineralization occurring as free gold associated with acicular arsenopyrite in a brecciated and intensely silicified northwest trending sinistral shear zone. Examination of outcrop and drill core show evidence of multiple reactivations along this structure and complex kinematics. This research investigates the structural and stratigraphic setting of the Ulu deposit area, and aims to provide a chronological framework for gold mineralization. This will assist exploration companies in better understanding characteristics of other gold systems hosted in high-grade metamorphic rocks.

Reid Legére - BSc
rlege072@uottawa.ca

Lamprophyres spatially associated with gold mineralization at the Monique deposit, Val-d'Or, Quebec (108)

The Monique lode-gold deposit is found along the Larder Lake-Cadillac Break, within the Abitibi greenstone belt. The Monique deposit, which produced 51,488 oz Au from 660,655 t of ore (2.47 g/t Au) between 2013 and 2016, has the current resource of over 4 M oz Au in the Val d'Or East project. The deposit is hosted by the tholeiitic basalt lavas, and pyroclastic, and ultramafic rocks of the Jacola and Dubuisson Formations, which are metamorphosed to greenschist facies conditions. A series of syn-tectonic dyke swarms are found in the deposit, including lamprophyres as well as gabbro, diorite and feldspar porphyry dykes; the lamprophyre dykes are spatially related to zones of gold mineralization (> 1 g/t). Lamprophyre are hypabyssal rocks containing phenocrysts of phlogopite mica and amphibole ± clinopyroxene. Representative samples were collected from diamond drill cores. The mineralogy and bulk rock compositions confirm that these rocks are calc-alkaline lamprophyres. Minette lamprophyre is the predominant type; characterized by coarse-grained phlogopite mica (Mg#=[Mg]/([Mg]+[Fe]): > 0.6) and no feldspar or quartz phenocrysts. Vogesite lamprophyre are minor, containing hornblende and phlogopite phenocrysts in K-feldspar-bearing groundmass. Phlogopite commonly contains small phosphate minerals (apatite, monazite, xenotime) and oxides (rutile, titanite), zircons and bastnäsite. Hornblende phenocrysts are pseudomorphically altered to actinolite as well as calcite. Lamprophyre rocks are Mg-rich (Mg#=0.6 - 0.8) relative to tholeiitic basalt (Mg#= 0.3 - 0.6) and contain high concentrations of light rare earth elements (LREE, >100x chondrite values), which is reflected by the occurrence of minerals with high LREE, such as allanite, xenotime, monazite. Furthermore, chondrite normalized REE show a negative slope pattern with elevated LREE, in contrast to the flat normalized REE pattern for the tholeiitic basalt (~10x chondrite values). Minor and trace elements further support a calc-alkaline clan of lamprophyres, with elevated large ion lithophile element values (>100x of primitive mantle) coinciding with low values of high field strength elements, such as Nb, Ta, and Ti (< 10x primitive mantle values).

100 Orogenic Gold Deposits

Derek D.V. Leung - PhD
dleung@laurentian.ca

All that glitters is gold? Protolith and alteration controls on the mineral chemistry of Cr- and V-bearing muscovite and chlorite at the Kerr-Addison gold deposit, Virginiatown, ON (109)

The association between Cr- and V-bearing muscovite and lode gold deposits has been recognized for almost a century, but the genetic relationship between the two has not been interrogated. Here, we explore how protolith chemistry and proximal-to-distal alteration trends influence the mineral chemistry of Cr- and V-bearing phyllosilicate minerals (i.e., muscovite and chlorite) at the Kerr-Addison gold deposit (Virginiatown, ON), using energy and wavelength dispersive spectroscopy (EDS/WDS; major- and minor-element chemistry) and laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS; minor- and trace-element chemistry). Our preliminary results suggest that muscovite and chlorite are the major mineralogical hosts for Cr and V in the altered rocks, with a dichotomy between Cr-bearing phyllosilicate minerals being found in ultramafic protoliths versus V-bearing phyllosilicates in mafic protoliths. The distinction between Cr and V in different protoliths suggests that the protolith chemistry exerts a first-order control on the chemistry of the phyllosilicate minerals. In both protoliths, the Cr and V contents in chlorite remain consistent throughout the distal and proximal alteration zones, suggesting that the bulk of the Cr and V is derived from the early alteration of primary silicate and oxide minerals to chlorite, with the two elements being relatively immobile thereafter. Analyses of the Cr-bearing muscovite in the ultramafic protolith do not show significant systematic changes in mineral chemistry as a function of proximal-to-distal alteration or grade trends, except for decreases in V and Cs contents towards proximal alteration zones. These results imply that the mineral chemistry of Cr-bearing muscovite in ultramafic protoliths is relatively homogeneous on the scale of alteration facies, and thus is likely to be representative on the deposit scale. It is anticipated that these results will be applied to other deposits in the Abitibi greenstone belt and districts such as the Sierra Nevada foothills (CA).

Arnold Nuru Gan - BSc
nuruganarnold@gmail.com

Geochemical Vectors for Targeting Hydrothermal Gold Mineralisation in the Damang area, southern Ghana (110)

Damang gold mine is found in the southeastern part of the Ashanti gold belt in southwestern Ghana. Two kinds of gold mineralisation are identified in the area: Tarkwaian style paleoplacer mineralisation and hydrothermal mineralisation. In this study, petrographic studies of diamond drill samples and statistical analyses of trace element geochemical data were performed to identify the pathfinder elements of hydrothermal gold in the Damang area. Fifty (50) samples were collected from three drill holes for whole rock geochemistry, and thin and polished sections were prepared from some of the samples taken for petrographic studies. The petrographic studies revealed the dominance of quartz, biotite, hematite, magnetite chalcopyrite and minor presence of amphiboles, sphalerite, apatite and feldspars. The geochemical data of the 50 samples extracted for statistical analysis revealed the dominance of Na, Mg, K, Al, Ca, Fe, and Mn. Q-Q plots revealed deviations from the normal distribution and outliers in the dataset, which were corrected by centred log-ratio transformation and proven to be normal by both the Kolmogorov-Smirnov test and Shapiro Wilks test for normality. Spearman correlation revealed that Te, Ba, Ti, Bi, and U showed positive correlation with Au. Hierarchical cluster analysis revealed 3 multi-element associations: (1) Au-Te- Bi- Ag, (2) Mn-Cd-Pb-Mo, and (3) Rb-Ti-K-Ba-U-Al-Ga-Be-Sr-Na-Li-Cr-Ni-V-Fe-Mg-Ca-Co-Zn-Cd. Factor analysis confirmed the elemental

association of Te, Bi, and Ag as directly related with gold (Au) as they loaded strongly with it in factor 4. Therefore Te, Bi, and Ag are the established pathfinders for gold in the Damang area. Single and multi-element anomaly mapping revealed that geochemical anomalies involving these elements are found in the southwestern, central, and northeastern fringes of the area.

Adrian Rehm - PhD
arehm@laurentian.ca

Metamorphic constraints on the geodynamic setting of the Quetico metasedimentary belt and implications for gold mobility in the Western Superior Province (111)

The Quetico subprovince (QS) is an east-striking Neoarchean sedimentary belt dominated by thick successions of metamorphosed graded wackes and pelites, with minor interlayers of pillowed basalt and ubiquitous syenitic to granitic plutons, which stretches over 1200 km across Northern Ontario. It is bound by greenstones of the Wawa, Wabigoon and Marmion subprovinces. Regional structures that separate the metasedimentary and greenstone belts are variably endowed with gold deposits, but the underlying processes controlling endowment in these systems are poorly understood. This study aims to 1) test the hypothesis that metamorphic devolatilization of the Quetico metasedimentary rocks was a major control on fluid production and mobilization of metals in these systems and 2) investigate how variations in pressure-temperature-timing-deformation-composition conditions (P-T-t-D-X) in this potential source area may have affected gold endowment. New field relationships, petrography, phase equilibria modelling, and U-Pb dating of pelitic rocks point to two distinct metamorphic events. A M1 event (c. 2680 ± 4 Ma ; preliminary U-Pb monazite-I age) expressed as a paragenetic sequence of biotite → cordierite → melt assemblages along a low pressure-high temperature (LP-HT) apparent gradient and interpreted to have developed coeval with (initially) flat-lying isoclinal folding (D1) and a weak bedding-parallel foliation (S1). An M2 event (c. 2660 ± 3 Ma; preliminary U-Pb monazite-II age) is characterized by a regional isogradic sequence of chlorite → biotite → garnet → staurolite/andalusite → cordierite → sillimanite → melt → orthopyroxene, reflecting an apparent medium pressure/temperature (MT-MP) gradient and is coeval with upright folding (D2) and a strong subvertical foliation (S2). Though early recumbent folding has been typically interpreted as the formation of nappe-like structures in a collisional setting, the presence of intercalated pillow basalts and LP-HT metamorphism points to a rift setting. This setting is not compatible with orogenic gold models, which generally invoke convergence and crustal thickening to form regional subvertical structures and Barrovian-style (MP-MT) metamorphism. In the QS, the development of subvertical structures (D2/D3) and MP-MT metamorphism is related to M2, which precludes a potential metasedimentary source for gold deposits older than ~2660 Ma . Future work will involve assessing the control of protolith compositions on fluid release and along-strike metamorphic variations in the QS.

Diogo Ribeiro - PhD
diogo-miguel.teixeira-ribeiro.1@ulaval.ca

Metal and ligand mobility during prograde metamorphism of metasedimentary belts in the Superior Province: Implications for Au endowment (112)

It is broadly accepted that the fluids involved in the genesis of orogenic gold deposits result from metamorphic devolatilization of crustal rocks during prograde metamorphism. Previous studies have shown release and mobility of key elements (e.g., S, Au, As, Sb) from metasedimentary

rocks during prograde metamorphism, indicating that they may represent a viable source of metals and ligands. Although metasedimentary rocks are generally recognized as source of metals in Phanerozoic deposits, they have often been overlooked in Archean greenstone belts, given their low abundance. However, in the Superior Province, strongly metamorphosed metasedimentary belts (up to granulite facies) occur adjacent to, and are commonly overthrust by moderately metamorphosed greenstone belts (up to lower amphibolite facies). This tectonometamorphic setting suggests that devolatilization of the metasedimentary belts may have sourced significant volumes of metals and ligands to the overlying greenstones.

This study focuses on the Pontiac and Quetico subprovinces, two metasedimentary belts in the Superior Province adjacent to and overthrust by the Abitibi and Wabigoon greenstone belts, respectively. Representative metasedimentary and subordinate interlayered mafic volcanic rocks metamorphosed at different metamorphic grades (e.g. greenschist to granulite facies) were sampled along three different transects representing well-endowed (Rouyn-Noranda, Pontiac), moderately-endowed (Geraldton, Quetico), and poorly-endowed (Thunder Bay, Quetico) areas. We report whole-rock geochemistry data for trace elements and ultra-low-detection-limit data for Au acquired by pressed powder pellet (PPP)-LA-ICP-MS. The results suggest that As and Sb were released during prograde metamorphism in all the study areas. However, decreasing gold contents with increasing metamorphic grade, indicative of Au mobilization during prograde metamorphism, was only observed in endowed areas, while no variation was recognized in the poorly-endowed area, suggesting limited Au mobilization.

Since sulfides are likely the main hosts for Au in the metasedimentary rocks, to understand this contrasting Au mobility, the textural and chemical evolution of sulfides during prograde metamorphism is being investigated. Previous studies predict the breakdown of pyrite into pyrrhotite at the greenschists to amphibolite facies transition. Preliminary results from the Geraldton transect reveal an evolution featuring: (1) pyrite- pyrrhotite transition (biotite to cordierite zones) involving poorly-crystallized transitional sulfide phases with an intermediate composition between pyrite and pyrrhotite, followed by (2) a pyrrhotite- pyrite transition at higher grades (i.e., sillimanite zone) where euhedral pyrite grows inside pyrrhotite. These observations suggest that the prograde sulfide evolution is more complex than previously thought. The impact of these transformations on trace element mobility is currently being accessed by LA-ICP-MS analysis.

Nelson Roman - PhD
nelson.roman@mail.utoronto.ca

Sulfide occurrence at the Lone Star gold deposit, Klondike gold district, Yukon (113)

The Lone Star gold deposit is the main known bedrock gold occurrence in the Klondike gold district, Yukon. Exploration for bedrock gold in the Klondike district is particularly attractive because the district has produced more than 12 Moz of gold from placer sources, but only ~1,240 oz of gold from bedrock sources, suggesting the possibility of the existence of undiscovered bedrock resources that might explain this extreme disparity. In fact, recent exploration efforts in Lone Star and the immediate surrounding areas have been successful in expanding its known gold resource, leading to the first-ever bedrock mineral resource estimate for the Klondike district in its history.

Even though the mineralization at Lone Star is thought to be orogenic, the sources of gold, associated elements, and mineralizing fluids remain debated. This hinders efficient exploration targeting in the district. To better constrain the potential source of gold and related elements for Lone Star, here we report preliminary data on the occurrence of sulfides along two cross-sections across Lone Star, which crosscut the main mineralized area and surrounding low grade rocks. Future work related to this project include the quantification of trace elements in pyrite and other sulfides through LA-ICP-MS and sulfur isotope analyses by SIMS. The results of this research are expected to aid in exploration efforts in the Klondike gold district and elsewhere in Yukon.

Bradley Squires - MSc
bsquires@mines.edu

Unraveling the history of orogenic gold deposits in the Corona de Oro district, north western Nicaragua (114)

The northwestern region of Nicaragua preserves a protracted history of deformation, magmatism, and tectonism spanning multiple Phanerozoic events. Recent exploration work conducted by Mako Mining Corp. has defined a broad, >30 km trend of gold mineralization termed the "Corona de Oro" Gold Belt. This trend is host to the San Albino mine, one of the highest-grade open pit mines in the world. Deposits and occurrences are characterized by quartz-carbonate (±ankerite) vein sets that yield high gold grades (>100 g/t) over relatively narrow (1-2 m) intervals, with ore assemblages containing ankerite, pyrite, sphalerite, arsenopyrite, and galena with native gold. Furthermore, the vein sets are hosted by regionally extensive, multiply deformed carbonaceous schist units, occurring as banded sets that are often stacked and shallowly to moderately NW-dipping. However, the timing, structural setting, and deposit style are poorly understood within the complex framework of Central American tectonics. Petrographic observations, fluid inclusion analysis, drill core observations, and pit wall mapping are being used to investigate the tectonic setting and processes related to deposit formation. Preliminary fluid inclusion analysis indicates that fluids related to mineralization contain high CO_2 contents consistent with vein formation at the brittle-ductile transition zone of the upper crust. Pit mapping and drill core observations indicate that shear and extensional vein arrays formed by episodic emplacement with the gold being paragenetically late. While largely forming flat-lying arrays, shear within the host schist is localized along and near vein margins and, locally, the veins are folded and thrust stacked. Lastly, late, NNE- and NNW-trending strike-slip faults form vertical zones of gouge and breccia that crosscut the mineralized veins producing locally complex structural domains. Ongoing work will include further (micro)structural analysis, field work, constraint of the absolute age of mineralization by isotopic analysis of sulfide and/or hydrothermal phosphate phases, and paragenetic sequencing.

200 Intrusion-Related Deposits

Jessica Baldwin - MSc
jbaldwin@eoas.ubc.ca

Lithogeochemical and Temporal Framework of the Treaty Creek Cu-Au Porphyry System (201)

This work is being done under the supervision of Dr. Shaun Barker and Dr. Kate Rubingh as part of MDRU's Golden Triangle Stratigraphy Project. This poster will outline the initial data collection, methods and results of the development of the geologic framework of Tudor Gold's Treaty Creek Goldstorm Deposit. The Goldstorm deposit is an alkalic leaning, Cu-Au rich porphyry, located in the Golden Triangle of northwest BC. The deposit consists of multiple phases of mineralized and unmineralized intrusive units, hosted within a package of Lower Hazelton volcaniclastics. As the first academic work specific to the property, it aims to define lithologies, temporal relationships, alteration and mineralization styles. The lithologic units will be characterized texturally, chemically and temporally via petrography, geochemical characterization, and U/Pb isotope analysis. A collaboration with GoldSpot Discoveries Corporation will support the incorporation of multivariate clustering analysis and image analytics through their proprietary core imaging technology 'LithoLens'. The mineralization will be characterized through Re/Os isotopic analysis, petrography and pyrite trace element analysis. The alteration assemblages are assessed through short wave infrared analysis and geochemistry. The combination of the proposed set of analyses will greatly enhance the understanding of this world class deposit.

Catriona Breasley - PhD
cbreasley@eoas.ubc.ca

Mining and processing of micro spodumene-quartz intergrowths at the Tanco pegmatite, Manitoba (202)

The Li-Cs-Ta (LCT) Tanco pegmatite in southeastern Manitoba represents one of the most economically important and fractionated pegmatitic bodies in the world. Tanco is Canada's only current lithium-producing mine with spodumene as the main targeted ore at the deposit. This is typically found as spodumene and quartz intergrowths (SQUI). There are two dominant textural varieties of SQUI at Tanco including classic SQUI which hosts elongated and oriented growths of spodumene often infilling relic parental crystal outlines. Classic SQUI is the most abundant variety at Tanco. A second textural variety of SQUI found at Tanco is termed micro SQUI due to the small-scale nature of the intergrowths which often make individual crystals indistinguishable in hand sample. This textural variety is of particular importance as it is much more resistant to mineral processing than the larger intergrowth textures of the deposit. Therefore, understanding the origins and spatial relations of this variety of SQUI is of economic importance for processing estimations. Thin section petrography revealed micro SQUI to comprise of radial symplectic intergrowths which often show reaction crystallization fronts. Complimentary cathodoluminescence imaging revealed micro SQUI to represent a second generation of crystallization in relation to Classic SQUI. LA-ICPMS highlighted the geochemical similarity of classic SQUI and micro SQUI. Due to this textural and geochemical evidence, it is hypothesized that micro SQUI formed via a post-crystallization reactive hydrothermal fluid. Future work will investigate the spatial distributions of the different SQUI types at the Tanco pegmatite to provide insight into where micro SQUI is found.

200 Intrusion-Related Deposits

Kate Canham - PhD
krc18@leicester.ac.uk

PGE-Ni-Cu mineralisation in the Critical Zone at Sandsloot, Northern Bushveld (203)

The extraction of new resources of PGE, Cu, Ni and Co is critical to satisfy increased demand driven by the energy transition. One important aspect of producing the quantities of these metals required for the coming decades is understanding the geometallurgy of deposits, as this is paramount to improving efficiency of processing of ores. The Critical Zone of the Northern Limb of the Bushveld Complex hosts the world-class Platreef PGE-Ni-Cu-(Co) deposit. It has been recognised the Platreef thickens and increases in grade down-dip, reaching >10 g/t (4E) over several metres in places, making it one of the Earth's largest resources of PGE. In the Sandsloot area of the limb, recent exploration and re-evaluation has identified several zones of mineralisation, at different levels within the Critical Zone, including multiple high-grade PGE-rich zones on the scale of 10s of metres and thick base metal sulfide (BMS)-rich zones up to several hundred metres below. To date, these down-dip zones at Sandsloot have received no detailed mineralogical studies and the mineralogical attributes of the PGM, BMS and their surrounding host minerals are unknown.

The upper PGE-rich zone has around 1-2 vol % sulfides, with a typical assemblage of pyrrhotite-pentlandite-chalcopyrite (average proportion of 50/35/15%). The most common PGM are Pt-Fe alloys, Pt-Pd-Pb alloys, Pt-Pd bismuthotellurides, Ru sulfides and Pt arsenides. In contrast, the lower BMS-rich zone contains lower tenor semi-massive to massive sulfides, comprised dominantly of pyrrhotite, with lesser pentlandite and chalcopyrite (average proportion 60/25/15%). Relative to the PGE-rich zone this zone contains much lower PGE grades, and notably an IPGE dominant PGM assemblage of Ir arsenides, Ir-(Pt,Rh,Rh) arsenosulfides and Ru sulfides (62%), with lesser Pt arsenides (18%), Pt-Pd bismuthotellurides (9%) and Pd-Pd alloys (4%).

In this ongoing study we characterise the PGM and BMS variation throughout the Critical Zone, integrating this with hyperspectral and geochemical analysis. This will aid in establishing the relative controls, magmatic (fractionation), syn-magmatic (contamination) and hydrothermal, which control the metal budget and geometallurgy of both the PGE-rich and BMS-rich ores at Sandsloot.

Youcef Cherfi - PhD
youcherfi94@gmail.com

Nb–Ta and REE mineralization in the Tioueine alkaline complex, Western Hoggar (Southern Algeria) (204)

Post-Panafrican granite-related rare metal deposits are found in the Hoggar shield (Southern Algeria). Niobium and Ta are associated with the highly evolved (i.e. fractionated) granite units, Li and Be are mostly concentrated in granite-hosted pegmatites, and W-Sn mineralization is largely associated with late hydrothermal quartz veins. The Tioueine alkaline granitic complex is a relatively understudied plutonic massif in the Hoggar shield but has the potential for economic accumulations of rare metals. This work explores the rare metal potential of the Tioueine complex using fieldwork, petrography, and geochemistry.

The magmatic evolution of the complex was previously examined using whole-rock geochemistry of large-ion lithophile elements (Rb/Sr, Rb/Ba, and K/Rb) and we are enhancing this previous work with fieldwork, petrography, scanning electron microscopy, and laser ablation ICP-MS.

The Outer unit of the complex is the most evolved and contains coarse-grained alkali feldspar granite that is cut by syenite-dominant dykes. The peripheric alkali granite is dominated by quartz and perthite with subordinate plagioclase and biotite, as well as accessory muscovite, zircon, magnetite, fluorite, sphene, allanite, and thorite. The syenite dykes contain perthite and quartz, hornblende and pyroxene, as well as accessory zircon, magnetite, ilmenite, epidote, allanite, and fluorite.

Electron dispersive spectroscopy analysis reveals small inclusions (10–40 µm) of Nb–Y oxides in biotite of the peripheric alkali feldspar granite. Allanite occurs in all facies of the complex. However, it is widely dispersed in the syenite as large (up to 2.5 mm long) zoned crystals. The peripheric alkali feldspar granite contains large zircon (up to 350 µm) and Ti-Fe oxides resolvable Ta-Nb contents.

The Nb–Ta-rich and REE-rich minerals are interpreted to be the magmatic products of fractionation of the alkali granite and syenite. Further work will investigate bulk rock and accessory mineral (allanite, zircon, Nb-Ta and Y oxides, and zircon) trace element compositions to further understand the petrogenesis of the complex and to evaluate the potential economic importance of the Tioueine alkaline complex for rare metals.

Kathleen Clark - MSc
kt747032@dal.ca

Trace element geochemistry of biotite from the Scrag Lake and New Ross plutons of the South Mountain Batholith, NS, Canada: Implications for critical metal behaviour during magma differentiation (205)

The South Mountain Batholith (SMB) is a large, peraluminous, felsic intrusion occurring in SW Nova Scotia. The batholith consists of 13 plutons emplaced in two different phases between ~385 (Stage 1) and ~368 Ma (Stage 2), with the only significant ore deposit (Sn at East Kemptville) associated with Stage 2 pluton emplacement. Previous research revealed that samples from Stage 2 plutons show significant variability in trace elements in biotite, including several critical metals (Sn, W, Nb, Ta), compared to Stage 1 plutons, despite both stages showing a similar range in whole-rock geochemical variation. It is not clear if this difference arises due to sampling bias or is an intrinsic property of the second stage of batholith emplacement. Therefore, the goal of this work is to better characterize biotite compositions across a broad compositional range from representative Stage 1 and Stage 2 plutons with a goal to better understand critical metal enrichment processes. Here we present results of analyses of samples from the Stage 1 Scrag Lake pluton (SGP) and the Stage 2 New Ross pluton (NRP). An electron microprobe and laser ablation ICP-MS have been used to collect major and trace element spot analyses and compositional maps on biotite from a suite of 5 samples from each pluton covering a compositional range of ~68 to ~75 wt% SiO_2. Data for 34 trace elements were obtained, and 18 of these trace elements were used to create trace element maps of 10 different biotite grains. Incompatible trace elements, which include the critical metals Sn, W, Nb, and Ta, show increases from core to rim within these biotites. For similarly-sized grains and similar whole-rock wt% SiO_2, Stage 1 samples show within grain variation from 10s- 100s ppm, while variation within Stage 2 biotites is 10s- 1000s ppm. This indicates that the more extreme extent of incompatible trace element variation is an intrinsic property of Stage 2 plutons. Comparing data to simple fractional crystallization models shows that there are trends in the more evolved samples that cannot be explained by fractional crystallization alone, suggesting a non-magmatic, potentially hydrothermal, contribution to critical metal enrichment. The modelling also suggests that

Stage 2 biotites are crystallizing at a later point during the pluton's cooling, from more evolved melts compared to Stage 1 biotites, explaining the differences in trace element concentrations between the two phases.

Michael Cloutier - PhD
michael.cloutier.2@ulaval.ca

Magmatic evolution of the Upper Beaver intrusive complex and its implications for Au-Cu mineralization (206)

The rarity of large Archean magmatic-hydrothermal Au-Cu deposits has limited study on the processes controlling the metals fertility of these deposits. Compared to the Phanerozoic, this deposit type is scarce in Archean terranes which has been variably attributed to differences in geodynamics, poor preservation potential, and/or to differences of the physiochemical conditions (P, T, fO2, fS2, Cl and S concentration) during magmatic evolution. The Archean Upper Beaver magmatic-hydrothermal Au-Cu deposit (~1.4 Moz Au and 20 kt Cu of reserve) of the southern Abitibi greenstone belt represents a rare opportunity to investigate these hypotheses. This deposit is located approximately eight km north of Larder Lake (Ontario), and approximately five km north of the Larder Lake-Cadillac break. The deposit and associated intrusive rocks of the Upper Beaver Intrusive Complex (UBIC) are hosted by tholeiitic mafic volcanic, volcaniclastic, and sedimentary rocks of the lower Blake River assemblage (ca. 2704 – 2701 Ma). The UBIC comprises five texturally and temporally distinct dioritic to quartz monzonitic phases which are later crosscut by two phases of feldspar porphyry (FP) dykes. Two Au mineralization events are recognized, the first (minor in tonnage) is associated with the dioritic to quartz-monzonitic intrusive phases and the second is associated the first stage of FP dykes. New LA-ICPMS U-Pb zircon geochronology for each individual phase constrains emplacement of the UBIC to ca. 2680 Ma; consistent with previous Re-Os molybdenite ages for the mineralization and a U-Pb crystallization age of ca. 2679 Ma for the latest post-mineralization FP dyke.

Whole-rock geochemistry is consistent with the UBIC having formed through mixing between mafic sanukitoid-like and felsic TTG-like magmas. Amphibole chemistry indicates that the earlier dioritic to quartz monzonitic phases crystallized at temperatures of 915°C ± 30°C with $fO2$ values between ΔNNO 0 and +1. The first FP phase had lower crystallization temperatures of 800°C ± 30°C and higher $fO2$ values between ΔNNO +0.5 and +2.4. Sulfur concentrations in apatite from the earlier dioritic to quartz monzonitic phases is variable but high S apatite (0.18 wt.% - 0.33 wt.% S) are associated with the most voluminous phases. Whereas apatites from the FP phases, including the one associated to the second Au event, show low S concentrations (0.00 wt.% - 0.15 wt.% S). The UBIC has similar characteristics to Phanerozoic magmatic-hydrothermal Cu-Au systems, suggesting that differences in physiochemical conditions is not an explanation for the scarcity of Archean magmatic-hydrothermal Au-Cu deposits.

Jérémie Darveau - BSc
jeremie.darveau.1@ulaval.ca

Epidote paragenesis and geochemistry from the Upper Beaver Au-Cu deposit, Abitibi Sub-province, Ontario (207)

Epidote is a widespread mineral in the Abitibi greenstone belt and is not typically regarded as a local indicator of mineralization. However, the association of native gold and epidote do occur at the Upper Beaver Au-Cu deposit in the Kirkland Lake-Larder Lake mining camp. Nonetheless, the variability of epidote's texture, cross-cutting relationships, and mineral associations suggests

many epidote generations, not all associated with gold mineralisation. Accordingly, this project aims to characterize the paragenesis and geochemistry of epidote at Upper Beaver to distinguish the gold associated epidote from the barren epidote in the purpose of vectoring mineral exploration. To achieve this objective, 14 selected drill holes with epidote rich intervals were logged, 25 thin sections were described by optical petrography, 7 samples were analysed using both EPMA and LA-ICP-MS and a partial least squares-discriminant analysis (PLS-DA) was applied to geochemistry results.

Based on petrographic observations, epidote is grouped into five generations: 1) gold and potassic feldspar associated with strong zoning and a replacement texture, 2) gold associated in stringers, 3) barren and quartz associated, 4) barren and axinite associated and 5) barren and calcite associated, where 3), 4) and 5) are all found in extension veins. In terms of geochemistry, zoned grains of generation 1) show an intern zone enriched in Ti and Fe surrounded by an external zone enriched in Al and Mn.

Through generations, epidote at Upper Beaver becomes richer in Al, Pb and Sr and depleted in Ca, Fe3+, Ti, Eu, Zr, Bi, Ga, Sc, Sn and Co. The PLS-DA analysis on major and minor elements of epidote shows good separation between gold associated generations and barren ones. The geochemical evolution between epidote generations is thought to witness the decreasing temperature and oxygen fugacity of the nearby intrusion syngenetic to mineralization. In sum, the outlined possibility to distinguish both petrographically and geochemically gold associated from barren epidote at Upper Beaver highlights the potential use of epidote as an indicator mineral for intrusion-related Au-Cu deposits in the Abitibi Sub-province.

Ben Eaton - MSc
beaton@eoas.ubc.ca

Rapid Cu-porphyry indicator mineral characterization by µXRF: a case study investigating µXRF corescanners as a prospective automated indicator mineral analytical tool on HMC till samples from central British Columbian Cu-porphyry exploration properties (208)

As the global population rises and the world economy transitions towards decarbonization, electrification upgrades to energy, transportation, and industrial infrastructure will result in an increase in copper demand by upwards of 350% worldwide by 2050. Cu-porphyry deposits are large tonnage low-grade intrusive mineral deposits that supply over three-quarters of the global copper resources. Continued exploration for Cu-porphyries is critical to meeting this demand, however, the remaining undiscovered deposits are in regions that are mostly or entirely obscured by post-mineral surficial cover. Effective, timely, and economically feasible exploration approaches must be developed to meet the rise in copper demand and address the challenges associated with exploring for obscured deposits. Indicator minerals (IMs) are minerals that contain textural or chemical information indicating the presence of specific mineralization in the bedrock from which the minerals were derived and are commonly used to vector towards and/or assess the fertility of a potential deposit. In Cu-porphyry exploration, IMs have been widely used in regions of extensive surficial cover to explore for obscured deposits.

This project aims to contribute to the development of industry-applicable quantitative mineral identification methods at lower costs and faster analytical times than traditional optical microscope visual analysis by an expert technician and/or automated scanning electron microscopy methods. The research goal is to improve, quantify, and expedite the identification of porphyry copper IMs by investigating rapid cost-effective analytical technologies and approaches.

In this study, Cu-porphyry IM identification methods were developed utilizing benchtop micro-X-ray-fluorescence (μXRF) corescanners and automated scanning-electron-microscopes with energy-dispersive-detectors (ASEM-EDS). ASEM-EDS and benchtop μXRF corescanners both provide spectral information that reflects mineral chemistry and can be used to produce chemical or mineral maps of geological material. Heavy-mineral-concentrates (HMCs) of till samples from Northwest Copper's Kwanika, Lorraine, and East Niv Cu-porphyry exploration properties in central British Columbia were analyzed using μXRF corescanners and ASEM-EDS. The IM mineralogy of the HMCs was characterized using the Bruker AMICS automated mineralogy software to identify IMs from μXRF and ASEM-EDS data. HMC mineral characterization and IM identification by μXRF corescanners and ASEM-EDS is presented, and the opportunities and challenges associated with applying μXRF corescanners to rapid Cu-porphyry IM characterization are discussed. Benchtop μXRF corescanners appear to be a promising IM analytical tool, however, the relatively low spatial resolution and resulting mixed mineral spectra may complicate the identification of fine minerals or textures.

Alexander Holmwood - MSc
alexholmwood@nevada.unr.edu

Temporal evolution of the Majuba Hill Cu-(Mo)-(Sn) deposit, Pershing County, Nevada (209)

The Majuba Hill intrusive complex of northern Pershing County, Nevada, exhibits an atypical example of Cu-(Mo)-(Sn) mineralization hosted in a subvolcanic rhyolitic stock. This metal association is atypical because Sn and Cu-(Mo) deposits are usually related to geochemically distinct magmatic sources. Porphyry Cu-(Mo) systems are genetically related to oxidized, magnetite-series, and mantle-derived porphyritic quartz monzodioritic to granitic intrusions. In contrast, granite-related Sn deposits are genetically linked to highly fractionated and ilmenite-series felsic intrusions that are derived from crustal melting of sedimentary protoliths. The paradoxical existence of porphyry-style Cu-(Mo) and rhyolite-hosted Sn mineralization at Majuba Hill thus raises the question as to whether the deposit formed from a single or multi-stage magmatic-hydrothermal system. If this is the case, then current genetic models for porphyry Cu deposits will need to be reexamined to account for unusually high Sn contents.

Observations collected by optical microscopy, SEM images, and geochronological analyses reveal a spatial association between Mesozoic and Cenozoic hydrothermal systems. Quartz-molybdenite veins hosted in granodiorite were dated to 164.7 ± 0.7 Ma with the 187Re-187Os system, while other quartz-molybdenite veins crosscut porphyritic Oligocene rhyolites that are superimposed on Mesozoic granodiorites and feldspar porphyries. Vein-hosted and disseminated chalcopyrite additionally postdate hydrothermal tourmaline that is coeval with Oligocene breccia-hosted quartz-cassiterite mineralization.

Whole-rock geochemical data collected from subvolcanic rhyolites display high wt.% SiO_2 values, variable wt.% $Na_2O + K_2O$, and enrichment in many incompatible trace elements relative to upper continental crust. Rhyolitic host rocks are thus strongly fractionated and were also hydrothermally altered by alkali leaching and silicification. In contrast, deep granodiorites and feldspar porphyries are dacitic in composition and are depleted in HREEs relative to the Oligocene rhyolites.

As chalcopyrite postdates Jurassic molybdenite, Oligocene molybdenite, and Oligocene tourmaline-quartz-cassiterite episodes, Cu mineralization at Majuba Hill appears to have occurred across two superimposed hydrothermal systems. The earliest hydrothermal system is

associated with Jurassic quartz veins hosted in granodiorite and feldspar porphyries. The later system, in contrast, consists of vein-hosted and disseminated chalcopyrite postdating Oligocene cassiterite and shallow, chemically evolved rhyolite intrusions. This indicates Majuba Hill is a composite mineral deposit characterized by rhyolite-hosted Cu, Mo, and Sn that overprinted an older vein-hosted, possibly porphyry-type Cu-(Mo) deposit.

Tramaine James - MSc
tjames1@laurentian.ca

Preliminary investigation of the Proterozoic Toroparu Au-Cu(-Ag) Deposit Setting, Guyana, South America (210)

The Paleoproterozoic Toroparu Au-Cu(-Ag) system, located within the Mazaruni greenstone belt of the Guiana Shield, Guyana, South America, consists of two main deposits – an intrusion-related system at Toroparu and an orogenic type at Sona Hill – with a total preliminary resource estimate of 8.4 Moz Au, 6 Moz Ag, and 396 Mlb Cu. The Rhyacian-age mafic to intermediate volcanic, volcaniclastic and intrusive host rocks were metamorphosed to greenschist facies assemblages. The ore setting lies on a regional NW-trending, sub-vertical high-strained zone with a protracted deformation history. The intrusion related Au-Cu(-Ag) mineralization is hosted within polymictic to monomictic volcaniclastic rocks and a ~2160 Ma (U-Pb zircon) fine- to medium-grained porphyritic tonalite-granodiorite intrusive complex.

Two stages of Au mineralization are identified. The first, present only at Toroparu, has an assemblage of gold, chalcopyrite, bornite, pyrite II, covellite, molybdenite, and magnetite hosted within NW-trending extensional quartz carbonate ± chlorite (QCBCHL) veins, veinlets and fractures associated with dextral strike-slip movement. A molybdenite Re-Os age of ~2160 Ma overlaps the time for emplacement of the mineralized granodiorite. Petrography and hyperspectral imaging indicate the host rocks record early potassic alteration (i.e., biotite) and a later overprinting assemblage of quartz, albite, sericite, calcite and hematite. The second ore stage, dominantly at Sona Hill, contains pyrite III ± gold within SW-trending and subhorizontal quartz carbonate (QZCB) veins with tourmaline, albite, sericite, carbonate, and silica alteration halos are associated with late sinistral transpression.

Fluid inclusion studies indicate two different fluid types in QZCBCHL and QZCB veins. The former hosts secondary two-phase aqueous types (L H_2O -V H_2O) having Th = 100 to 160°C with moderate- to low-salinities (22.0 to 0 wt. % NaCl equiv.). In contrast, the latter hosts secondary and indeterminate CO_2 -rich, low-density, aqueous-carbonic types having X CO_2 = 0.35 to 0.5, Tm CO_2 = -56.2°C, and Th = 300 to 320°C with low-salinities (2 to 5 wt. % NaCl equiv.). These inclusions have decrepitate textures which, along with crack-seal textures, are attributed to pressure cycling.

The Toroparu deposit setting has two stages of mineralization. Whereas most of the base metals and Ag are syn-magmatic at ~2160 Ma, the Au is both syn-magmatic but also due to later orogenesis, possibly as young as ~2080 Ma as noted elsewhere in the Guiana Shield. The Las Cristinas Au-Cu deposit (32 Moz) in Venezuela is hosted in a similar geological setting, which emphasizes the potential for discoveries of magmatic-hydrothermal Au-Cu systems elsewhere in the Guiana Shield.

200 Intrusion-Related Deposits

Russell Johnston - MSc
rjohnston@eoas.ubc.ca

Structural geology of western Galore Creek area, northwestern British Columbia (211)

The Galore Creek Cu-Au porphyry deposit is hosted in a Late Triassic alkalic silica-undersaturated volcano-intrusive complex. The deposit is bordered to the west by a 2-3 km wide, > 6 km long, poorly understood, foliated and folded zone juxtaposed against the deposit by faults. The deformation zone records anomalously high strain in Stuhini Group rocks compared to elsewhere in the Galore Creek area, and its origin is enigmatic. We mapped three transects across the zone at 1:5000 scale and identified two generations of nearly coaxial folding (F1 and F2), and one axial planar cleavage (Sm). Type 3 interference patterns provide proof of refolding. F1 folds are tight to isoclinal, steeply inclined, east-verging, moderately south-plunging folds (~40 towards 200). The folds can be < 10 cm in wavelength as intrafolial folds, and outcrop scale (< 1 metre wavelength). The F1 folds typically have thickened hinges indicative of relatively higher temperature passive (Class 2) folding mechanisms. North of the Saddle thrust, F2 folds are open-close, upright, plunge 35->205, F2 folds generally have constant bed thickness across the folds, indicative of relatively lower temperature, Class 1B folds; but can also have thickened hinges. It is difficult to distinguish F1 and F2 in the field.

Preliminary observations suggest that changes in deformation style and strain intensity are a result of faulting that has juxtaposed rocks from different structural levels along west dipping reverse faults. It is unclear if these two folding generations represent progressive or discrete deformation events.

Michael Kirschbaum - PhD
michaelkirschbaum@gmail.com

Far field geochemistry and C-O isotope signatures of the Bingham porphyry Cu-Au-Mo deposit in carbonate wallrocks (212)

Far field signals in carbonates around the giant Bingham Canyon porphyry Cu-Mo-Au deposit (Utah, USA) may be useful in vectoring toward ores in other exploration projects. Bingham comprises a multi-phase sequence of Eocene-aged igneous rocks emplaced in a folded and thrusted Paleozoic carbonate and siliciclastic sequence, producing proximal Cu-Mo-Au porphyry-style mineralization and adjacent Cu-Au skarn deposits in carbonate host rocks, mainly in the Jordan and Commercial beds. Outboard from the porphyry-skarn zones (~0.5-2.5km) there are Pb-Zn-Ag vein and carbonate replacement orebodies. Carbonate veins occur in the carbonate wallrocks throughout this area. This study sampled whole rocks and veins of the Jordan and Commercial limestones, starting from the Bingham open pit and extending 17km to the W-SW along a transect terminating at the sub-economic Stockton porphyry system.

The 182 whole-rock C-O isotope data show that most samples within ~2.5km of both Bingham and Stockton have hydrothermal signatures (<19‰ δ18O and <-1.8‰ δ13C) and the samples farther out have marine carbonate signatures, with some exceptions. There is not a smooth trend, indicating untreated WR C-O isotope composition is a moderately strong indicator but not a vector. Temperature-corrected data are expected to show smooth trends.

In carbonate whole-rock geochemistry data, Cu, Mo, Fe and other elements drop off to background levels in <1km, whereas Ag, As, P, and REEs decrease over a long distance, over ~4-6km. Sr increases then levels off over <1km. Mn, Zn, Cd, and Ba increase to ~1 km then

decrease to backgrounds at ~2-4 km distance. Vein calcite LA-ICP-MS data show a decreasing trend in REE, Fe, Mg, S, and Pb whereas Ba and P shows an increasing trend from the Bingham Mine outboard to a distance of ~2-8km, while Mn and Zn display an increase to ~2km distance before dropping off to background levels ~4km outboard. Compared with whole-rock data, calcite data show stronger signals. In wallrock calcite, the trends of Fe and Pb persist but in shorter ranges, whereas other trends disappear, likely because the original sedimentary calcite contains more S, Mg, P, etc, which masks the hydrothermal signals. Additional samples along the transect being analyzed will refine, strengthen, or verify the above trends.

Klaus Kuster - PhD
kkuster@laurentian.ca

Spatial association between Cr and Ni-Cu-(PGE) mineralization in the Lac des Montagnes and the Levack (Nisk) intrusions within the Lac des Montagnes greenstone belt, Eeyou Istchee Baie-James, Québec, Canada (213)

Ultramafic and mafic magmatic flows/intrusions often host Ni-Cu-(PGE) or Cr deposits, but they less commonly host both Cr and Ni-Cu-(PGE) mineralization within the same magmatic system. In the Superior Province, a few examples of this spatial association occur in the Bird River sill in Manitoba, and the Ring of Fire, Shebandowan, and Big Trout Lake intrusions in Ontario. This metal association also occurs in the Lac des Montagnes (LdMI) and Levack (LI) intrusions of the Caumont mafic-ultramafic suite within the NE-SW trending Lac des Montagnes greenstone belt in the southern part of the La Grande Subprovince of the Superior Province. The LI consists of a lower black peridotite phase and an upper grey peridotite/olivine pyroxenite/feldspathic pyroxenite phase with an overall thickness of 150 m that extends over a strike length of ~4 km. Massive and disseminated Ni-Cu-(PGE) sulfides of the Nisk deposit occur at or near the contact between the lower and the upper phases. Up to 15 cm thick semi-massive and up to 3 m thick disseminated chromitite layers occur near the top of the upper phase, ~50 m above the sulfide mineralization. The LdMI is a differentiated unit composed, from base to top, of peridotite, olivine pyroxenite, pyroxenite, mesogabbro, and melanogabbro with an overall thickness up to 250 m that extends over a strike length of ~5 km. Several semi-continuously chromite-rich layers are intercalated with the peridotite which can be grouped into three horizons: the lower, middle and upper horizons. The middle horizon is the thickest (up to 2.4m-thick) and most continuous horizon throughout the intrusion. In the central part of the intrusion, it is composed of a single layer of massive to semi-massive chromitite overlain by layered chromitites. Semi-massive to massive Ni-Cu-(PGE) sulfide mineralization (e.g., Valiquette showing - up to 2.6% Ni) occurs near the base of the intrusion and is overlain by semi-massive to massive chromitite layer (up to 1.2 m-thick), which is located, on average, ~20 m above sulfide mineralization. In summary, both intrusions exhibit close spatial association between sulfide and chromite mineralization within the same intrusive body, where the chromite mineralization always occurs stratigraphically above sulfide mineralization. This spatial relationship is also observed in other intrusions (e.g., Shebandowan, Ring of Fire). Future work will try to establish if any genetic link could exist between these two types of mineralization and why some intrusions contain both types and others do not.

200 Intrusion-Related Deposits

Ying Zhou Li - PhD
yingzhouli@cmail.carleton.ca

Quantitative analysis of globular sulfide texture: A novel technique for discovery of deep-seated massive magmatic sulfide accumulation (214)

Magmatic sulfide deposit accounts for majority of the world's supplies of Ni and platinum-group-elements (PGEs) which are essential to the clean energy transition. However, discovery of these deposits is notoriously difficult to be made mainly due to the lack of large-scale geochemical anomalies, such as the alteration halos that are commonly associated with hydrothermal orebodies. It has been previously suggested that population of large sulfide globules (>2 mm) is an indicator of proximity to a sulfide source or massive sulfide ores. To build on this idea, we present the first systematic statistical analyses on the geochemistry and size distribution of sulfide globules collected from the Raglan Horizon in northern Québec, with standard fire assay and 3D X-ray computed tomography (X-ray CT) techniques. While sulfide globules can be found immediately outside the periphery of a massive ore system (e.g., the proximal population), they can also be found over 100m above the ore horizon with no relationship to the massive accumulations (e.g., the distal population). Geochemistry analysis suggests that these sulfide globule populations have similar metal tenors and are virtually indistinguishable. However, while kinked globule size distribution (GSD; similar to the concept of crystal size distribution) are very commonly associated with proximal sulfide globule population, such trend is rarely observed with the distal sulfide globule population that shares no spatial relationship with the massive ore. The kinked GSD feature can be explained by addition of fine-grain sulfide population or sulfide coalescence triggered by sulfide liquid percolation through the olivine cumulate pore network. Furthermore, statistical analysis on the GSD shows that the proximal and the distal populations have similar characteristic lengths which suggests that size of sulfide globules may not be the best indicator for proximity to massive ores. Instead, the total number density of sulfide globules which is derived from GSD, has shown to be a robust tool for predicting locations of nearby massive sulfide accumulations. Therefore, we conclude that a large population of fine-grain sulfide globules in addition to the population of coarse-grain globules which together yields a high total number density is a strong indicator for proximity to massive sulfide ores, and magmatic sulfide pools are likely formed by accumulation of massive sulfide microdroplets with sizes less than the critical pore throat radius.

Mary Macquistan - MSc
mary.macquistan@gmail.com

Mineralogy, mineral chemistry, and preliminary paragenesis of the Gun occurrence: A barium skarn near Macmillan Pass, Yukon Territory. (215)

The Gun occurrence is an unusual barium silicate (Ba-Si) mineral locality 38 km south of Macmillan Pass in Yukon Territory, Canada. The skarn is hosted in the Frasnian age Portrait Lake Formation, in which regional baryte mineralization is prevalent. It is hosted in the same regional environment as the Pb-Zn Tom and Jason SEDEX deposits. The initial Ba-Si mineral assemblage formed through contact metasomatism of the host rock due to the intrusion of the Gun pluton during the Cretaceous. The assemblage has undergone multiple phases of alteration since its original crystallization.

The Gun occurrence represents a rare opportunity to explore variations in the texture and chemistry of mineral assemblages in a barium-saturated skarn. It is one of the most diverse Ba-Si mineral assemblages known with over 17 Ba-Si minerals present. The Gun is the type-locality for

pellyite ($Ba_2CaFe^{2+}{}_2Si_6O_{17}$), itsiite ($Ba_2Ca(BSi_2O_7)_2$), meierite ($Ba_{44}Si_{66}Al_{30}O_{192}Cl_{25}(OH)_{33}$), and bavsiite ($Ba_2V_2O_2[Si_4O_{12}]$). Bazirite ($BaZrSi_3O_9$) and cymrite ($Ba(Si,Al)_4(O,OH)_8{\cdot}H_2O$) were identified at the Gun during this project.

Thin section petrography, automated mineralogy maps, backscatter electron imaging, and electron probe microanalysis were utilized to create a preliminary paragenetic sequence for this occurrence. Thin section petrography revealed textural and mineralogical information which forms the basis of the current working paragenetic sequence. Future work will expand to include other observed textural and mineralogical assemblages and provide nuance to the proposed paragenesis of the occurrence.

Tercio Nunes - PhD
tercioanunes@gmail.com

The Ni-rich Umburana and Vermelhos mineralized systems of the Curaçá Valley mineral district, Bahia, Brazil: Mineralogical constraints and evidence for crustal contamination. (216)

The Curaçá Valley district is well-known for Cu sulfide mineralization in Proterozoic mafic-ultramafic intrusions with unusually high Cu:Ni ratios. Despite the overall predominance of chalcopyrite-bornite-rich mineralization in mafic-ultramafic intrusions, Ni-rich mineralized zones have been identified within the Vermelhos and Umburana sulfide systems.

The Vermelhos deposits (Cu/Ni = ~6 to 40) are hosted in orthopyroxenite, norite, gabbro-norite and in lesser amount clinopyroxenite and websterite units. These units are comprised of variable proportions of magmatic orthopyroxene, clinopyroxene, plagioclase, apatite, monazite, phlogopite and various spinels, with the latter two occurring in high concentrations at Vermelhos. The early magmatic sulfides include pyrrhotite, pentlandite and minor Ni-tellurides. Chalcopyrite, various precious metals tellurides and electrum commonly occur filling corroded zones and fractures in the magmatic silicates, Cr-spinels and pyrrhotite. The Umburana deposits have lower Cu:Ni ratios (~0.1 to 8) and are hosted mainly in hornblende-websterite units, which are overlain by orthopyroxenite with minor mineralization. The Ni mineralization at Umburana is characterized by pyrrhotite-pentlandite-pyrite, and unlike in Vermelhos, chalcopyrite is only found in small amounts. In the mineralized unit, orthopyroxene and clinopyroxene are cumulus phases, whereas plagioclase, hornblende, minor phlogopite and local apatite (+LREE) are intercumulus. Pentlandite occurs in rims around pyrrhotite (forming loop textures in the high-grade zones) and both occur in sharp contact with chalcopyrite. Pyrite is found as large inclusions in the pyrrhotite-pentlandite rich zones, with the latter two filling in corroded zones in the former. Both the Umburana and Vermelhos systems exhibit evidence of complex interactions with wall-rocks, including abundant country-rock xenoliths surrounded by reaction margins that may indicate mixing and assimilation. "Pegmatoidal" bodies at the contacts between the mafic-ultramafic intrusions and gneisses are interpreted as partial melts of country rocks during intrusion emplacement.

We propose that mafic-ultramafic intrusions that host Cu-Ni mineralization containing spinels, phlogopite, phosphates and country rock xenoliths, formed from the contamination of mafic-ultramafic magmas with crustal rocks. Sulfur may have been introduced from country rocks (e.g., sulfide-bearing graphitic paragneiss at Umburana). Based on the mineralogical associations, the mineralization in the Umburana system represents crystallization from monosulfide solid solution (MSS), whereas Vermelhos was dominated by fractionated intermediate solid solution (ISS), overprinted by hydrothermal alteration.

200 Intrusion-Related Deposits

Jordan Peterzon - MSc
jpeterzo@lakeheadu.ca

Fault zone architecture in mafic-ultramafic protoliths at the Lac des Iles Mine, northwestern Ontario (217)

Fault zones are complex structures that produce an array of textures, fabrics, and architectures. A fault zone typically consists of 3 components: 1) a fault core where most of the slip has been accommodated, 2) a damage zone bounding the fault core where fracture density increases as distance to the fault core decreases, and 3) an undeformed and less altered protolith. Fault zone architecture has seen a great deal of study, but a focus on mafic-ultramafic rocks is lacking. This study examines fault zone architecture surrounding late brittle faults hosted in mafic-ultramafic rocks at the Lac Des Iles Mine, northwestern Ontario, Canada. Five drill holes that cross late reverse faults were logged and sampled in detail, with a fracture density counting program conducted systematically in the hanging wall and footwall. Fracture density increases exponentially with proximity to the fault core, with alteration increasing as well. Fracture density and hematite/epidote alteration are more intense in the damage zone when faults cut through tonalite than when faults cut through gabbro. Fault cores in tonalite display a range of textures from chlorite-rich gouges to fault breccias with calcitic matrix, while fault cores in gabbro only display chlorite-rich gouges. This implies that host rock lithology strongly affects fault zone structure, including alteration assemblages, fracture densities, and permeabilities. Permeability is a direct control on fluid flow which may allow for precipitation of ore minerals or their remobilization.

Marc Rochette - MSc
marcsrochette@gmail.com

Autoliths in the Parisien Lake Zone of the East Bull Lake Intrusion, Ontario, Canada: Implications on mineralization genesis and mineral exploration (218)

The East Bull Lake intrusion occurs approximately 80 km west of Sudbury, Ontario and hosts a widespread, disseminated sulfide mineralization that has been classified as contact-type PGE-Cu-Ni mineralization. Contact-type mineralizations occur at the base and margins of most of the co-eval mafic-ultramafic intrusions in the greater Sudbury region, though none of these occurrences have proven to be currently economically viable. The lowermost stratigraphic units of the East Bull Lake intrusion hosts Pd grades in the range of 1 - 10 g/t. The Pd mineralization is associated with poorly characterized epidote rich, sulfide-bearing autoliths in a gabbronorite matrix and a chalcopyrite-dominated disseminated sulfide mineralization. Narrowing the source and mechanisms of Pd enrichment in the mineralized autoliths will help develop a better understanding of the mineralization-forming processes and improve the potential for higher grade targets. Core samples were taken from seven DDH with >1.0 g/t Pd at the Central Parisien Lake Zone, which is >1.0 km2. DDH were quartered with half used for whole rock geochemistry and the remaining material was billeted for 54 thin sections. Optical mineralogy and automated mineralogy scanning electron microscopy (MLA-SEM) were used to analyze mineralogical and textural characteristics of the samples for in-situ trace element analyses. Laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was used to define trace element chemistry of sulfides and platinum group minerals (PGMs). The aim of these analyses is to identify PGE mineral hosts and to compare mineralogy of autoliths, host magmas and occurring lower in the stratigraphy. Initial findings indicate that Pd occurs mostly as a stoichiometric replacement in sulfides such as (in order of highest Pd concentration to lowest) pentlandite, chalcopyrite,

pyrrhotite, bornite, and pyrite. Palladium also occurs as a major element in platinum group minerals which occur near sulfides within the autoliths such as kotulskite (Pd(Te,Bi)), merenskyite (PdTe2), and other palladium tellurides and arsenides. LA-ICP-MS targeted sulfide minerals and PGMs near and within the mineralized autoliths, and from lower in the stratigraphy where sulfides occur as interstitial phases. The targets from lower in the stratigraphy are currently being analyzed, and the new data will help determine what, if any relationship exists between the mineralized autoliths and their host rocks. By further characterizing the mineralization-forming processes within the Parisien Lake Zone of the East Bull Lake we hope to develop more robust techniques for future exploration.

Erin Thompson - PhD
et201@leicester.ac.uk

Controls on PGE fertility in Bushveld magmas: Examples from the northern limb (219)

The platinum-group-elements (PGEs) are critical for the development of many modern day technologies, including electric vehicles and specialist alloys. As a result they have been labelled as 'critical metals' due to the dominance of only a handful of countries in their production, and their importance to the growth of sustainable and environmentally friendly technologies.

The Bushveld Complex, South Africa, is widely regarded as one of the world's largest resources of PGEs, containing two thirds of global reserves and resources. The Platreef forms the major PGE deposit in the northern limb of the Bushveld Complex, alongside significant quantities of base metals (Ni, Cu, Co). It is part of a complex package of Critical Zone rocks which have been mined at the Sandsloot by Anglo American since 1993. The Platreef differs to the wider Bushveld in that high grade PGE mineralization is spread over a much greater thicknesses compared to the Merensky Reef of the eastern and western limbs, as well as a higher Pd/Pt ratio. The Platreef also differs as it lies north of the Thabazimbi-Murchison lineament, and rests directly on the metasedimentary Transvaal Supergroup, and accompanying footwall structures. The magmas which formed the Platreef are believed to have been emplaced as discrete units, each with their own geochemical character and associated grades.

Previous studies have shown that the Platreef magmas have undergone two contamination events, both prior to, and post-emplacement. The post-emplacement event is known to have created significant variation in Platreef mineralogy and geochemistry along strike. However, debate remains as to which contamination event was critical to sulfide saturation and thus PGE mineralisation. In this study, the magmatic controls on PGE mineralisation are examined at Sandsloot and Tweefontein in the northern limb. This includes establishing the primary magmatic stratigraphy of the newly discovered deep Platreef, down-dip of the Sandsloot open-pit mine. Significant PGE and base metal mineralisation are observed in some, but not all of these packages. Varying degrees of local contamination is observed in packages in both locations, however this does not always correlate to PGE or base metal mineralisation. This study is among the first to examine Pb and Hf isotope systematics in the Bushveld setting, and combines bulk rock trace element geochemistry, as well as Sr, Nd, Pb and Hf isotopic data to examine the role of contamination, as well as magma source conditions, on the PGE fertility in the Platreef magmas.

200 Intrusion-Related Deposits

Laurence Hamel - BSc
lhame026@uottawa.ca

The Valley discovery: a new reduced intrusion-related gold system hosted in the Tintina Gold Province, eastern Yukon, Canada (220)

The Valley intrusion is a recent discovery located in the Selwyn basin (Eastern Yukon, Canada) and is thought to represent a reduced intrusion-related gold system (RIRGS). The Valley intrusion is part of the Tintina Gold province, which comprises the Tombstone-Tungsten belt (TTB), a group of mid-to late-Cretaceous plutons associated with Au+Bi+W+Te±Cu±Mo-mineralization. The TTB is divided into three plutonic suites with different magma characteristics: the Tombstone, Mayo and Tungsten suite. Preliminary data suggest the Valley intrusion is part of the subalkalic Mayo suite. To provide more insight into this deposit type, 21 drill core and field samples of the intrusion were examined petrographically and seven of them submitted for whole rock analysis. The intrusion is an equigranular to porphyritic biotite- and amphibole-bearing granodiorite with abundant titanite intruding Ordovician sediments with a hornfels carapace. Gold is hosted in quartz-carbonate veins surrounded by sericite ± chlorite alteration envelopes. Ore minerals occur in the veins and in the alteration haloes. The ore mineralogy of the veins was examined petrographically and by scanning electron microscopy (SEM) and their composition verified by energy dispersive X-ray spectroscopy (EDS). The quartz-carbonate veins contain scheelite, pyrrhotite, chalcopyrite, pyrite, arsenopyrite and marcasite as major ore minerals. The gold is late stage, with a purity of up to 96 wt.% Au. It is closely associated with a variety of Pb-Bi±Te-sulphides and native bismuth. The mineral assemblage suggests the veins were formed by up to 400°C, where CO_2-rich hydrothermal fluids with native bismuth potentially acting as a scavenger of Au.

300 Epithermal Deposits

Edward Baker - PhD
edward.baker@manchester.ac.uk

A Novel Approach to Proximitry (301)

Vectoring techniques for hydrothermal orebodies are vital to quickly localise deposits and plan efficient drilling campaigns. The current approach commonly uses mineral chemistry, e.g., critical element ratios or thermometry, to infer distance from deposit. A novel approach we present is to calculate the equilibrium fluid composition from the crystal chemistry, then use the fluid composition to vector. This study has applied a theoretical approximation to calculate fluid composition, calibrated the proximitor for a porphyry ore deposit. I have found a significant improvement in proximitor performance.

The method uses the fluid composition predicted by the strain partitioning model of Blundy & Wood, which was calibrated on both silicate liquids and hydrothermal fluids in the original experiments. The procedure accounts for the effect of temperature and ionic radii to estimate the original concentration of metals in the parental fluid. Thermodynamically, the approximation works because the work done deforming the lattice - by the cation - is greater than that of breaking ligand coordination bonds, found in geological fluids, or non-bridging cation bonds, found in silicate liquids; making lattice strain energy the dominant control. The proximitor then correlates ratios of trace elements with distance from a known deposit, as is common with existing proximitors.

I have applied this novel approach to an existing geochemical data set. In comparison to mineral based proximity approaches, the method shows a consistent trend from a greater distance and significantly improves fitting statistics. The theoretical approach could be further improved with experimentation and fluid inclusion sample analysis. Another line of work would specialise critical element ratios for deposit type to enable more accurate triage of fertility.

Joshua Ebner - MSc
jebner@mines.edu

The Epithermal-Skarn Transition at the La Colorada Deposit, Chalchihuites District, Zacatecas, Mexico (302)

The La Colorada deposit in the Chalchihuites District of Zacatecas, Mexico, features intermediate sulfidation epithermal (IS), carbonate replacement (CRD), skarn, and porphyry ores. The IS veins extend from overlying volcanic cover into underlying carbonate stratigraphy, with resources of 20.2 Mt including 127.7 Moz Ag, 124.6 koz Au, 0.2 Mt Pb, and 0.4 Mt Zn as of June 30th, 2022. Extensive drilling since 2018 by Pan American Silver has discovered a significant Zn-Pb-Ag CRD-skarn with porphyry Cu-Mo mineralization below the eastern part of the IS vein zone, with 243.7 Mt of resources containing 227.3 Moz Ag, 2.7 Mt Pb, and 6.1 Mt Zn (06/30/2022), ranking La Colorada among the top five Zn-Pb skarns in the world. The presence of CRD-skarn mineralization below IS veins at La Colorada and >20 other deposits in Mexico has incited interest in exploring for CRD-skarn-porphyry deposits beneath IS veins throughout the Americas. This study aims to investigate the relationship between the IS and CRD-skarn styles of mineralization at La Colorada to assess this exploration strategy. If the two styles are found to be transitional, this study will also identify vectors in the epithermal environment that can lead to CRD-skarn mineralization at depth.

The IS veins in the volcanic rocks have been found to cross the volcanic-carbonate boundary and extend downwards into carbonates in underground workings. The vein mineralogy is similar above and below the boundary, consisting mainly of quartz, calcite, pyrite, sphalerite, galena,

and native Ag, although the proportion of calcite increases downwards from the boundary and decreases upwards. IS vein/breccia zones that extend beneath the volcanic-carbonate boundary increasingly demonstrate textures akin to chimney-style CRD mineralization to depth. Illite crystallinity of white mica in the alteration halos of the IS veins based on SWIR (Short Wavelength Infra-Red) spectral analysis, which is a proxy for formation temperature, declined from 1.5 to 0.6 along a 1.5km transect away from the hypothesised position of the causative intrusion responsible for the skarn-porphyry ores. U-Pb dating of zircon and garnet, and K-Ar dating of illite is ongoing to constrain the age of the IS veins and skarn. Fluid inclusion microthermometry is also being conducted to confirm, refine, and extend the temperature gradient indicated by illite crystallinity.

Nima Esmaeilzadeh - MSc
nima.esmaeilzadeh174@topper.wku.edu

Application of principal component analysis and band ratios for critical minerals prospecting using multi sensor remote sensing data in the Mountain Pass Mining District, California. (303)

The Mountain Pass mining district, located in the northeast of the Mojave Desert in California, has a significant potential for exploring light rare earth elements and critical minerals due to its special geodynamic conditions and large carbonate platforms. This district hosts the Sulfide Queen rare-earth element (REE) mine, the only major REE ore producer in the United States. Evaluating images from the advanced spaceborne thermal emission and reflection radiometer (ASTER) and the Landsat-9 operational land imager indicates that several high-potential host rocks can be mapped in areas with good exposure using various image processing techniques. We used the principal component analysis (PCA) and band ratio (BR) techniques to generate the thematic layers using both the short-wave infrared (SWIR) and visible and near-infrared (VNIR) spectral bands of each satellite. In this investigation, several band ratio combinations were proposed and utilized to distinguish between different types of hydrothermal alteration zones using spectral bands from Landsat-9 and ASTER. The results reveal that the proposed methods can accurately map diverse hydrothermal alteration zones in the study region, including argillic, phyllic, and propylitic alteration hallows. Hydrothermal alteration zones associated with the Sulfide Queen rare earth element deposit and a new prospect zone were successfully detected and introduced in the study region using the PCA approach in ASTER data for future studies. The high correlation of the Landsat-9 resultant maps with ASTER results and previous remote sensing studies of the study area for mapping hydrothermally altered zones in the northeast Mojave Desert verified the potential of suggested band ratios and PCA techniques for spectral discrimination of various lithological units and hydrothermally altered rocks.

Natalia Goszczynski - BSc
ngoszczy@uwo.ca

Distribution and Textural Characterization of Tin in the Iska Iska Polymetallic Project, Bolivia (304)

The Iska Iska polymetallic project located in the Eastern Cordillera of the Bolivian Andes is a new discovery and the focus of ongoing exploration by Eloro Resources Ltd. It is situated in the southwestern part of the Eastern Cordillera geological province of Bolivia, which is endowed with several world class polymetallic mines and mineral deposits. The Bolivian tin belt has been a major producer of tin globally for the last century, but only limited research focused on tin

mineralization has been published over the last few decades. Tin mineralization occurs mainly as veins, vein breccia, subsidiary vein swarms, veinlets, stockworks, and disseminations, forming a subvertical vein system in intrusive, volcanic, and sedimentary rocks within a porphyry style system at depth and an epithermal style system near surface. The main tin-bearing mineral is cassiterite, associated with quartz and tourmaline mineralization in breccia pipes. Stannite has only been identified in a small portion of samples analyzed. Laboratory X-ray fluorescence (XRF) microscopy, scanning electron microscopy (SEM), and electron probe microanalysis (EPMA) were used to produce backscatter electron (BSE), energy-dispersive spectroscopy (EDS), and XRF element maps to characterize compositional and textural variation of tin mineral phases in ore assemblages. Tin distribution patterns and textures can be used as an indicator for targeting mineralization during exploration. Knowing what elements are associated with tin can benefit metallurgical design by streamlining milling and refining processes.

Duncan McLeish - PhD
duncan.mcleish@mail.mcgill.ca

The electrochemical flocculation of colloidal gold by semiconductive p-type pyrite at the high-grade Brucejack epithermal Au-Ag deposit, NW British Columbia: a solution to the bonanza gold ore paradox? (305)

A growing body of evidence suggests that bonanza-grade hydrothermal gold deposits (e.g., Brucejack) are formed by the physical transport of gold as a colloid (i.e., a suspension of ≤10 nm, negatively-charged nanoparticles in an electrolyte solution) rather than direct deposition from dissolved, aqueous Au-complexes. While there is general consensus that colloidal suspensions can explain how gold may be mobilised within hydrothermal systems at concentrations many orders of magnitude greater than those predicted by solubility models, there is little consensus regarding the processes by which colloidal gold suspensions aggregate (i.e., flocculate) to produce ultra-high-grade gold occurrences in hydrothermal veins. Detailed paragenetic observations at Brucejack show that ore-stage epithermal carbonate-quartz-electrum veins commonly host bonanza gold where these veins cross-cut earlier mesothermal pyrite veins. This observation, coupled with the discovery of abundant arsenic-rich growth zones in pyrite during laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), synchrotron micro X-ray fluorescence (SR-μXRF, and electron microprobe wavelength-dispersive X-ray spectroscopy (EMP-WDS) trace element analyses, offers insight into how such flocculation might occur. Specifically, we propose that charged surfaces on arsenian pyrite, which behave as p-type semiconductors (due to As substitution in the sulphide structure), promote cationic bridging and electrochemically destabilise colloidal gold suspensions circulating in the epithermal carbonate-quartz veins. This destabilisation triggers flocculation (deposition) of the colloidal gold particles and explains why, at Brucejack, many spectacular gold occurrences appear to have been triggered by the intersection of ore-stage veins with earlier pyrite veins. This genetic model can be used to predict the potential locations of bonanza gold from the block-modelled distribution of arsenic based on exploration and resource drill data. Compared with standard LA-ICP-MS analyses of pyrite, (SR-μXRF can be used to rapidly evaluate the presence/distribution of As in pyrite without the need for making thin sections (measurements can be done directly on drill core). In addition, synchrotron-based analyses can determine the speciation of trace elements which is not possible by LA-ICP-MS methods. Such information is useful in characterising the nanoparticulate vs. lattice-bound nature of the trace element anomaly (e.g. metallic vs. refractory Au).

300 Epithermal Deposits

Kingslei Medina - BSc
kim282@usask.ca

Pyrite in the Golden Marmot target, Brucejack Au-Ag deposit, British Columbia: Variations in texture, relationship to Au, and comparisons with the Valley of the Kings (306)

Pyrite is the most common sulphide mineral in hydrothermal mineral deposits, and the textural and compositional variations exhibited by pyrite can provide critical information about the evolution of a hydrothermal system. However, despite its abundance and long-recognized utility as a powerful geochemical tracer, only recently have studies started to explore the links between the textural and compositional features of this ubiquitous mineral with specific ore forming processes, such as boiling. Newcrest Mining's ultra-high-grade Brucejack epithermal gold-silver deposit in British Columbia's Golden Triangle region provides a unique opportunity to further investigate these links. Pyrite is the only sulphide mineral to have crystallized through every major ore and alteration event in the paragenetic sequence of the deposit. As such, it contains an unmatched textural and compositional record of the boiling and fluid mixing events that gave rise to bonanza-style electrum mineralisation in multiple generations of quartz-carbonate veins following an early, low-grade (invisible) gold-in-pyrite mineralisation event. Previous work has focused on the Valley of the Kings zone (VOK) where a close spatial association has been documented between older, arsenian pyrite and younger electrum mineralisation, leading to the suggestion that arsenian pyrite may have had direct control on the location of bonanza-style gold occurrences in the deposit. The focus of this project is to compare the pyrite from one of the other significant gold targets on the property (i.e., Golden Marmot) with the VOK. Twenty-five core samples were carefully selected and prepared for thin sections during the summer of 2022 and have been examined using transmitted and reflected light microscopy and backscattered electron (BSE) imaging.

Six texturally unique types of pyrite at Golden Marmot were identified, all of which appear to predate quartz-calcite-electrum veins: medium-grained disseminated pyrite, framboidal pyrite, fine-grained disseminated pyrite, coarse-grained locally porous brecciated pyrite, fine to medium-grained subhedral to anhedral pyrite, and inclusion rich with consistent periodic banding in a euhedral to subhedral pyrite. A distinctive texture in one pyrite generation is a recurrent rhythmic pattern of zoning, with corroded pyrite at the core, followed by inclusion-free and inclusion-bearing zones. Similar type of pyrite is observed in the VOK , where BSE imaging coupled with EMPA-WDS analyses has identified oscillatory zoned arsenian pyrite bands containing high levels of invisible gold. EMPA-WDS will be used to further constrain elemental composition of Golden Marmot pyrite to better understand its relationship with that of the VOK and the Brucejack system on a deposit scale.

Kevin Man Hoi Ng - PhD
man.h.ng@mail.mcgill.ca

The Origin of the Brucejack Bonanza-Grade Gold-Silver Epithermal Deposit, Northwestern British Columbia: Insights from Syn- to Post-mineralisation Dykes (307)

The absence of a recognized source intrusion for the auriferous vein system of the Brucejack epithermal Au-Ag deposit, in the Golden Triangle of northwestern British Columbia, poses a challenge for constraining the timing and origin of the mineralisation. However, the volcanic and volcaniclastic rocks hosting the ore are commonly cut by dykes believed to be syn- to post-mineralisation. This provides an excellent opportunity to address this challenge. The syn- to late-mineralisation phase I mafic dykes exploit the steeply dipping mineralised structures and

continue at depth. As the closest expression of magmatism that may be genetically linked to gold mineralisation, these dykes could potentially target and fingerprint the source of the fluids and mineralisation at Brucejack.

In this paper, we present a summary of the geochemical characteristics of the above dykes with the objective of gaining insights into the magmatic evolution of the potential source of the bonanza-grade gold mineralisation. Six types of dyke have been classified in the Brucejack deposit, based on 1) immobile-element (i.e., rare-earth element, high-field-strength element) concentrations and ratios; 2) enriched mid-oceanic-ridge basalt-normalised rare-earth element distributions; 3) spatial distribution and crosscutting relationships with mineralisation.

Discrimination diagrams suggest a geochemical affinity ranging from subalkaline basalt for the syn- to late-mineralisation dykes, to basaltic-andesite and basalt for the post-mineralisation dykes. Systematic differences in rare-earth element profiles (i.e., ΣREE, [La/Yb]N), and the concentrations of other high-field-strength elements suggest an enriched magma source that could possibly have been generated during rifting. The discrimination diagrams also suggest a genetic link between the syn- to late-mineralisation mafic dykes intersected in deep drillholes and those occurring within high-grade mineralised corridors in the current mine workings.

Ethan Placek - BSc
eplacek@uwo.ca

Characterization of Alteration, Mineralization and Mineralogy at the Wildcat Low-Sulphidation Epithermal Gold-Silver deposit, Nevada (308)

The Wildcat low sulphidation epithermal gold-silver deposit is located in the Farrell Mining district which is ~55km north of Lovelock in northwestern Nevada. Oxide mineralization is hosted in a 14.8 ï‚± 0.2 Ma volcaniclastic rhyolite tuff on top of the biotite granodiorite basement.

Exploration for low sulphidation epithermal gold deposits can employ a variety of different techniques to classify the critical aspects of the deposit, including optical microscopy, synchrotron x-ray diffraction (SR-XRD), and electron microprobe analysis (EPMA). At Wildcat, the aforementioned techniques were used in conjunction to determine the alteration, mineralogy, and mineralization which can provide significant value. These techniques can produce information quickly without the need for any substantial sample preparation, the information can then be used to explore for high-grade feeder zones or areas with potential for significant ounces. A suite of thirty-eight pulps and rejects was examined using SR-XRD and 16 thin sections from 8 core samples were examined using optical microscopy plus EPMA.

The mineralogical make-up of the main ore body is primarily quartz with significant amounts of adularia present. Alteration is defined by the presence of several different temperature sensitive clay minerals including kaolinite, montmorillonite, nontronite, dickite, smectite, beidellite, and halloysite. Further alteration present is also classified by jarosite, goethite, and muscovite. Classification of the clay minerals can provide significant exploration value, as clays can be used to determine where areas of increased heat and fluid flow may have been, allowing for vectoring toward prospective high-grade zones. Mineralization is defined primarily by pyrite, iron and titanium oxides, plus other minor minerals including arsenopyrite, pyrrhotite, barite, molybdenite, galena, chromite, and cerium oxides. Preliminary results indicate that high grade samples are possibly associated with silicification, quartz veins and veinlets plus increased levels of smectite and kaolinite minerals. Additionally, these samples contain elevated levels of sulphides, mainly pyrite + arsenopyrite + molybdenite, compared to the lower grade samples.

300 Epithermal Deposits

Catherine Suclan - MSc
csucl094@uottawa.ca

Mafic volcanism contemporaneous with the Mineralization at the Hishikari deposit, Japan (309)

The Hishikari epithermal gold deposit (409t Au) is a high-grade low-sulphidation epithermal gold deposit where the high grade veins of Honko and Sanjin Zones formed 1.11-0.75 Ma. The gold veins are hosted by the Cretaceous Shimanto metasedimentary rocks, which are overlain by the Hishikari Lower Andesites (1.62-0.84 Ma), Hishikari Middle Andesites (~0.78Ma), Shishimano Dacites (1.1-0.66 Ma), Hannyaji Rhyodacites (0.7-0.6Ma) and Hishikari Upper Andesites (0.58-0.51Ma). The Hishikari Lower Andesite is contemporaneous with mineralization and is composed of lavas and pyroclastic rocks with andesite and basaltic andesite composition. Samples show a negative sloped chondrite-normalized REE pattern with elevated light REE up to 100 times of chondrite values. The basaltic andesite is Mg-rich (MgO ≥ ~ 3.0wt%) where olivine phenocrysts (76Fo, 0.05wt% NiO, 0.13wt% CaO, ~0.35wt% MnO) are common in the pyroclastic rocks 1.5 km east of the mine and lavas ~ 12 km west of the mine. These volcanic rocks also contain phenocrysts of plagioclase (~An60), zoned augite (Mg#77), hypersthene (Mg#67, En65), magnetite (9.64wt% TiO2) and apatite in a groundmass of glass, plagioclase laths, and two pyroxenes. The andesite lavas contain phenocrysts of plagioclase (~An64), compositionally zoned augite (Mg#64) and hypersthene (Mg#60, En61), magnetite (~12.0wt% TiO2), ilmenite (13.6 % hematite component) and apatite. Abundance of Mg and Mn show that Fe-Ti oxides are in equilibrium, yielding ~ 820 oC. The data suggests slow cooling of lava. The oxidation conditions, FMQ+1.1, based on Fe-Ti-oxides, are lower than fO2 values of ~ FMQ+2, for younger units in the area, such as Hannyaji Rhyodacite. The Fe2+/Mg ratio of olivine (Fo76) is in equilibrium with that of the bulk rock composition assuming 90% Fe2+, confirming that olivine is a phenocryst. Inclusions of Cr-magnetite (1.58 % Cr2O3) in olivine and high Mg contents of olivine suggest an injection of a high temperature, mantle-derived mafic melt during mineralization.

Lauren Zeeck - PhD
lzeeck@mines.edu

Microtextures of precious metal-bearing quartz veins from low-sulfidation epithermal deposits: evidence for the occurrence of fluid flashing (310)

Low-sulfidation epithermal precious metal deposits form in the shallow crust, typically less than 1 km below surface, from near neutral, low-salinity fluids. These deposits frequently contain ore minerals in dendritic arrays within colloform banded quartz-rich veins. High-magnification optical microscopy and micro-XRF mapping show that ore minerals occur within certain bands that are commonly less than one millimetre thick. Examples from the McLaughlin deposit in California and the Sleeper deposit in Nevada show that these bands containing the ore minerals are composed of microspherical opal-A, or have been partially recrystallized to quartz. The quartz that formed as a result of maturation of the noncrystalline opal-A is microcrystalline and characterized by mosaic texture. Original ore mineral textures also can be modified as the opal-A is converted to quartz. The primary textures in the vein samples studied suggest that the deposition of the mineralized bands occurred rapidly under nonequilibrium conditions. It is proposed that precipitation occurred during discrete events of fluid flashing. The production of variable amounts of vapour during these events destabilizes precious metal-carrying complexes and triggers the supersaturation of silica in the coexisting liquid.

400 Volcanogenic Massive Sulfide (VMS) Deposits

Thomas Gemmell - PhD
tgemmell@laurentian.ca

Volcanic evolution and differential base metal endowment of the Swayze area, Abitibi greenstone belt, Ontario – An update (401)

The Swayze area of the western Abitibi greenstone belt (AGB) contains most of the chronostratigraphic metavolcanic episodes present in the metal-endowed eastern AGB; however, fewer ore deposits have been discovered. New mapping, lithogeochemical and geochronological data, in conjunction with Metal Earth geophysical surveys, have resulted in a new interpretation of the crustal architecture for the Swayze area. Although the Swayze area contains the oldest and youngest AGB volcanic episodes, significant differences include: 1) an absence of Tisdale (2710-2704 Ma) volcanic rocks, 2) an abundance of Pacaud (2750-2735 Ma) and Blake River (2704-2695 Ma) volcanic rocks, with the latter lacking volcanic centres containing subvolcanic plutons 3) an absence of ultramafic rocks in all volcanic episodes except for the Blake River; 4) anomalously thick (up to 200m) and extensive (up to 20 km) intra-volcanic episode iron formations which contain the known base metal mineralization, and 5) significant inherited zircons compared to volcanic rocks of the eastern AGB. These differences, together with the thicker crust of the Swayze area compared to the eastern AGB, suggest that a volcanic evolution characterized by fewer and intermittent volcanic episodes and punctuated by long volcanic hiatuses during which iron formations containing the known base metal prospects (e.g. Shunsby and Jefferson) are deposited, are less favourable for VMS formation.

Charles Lapointe - MSc
clapointe@mun.ca

The Aurora Vent Field, Gakkel Ridge: First geological exploration of a seafloor hydrothermal system in the Arctic Ocean (402)

Hydrothermal activity is common at mid-ocean ridges, where shallow magmatism drives convective seawater circulation through permeable crust. The heated fluid leaches metals from the host rock, transporting them to the seafloor where, upon mixing with cold seawater, metal-rich sulfide and sulfate minerals precipitate at hydrothermal vents, forming chimneys and mounds. This process can lead to the formation of seafloor massive sulfide (SMS) deposits, which represent modern analogues for volcanogenic massive sulfide deposits found on land today.

The ultraslow-spreading Gakkel Ridge in the Arctic Ocean remains one of the least explored mid-ocean ridges, owing to the remote, harsh, ice-covered conditions associated with its high-latitude location. The Aurora Vent Field is located at a depth of ~3900 m on a broad ~300 m high volcano at the southwestern terminus of Gakkel Ridge. In 2021, scientists performed the first successful direct sampling of hydrothermal vents on the Gakkel Ridge during the HACON21 expedition on the Norwegian Icebreaker Kronprins Haakon. Using the remotely operated vehicle (ROV) Aurora Borealis, 15 rock samples along with 12 hours of high-resolution video footage were collected from the seafloor as part of a multidisciplinary geological, geochemical and biological survey and sampling of the vent field.

Here, we present the first geological map of the Aurora Vent Field, informed by visual analysis of the video footage in conjunction with 20 m-resolution multibeam sonar bathymetry and the ultrashort baseline positioning system on board the ROV. The site consists largely of inactive and collapsed hydrothermal sulfide edifices on a sedimented pillow basalt substrate. Three active ‘black

smoker' vents occur within a ~10 m diameter cluster located near the center of the vent field. We also present preliminary results of the mineralogical and geochemical characterization of the hydrothermal deposits, based on thin section, X-ray diffraction, and bulk chemical analyses of the collected rock samples. The results of these analyses will provide insights into hydrothermal ore-forming processes and the SMS resource potential along the Gakkel Ridge, as well as the geological controls on the vent-associated macrofauna and microbial communities, the composition of the sub-seafloor volcanic substrate and the style of rifting along this segment of the Gakkel Ridge. Finally, we describe some of the unique challenges posed by the collection and interpretation of data and samples from an area overlain by perennial sea-ice.

Ryley Penner - MSc
rpenn090@uottawa.ca

Trace Element Fingerprinting of Ore Mineral Separates: Implications for Volcanogenic Massive Sulfide Endowment (403)

The Neoarchean Abitibi Greenstone Belt (AGB) of the Canadian Superior Province hosts world-class Au and base metal (Cu-Zn-Pb) volcanogenic massive sulfide (VMS) deposits with geological features reflected in the trace element signatures of their ores. This study investigates how trace element patterns in mineral separates from >50 VMS deposits reflect both small- and large-scale geochemical behaviour that may be influenced by host rocks and correlate with base/precious metal grades and deposit tonnages. The study focuses on the analysis of pyrite comparing similar ore types between the different deposits of the AGB. We used unsupervised machine-learning methods to characterize the pyrite chemistry in samples from VMS deposits in different settings. The statistical analysis shows that certain labile trace elements in pyrite are a useful fingerprint of the different mineralizing systems, with different enrichments and depletions reflecting the source and temperature controls on the deposits. Pyrite from large-tonnage deposits commonly have the highest Sn possibly reflecting extensive leaching of felsic host rocks by hydrothermal fluids, although Sn co-enriched with Bi and In from large siliciclastic-felsic type deposits in younger terranes suggests a magmatic input. Pyrite from Au-rich VMS deposits (e.g., Horne, Quemont, and Bousquet #2-Dumagami) have anomalous Te often co-enriched with Bi, Se, In and Sn that may similarly reflects a felsic magmatic source and possibly a crustal heritage that favours precious metal endowment in the Blake River Group. We also compare mineral separates of individual grab samples to similar data on much larger bulk samples from the same deposits (i.e., monthly concentrates representing tens of thousands of tonnes of ore). The trace element distributions in pyrite mineral separates agree well with monthly bulk concentrates (pyrite tailings) from the same deposits. Similarly, trace elements concentrations in chalcopyrite samples prepared from the grab samples are comparable to those in the monthly composites of Cu concentrates from the mill giving us confidence that the ore samples provide a first-order geochemical fingerprint of the deposits as a whole. Our findings demonstrate that a limited number of mineral separate samples from a single deposit or district can reflect large-scale influences on the whole system, such as the composition of the leached volcanic rocks and the nature of the hydrothermal fluid. This has important implications for exploration, wherein a few samples of exposed mineralization may record defining attributes of nearby deposits, including metal endowment.

400 Volcanogenic Massive Sulfide (VMS) Deposits

Kyle Powers - MSc
kpowers@eoas.ubc.ca

Strontionite Enrichment as Identified by Micro-XRF; Exploration Implications at Mountain Boy Minerals' BA VMS Deposit of NW British Columbia. (404)

The BA Pb-Zn-Ag-Au VMS deposit is located in the Golden Triangle of NW British Columbia. The property is owned by Mountain Boy Minerals, which has been exploring and developing the resource since the late 2000's. In this study, historic drill core was sampled during the 2022 summer field season. Data was acquired Bruker Tornado micro-XRF data was analysed and filtered for over 15 key elements. By overlaying elements maps, major rock forming minerals can be identified. Trace and accessory minerals such as Strontionite ($SrCO_3$) can be confirmed using known x-ray fluorescence spectra and mineralogy. Micro-XRF results were then compared spatially against mineralization both down drill hole and regionally across the property. Calcite veins were described in drill core without any known significance to mineralization. Elemental maps and spectra produced by the micro-XRF, from these veins / stratabound layers returned very high counts of Sr, with only traces of Ca. Strontium observed in micro-XRF imagery sharply increases immediately below massive mineralization and into the footwall. Sr is correlated with Zn. More significantly important to exploration, Sr is elevated 2km distal from the ore zone, and appears to mark an alteration footprint within the footwall of the hydrothermal system.

David Summer - PhD
david.summer@mail.utoronto.ca

The Tectonic Evolution of the Jean Charcot Troughs: A Remote-Predictive Mapping Approach (405)

The opening of backarc basins behind trench-ward migrating volcanic arcs are common in intra-oceanic subduction zones. However, little is known about the tectonic processes involved during the initiation and progression of nascent backarc basin opening prior to the establishment of stable seafloor spreading by passive mantle upwelling. This study addresses the question: what is the geodynamic evolution of the over-riding plate during the early stages of backarc basin development? To answer this, the geodynamic history of the Jean Charcot Troughs (JCT) in the Solomon-Vanuatu subduction zone is evaluated with respect to tectonic complexities specific to the region, including slab roll-back, a sharp bend in the north end of the subduction zone, and ridge/plateau collisions to the south. The JCT is a ~350 km long and ~100 km wide region of discontinuous horst and graben structures featuring variably oriented lineament fabric, notably, normal faults and fissure eruptions. Using a novel remote-predictive mapping approach, a 1:100,000 structural map of the JCT has been produced via integration of the breadth of available geophysical datasets including high resolution ship-track bathymetry, satellite altimetry, magnetic and gravity anomaly, and vertical gravity gradient data. Morphotectonic and lineament classifications are accomplished via visualization in an ArcGIS workflow. Changes in the regional stress regime are revealed in rose diagrams and lineament orientation maps and are interpreted from the crosscutting and superposition relationships of mapped features. Fault kinematics in seismically active areas are resolved using shallow earthquake focal mechanism data. Preliminary results reveal three stages of backarc basin opening including an arc breakup stage, an east-west rifting stage and a presently active transtensional rifting stage, which accommodate counterclockwise rotation of the arc. Arc migration is accommodated at the northern termination of the JCT along crustal-scale dextral faults, thereby producing a microplate boundary with an oceanic plateau to the north. This study will produce the most comprehensive synthesis of the tectonic evolution of the JCT and lend insight into the earliest phases of backarc basin opening.

400 Volcanogenic Massive Sulfide (VMS) Deposits

Jonathan Umbsaar - PhD
jonathan.umbsaar@mail.utoronto.ca

The hydrothermal history of the VOLPA Seafloor Massive Sulfide Deposit, SW Pacific (406)

The Volcano P Site A (VOLPA) deposit is a previously uncharacterized Seafloor Massive Sulfide (SMS) deposit that is located on the southern end of the Niua Volcanic Complex, which is an irregular arc volcano composed of coalescing volcanic ridges and accompanying fissures, craters and volcaniclastic mounds. This volcano is located at the northernmost end of the Tofua Volcanic Arc, along the Tonga-Kermadec Trench in the SW Pacific. SMS deposits form through circulation of hydrothermal fluids in the underlying oceanic crust, which are driven by the anomalous geothermal gradients of the imposing magma bodies associated with the arc volcanoes. Circulation of seawater, and influx of magmatic volatiles collectively produce a fluid that is relatively high temperature, acidic, and reducing, which are favourable conditions for the transport of metal cations, that tend to precipitate either via boiling or when mixing with seawater. These deposits are enriched in a variety of critical metals, and represent a modern analogue to Volcanogenic Massive Sulfide (VMS) deposits which are most commonly mined on land for copper, zinc, lead, silver, and gold, but can also host a variety of critical metals, including As, Bi, Cd, Ga, Ge, In, Hg, Sb, Se, Sn, Te, Tl, and W. VOLPA is an interesting case study as it is composed of especially barite-rich chimneys, in sulfur-encrusted host rocks of variable permeability, resulting in deposit scale zonation of mineral abundances. The presence of high-sulfidation-state mineral assemblages, and the anomalous metal enrichments and depletions present at VOLPA have implications for the provenance, precipitation, and transport mechanisms of the metal cations. Petrography, elemental mapping, and whole-rock geochemistry have allowed for classification of the chimney types across VOLPA, which display consistent critical metal abundances, with implications for hydrothermal processes such as boiling, seawater mixing, magmatic volatile influx, as well as the pH, temperature, and REDOX conditions of the hydrothermal vent fluids. The conclusions of this research indicate that the distribution of critical metals across VOLPA are largely dependent on host rock permeability, depth, and the influx of magmatic volatiles, in addition to adsorption, colloidal gold transport, and structural influences. These results can be directly compared to adjacent SMS deposits such as Niua South and the Brother's Volcano, as well as the analogous but ancient VMS deposits that are actively mined on land.

Kelsie Ojaste - BSc
kelsie.ojaste@icloud.com

Tellurides and trace elements in pyrite in Abitibi VMS deposits (407)

The Abitibi Greenstone Belt is one of the largest and best-preserved Neoarchean belts, hosting world-class Au and base metal (Cu-Zn-Pb) volcanogenic massive sulphide (VMS) deposits. This study investigates trace elements found both in the form of discrete tellurides (and similar minerals) and in situ in pyrite. The focus is to examine the composition of tellurides and trace elements in pyrite by comparing similar ore assemblages in the different VMS deposits of the Abitibi. To provide further insight, 33 historical polished sections from 15 Abitibi VMS deposits were examined petrographically. The telluride compositions were investigated using a combination of ore microscopy, scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). Trace element analysis on pyrite grains was conducted using laser ablation inductively coupled mass spectrometry (LA-ICP-MS).

Samples from the different Abitibi VMS deposits contain common tellurides including petzite, hessite, tellurobismuthite, calaverite, stützite, altaite, as well as native bismuth, silver, and gold. The Au±Ag±Bi±Pb-tellurides occur as discrete inclusions in chalcopyrite, pyrite, and pyrrhotite, and as nanoparticles within pyrite. Rare Te-rich canfieldite [Ag8Sn(S,Te)6] with 18wt.% Te was found in the Corbet deposit. Additionally, samples from the Au-rich VMS deposits (e.g., Horne, Bousquet, LaRonde) contained hitherto unreported occurrences of volynskite, muthmannite, and tetradymite. Trace element analysis of pyrite from each deposit display a wide range of trace elements (Co, Cu, Zn, Sn, Ag, Au, Pb, Bi, As, Sb, Te) present in pyrite, that vary widely throughout the grain (except for pyrite from Bousquet and LaRonde, which has very homogenous trace element distributions). Elevated Cu, Zn, Pb, As, and Ag in pyrite are due to discrete inclusions of chalcopyrite, sphalerite, galena, arsenopyrite, native Ag and Ag-tellurides. Most pyrites are significantly enriched in Te and Bi. The Te is concentrated within the pyrite core, often in association with elevated Cu due to chalcopyrite inclusions. The findings will provide a further understanding of how minor and trace elements are distributed in (Au-)VMS ore, with implications for future exploration.

Pei Yang - Postdoc
yangp37@mcmaster.ca

Delineation of ore-bearing deposits in Bathurst Mining Camp, NB, based on structural analysis and 3D FTG data inversion (408)

The Bathurst Mining Camp (BMC) in New Brunswick is one of Canada's oldest mining areas for volcanogenic massive sulphide (VMS) deposits. Although numerous previous works on VMS within the BMC have performed by using various geophysical data in the region, however, the distribution, geometries, and dimensions of the volcanogenic massive sulphide (VMS) deposits in the BMC as well as their evolution through time remain uncertain due to the limitations of vintage geophysical datasets and the complicated tectonic evolutionary history of the BMC. Integration of multiple high-resolution geophysical datasets is needed to get a better understanding of features of ore-bearing deposition of BMC to lead to more targeted exploration success. In this study, a regional-scale lineament analysis of the BMC using Full-Tensor Gradiometry (FTG) and magnetic datasets is first conducted. Then, 3D inversions of FTG data is carried out to obtain the density in subsurface. Next, key signature patterns that are diagnostic of specific ore-bearing geological features (e.g., VMS) are established by integrating lineament analysis and 3D FTG data inversion. Finally, this study not only reveals more detailed lineament patterns related to the tectonic evolution of BMC, but also demonstrates the advantages of FTG data for mineral exploration.

500 Sedimentary Environments

Brendan Bishop - PhD
bab495@uregina.ca

Lithium and rare earth element potential of the Western Canada Sedimentary Basin (501)

Due to their role in the clean energy economy, the price and demand for critical minerals including lithium (Li) and rare earth elements (REE) have increased substantially in recent years. They are among six metals identified as high priority in Canada's critical mineral strategy since we currently lack domestic production. Further, due to the onerous permitting and regulatory framework, it may take decades before domestic production of these metals begin which can have detrimental economic consequences and affect efforts to meet climate change goals. In light of these issues, there has been significant interest in extracting these metals from new sources.

This work investigates the Li and REE potential of basinal brines and coal combustion by-products (CCBs) of the Western Canada Sedimentary Basin. There has been increasing interest in recent years concerning the extraction of Li from basinal brines which has led to the burgeoning Li industry in western Canada. While Li concentrations have been measured in several formations across the basin, REE concentrations have yet to be determined. Furthermore, the sources of these metals are poorly constrained. As such, this study presents the first REE data for these brines and examines the sources of Li and REE enrichments in WCSB brines. The results indicate that Li enrichments in Frasnian-aged formations (i.e Duperow, Leduc, and Nisku Formations) may be more widespread across the basin than initially thought and both Li and REE could be sourced through water-rock interactions.

Coal waste, including fly ash and bottom ash (together CCBs), have received significant attention as a potential source of REE in the USA and China, however the metal potential of Canadian CCBs have yet to be thoroughly investigated. The second phase of this study involves assessing the REE potential of CCBs from coal-fired power plants in Alberta and Saskatchewan via geochemical (i.e. acid leaching and sequential extractions) and synchrotron x-ray absorption spectroscopy (i.e. XANES and XAFS) characterization. The geochemical study indicates that CCBs with elevated Ca content have a superior extraction potential, while XAS indicates that the REE are primarily hosted in phosphate and silicate minerals. The recovery of Li and REE from the WCSB can provide a near-term source of these metals required in the energy transition while providing new employment opportunities in western Canada.

Kathryn Cheng - BSc
Kathryn.cheng@utoronto.ca

Assessing the use of Hg and Hg stable isotopes during major global perturbations that may or may not have been associated with volcanism (502)

Large amounts of mercury (Hg) and carbon are released from volcanism, thus, Hg chemostratigraphy can be used to understand the relationship between volcanism and major carbon perturbations. Although four of the five biggest mass extinctions and global carbon perturbations were associated with large igneous provinces (LIPs), it is difficult to determine if volcanism was the reason for the mass extinctions and major carbon perturbations because evidence of LIPs is generally unavailable in sediment samples.

Carbon perturbations are also associated with major environmental perturbations, such as Paleocene-Eocene Thermal Maximum (PETM). The PETM is characterized as a period of rapid

carbon emissions and global warming, approximately 56 million years ago. In this project, we investigated PETM sediments from near hydrothermal areas. Mercury is enriched in hydrothermal systems due to leaching of Hg-containing materials in hot fluids. Previous studies show that Hg isotopes undergo substantial mass dependant fractionation in hydrothermal systems during several processes including the precipitation of Hg in siliceous sinters and during the volatilization of Hg0(aq) to Hg0(g).

The objective of this thesis is to evaluate Hg and Hg isotopes as paleo proxies over known major perturbations in the carbon cycle that may or may not have been associated with large scale volcanism. Both Hg concentrations and isotopic compositions of PETM hydrothermal sediments and the hydrothermal igneous rocks were measured in this study. An atomic absorption spectrometer was used to measure the total Hg in sediment samples, and a multi-collector inductively coupled plasma mass spectrometer (MC-ICPMS) will be used to measure Hg isotopes. Preliminary concentration measurements show elevated Hg levels (71 ppb to 723 ppb) with an average concentration of 273 ppb. These are quite elevated compared with other types of marine sediments with no volcanic or hydrothermal inputs (generally below 100 ppb).

Chakib Naoufel Groucene - PhD
chakib.groucene@gmail.com

Heavy Minerals in the Djebel Hech and Tabelbala Areas (Ougarta Range - SW Algeria) (503)

The Ougarta Range is a NW–SE-oriented unit that formed on an asymmetric rift and consists mainly of thick siliciclastic Palaeozoic rocks. The Lower Ordovician formations start with an argillaceous inner-shelf formation that is overlain by thick sandstone-dominated sequences (Kheneg El Aatène Fm.). These sequences locally display significant radioactive anomalies detected by air-borne gamma-spectrometric exploration campaigns carried out along the range. These anomalies have been verified on field investigations and concluded that elevated concentrations of Thorium are related to heavy minerals deposition in a coastal environment. However, the specific minerals that host the majority of Th (and other elements of economic interest) are not known. This study documents the assemblages, textures, and compositions of heavy minerals in these Th-rich sandstone horizons; this information is crucial for establishing the provenance and economic prospectivity of these sandstone sequences.

This study focuses on two of the most important anomalies hosted in Lower Ordovician formations: Djebel Hech in the south-eastern edge of the Ougarta Range; and Tabelbala in its north-westernmost limb. Stratigraphically these two areas are similar and consist mainly of quartz-rich sandstones with minor variations in grain size and maturity. Radioactive horizons of Djebel Hech are hosted in moderately-sorted mature orthoquartzites with siliceous cement. Horizons in the Tabelbala contain very-well sorted and fine quartzose sandstones with minor muscovite grains.

Based on microscopy, the heavy mineral assemblage is analogous at both sites, but the distribution of heavy minerals is different. In the Djebel Hech formation, heavy minerals are concentrated in microscale planar beds. By contrast, heavy minerals in the Tabelbala formation are randomly distributed. Refractory minerals such as zircon, tourmaline and rutile dominate this assemblage, generally displaying a euhedral to sub-rounded grains, as well as generally rounded REE-bearing minerals. Additionally, titanium oxide polymorphs were identified via Raman Spectroscopy as rutile, anatase and brookite.

After crushing, sieving and cleaning samples, the fraction below 250 µm was selected for heavy minerals separation. Future work will identify the heavy mineral assemblage using Scanning Electron Microscope (SEM) coupled with an Energy-Dispersive Spectroscope (EDS) and trace elements will be measured with a Quadrupole LA ICP-MS. These new data will quantify the concentrations of elements of economic interest (Th, REE) and will be used to constrain provenance and economic significance of these anomalously radioactive sandstone horizons.

Danielle McGill - MSc
danielle.mcgill@mail.utoronto.ca

Geology and geochemistry of the shale-hosted vanadium mineralization at the Van property, Northwest Territories (504)

Vanadium (V) is an increasingly important critical element, in part due to its use in vanadium redox flow batteries, a technology that will support the transition towards a green economy. To provide for this need, the discovery and development of new deposits is essential. The Van property, located in western Northwest Territories, contains several showings of shale-hosted V in the lower Ordovician to Devonian Duo Lake Formation of the Road River Group. The dominant structure of the area is a large-scale NW-trending, upright fold, and mirrored stratigraphy can be seen on either side of the valley floor. The genesis of this style of V mineralization is poorly understood and the mineralization at the Van property has not been characterized in much detail.

We will present geological observations from a field visit in summer 2022, which provide important context for understanding of the sedimentary environment and structural setting of the shale which hosts V mineralization. Approximately 100 samples were collected systematically from two sections of host strata at the Janice and Jim creek showings. An additional 28 samples were collected from around the property, including older rocks of the Road River Group and younger rocks of the Earn group. Initial geochemical analysis performed on the collected samples using a portable X-ray fluorescent analyzer found concentrations of V averaging at approximately 0.7 wt. % with some samples containing as much as 3 wt. % V. Optical and scanning electron microscopy will be used to identify the V-bearing minerals in the deposit and any alteration associated with V mineralization. Results will be used to develop a model for deposit formation, which will support future exploration efforts. This work will also have important implications for how V can be effectively and efficiently extracted during mining.

Megan Swing - PhD
megan.swing@mail.utoronto.ca

Measurement of sulfur isotopes using nanoscale techniques from sedimentary pyrite framboids (505)

Sedimentary pyrite has been hypothesized to be an important source of gold in orogenic systems. To better understand what factors may affect the concentrations of gold in pyrite the process of the formation of sedimentary pyrite needs to be explored in detail. In marine ecosystems, pyrite (FeS2) forms as spherical clusters of microcrystals, but the exact mechanisms of formation are poorly understood. Studies have shown these clusters, or framboids, are capable of recording water column chemistry of their environment during stages of crystallization. In low oxygen conditions sulfate (SO42-) is utilized instead of O2 for respiration, producing H2S which is ultimately incorporated in sulfide minerals, predominantly pyrite. As this pyrite forms in an open system, it is significantly lighter than the original sulfate, as

it is energetically favourable to use the lighter isotope (32S). Studies have also shown that S-isotope fractionation is related to the rate of reduction, and low rates using H2 exhibit lower fractionations. Differences in isotope concentrations may provide detail not only on the formative environments, but the types of microorganisms that may have been present at a given time. This makes the study of S-isotopes extremely important for analyses of anoxic ocean sediments and the evolution of S metabolism. Recently, TEM analyses by Gregory et al., from the Cariaco Basin and the Demerara Rise have shown that there is significant variation of trace elements in different parts of pyrite framboids. The relative timing of this later trace element enrichment and its relation to S-isotope ratios is unknown.

In the present study, sediment samples were taken from two sites located in Saanich Inlet (Vancouver Island, BC) – a seasonally anoxic fjord – as the cyclic nature of the site provided chemically distinct conditions over a relatively short period of time. On average, framboids are ~10 µm in size, making nanoscale analyses critical to observe variations within a single framboid, indicative of periods of growth. This study employed the use of nano secondary ion mass spectrometry (SIMS) to identify heterogeneity in S-isotopes within and between pyrite framboids to better understand the mechanisms involved in their crystallization. The nanoSIMS results will be compared to measurements collected via atom probe tomography (APT) to further develop the methods required to measure S-isotopes at the nanoscale using APT. Results will be discussed through the comparison of different sizes and shapes of framboids found at varying sediment depths from the two sites.

Ozgur Can Tekin - MSc
tekinozgurcan@gmail.com

Understanding the formation conditions of Selwyn Basin by studying redox state of Vanadium (506)

Vanadium is a metal that is used in several ways to support the transition to green energy. One of the most significant ways it is used is in vanadium redox flow batteries (VRFBs). These batteries are well-suited for large-scale energy storage, which is an important component of integrating renewable energy sources such as wind and solar power into the electrical grid. Another application is in the steel industry, V can be added to steel to make it stronger and more durable. This is significant in the production of wind turbines, transmission towers and high-rise building construction. It also has a positive impact in reducing the energy used in the production process and improving its lifecycle. Exploration for new V deposits is ongoing globally, with new deposits being discovered and developed in a variety of geologic settings. The discovery and development of new vanadium deposits in Canada are important to meet the growing demand for this important metal.

This project focuses on two sides located in the Selwyn Basin. The Selwyn Basin is a sedimentary basin known to have vanadium enrichments in Hyper-enriched black shales (HEBS). However, the source of HEBS is still debated. The enrichment is usually linked with either direct precipitation from seawater or seafloor hydrothermal activity. This will investigate the redox state of vanadium in HEBS. The redox state of V in HEBS can provide information about the depositional environment, the source of fluids that transported vanadium, and the conditions under which the vanadium was deposited. We will use X-ray absorption spectroscopy (XAS) to identify the redox state of V in the samples and use this information to interpret the depositional environment, fluid source and formation conditions. Our results will provide valuable insights into the formation conditions of the Selwyn Basin and the depositional environment of the V

deposits. This information will be used to improve the exploration and development of these resources, by focusing the exploration in the most favourable areas, and better understanding the geology of the deposit.

Thomas McLoughlin-Coleman - MSc
thomasmcloughlincole@cmail.carleton.ca

Pyrite-Gold association in Witwatersrand-style modified paleoplacer gold deposit, Pardo Township, Ontario (507)

The Huronian (ca. 2.4-2.2 Ga) Mississagi Formation is host to a modified paleoplacer gold deposit located 60 km north-east of Sudbury, Ontario in Pardo Township, where gold grains are distributed within basal cobble to boulder conglomerate in association with abundant detrital and epigenetic pyrite.

Gold occurs as irregular clusters scattered throughout a matrix of chlorite and quartz. Rare, rounded, possibly detrital, gold is preserved in quartz cement and gold transported in quartz-vein pebbles are locally observed, suggesting a point source for at least some of the gold.

Mineralogical associations for gold include uraninite and pyrobitumen, pyrrhotite, euhedral epigenetic and detrital pyrites. Similar to gold reefs of the Witwatersrand basin in South Africa, there is a particularly strong association between uraninite and gold, including having uraninite grains with gold coatings.

New LA ICP MS trace element mapping results suggest that much of the gold in detrital pyrite is enriched in gold as lattice-bound Au (1.5-4 ppm) or as rare micro-inclusions of <10 microns. Some detrital pyrite grains in the basal conglomerate texturally resemble pyrite nodules from organic-rich black shales in Archean basement rocks, including Fe-formation, exposed ~15km to the north, near a past producing gold mine. Hydrothermal dissolution fronts around the margins of some detrital pyrite highlight areas where much material has been dissolved.

In contrast, euhedral, epigenetic pyrite tends to be gold poor (below detection limit of 0.13 ppm). Previously published sulphur isotope results demonstrate that this type of secondary, gold-poor pyrite yield overlapping isotope signatures with the gold-bearing detrital pyrite, possibly indicating a similar source. Younger pyrite overgrowths may have developed during greenschist grade metamorphism of the Huronian basin during the Penokean Orogeny between 1.85 and 1.5 Ga.

Gold at Pardo appears to have been detrital and modified mainly by local hydrothermal dissolution and reprecipitation.

Darius Kamal - PhD
dkamal@eoas.ubc.ca

Deformation-induced sphalerite remobilization during Cordilleran folding of the Silurian Howard's Pass Zn-Pb deposits (508)

The shale-hosted massive sulfide Zn-Pb deposits at Howard's Pass, Yukon, were deformed during the Cretaceous Cordilleran orogeny. Rocks hosting the deposits were shortened into upright F1 folds with a pervasive axial-planar dissolution foliation, S1. Outside the ore horizons, S1 manifests as penetrative dissolution seams of insoluble material. Within the stratiform ore horizons, hosted by black shales of the Silurian Duo Lake Formation, S1 forms prominent

sulfide-rich seams. Sulfide laminae between these seams are relatively planar and little deformed. Sulfide seams are primarily composed of sphalerite (>80%) with two distinct textures: the first is located on the seam centrelines as coarse >0.5mm crystals. The second texture forms the bulk of the seam and comprises fine-grained sphalerite (<20µm) that wraps around the coarse sphalerite. The seams are depleted in quartz and carbonate and enriched in muscovite. It is common for the seams to transition along their length from sphalerite-dominant to galena-dominant. Preliminary estimates indicate that seam development involved >60% volume loss of the primary matrix with the near-total dissolution of quartz and carbonate. A two-stage model is proposed for the concentration of sphalerite in the seams: Firstly, the dissolution of the host rock resulted in the concentration of sphalerite and carbonaceous material as an insoluble residue within the S1 foliation. Secondly, once a specific threshold concentration of sphalerite was reached in the seams, sphalerite in the laminae was remobilized down chemical potential gradients to the sulfide seams, where it was able to deform in a more microstructurally compatible, lower internal energy manner.

Zhiquan Li - Postdoc
zhiquan1@ualberta.ca

Genesis and depositional environment of the iron metallogenic belt in the Taxkorgan region, West Kunlun Mountains, China (509)

Over the past decade several magnetite-rich iron ore deposits have been discovered in the Taxkorgan region of the western Kunlun Mountains of northwestern China. These include the Zankan, Jiertieke-Zankanbei, Yelike, and Taaxi iron deposits with prospective iron ore reserves exceeding 1 billion tons and an average magnetite grade of 28%. The orebodies in this region are mainly stratiform, and they have a conformable contact with a metasedimentary biotite quartz schist and amphibolite schist indicative of a sedimentary origin. Based on mineralogy, two ore types are identified: Type 1 (T1) is comprised of quartz and magnetite interlayered with schist, and it retains the sedimentary fabric of the precursor iron-rich sediments which were an iron formation (IF). Type 2 (T2) formed by the intrusion into the IF which led to magnetite remobilization and recrystallization as manifest in magnetite-actinolite venting. Geochronology studies from ore-bearing metasedimentary rocks indicate a depositional age of ~527 Ma for these magnetite-rich iron deposits.

The Zankan iron deposit (ZID) is the largest iron deposit in the region, and is estimated to contain 628 Million tons of iron ore, with at least 10% of the ores being high-grade (TFe > 50%). It is mainly composed of T2 ore. Rare earth element (REE) characteristics of the high-grade ore differs from those of the precursor IF, with chondrite normalized REE patterns showing enrichment of LREE and significant negative europium anomalies close to those of the dacite porphyry. The oxygen and sulfur isotopic composition of magnetite and pyrite in the high-grade ores suggests a further meteoric influence on the ZID with silica enrichment driven by leaching of the precursor IF from elsewhere in the sequence. Circulation of the ore forming fluid is attributable to the development of faults and fracture zones that resulted from the intrusion of the dacite-porphyry.

The Jiertieke-Zankanbei, Yelike and Taaxi iron deposits preserved the most primary iron ores (T1 ore). The REE patterns of T1 ores can be distinguished from modern Fe-exhalite deposits (e.g., lack of Eu anomalies in Taaxi and Yelike), and indicate a genesis similar to that proposed for Precambrian BIF. The absence of true negative Ce anomalies suggests that marine anoxia and ferruginous conditions extended well into the Early Cambrian, and indicating that the Early Cambrian was characterized, at least locally, by stratified, redox-heterogeneous basins.

Ana Carvalho - PhD
anamsmcarvalho@gmail.com

Connection between Mafic Intrusions and the Antimony Deposits of the Dúrico-Beirão Mining District, Northern Portugal (601)

The Dúrico-Beirão Mining District (DBMD) is located in Northern Portugal, within the Central Iberian Zone (CIZ). In the DBMD can be found several mineral occurrences. Some of these are antimony occurrences and can be found mainly on the western flank of the Valongo Anticline. The genesis of these antimony mineralizations is still debated. Some authors say their origin is related to non-outcropping granites. Others who have studied similar deposits within the Armorican Massif mention that they are related to mafic intrusions, and some also describe a spatial association between Sb deposits and mafic intrusions in the CIZ.

To study this genetic origin, we performed a gravimetric campaign around the entire Valongo Anticline. A Complete Bouguer Anomaly (CBA) was obtained, to which were applied 4 filters that highlight different anomalies: vertical and horizontal derivatives, tilt and analytic signal. The vertical and horizontal derivatives remove the long wavelengths and highlight the shallow structures. The tilt and the analytic signal highlight the edges of the anomaly sources.

With this data a spatial statistical analysis was conducted, allowing the correlation between the antimony deposits and the gravity values. We were able to create 5 histograms, one for each anomaly map (CBA and the 4 filters), that display the frequency of the gravity values within the entire studied area, which will be our reference values, as well as the gravity values associated with the locations of the antimony deposits.

On the CBA histogram, it is possible to observe that the antimony occurrences are mainly associated with higher values, i.e. higher densities. The tilt and the vertical derivative, appear to be associated with both intermediate and higher values. In comparison, the analytic signal and the horizontal derivative are primarily associated with the lower values.

These associations mean that a few antimony occurrences are close to the edges of the sources, but the majority of them are linked to the higher density sources. This means that there is a link between the antimony mineralizations and higher densities, which are assumed to be mafic intrusions due to the presence of dolerite dykes in the area where the antimony occurrences are located.

Farzaneh Mami Khalifani - PhD
farzaneh.mamikhalifani@unb.ca

Investigation Airborne Geomagnetic Data via 3D Modeling: A Novel Approach for Deep Mineral Exploration (602)

The New Brunswick portion of the Canadian Appalachians hosts different styles of gold mineralization, formed during various stages of the Appalachian orogeny. The major Acadian dextral transcurrent faults in northern New Brunswick play a significant role in the region's geology and mineralization. From north to south, these faults include the Restigouche, Rocky Brook-Millstream, McCormack-Ramsay Brook, McKenzie Gulch, and Moose Lake faults. The Williams Brook (WB) gold occurrence in northern New Brunswick is hosted by Early Devonian felsic volcanic and sedimentary rocks of the Wapske Formation (Tobique Group) in the Chaleur Bay Synclinorium. WB is characterized by low-sulfidation epithermal-style of gold mineralization, which occurs in K-feldspar porphyritic rhyolite and in sulphide-bearing quartz veins that cut

through these felsic units. Dextral movement along the Rocky-Brook-Millstream fault system during the Early Devonian (Acadian orogenesis) exerts control over the distribution of gold in WB. Structural features, such as faults and lineaments, might be linked to gold mineralization in WB. To assist mineral exploration, one should therefore try to identify such structural features. Herein, we explored the effectiveness of using aeromagnetic data, acquired in 2021 with a line spacing of 100 m, for delineating structural features, and intrusive bodies. We applied a suite of edge enhancement filters, namely Reduction to Pole (RTP), first vertical derivative (FVD), tilt derivative (TDR), and total horizontal derivative (THD) to the dataset, followed by the application of 3D inversion. The resulting 3D model of magnetic susceptibility measurements in the subsurface has been used to infer the locations and orientations/shapes of igneous bodies – be they felsic or mafic sequences, marked by a high magnetic response. This is confirmed by correlating our model with geological data, and drill cores (geological logs). The integration of our two- and three-dimensional models helps identify some structural features, and intrusive bodies, that might be linked to gold deposition. The prospectivity of these features is further assessed by their spatial association with gold mineralization in reported in drill cores. of the working environment; remote locations subject to extreme weather and terrain, difficulty recruiting skilled workers, lack of available resources, and most efforts conducted by companies with low market capitalization, all contribute to the unique health and safety issues. Mineral

Onum Stephen Adikwu - PhD
adikwustephen@gmail.com

Hydrothermal Altered Mineral Deposits Mapping using Airborne and Geophysical Techniques in Parts of the Middle-Benue Trough, Nigeria (603)

There is paucity of information about mineral deposits within the Middle-Benue Trough when compared with the upper and Lower Benue Troughs. Most researches are centred on structural analysis with little information on the stratigraphic deposition of sediments and their relationships to mineralization. As a result, the need to carry out a detail integrated geophysical research to further unravel the mineral potential and improve on the information base of the Middle-Benue Trough. The purpose of this study to delineate the subsurface structural trend in parts of the Middle-Benue Trough that lies between latitudes 7°30′–9°0′N and longitudes 9°00′–10°30′E as well as it implications for mineralization. Methods and Theoretical Orientation: The desk study stage involved the acquisition of Landsat 8 imagery, image processing (Atmospheric Correction, Colour Composite, Band Rationing, Principal Component Analysis) were applied and result shows imagery highlighting areas concentration of minerals and assemblage of alteration minerals. In order to validate the results, nine (9) High Resolution Aeromagnetics data used were subjected to various filtering operations. Findings: There is a NE-SW structural trend. The interpreted geological map from the aeromagnetic dataset shows the geologic units, structures, deformation intensity and OH bearing, ferrumagnetisation and ferruginization alteration zones. Ground magnetic survey, Em-Vlf, Electrical Resistivity and Induced Polarization were employed for further investigation. The 3D model was used to isolate chargeable bodies (potential mineralization) with chargeability >15msec regarded as anomalies of interest. The Volume of chargeable body is given as 853,250 m3 with nearest estimate of 2,730,400 tonnes and estimated value of $1.3Billion. Conclusion and Significance: Integration of airborne magnetic, satellite imagery analysis and ground geophysical survey was carried out to unravel the mineral potential of the study area which falls geologically within the Central Benue Trough. Recommendation: Geochemical analysis should be carried out on core samples.

Shenelle Agard - MSc
shenelleagard@gmail.com

In-situ gold resource estimation using satellite remote sensing and machine learning in defunct tailing storage facilities (South Africa) (701)

Every year, the mining industry generates billions of tons of waste, which is often stored in tailings storage facilities (TSFs). This waste comes from the extraction of ore from surface or underground mines, as well as from metallurgical processing and low-grade stockpiles. These facilities can have a significant environmental impact, as they can cover large areas and potentially cause issues such as acid mine drainage. In recent years, it has been suggested that TSFs could be a secondary source of critical raw materials, as demand for these materials continues to rise. To make use of mine waste in this way, it is necessary to accurately characterise it to ensure efficient extraction of valuable materials. One way to do this is by using satellite images from agencies such as the European Space Agency's Copernicus Sentinel-2 mission satellites, which can provide fast and cost-effective characterisation of mine waste in TSFs.

In this study, I used a combination of remote sensing data from the Copernicus Sentinel-2 or Sentinel-2 satellite and machine learning techniques to predict the in-situ gold grade in a tailings storage facility (TSF) in South Africa. Supervised machine learning algorithms, including adaptive boosting, random forest, k-nearest neighbours, and extra trees were trained using a combination of data collected from a TSF with known gold concentration and remote sensing data. The trained models were then deployed to predict the in-situ gold grade in another TSF located 3 km away. The results showed that these machine learning methods were effective in predicting gold grades in the TSF, with adaptive boosting, random forest and extra trees performing the best. The mean gold grade predicted was 0.44g/t by all machine learning models. The short-wave infrared band 11 at a 20 m spatial resolution had the highest correlation with the reflectance of gold in the TSF.

This study has demonstrated that using a combination of multi-spectral remote sensing data and machine learning can provide a rapid and inexpensive method for characterising mine tailings for valorisation. The Sentinel-2 satellite has a revisit time of 5 days, so new images are available every 5 days to update resource models generated for TSF characterisation. These images are free and do not require any prior knowledge of the facility to predict the presence of critical raw materials. The models developed in this research are robust and can be applied to other TSFs to predict the presence of critical raw materials.

Camila Aliaga-Morales - MSc
caliagam@uwo.ca

The Silver-Tin Polymetallic Iska Iska Project, Bolivia (702)

The Iska Iska silver-tin polymetallic project is a new discovery and the focus of ongoing exploration by Eloro Resources Ltd. It is located in the southwestern part of the Eastern Cordillera of the Bolivian Andes and is emplaced in the famous tin belt which hosts a number of world-class deposits including Cerro Rico de Potosi and Chorolque. Seven major mineralized targets (Huayra Kasa, Porco, North Central, South Central, Santa Barbara, NW Santa Barbara and SE Santa Barbara) and two potential nearby prospects (Mina Casiterita and Mina Hoyada) have thus far been identified as important for mineral exploration based on initial exploration techniques including surface and underground geological mapping, surface and underground grab and channel sampling, geophysical analysis, reconnaissance diamond drilling and core scanning

analysis. The deposit is interpreted to have formed by means of prolonged caldera collapse causing repeated episodes of intrusion, brecciation, and mineralization along zones of weakness. Ordovician basement sedimentary rocks are intruded by Miocene dacitic domes and are cut by several brecciation events related to intrusion, phreatic, phreatomagmatic, and injection events. Mineralization is interpreted to comprise a complex silver-tin polymetallic (Ag, Sn, Au, Pb, Cu, Bi, Zn, In) porphyry-xenothermal-epithermal deposit with a telescoping component as a mineralizing factor that is characteristic of the Bolivian-type polymetallic deposits. The current stage of exploration is focused on analyzing the geochemical, mineralogical, and structural complexity of drill core samples to characterize geochemical, mineralogical, and structural signatures of polymetallic mineralization. These data are being used to develop a consistent and predictive depositional model, which will help target more promising areas to drill.

Rhian Dentelbeck - BSc
rdent087@uottawa.ca

Intraplate volcanism and implications for crustal growth and metal endowment in back-arc basins: Evidence from the Niuafo'ou Volcanic Complex in the Northern Lau Basin (703)

Oceanic crust formed at MOR-type and BAB spreading centers accounts for two-thirds of the total volcanic output on the planet each year. Once the crust has moved away from the spreading centers it is assumed that additional volcanism and crustal growth (referred to as 'intraplate' or 'off-axis' volcanism) is limited. However, recent studies in the Lau Basin in the southwestern Pacific Ocean have shown that significant volcanism occurs away from the spreading centers. This intraplate magmatism manifests as large volcanic centers such as the Niuafo'ou Volcanic Complex in the northern Lau Basin This study attempts to quantify the amount of intraplate volcanism occurring in the area around the Niuafo'ou volcano, and to determine the dominant processes controlling the location of the large magmatic complex. The complex comprises the large 22-km diameter Niuafo'ou volcanic edifice and volcanic island, the Dugong submarine volcano, ~20 km north of Niuafo'ou, and a chain of smaller volcanic cones and calderas passing through the complex. Hydrothermal activity is present in the subaerial caldera of the Niuafo'ou volcano and a small hydrothermal plume occurs on the Dugong volcano. Fresh basaltic pillow fragments have been recovered from a dredge of near the base of Dugong. We propose that: (i) the location of the intraplate volcanoes is controlled by the intersection of major crustal structures related to the emergence of a new microplate boundary in the area, (ii) the sources of magma for the volcanoes are not solely decompression melting, typical of back-arc spreading centers, and (iii) that the volume of intraplate volcanism in the area is comparable to that at the spreading ridge segments. A detailed geological map of the region at a scale of 1:500,000 was constructed using remote predictive mapping (RPM) techniques as on land. The RPM approach integrates multiple geophysical, acoustic and ground-truthing datasets, such as seismic, magnetic, and gravimetric data, together with ship-based multibeam bathymetry, and samples collected during marine expeditions. A comprehensive assessment of faults and other lineaments, including quantitative analyses of fault orientations, lengths and fault throws, reveals the structural framework in the mapped region and the local and regional plate motions and kinematics. Together with area-age relationships of the mapped formations and the volumetric proportions of the geological units we have developed a model for the evolution of the volcanic complex and identify key stages that were responsible for the major crustal growth and probably hydrothermal activity.

Tyler Hall - PhD
trhall@stanford.edu

Sequential decision-support for optimal exploration data acquisition (704)

Initiating an exploration borehole drilling campaign represents a significant commitment of resources subject to complex operational and environmental constraints. The proposed locations of boreholes may vary greatly due to uncertainty in the subsurface geology, and it is important to understand the proposed drilling locations in good detail and, crucially, incorporate information from subsequent drilling locations. To address this, explorers often choose to collect additional data (e.g., magnetic, gravity, or electromagnetic surveys) to constrain borehole placement. Such data collection is costly itself, and a quantitative method which shows the effect of additional data collection on drill planning is needed. In this work, we propose and test such a method by formulating exploration mathematically as a belief-state Markov decision process (MDP). Solving our formulation allows for sensitivity analyses to be performed, which shows how exploration planning might change given 1) differing geological hypotheses, 2) operational constraints, and 3) various reward functions. A belief-state MDP requires several elements that need to be translated from mineral exploration. This necessitates methods for geological modelling and updating such models which are not employed in a geologist's traditional workflow. We show such methods and demonstrate this work using real data from a prospective magmatic sulfide nickel-copper deposit in Western Australia.

Kudzai Henry Mabika - PhD
kudzaihenrymabika@yahoo.co.uk

Exploration for Gold using Geological Mapping, Ground magnetics, Induced Polarisation in Mukaradzi Mt Darwin, Zimbabwe- Resistivity Methods (705)

Gold deposits in the greenstone belts of Mukaradzi Mt Darwin, Mashonaland Central are of major importance to the economy of Zimbabwe. Tonnes of gold deposits have been already extracted in the area of the country. This project aims to determine the potential mineralised zones within and around the mine, to delineate the potential gold hosting belts in order to carry out physical gold production. Hosts rocks are the sericite schists of the Darwin schist belt that are folded and interbedded by banded ironstone rocks. Intense shearing played a major role in the distribution of rocks generally of quartz which contain galena, pyrites and pyrrhotite. Traditional ground magnetic survey were carried out in the area followed by an induced polarisation-resistivity survey, using a Geometrics G-859 caesim vapour magnetometer to acquire ground magnetics data both as a rover and for base station readings. Magnetic data collected along north-south traverse lines separated by 25 m and data was collected at about 10 m station spacing along each line. An induced polarisation - resistivity survey was carried out cutting across the enhanced magnetic anomalies that coincided with altered rocks. Data was collected along three north-south lines (L354260, L354460 and L354600) at 25 m station spacing. Based on the regional and local geology, data acquired from the artisanal pits, ground magnetics and induced polarisation, gold mineralisation is likely to be found within the sheared rocks and along the veins in the greenstone rocks. The findings geological targets (ML1, ML2, ML3, ML4 and ML5) striking Northwest or Eastwest and North Northeast and dipping towards the North and South attributed to: Sheared greenstone rocks or schists hosting quartz veins with sulphides and or the north-south trending major fault and its satellite minor faults. Induced polarisation survey-resistivity intersected high chargeability anomalies within the surveyed area mostly sheared rocks schists. The integrated preliminary geophysical results coincide impressively with the geological map, with the high chargeability and low resistivity anomalies coinciding with the structured

form of the area. To understand the genesis of sulphides gold zone local deposition economic mineralisation it is recommended to do trenching and detailed sampling across strike on high chargeability anomalies as targets.

Julian Melo-Gomez - MSc
jmelo_gomez@laurentian.ca

Using gold to explore for gold: Trace element content of native gold across Ontario (706)

Gold is one of the most important resources for Ontario's economy, but few investigations have directly studied native gold to explain gold systems. The present study aims to better understand the geochemical signature of native gold using in-situ techniques such as electron probe micro analysis and laser ablation inductively coupled plasma mass spectrometry to characterize 201 samples from 69 gold deposits across Ontario. This will help define unique elemental attributes in gold ore systems and better understand the processes responsible. Generally, Ag, Cu, and Hg occur in greater concentrations, with Sb, Pd, Cd, and Bi typically as trace elements. The samples have been grouped spatially based on the metallogenic belt where they occur or are close to. The elemental content of gold shows spatial variations at different scales: provincially, Sb decreases systematically from west to east, whereas Hg has the opposite trend. At the metallogenic camp scale, differences were identified between samples from the Larder Lake-Cadillac Fault zone versus those from the Porcupine-Destor Fault zone (Abitibi greenstone belt); the latter have higher concentrations of Sb, Cd and Cu relative to the former. Ratios of Sb/Cu versus Hg/Cd can discriminate between metallogenic camps in Ontario: Red Lake, Geraldton-Beardmore and Confederation Lake have similar values but are different from those in the Abitibi, Temagami or Wawa greenstone belts. Samples with very high fineness (>975) are close to high-metamorphic grade zones and exhibit an elemental depletion implying a natural metamorphic refinement of gold. In addition, these spatially distinct geochemical fingerprints are independent of host rock and deposit types, which have significant implications regarding the controls on the metal content of gold deposits and ore-forming mechanisms, which may reflect craton-scale processes and variations in gold source. These data also have important practical applications for industry in ranking elemental vectors for exploration and in metallurgical processing.

Ofure Onodenalore - MSc
oonodenalore@mun.ca

Geochemistry of detrital corundum recovered by heavy mineral surveys: A potential new method for finding ruby and sapphire deposits in Canada (707)

Gem corundum deposits are usually discovered fortuitously, as exploration is currently limited by the lack of existing region-scale methods that could be used to identify potential for these deposits. Ruby and sapphire deposits form in a wide range of geologic environments, many of which exist in Canada, where several gem and near-gem corundum occurrences are known. A collection of 380 corundum grains from till and fluvial sediments were provided by the Geological Survey of Canada, multiple provincial and territorial surveys (NL, NU, BC, NWT, YK), and an independent claim owner. Representative grains were selected from each study area in addition to grains that could be indicative of a gem deposit (i.e., highly transparent, coloured

grains). These grains were characterized with regard to physical properties (including colour), mineral inclusions, adhering materials, and trace element composition (Mg, Ti, V, Cr, Fe, Ga, and others). The oxygen isotope composition of a selected subset of corundum grains was determined using in situ secondary ion mass spectrometry (SIMS). These data were compared to that of corundum from known deposit types. Bedrock geology and surficial geology ice direction maps were examined for each locality, and the bedrock geology of the probable source region was used to identify potential corundum-forming environments that are most geologically compatible with this local geology. The combination approach to detrital corundum provenance estimation - using (1) corundum trace element chemistry discrimination, (2) corundum mineral associations, and (3) geology of the sediment source region - offers a new way to identify potential ruby/sapphire greenfields using existing heavy mineral surveying efforts and adding minimal additional costs. Detrital corundum can originate from fine-grained and non-gem quality corundum sources; thus, while fine-grained detrital corundum has the potential to be used as a pathfinder for ruby/sapphire deposits, survey results would require careful follow-up sampling and assessment to identify whether gem deposit potential truly occurs in the area.

Carlos Rodriguez - MSc
carlos_jrv@hotmail.com

New Concepts for the Recategorization of Mineral Resources in the San Gerardo Pit - Atacocha Mine (708)

Atacocha mine is located in the Western Cordillera of central Peru, within the Province and Department of Pasco, between elevations 3,900 to 4,330 metres above sea level. It is 331 km northeast of the city of Lima.

Atacocha is a polymetallic deposit of Zn, Pb, Ag with Au content. The sedimentary sequence made up of limestone from the Pucará Group and sandstone from the Goyllarizquisga Group outcrops in the area. These sediments were cut by San Gerardo intrusive of dioritic composition. These rocks have been dated by the potassium-argon method as between 25-30 Ma.

The 2020 drilling program has focused on Phase 02 and Phase 03 of San Gerardo Pit, where the main mineralization controls and formation conditions of the Chercher Ore Body and Asunción Ore Body had not been defined. Petro-mineragraphic studies, mineralogical analysis by X-ray diffraction, and fluid inclusion studies have been carried out and this information is useful to know the type of deposit to which it is related and to define the main mineralization controls.

Studies of thin sections of the San Gerardo intrusive indicate the presence of illite-smectite, adularia, quartz, and carbonates. Mineralization occurs in veins and bodies filled with sphalerite, galena, bournonite, freirbergite. In addition to Au values, the gangues consist of pyrite and rhodochrosite associated with structures of alabandite, quartz and calcite, which are controlled by a NW-SE structural system parallel. In addition to being present within a Riedel system of sinistral faults conjugate and transcurrent-normal faults, which is defined as extension zone and related to subsidence, called structures of negative flower type. The study of fluid inclusions reveal the existence of mineralizing flows with temperatures between 200°C and 320°C, with a salinity of 3% to 5% NaCl equivalent weight. The possible mineralization environment of the San Gerardo Pit, in Atacocha mine, is represented as a low to intermediate sulphidation epithermal environment with significant Au and Ag content.

Kristine Glomsås Nymoen - PhD
knymoen@laurentian.ca

Integrating zircon Hf-O- isotopes with whole-rock geochemistry: implications for architectural controls on mineral systems in Wawa, Superior Craton, Canada (709)

The Superior Craton is the largest remnant of Archean crust on Earth and hence provides the most representative information on the geology of our early planet. The craton hosts numerous world-class ore deposits, particularly in the Abitibi-Wawa Terrane, where volcanogenic massive sulfide (VMS) and orogenic gold deposits dominate, together with a number of small komatiite-hosted Ni-Cu-PGE deposits. These deposits are often clustered in both space and time into 'camps'. However, the controls on the formation of these clusters, as well as the role of geodynamic processes, are yet to be resolved. Previous studies have shown that combining U-Pb geochronology with radiogenic isotope data (Sm-Nd, Lu-Hf) can be used to map the time-space evolution of the crust and its architecture. In numerous cases, these studies resolved the spatial distribution of mineral systems within terrane- to continent-scale areas, i.e., the Yilgarn Craton, Western Australia. Our study applies this technique to the eastern Wawa subprovince of the Superior Craton and aims to advance the method by integrating whole-rock geochemistry, which will allow the mapping of petrogenetic variations in the crust. We use whole-rock geochemistry on tonalite-trondhjemite-granodiorite (TTG) samples as tracers for the type and petrogenesis of the crust, combined with zircon trace element and zircon O- and Hf-isotopes to constrain the role of low/high-temperature, juvenile/crustal components. In our data, we find evidence for a geochemical and isotopic transition at ca. 2695 Ma. Spatially, whole-rock geochemistry from pre-2695 Ma rocks show a central part of Wawa dominated by sodic (K_2O/Na_2O <0.7) rocks with mantle-like δ18O (VSMOW‰) values (4.7-5.9‰) and εHf values indicating a crustal component, whereas the exterior part shows higher proportions of more potassic rocks (K_2O/Na_2O>0.7), low-temperature hydrothermal processes-like δ18O values (>5.9‰) and εHf values suggesting greater juvenile input. Post-2695 Ma rocks record a shift, particularly apparent in the central part of Wawa where the overall δ18O values are heavier (5.9-6.9‰) and the εHf values point to a greater crustal component, with the exception of a small area in the SW that may represent younger, more juvenile crust. Our results demonstrate both spatial and temporal variability in the crustal petrogenesis of the eastern Wawa subprovince. This may have a major controlling influence on mineral systems distribution and occurrence, with VMS more likely in a more primitive crust (sodic, mantle-like δ18O) and which may represent a thinner crust. Less primitive crust (potassic, heavy δ18O) may reflect a metasomatized component, potentially important for gold mineralization.

Wenyao Liang - MSc
w54liang@uwaterloo.ca

Till stratigraphy and sediment provenance of the Dessert Lake drumlin field area, west of Great Slave Lake, Northwest Territories: Implications for mineral exploration (710)

Subglacial till is routinely sampled in mineral exploration to trace indicator minerals back to a buried bedrock source up regional ice flow. In drumlin fields, however, till is sometimes several meters thick, and some of it may be unrelated to the ice flow phase that created the drumlins. In addition, erosional processes play a role in the formation of drumlins. As a result, till from different stratigraphic positions could be exposed at the surface, thus complicating the provenance analysis of surficial till. Here, we report new evidence for ice flow shifts in the

Dessert Lake drumlin field located West of Great Slave Lake (GSL), even though its drumlins indicate a single ice flow direction (~249 deg.). Outcrops on two isolated inliers of Precambrian bedrock show erosional evidence (e.g., striations) for a clockwise ice flow shift from south to southwest close to the drumlin field and from south to northwest closer to the GSL. Several road cuts along highway 3 expose the cores of drumlins, which consist primarily of till. Clast fabrics measured along vertical till profiles from three drumlins show a clockwise ice flow shift up section, similar to the one recorded on outcrops. The clast fabrics near the top of the drumlins are consistent with the orientation of the landforms. We conclude that glacial dynamics shifted in the area, and the evidence is well-preserved in both the erosional and depositional records. The new data tell a more complex glacial history than the single ice flow direction of the drumlin field. In this context, it is likely that surficial till samples in the Dessert Lake drumlin field, and perhaps in other similar settings, will include till with different glacial transport pathways and bedrock source regions. It is thus critical for applications like mineral exploration to determine if the till in lower stratigraphic positions occurs at the surface in the drumlin field. Future work in this study will incorporate results from indicator mineral sampling and till geochemistry analysis from surficial and section samples.

Felipe Rodríguez-Novoa - PhD
ofrodrigueznovoa@mines.edu

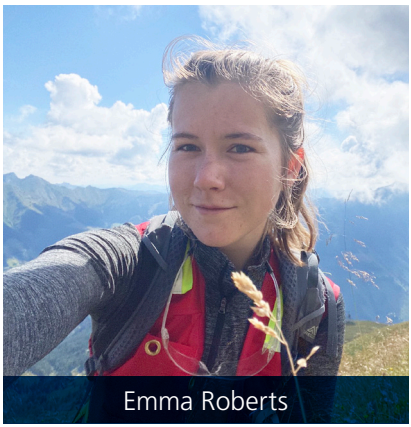
Coexistence between large-scale mining (LSM) and artisanal and small-scale mining (ASM) in Perú and Colombia (711)

Artisanal and small-scale mining (ASM) is common in mineral-rich locations in the developing world, generating a significant share of production for commodities such as gold. This sector is expanding due to economic and environmental pressures. Large-scale mining (LSM) will also need to expand to meet future demand for minerals and metal resources. The likelihood that these expansions will result in further points of contact between the LSM and ASM sectors is high. In this scenario, coexistence between ASM and LSM is key and should be seen as the capacity to build synergies and operate together. Our aim is to document the characteristics of sites where a LSMASM coexistence has been attempted, to identify key characteristics that are permissive or indicative of success. We built a database of sites in Colombia and Peru where ASM and LSM both occur, documenting the technical characteristics such as deposit and mineralization type, mining methods, recovery process and the social context including ethnicity, demographics, economic activities, and social organizations. We observed that coexistence occurs between ASM and both junior and senior LSM companies, covering all the stages of the mining cycle. Coexistence scenarios are most common in gold projects but cover a wide variety of deposit types including epithermal, porphyry and VMS among others. We observed differences in the mining laws between Colombia and Perú which result in contrasting approaches to ASM formalization, leading to variation in the observed coexistence scenarios. We conclude that governments have taken significant efforts to create tools for LSM companies and holders of mining titles to reach agreements with ASM miners. However, governments have failed to give ancestral ASM miners who do not belong to an ethnic minority the tools to defend their livelihoods, resulting in power-imbalanced negotiations. Nevertheless, the success of these agreements largely depends on the willingness of the parties to collaborate.

2023 SMC Organizing Committee

Shalaila Bhalla

Evan Hall



Emma Roberts

Visit
merc.laurentian.ca/seg-smc

PDAC
PROSPECTORS & DEVELOPERS ASSOCIATION OF CANADA

SOCIETY OF ECONOMIC GEOLOGISTS
FOUNDED 1920

Laurentian University
Université Laurentienne
HARQUAIL School of Earth Sciences
École des sciences de la Terre

uOttawa

MERC
Mineral Exploration Research Centre
at the HARQUAIL School of Earth Sciences

METAL EARTH