10th Annual PDAC-SEG Student Minerals Colloquium Abstracts

March 5th, 2019

METRO TORONTO CONVENTION CENTRE Room 701

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101 - Trace element content in pyrite as a vector toward SEDEX Pb-Zn mineralization in the MacMillan Pass, Yukon

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The Tom and Jason sedimentary exhalative (SEDEX) Pb-Zn-Ag-(Ba) deposits in the Yukon Territory, Canada grade 7.4 wt% and 7.0 wt% Zn, and 6.5 wt% and 4.6 wt% Pb, with Zn + Pb tonnages of 15.7 and 10.1 Mt, respectively. Pyrite-bearing samples from seven drill holes situated within and distal (in time-stratigraphically equivalent rocks, 2 – 4 km away) to mineralization were sampled, and four pyrite textural varieties are identified, each with distinct morphological characteristics and mineralogical associations. Earliest diagenetic and/or chemical sedimentation (Py_1), early diagenetic (Py_{2a}), late diagenetic (Py_{2b}), and metamorphic (Py_3) are identified. The timing for SEDEX Pb-Zn mineralization was syn and/or post late-diagenesis (Py_{2b}), and pre-metamorphism (Py_3). A representative subset of pyrite grains was analysed for trace element contents by laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) using raster grids to create quantitative trace element composition maps, in order to characterise the trace element composition of each pyrite generation and investigate how trace elements spatially vary. Pyrite formed in three discrete time domains of early diagenesis (Py_1), diagenesis (Py_{2a}, Py_{2b}), and late stage metamorphism (Py_3), and each of these have different trace element signatures. Trace element abundances are (high to low): Py_1 (10s – 1000s ppm), Py_2 (10s – 100s ppm), and Py_3 (1s – 100s ppm). A hydrothermal expression of SEDEX mineralization is recognized in Py_2 (in Tl, Pb, As, Zn, Cd, Zn/Ni, Tl/Co, and Co/Ni), and this trace element composition within stratiform mineralization is typical of pyrite in SEDEX deposits, when compared to hydrothermal trace elements in pyrite from the Howard's Pass and HYC deposits. Redox sensitive elements (Mo, Ni, Se, Co, Bi) and Sb are less enriched within mineralization, and more enriched in carbonaceous and sedimentary units that likely formed in reduced, organic matter-rich, diagenetic environments. Trace elements in diagenetic pyrite show trends with lateral and vertical distance from intercepted mineralization. Abundances/magnitudes of Ag, Pb, Cu, Tl, Zn/Ni and Tl/Co can be used to vector toward mineralization on the metre-scale within a single drill core, and only Zn can be used as a vector on a larger kilometre-scale.

102 - Understanding potential linkages between magmatism and SEDEX mineralisation in the Selwyn Basin, Yukon, Canada: Initial findings and future work

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The Selwyn Basin in the Yukon Territory, Canada, is host to multiple large Pb-Zn (±Ba, ±Ag) sediment-hosted deposits. Sediment-hosted deposits, commonly termed sedimentary exhalative or 'SedEx', are one of the world's largest Pb-Zn resources and producers. Several of these mineralised districts are spatially

and temporally associated to mafic volcanism, including the MacMillan Pass district (Tom, Jason, Boundary Creek Deposits) and the Anvil district (Faro, Vangorda, Grum, DY Deposits). This project uses geochemical techniques to examine linkages between volcanism and mineralisation in these two areas to determine if there is: 1) no relationship; 2) heat provided by volcanism; or 3) metals (± heat) provided by volcanism. The first part of this project involves characterising the volcanism throughout the Selwyn Basin, including the Misty Creek Embayment and the Keno Hill District. Characterising the volcanism involves analysing the precise timing of volcanism through zircon and apatite dating. Isotope systematics (Sr, Nd, Pb) will be used to analyse the source of the magmas whereas combined petrographic and scanning electron microscopy (SEM) analysis are being used to help characterize eruption styles. Preliminary findings indicate volcanism in the region is alkaline except for the Keno Hill District. Eruption and alteration styles vary between the four districts. Barium concentrations are elevated (hundreds to thousands of ppm). Thallium and Ba concentrations of the volcanic rocks exhibit a positive correlation, which is similar to the Howards Pass Pb-Zn deposit. However, the Canol Formation (diagenetic barite) shows a negative trend. To further investigate this similarity, ten ε205Tl values have been measured and exhibit a large fractionation trend, with values ranging from -0.9 to -14.2. Samples from MacMillan Pass have the most fractionated values (-5.9 to -14.2 ε205Tl) whereas those from the Anvil District are less fractionated (-0.9 to -6.4 ε205Tl). Future work will also expand upon these Tl isotopes and use Mo and Ba isotopic systems to compare the magmatic and mineralised systems.

103 - A Study of a Mineralization Occurrence on Somerset Island, Nunavut, Canada

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An occurrence of Zn and Cu mineralization has been found on Somerset Island, Nunavut, Canada, within what is previously thought to be the 3.6 to 1.8 Ga Rae Province. A grab sample returned values of 1.15 % Zn, 1.91 % Cu and 6.6 ppm Ag in gahnite and chalcopyrite mineralized garnetite. The rocks at this locality have undergone at least three deformation events and have granulite facies mineral assemblages. The main objective of this study is to characterize the mineralization found at this location, determine the type of mineralization this occurrence represents and assess its potential economic value. This will be achieved through geologic mapping, and geochemical analyses. The results to date are highly significant because they constitute the first known occurrence of base metal mineralization in the Precambrian rocks of Somerset Island important as few studies have been conducted in the Somerset Island area in general, and even less have been focused on mineralizing processes.

104 - Sediment-hosted zinc mineralization in the Central Metasedimentary Belt (CMB) of the Grenville Province, Canada: Calumet-Sud case study

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The Grenville Province, with its high-grade metamorphic terranes and ductile deformation, has not been a prioritized setting for exploration. Still, the carbonate and volcano-sedimentary sequences of the southeastern CMB in the Grenville Province host several zinc deposits and occurrences (e.g., Balmat-Edwards, Franklin, Renprior/Cadieux, New Calumet, Calumet-Sud). Except for New Calumet, these deposits are hosted in stratiform marbles of the Grenville Supergroup and are associated with the basin-margin faults that border the CMB. Their geological setting and the processes by which these styles of mineralization formed, however, are still poorly understood. This research, in collaboration with Sphinx Resources and SOQUEM, aims to identify the major geological units, structural controls, and styles of zinc mineralization hosted in the metamorphosed carbonate rocks of the Grenville Supergroup in the Calumet-Sud project area on Calumet Island in Quebec. Surface mapping and core logging results will be integrated with mineralogical, lithogeochemical, and isotopic studies to understand the processes by which the various styles of mineralization have formed, provenance of sedimentary units, petrogenesis of intrusions, and vectors to mineralization. The preliminary results of this study reveal distinct features of the mineralized zones compared to the surrounding barren marbles. The mineralized zones consist of folded semi-massive to massive sphalerite ± pyrite bands with lengths on the meter scale and thicknesses on the centimeter scale. The mineralized bands can be trace over 1500 meters along a N-S trend and are hosted in a coarse grained, pale grey, graphitic dolomitic marble. Grades from composite channel-sampled intervals of the northern mineralized zone included: 8.14% Zn over 1.5 m, 6.61% Zn over 5 m, including 21.1% Zn over 1 m, and 6.72% Zn over 1 m. The mineralized zones are enriched in Cd, Cu, Fe, Hg, In, Pb, Sb, and have a higher Ca/Mg ratio than the barren marbles. The higher-grade intervals (6-25% Zn) contain elevated Ag, As, P, Se, and Tl. The host dolomitic marble is interbedded with calco-silicate units containing variable amounts of tremolite, diopside, phlogopite, talc, serpentine, and quartz. Zones with open spaces described in the hanging wall of mineralization are tentatively interpreted as meta-evaporite horizons. Rare mafic rocks were also locally observed. Future studies will include microprobe analysis of the ore and related minerals in order to identify indicator minerals useful in exploration of this type of deposit. They will also include isotopic studies in order to decipher the cryptic hydrothermal alteration in those highly metamorphosed rocks.

105 - The Paleozoic Sedimentary Rocks of the Ouachita Mountains and Arkoma Basin and their Genetic Relationship to the Mississippi Valley-Type Mineralization in the Southern Ozark Region: Insights from Radiogenic Pb Isotopes and Trace Elements Studies

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Mississippi Valley Type (MVT) lead-zinc deposits are epigenetic ore deposits hosted mainly in dolostone and limestone. Accounting for 24 % of the worldwide Pb and Zn (Pb-Zn) resources, the Mississippi Valley-

Types Pb-Zn deposits comprise the largest recognized concentration of Pb in North America in the Ozark region. Scattering Pb and/or Zn deposits in North America encompass, among others, the well-known Tri-State, Central Missouri and Northern Arkansas districts located north of the Arkoma basin and the Ouachita fold-thrust belt. The genetic model for the Ozark MVT ore formation is still a matter of hot debate among scholars. Nevertheless, it is generally believed that the mineralization is connected to the Pennsylvanian-Permian Ouachita orogeny, which triggered a South-North topographic gradient flow of basinal brines, leaching metal rich sediments en route. The objective of the research is twofold. First, to ascertain whether the organic-rich shales and sandstones from the study area (Ouachita Mountains, the Arkoma Basin, and the Ozark Region) provided metals during the mineralization event, which was coeval with the Ouachita orogeny. Second, to assess the depositional environment of the potential source rocks, which will shed light on their ability to sequester metals. The Pb isotope compositions of the ores (sphalerite) have been compared to their associated sedimentary rocks (Collier, Mazarn, and Polk Creek, Womble, Fayetteville, Stanley and Chattanooga shales and Jackfork Sandstone) and metal sources have been evaluated. In addition, the role of environmental deposition of sedimentary rocks to sequester adequate amounts of metals has been appraised using redox sensitive trace elements (U, V, Mo, Cr, etc.). Pb isotope compositions of whole rocks and leachates, and their associated ores from the Northern Arkansas and Tri-State districts, indicate a mixing model of fluids sourced from high and less radiogenic rocks, with the Chattanooga rock samples being the most prominent source rocks. Paleoredox proxies indicate deposition mainly under suboxic to anoxic conditions, which are favorable for metal enrichment. However, oxic conditions are also indicated by other geochemical proxies, suggesting possible additional factors such as the rates of sediment accumulation, post depositional alteration processes associated with diagenesis and low-grade metamorphism during the Ouachita orogeny.

106 - The Morro Agudo Pb-Zn Mine: Mineralogical and Lithogeochemical Evidence of Multiple Mineralizing Events

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The Morro Agudo sulfide Pb-Zn Mine is hosted by Mesoproterozoic carbonate rocks in the northern part of the Vazante-Paracatu district in Minas Gerais, central Brazil. The Vazante Group hosts both sulfide-zinc and hypogene-silicate zinc deposits and occurrences within dolomitic formations that are underlain by and interbedded with siliciclastic rocks. The genesis of Morro Agudo deposit is controversial and various models have been proposed (MVT, Irish-type, or SEDEX-type). This deposit contains six orebodies, with increasing depth, N, M, L, K, J, H, G, and I (also referred to as Basal), which are bounded in the NE part by a major fault (N15-70E/60-75NW). All orebodies, except in N, are hosted in dolarenite and dolomites with varying degrees of brecciation and exhibit similar mineralogical and textural features characterized by various generations of sphalerite, pyrite, ± galena, and hydrothermal dolomite filling open-space and veins, and replacing the host rocks. Representative samples from these orebodies contain similar concentrations of Pb, Zn, Cd, Fe, As, Hg, Co, Cu, Ba, Cr, Zr, as well as Zn/Cd ratios. However, orebody N is hosted in an upper unit (intercalated shale-dolomite sequence) and is texturally and mineralogically distinct, characterized by laminated sphalerite, pyrite, chert, and barite, ± galena. Furthermore, orebody N yielded anomalously high concentrations of Ba, Co, Cr, Cu, Ni, Ga, and Zr and lower average

concentrations of Pb, Ag, Cd, Hg, Sb, and Se relative to the other orebodies and their respective host rocks, although some parts of N are particularly enriched in Pb. Interpreted paragenetic relationships and geochemical data indicate various episodes or stages of mineralization at distinct conditions during the evolution of the deposit. Based on structural, textural, mineralogical and geochemical evidence, it is tentatively proposed that part of the N orebody mineralization may have formed early during the evolution of the basin. However, the other orebodies may have formed during the Neoproterozoic Brasiliano Orogeny coeval with the formation of silicate-zinc deposits in the southern part of the Paracatu-Vazante district. Further studies on structural geology, mineral chemistry analyses, isotopic and fluid studies, and comparisons with other sulfide-zinc occurrences within the Vazante Group (e.g. Ambrósia and Fagundes) will be conducted to assist in better constraining the evolution of metalliferous fluids and the mineralizing processes in the Vazante basin.

107 - Nature and role of deformation bands in post-Athabasca faulting and genesis of unconformity-related uranium deposits; case study of the C1 fault zone in the eastern Athabasca Basin, northern Saskatchewan

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The Athabasca Basin of northern Saskatchewan hosts numerous world-class uranium deposits. The deposits have a strong spatial association with post-Athabasca faults that offset the unconformity surface and represent reactivation of older basement structures. This study examines a newly recognized phenomenon known as 'deformation bands' which are localized products of strain, resembling micro-faults. Deformation bands are constrained to formation in highly porous rocks, often spatially associated with damage zones related to faulting and other deformation features. Due to the nature of formation they may cause a change in porosity due to grain rotation and flow which gives them the potential to act as fluid baffles or conduits. Examination of deformation bands took place within the Athabasca Basin using a series of drill-hole fences that transected across the C1 fault trend, which extends from the Gryphon deposit in the south to about ~5 km west of the MacArthur River deposit. The three main types of deformation bands observed were: compaction (loss of pore space), shear (measurable amount of offset) and cataclastic (destruction of grains to reduce porosity) bands. The number of bands observed throughout the sandstone is related to the porosity of the formation hosting the structures. All bands types are observed in each formation but the proportion of cataclastic bands increases with depth. The observed deformation bands conform to three major trends; a subhorizontal trend (286°/11°), and two trends which appear to share a conjugate relationship, a northeast trend (074°/57°) and a northwest trend (324°/65°). This conjugate relationship suggests a stress field is incompatible with documented trend of the C1 faults, which display reverse/thrust movement along a trend of 020°/50°. This suggests that it is highly likely the fault zone was reactivated after the sandstone deposition under a new stress regime (inferred from orientation of the deformation bands). Alteration products related to mineralization were also observed with druzy quartz veins defining the same conjugate relationship as the general population of deformation bands whereas dravite veins preferentially occur along the northeast trend. Further work in this study aims to improve the understanding of deformation band genesis in relation to post-

depositional fault reactivation, as well as the role these structures have in constraining fluids associated with uranium mineralization.

108 - White Micas in the Arrow Uranium Deposit, Patterson Lake Corridor, Southwestern Athabasca Basin, Northern Saskatchewan

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The Arrow Deposit in northwestern Saskatchewan is one of the largest undeveloped uranium deposits in the world, with an indicated mineral resource of 256.6 Mlbs U3O8 at a grade of 4.03%. The deposit lies within NexGen Energy's Rook I property and is associated with steeply-dipping, stacked shear zones in the metamorphosed basement rocks of the Taltson domain below the sedimentary rocks of the Athabasca Supergroup. This structural zone forms part of the NE-SW-trending Patterson Lake corridor, along which there are numerous other significant uranium discoveries. The paragenetic relationship between structures, mineralization, and alteration at the Arrow Deposit has been constrained, and attempts have been made to determine the age of uranium mineralization from electron microprobe and secondary ion mass spectrometer analysis of uraninites. The range of ages obtained indicates that the uraninites have been variably affected by younger fluid events, but yield a minimum crystallization age of approximately 1,425 Ma. Perhaps the most ubiquitous and prominent mineral groups that occurs in multiple stages throughout the paragenesis of the deposit are white micas (coarse euhedral/fine-grained sericitic). The present research aims to provide more robust ages constraints on the Arrow paragenetic sequence, through Ar-Ar dating of well-constrained, mica-bearing samples. Detailed textural and compositional analysis of white mica generations is the focus of this study. Polished thin sections of samples containing variable amounts of white mica from throughout the mineralized system were examined using transmitted and reflected light microscopy and electron microprobe analyses. Three generations of white micas have been identified to date, and fine-grained (sericitic) white mica appears to be more closely related to uranium mineralization. Preliminary electron microprobe analyses of coarser-grained white mica generations indicate that they contain elevated Al in the octahedral site, although there is a range of values for interlayer cations (0.76-0.89 apfu) indicating both end-member muscovite and illite. The K, Fe, and Mg content of the white micas suggest crystallization temperatures of about 250^{o}C. From the analyses completed on the current sample set, there is no obvious spatial variation in composition with respect to the Arrow uranium mineralization system. Further work will focus on samples proximal to and within the high-grade core of the deposit, and from the periphery of the alteration system in which pre-ore white mica is preserved.

109 - The evolution of metasomatic uranium ore systems in the Central Mineral Belt of Labrador

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Uranium mineralization at the Kitts, Gear, Inda and Nash deposits of the Central Mineral Belt (CMB) is concentrated in the upper portion of the Post Hill Group, along a structurally complex shear zone located within the Makkovik Province of Labrador. Mineralization is primarily developed within the Metasedimentary Formation argillite unit, interbedded at times with the Kitts Pillow Lava Formation and seems to be structurally controlled along foliation and shear zones. Recent research in the CMB has highlighted regional- to deposit-scale sodic, calcic, potassic and iron alteration, as well as local hydrothermal breccia; all of which are characteristic of iron oxide and alkali-calcic alteration (IOAA) systems worldwide. Iron oxide and alkali-calcic altered systems can host a variety of economically significant deposits (e.g., iron oxide-copper-gold, iron oxide-apatite, albitite-hosted uranium, certain skarns and certain intrusion-related deposits) that are rich in base, precious, specialty and/or actinide metals. These seemingly distinct deposit types form in systematic metasomatic-hydrothermal assemblages that evolve from depth-to-surface across very high-temperature geothermal gradients within the upper crust. Samples from the Kitts deposit were mineralogically characterized using a scanning electron microscope, electron microprobe and geochemically analyzed using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Quantitative LA-ICP-MS element mapping on uraninite, in addition to uraninite trace element abundances, were used to distinguish uraninite geochemical characteristics of the samples. The 2D element maps and REE geochemistry revealed that each sample exhibits unique geochemical characteristics. In chondrite-normalized plots, all three samples are depleted in LREE relative to HREE yet both positive and negative Eu anomalies are observed. Contrasting REE signatures imply at least two uranium mineralization events along the corridor, at different temperatures and physico-chemical conditions based on the REE chemistry of uraninite.

110 - Exploring for Carlin-type Au-deposits using ore-stage, Mn-rich veins: implications for the timing, temperature and scale of hydrothermal fluid flow

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This poster presents evidence for easily identifiable calcite veins genetically associated with Au-mineralization in the Carlin-type Au-deposits (CTGDs) of the Nadaleen trend, Yukon. These veins fluoresce bright pink to orange under shortwave ultraviolet (UV) light due to their anomalously high Mn content. Their hydrothermal origin is evidenced by their depleted $\delta^{18}O$ signature and they are spatially associated with Au-mineralization and realgar/orpiment precipitation. Realgar is often co-precipitated with Mn-rich calcite, providing a temporal link to Au-mineralization. Micro X-ray fluorescence Mn maps suggest that Mn is stripped from host limestones during decalcification, providing a probable source of Mn. Fault-vein cross cutting relationships indicate that Au-mineralization occurred post folding and post movement on

major faults. The majority of the veins are bedding-parallel or bedding-normal in orientation, suggesting that they formed as a buckle-fold fracture network. U-Pb dating of Mn-rich calcite provides a date for Au-mineralization that post-dates folding, suggesting that Mn-rich calcites are pseudomorphs of calcite in pre-existing veins. Clumped isotope analysis of Mn-rich veins give a cool fluid temperature consistent with other published calcite formation temperatures from CTGDs in Nevada. The retrograde solubility of calcite means that it is unlikely that this calcite formed due to a cooling fluid. This supports our preferred model; that these veins are the product of fluid:rock interaction. UV fluorescent veins can be used to explore for or vector in towards CTGDs, while Mn lithogeochemistry may give clues on the scale of hydrothermal fluid system that formed the deposit.

200 - Volcanogenic Massive Sulfide (VMS) Deposits

201 - Petrogenesis of iron formation and metasedimentary units of the Archean Beaulieu greenstone belt, Slave Craton, Northwest Territories

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The Beaulieu greenstone belt is approximately 100 km ENE of Yellowknife, in the southwest part of the Slave Craton, Northwest Territories, and has been mapped in detail as it hosts the Sunrise volcanogenic massive sulfide deposit. The belt consists primarily of mafic volcanic and felsic volcanic rocks with minor amounts of metasedimentary rocks which have undergone greenschist to amphibolite facies metamorphism. These rocks overlay basement rocks of the Sleepy Dragon complex. The metasedimentary rocks include quartz wacke, lithic wacke, and an iron formation, and primary sedimentary features are recognizable. The objective of this study is to understand the petrogenesis of these rocks in order unravel the origin of the iron formation and to compare them with similar age metasedimentary rocks in the Slave Craton. In summer 2018 eight representative samples were collected from the three metasedimentary units. Polished thin sections have been examined, and whole rock geochemical and Sm-Nd isotope analyses have been conducted to provide constraints on the origin of these rocks. The iron content varies from 1-3 wt.% Fe2O3 in the wackes to 15.8 wt.% in the iron formation. The Fe-bearing minerals include hematite, pyrite, and Fe-rich biotite, and the overall mineral assemblages suggest metamorphism to greenschist grade. The wacke samples have epsilon Nd values of – 1.2 and – 2.2 at the assumed age of formation of 2.671 Ga and indicate mixed detrital sources. Epsilon Nd values of +3 for the iron formation suggests a juvenile source, and thus a hydrothermal input may dominate. Further analysis of the geochemical data of this rock will determine the relative proportions of hydrothermal and detrital input, and whether the rock is an iron formation or an iron-rich shale.

202 - Tectonic setting of the Sunrise Volcanogenic Massive Sulfide Deposit, Beaulieu River Volcanic Belt, NWT

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The Sunrise deposit is a Zn-Pb-Ag rich volcanogenic massive sulfide (VMS) deposit located within the ca. 2.6 Ga Beaulieu River Volcanic Belt (BRVB) in the Slave craton, Northwest Territories (NWT) and is the largest VMS deposit in the NWT. The BRVB, adjacent to the Beniah Lake Fault Zone (BLFZ), is part of the Yellowknife Supergroup and is underlain by the ca. 2.8 Ga Sleepy Dragon Complex of the Central Slave Basement Complex. The deposit is spatially associated with a rhyolite flow-dome complex and felsic volcaniclastic rocks; however, the majority of the footwall stratigraphy (and the BRVB) consists of andesite and basalt pillow lavas. The banded massive sulfide ore zone, which does not outcrop at surface, is hosted by a strongly silicified and sericitized rhyolite lapilli tuff with a maximum thickness of 40m and strike length of 350m at surface. The immediate hanging wall is composed of moderately carbonate and chlorite altered basalt that also contains trace pyrite and chalcopyrite. While the Sunrise deposit has been explored since the late 1980's, its tectonic setting has not been examined. Based on geochemical characteristics of the surrounding felsic and mafic rocks, this study indicates that the deposit was formed in an extensional continental arc environment, possibly during the initiation of back arc rifting. The rocks are primarily calc-alkaline with low values of Nb/Th (Felsics: ~1.92; Mafics: ~1.01) that suggest a high degree of crustal input and indicate an arc environment. Some of the mafic rocks also feature mixed calc-alkaline and E-MORB Zr/Yb and Nb/Yb signatures, implying that the parental magma may have erupted during early stage back arc rifting. Future work will include O isotope and mineral analyses (X-ray diffraction) to identify the petrogenesis and alteration zones of the lithofacies surrounding the Sunrise deposit. Sunrise has numerous similarities to the larger VMS deposits of the Slave craton in Nunavut. All are located close to the BLFZ (e.g., Hood, Izok Lake, High Lake) and date to ca. 2.6 Ga. Most are Zn rich, felsic-hosted deposits. The only deposit whose tectonic setting has been studied - Hood - is also interpreted to have formed in a continental arc/back-arc setting, hosting mineralization in A-type felsic rocks derived by crustal melting, which are located close to a geochemically identical coeval granitic pluton. These metallogenic similarities may suggest the potential for additional VMS mineralization proximal to the BLFZ across the length of the Slave Craton.

203 - Isotopic and Geochemical Signatures of Base Metal Indicator Minerals from Regional Surficial Samples in the Southern Mackenzie Region, Northwest Territories, Canada

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In glaciated terrain, sampling stream sediments and till for heavy indicator minerals is a powerful means of exploring for undiscovered economic mineral deposits. Geochemical and isotopic studies of recovered

heavy minerals can then be used to provide information on sources of the grains, deposit types and potentially a vector towards mineralization. As part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals Program (GEM), stream sediments and till samples were collected across a 35,000 km2 region of southern Northwest Territories, Canada. The region includes the world-class Pine Point Mississippi Valley-type (MVT) mining district, in addition to several smaller mineral occurrences. Despite its past producing history, very little exploration has been undertaken in the region outside of Pine Point. Till sampling programs conducted as part of three Northwest Territories Protected Area Strategy (PAS) surveys recovered anomalous concentrations of base metal indicator minerals including sphalerite, galena, chalcopyrite, and arsenopyrite from samples up to 400 km from the Pine Point mining district, suggesting the presence of undiscovered mineralization. Secondary ion mass spectrometry (SIMS) determinations of S- and Pb-isotopic compositions and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) of galena grains indicate they were sourced from MVT deposits, which are clearly distinct from those at Pine Point. LA-ICP-MS and electron probe micro analyser (EPMA) data from sphalerite grains also suggests they originated from an MVT-deposit other than Pine Point. Chalcopyrite grains show potential for manto and/or sediment-hosted Cu deposits. Arsenopyrite grains were recovered in much lower concentrations and were likely sourced from orogenic Au systems in the Canadian Shield northeast of the study area. Previous glacial dispersal studies and comminution characteristics of galena and sphalerite grains suggest that undiscovered buried mineral occurrences may lie as little as 700 m away from peak sample abundance sites.

204 - Structural Analysis of the Glennie, Wapassini, Robertson and Palmer Lakes Area, Glennie Domain, Reindeer Zone, Saskatchewan, Canada

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In 2017 and 2018, bedrock mapping conducted by the Saskatchewan Geological Survey focused on a portion of the Glennie domain, Reindeer zone, Saskatchewan. The study area consists of sedimentary, volcanic and plutonic rocks affected by multiple phases of folding, preserving an upper amphibolite facies. In this study, structural analysis was performed on a regional-scale dataset (2625 measurements) with the purpose of identifying interference patterns and characterizing the deformational events. The area was split into nine structural domains, each selected to represent a structurally uniform, sub-cylindrical portion of folding. Poles to foliation (S_1/S_2) from each domain were plotted on lower hemisphere, equal area stereonets to determine related fold geometries. From this analysis we were able to conclude that while F_1 is no longer recorded at map-scale due to subsequent overprinting and metamorphism, S_1 is the dominant structural fabric. F_2 is also hard to distinguish except for domain 2 where F_2 is manifested as isoclinal folds that are co-axially refolded about NE-trending axes (F_4). F_3 folds are well preserved and generally upright to open with local variability in trend; their original orientation is estimated as upright and SE-NW trending. F_4 folds trend SW-NE and plunge moderately to shallowly towards the NE. They vary from upright, open folds in domains 6 and 8 to strongly overturned in domains 2 and 3. The hingeline of F_4 is highly non-cylindrical and plunges towards both the NE and SW; this is potentially the result of superposition on variably dipping limbs of F_3 folds. Since F_3 and F_4 are nearly perpendicular, the map pattern is dominated by Type 1 and Type 2-fold interference patterns, or a hybrid between the two. To accompany map-scale structural analysis, thin sections were prepared from representative lithologies in all domains to characterize the tectonic fabric elements and related mineral assemblages associated with

each deformational phase. We also aim to determine if any U-bearing minerals like monazite and/or zircon are present to (in future) help to constrain the timing of development of these fabrics. Lastly, the Reindeer zone is known to host significant VMS and gold deposits although none have been detected in the immediate area. Nevertheless, the structural approaches in the study should be highly transferrable to other parts of the Glennie domain that are potentially more prospective. Attention is also being focused on economic indicator minerals (i.e sulphides) to place constraints on their occurrence and timing with respect to structural events.

205 - Metallogeny of the Woman River Iron Formation: implications for timing of hanging wall and foot wall volcanic successions, Swayze area of the Abitibi greenstone belt, Ontario

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The Swayze Area (SA) represents the southwestern extent of the Abitibi greenstone belt as they are comprised of the same volcanic episodes. Metasedimentary rocks, principally the Woman River iron formation (WRif) and associated, fine-grained clastic metasedimentary rocks, define the end of felsic volcanism through the central section of the SA. Volcanic stratigraphy associated with the WRif comprises a footwall sequence of felsic to intermediate, ca. 2735 +6/-4 Ma, and a hanging wall succession of intermediate to mafic flows, the age of which is currently under investigation. The WRif and associated argillaceous metasedimentary rocks mark a hiatus between major volcanic episodes. Base metal mineralization within and proximal to the WRif is well exposed at several sections along its northeastern trend. Trenches expose massive to semi-massive pyrite, pyrrhotite and more localized massive and stockwork sphalerite, galena and chalcopyrite sulphide zones in the WRif. The sulphide mineral associations of chalcopyrite-galena-sphalerite, and pyrite-pyrrhotite suggest mineralogical zoning within ore lenses. Stockwork mineralisation crosscuts felsic footwall volcanic flows. Hydrothermal alteration associated with the base metal mineralization occurs throughout the WRif, and in the underlying felsic to intermediate volcanic rocks. Metamorphosed alteration occurs as a pervasive chlorite-garnet mineral association. Late pervasive and localized iron-carbonate alteration occurs in areas of intense deformation. In order to constrain timing of formation of the WRif the volcanic rocks in the hanging wall and footwall to the WRif were sampled for U-Pb zircon geochronology analysis. Historically mineralization along the WRif has been interpreted to be syngenetic with the WRif, however, evidence from field work suggests that base metal mineralisation is synvolcanic with hanging wall volcanism and related sills.

206 - Metallogeny and chemostratigraphy of the Elmhirst-Rickaby tectonic assemblage: An Archean andesitic package

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Calc-alkaline volcanic rocks and basalt-rhyolite fractionation typify modern collisional settings. The lack of extensive calc-alkaline andesitic successions and the distinct bimodality of Archean volcanic successions

suggest their formation mainly in extensional environments where initial melts rise quickly to the surface without undergoing significant fractionation or mixing. Accordingly, most of the syn-volcanic mineralisation present in Archean successions is associated with volcanogenic massive sulphide (VMS) processes that form in high-heat flow extensional tectonic settings. The ca. 2740 Ma Elmhirst-Rickaby (ER) assemblage represents the southernmost margin of the Onaman-Tashota (OT) greenstone belt, a portion of the Eastern Wabigoon Sub-Province within the Superior Craton, and comprises one of the largest calc-alkaline andesitic volcanic packages currently recognised in the Archean. The OT belt is frequently cited as one of the least-endowed Archean greenstone belts, and currently contains no producing VMS deposits or former VMS mines; however, numerous mineralisation styles are recognised throughout the belt. Here we show that the andesitic portion of the ER assemblage formed either in a compressional setting, or through over-thickened crust, and that the unique metallogeny of this assemblage can be attributed to this unique Archean geodynamic setting. We subdivided the ER into three main lithostratigraphic units: 1) a lowermost, calc-alkaline, pillowed mafic flow sequence; 2) a calc-alkaline, andesitic package dominated by coarse, resedimented volcaniclastic, epiclastic, and pyroclastic rocks with minor intermediate flows and intrusions; and 3) a thin succession of blocky, FII affinity, rhyolitic flows. These three packages appear to represent a progressive fractionation trend from mafic to felsic compositions, suggesting significant source residence time in the crust prior to eruption. Hydrothermal base-metal mineralisation is concentrated within the uppermost portions of the 2nd unit and within the 3rd unit, and occurs in two main styles: 1) base-metal sulphide stringers associated with sericitic alteration, and 2) comb-textured, quartz-base-metal sulfide-magnetite veins associated with amphibole-chlorite alteration and magmatic-hydrothermal tourmaline breccias. Both of these occurrence styles are associated with syn-volcanic tonalitic-dioritic intrusions and have a distinct trace element association of Te-Cs-Cd-W-Sn-Hg-Se. The mineralisation styles, associated alteration, and host rock petrology of these occurrences are atypical in the context of extensional VMS systems, and the metal association is consistent with magmatic fluid input compatible with the evolved, fluid-rich nature of the host calc-alkaline sequence. The unique chemostratigraphy and metallogeny of the ER points to a geodynamic environment that would allow for significant magma storage, either from compressional stresses, or via an over-thickened crust.

207 - The Powell fault, Rouyn-Noranda, Québec: Evidence for a synvolcanic origin

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Notwithstanding almost 100 years of exploration and research in the Rouyn-Noranda district, uncertainty remains as to the volcanic and deformation history of the Powell Block (PB), which separates the Au-rich Horne and Quemont volcanogenic massive sulfide (VMS) deposits from conventional VMS deposits to the north. The stratigraphy of the PB has not been established and there is a distinct lack of structural data. In particular, a better understanding of faults within the PB is critical to reconstruct the volcanic stratigraphy and to map potential hydrothermal upflow zones for VMS style mineralization. The Powell Fault (PF), which cuts across the centre of the PB, is one of these structures. The PF is an east-west trending 2-4 m wide zone of intense schistosity, occurring over a strike length of approximately 2.5 km. Parallel to the schistosity is a sub vertical lineation, defined by elongate quartz-sericite alteration spots. On vertical surfaces, shear bands and asymmetrical strain shadows around carbonate vein clasts suggest north-over-

south, reverse movement parallel to the lineation. The lack of intense crenulation of the main shear foliation and the limited distribution of younger dextral shear sense indicators (z-folded quartz veins and associated weak, spaced, axial planar cleavage) suggests that major dextral reactivation of the PF did not occur. This is in contradiction to the apparent 700 m dextral offset of a marker tuff unit, which is found on both sides of the PF. This offset is inferred to be related to early synvolcanic movement along the PF, which is supported by the following observations: 1) older volcanic units show larger offsets than younger volcanic units; 2) the PF is sub-parallel to other mapped synvolcanic structures; and 3) a post-volcanic lamprophyre dike is deformed (emplaced pre-syn deformation), however it shows minimal offset by the PF. The other mapped synvolcanic structures are spatially associated with VMS style alteration and Cu-Zn vein mineralization, suggesting that they acted as conduits for syn-volcanic hydrothermal fluids. Because the PF is synvolcanic and parallel to these structures, it represents a new favourable exploration target for proximal VMS mineralization in the PB.

208 - A metalliferous exhalative horizon in the Pontiac Subprovince: characterization and potential for mineral exploration, Lac Bellecombe, Rouyn-Noranda, Québec, Canada

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A newly discovered metalliferous exhalative horizon in the Archean Pontiac Subprovince offers mineral exploration potential in an area otherwise characterized by low metal endowment. The Pontiac Subprovince near Lac Bellecombe is comprised of a thick sequence of metagreywackes with lesser intervals of ultramafic-mafic metavolcanic rocks. The exhalative horizon is located within the contact zone between Pontiac Group metasedimentary rocks and an ultramafic-mafic volcanic package that forms a ~15-kilometer continuous belt. Fieldwork involved detailed mapping and sample collection for thin section petrography (n=13) and Cu-Zn-Au-Ag assay (n=12). Detailed mapping delimited the exhalative horizon to have a thickness of ~3 m and a strike length of at least 250m in the Lac Bellecombe Area. The exhalative horizon outcrops as thin, laminated beds of dark grey graphitic mudstone to siltstone, and thin sulphide quartz beds. The unit has been strongly deformed along with its host rocks and locally displays isoclinal folding. The mineralized samples contain sphalerite, and minor amounts of chalcopyrite, pyrrhotite and galena which occur within the sulphide quartz beds. Coarse-grained, euhedral pyrite (>5mm) within the sulphide quartz beds have secondary overgrowths containing inclusions of sphalerite and chalcopyrite. Sphalerite occurs as rounded grains (>1mm) displaying chalcopyrite disease. The host mudstone beds contain fine-grained rutile rimmed by titanite and are interpreted as possible alteration of ilmenite. Cu-Zn-Au-Ag assay results revealed anomalously high Zn values up to 3000 ppm, along with 330 ppm Cu, 1 ppm Ag, and Au values below the detection limit. Future petrographic and mineralogical analyses, including microprobe analyses of the various generations of sulfides, will be undertaken to help constrain textural relationships, mineral compositions, and sulfide paragenesis. The results will be compared with similar Zn occurrences hosted in the Pontiac Subprovince. The discovery of this Zn occurrence has implications for the metallogeny of the Pontiac Subprovince and could open a renewed exploration interest in the study area.

209 - Volcanic reconstruction of the ca. 2701 Ma Duprat-Montbray formation and implications for targeting new volcanogenic massive sulfide deposits in the Lower Blake River Group, Rouyn-Noranda, Québec

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New geological mapping, geochronology, and geochemical data indicate a continuation of the VMS-hosting stratigraphy within the ca. 2701 Ma Duprat-Montbray formation (DMF). The DMF is part of the Lower Blake River Group volcanic succession in the prolific Noranda VMS camp. Volcanic strata of the DMF comprises basaltic andesite flows that surround the newly dated 2700.4 ± 1.1 Ma lower rhyolite unit, which are overlain by andesite units containing the VMS-hosting 2701.9 ± 0.9 Ma upper rhyolite unit. Volcanic activity of the DMF is constrained to a 500 000-year time interval at ca. 2701 Ma. Bedrock exposures indicate that volcanism included pyroclastic and effusive processes in a shallower submarine environment based on the occurrence of ballistically emplaced volcanic bombs and tuffs generated by explosive hydrovolcanic fragmentation. The 2700.6 ± 1.0 Ma synvolcanic Fabie pluton, a composite hypabyssal intrusion consisting of quartz-feldspar porphyritic tonalite and lesser diorite, intrudes the volcanic succession. The pluton is located stratigraphically below the upper rhyolite, which is host to the Fabie and Magusi VMS deposits and may have acted as a heat source for the hydrothermal system. Bedding orientations indicate that the DMF strata define an open, steeply inclined, and moderately SW-plunging anticline. The fold wraps strata around the more competent Fabie pluton and allows for a previously unrecognized western continuation of the VMS-hosting rhyolites into the southern portion of the DMF. This westward extension of VMS favourable strata offers a new potential target for VMS exploration.

210 - Siting of the seafloor massive sulfides at the Lucky Strike segment, Mid-Atlantic Ridge

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Seafloor massive sulfide (SMS) deposits are commonly found associated with magmatism and faulting at Mid-Ocean Ridges and other extensional settings. The Lucky Strike segment is located on the Mid-Atlantic Ridge, near the Azores hot spot, and hosts the large Lucky Strike hydrothermal vent field and associated SMS mineralization. Previous studies have shown mantle plume related influence in the volcanic package at this ridge, and this plume influence is also reflected in high concentrations of barium (abundant barite) within the SMS deposits, which is not common for typical mid-ocean ridge deposits. Hydrothermal barite can be dated using the ^{226}Ra/Ba method, thus providing a tool to examine the temporal evolution of the Lucky Strike deposit. The Lucky Strike deposit was sampled using a remotely operated vehicle (ROV), and SMS mineralization has been identified both on and off the main spreading axis. Furthermore, recently collected high resolution (~1m) bathymetry from the central area of the segment and has allowed to extract fault information (strike and dip) within the host volcanic complex. The presence of barite and the high resolution bathymetry allows for the timing and structural controls on the growth of the deposit to

be determined. This study shows that the oldest and largest sulfide deposits at this hydrothermal site are located at the intersection of the axial magma chamber (heat source) and an accommodation zone (enhanced permeability) where principal stress fields have shifted and a clockwise rotation has occurred. These results highlight the value of high resolution bathymetry to study seafloor massive sulfides and how structural and geochronology constrains are key to understand the evolution of these hydrothermal systems. Lessons from active SMS deposits can be applied to ancient volcanogenic massive sulfide deposits.

211 - Exploring lineament analysis (volcanic ridges and faults) and the distribution of seafloor massive sulphide deposits in the Lau Basin

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Numerous seafloor massive sulphide (SMS) deposits are reported from the Lau back–arc basin in the southwest Pacific, which opened due to trench rollback at the Tonga Trench approximately 6 m.y. ago. Multiple vent fields are located within the Eastern Lau Spreading Centre, the Valu Fa Ridge, and the Fonualei Rift. These spreading centres are characterized by a typical spreading fabric, which develops perpendicular to the spreading direction and is manifested as volcanic ridges and faults. Mineral-rich hydrothermal fluids use these structures to migrate through the crust and discharge onto the seafloor to form SMS deposits. However, the structural control on the occurrence of the deposits is not well understood. Satellite-derived gravity models and ship-based multibeam bathymetric data were combined in the Eastern Lau Spreading Centre, the Valu Fa Ridge and the Fonualei Rift to identify crustal fabric and lineations in each area. The lineaments, classified as faults or volcanic ridges, were mapped in a GIS program, and the orientations and lengths of each feature compiled, tabulated, and compared to the locations of the SMS deposits. Correlations were examined based on the position, length, and size of faults and ridges at each site. The majority of vents in the Eastern Lau Spreading Centre are distributed alongside major ridge structures with lengths >3 km long. Highly active SMS vents in the Valu Fa Ridge occur on shorter ridges that are approximately 1.5 km in length. Fonualei Rift vents are on the shortest segments (~1 km long) where rifting has only just started, although some plumes in the north have been found on longer ridges where seafloor spreading is observed. The link to the length of ridge segments, occurrence of hydrothermal vents, and different conditions of rifting versus spreading implies a highly variable magma supply along strike that is most likely controlled by a complex regional stress regime. The Lau back-arc basin is frequently used as a modern analogue for Archean greenstone belts such as the Abitibi subprovince in Canada, which contains significant VMS deposits. Understanding the link between the location of modern SMS deposits and the pathways by which they form at or below the seafloor may help to explain the distribution and emplacement mechanism of VMS deposits in Archean greenstone belts.

212 - Host rocks in the active Lau Basin and ancient mineralizing systems

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The Archean Abitibi greenstone belt is host to world-class Cu-Zn volcanogenic massive sulfide (VMS) deposits and continues to be a primary exploration target. However, discovery of the next generation of

deposits at greater depths will rely on improved geological models. In Archean terranes, overprinting deformation and metamorphism complicate the correlation of host-rock geochemistry with mineral potential. In contrast, modern submarine volcanic systems, such as the Lau Basin of the western Pacific margin, provide the opportunity to observe active ore-forming environments, including host rock geochemical signatures and structural controls. We present a lithogeochemical investigation of the relationship between volcanic host-rock compositions and magmatic-hydrothermal mineralizing systems in the Lau Basin as a comparison for the Abitibi greenstone belt, with a particular emphasis on the geological evolution of arc rifting events at the initiation of backarc spreading. A complete compilation from published literature and cruise reports of data collected in the Lau Basin since 1970 forms the basis of this study. This dataset is complemented by a lithogeochemical database for the Abitibi greenstone belt compiled from literature and government databases. Major similarities and differences in the lithogeochemical signatures of modern and ancient host rocks are highlighted. Significantly, geochemical shifts in the compositions of volcanic rocks signal changes in m antle and crustal processes that may be favorable for ore formationClick or tap here to enter text., which is similar to what is observed in ancient settings. This lithogeochemical study provides further insight into the development the Lau Basin and evolution of the Abitibi greenstone belt, which are both of significant interest for industry and the academic community. Lithogeochemical signatures of mantle processes associated with ore-forming environments in the Lau Basin will help identify exploration vectors in Archean greenstone belts and target the next generation of ore deposits in Canada and globally.

213 - Structural Evolution of the NE Lau Back-arc Basin: Links to Tectonic Regime and Magmatic-hydrothermal Systems

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A series of cruises have identified an unusual amount of hydrothermal and volcanic activity in the NE Lau back-arc basin. Hydrothermal systems operate and mineralize the seafloor in multiple settings, including along spreading centres, and surrounding submarine calderas and volcanoes. The area is very tectonically complex as a result of microplate interactions, changing subduction regimes and tearing of the under-riding Pacific Plate. These interactions lead to the fastest back arc spreading rates on the planet and produce a dynamic environment with abundant heat sources capable of driving hydrothermal systems, generating ore deposits and nurturing chemosynthetic/biologic communities. Strike-slip tectonics in the north lead to the ridge-trench-trench triple junction, a rare phenomena and of interest due to the nearby presence of boninites and other arc-like affinities, which are often associated with VMS style mineralization. This project aims to identify the generations of structures acting as hydrothermal conduits,which transport fluids and precipitate metals. Parameters of digitized structures, cross-cutting relationships, magnetic anomalies, gravity data, and earthquake centroid moment tensors were used to constrain the structural evolution of the basin. Known mechanisms based on mid-ocean ridge and back-arc models were tested in an attempt to explain why there is increased volcanism and hydrothermal activity in certain areas of the basin. Preliminary results include; (1) the first geological map of the area (1:5000) based on bathymetry, backscatter, and lithologic sampling. (2) Identification of ~10000 faults/lineaments, and ~500 volcanic features. These are separated into seven structural provinces. (3) Results indicate the Subduction-Transform Edge Propagator (STEP) strongly controls the orientation of features within the basin, strain appears to be accommodated dominantly at 75° to imposed shear (R’),

and to a lesser degree at 15°(R). R' and R form two main structural corridors which intersect in an area near a large, eight kilometre wide, submarine caldera (Niuatahi). It is possible that the interplay of these sinistral and dextral fault sets provided the shallow fracture network needed to accommodate large scale volcanism and hydrothermal activity. This project will add a structural data set which researchers can use to further understand ore forming processes in both modern and ancient subduction-related settings; and may provide insights on the influences of basement structures on the emergence on microplates in the Lau basin.

300 - Epithermal Deposits

301 - The formation and origin of ultra-high-grade gold ore at the Brucejack deposit, northwest British Columbia: insights from nanoscale imaging of electrum and high-resolution trace element and sulphur isotope analyses of pyrite

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A major shortcoming of existing genetic models for epithermal gold deposits is that they do not satisfactorily explain the mechanisms responsible for the formation of ultra-high-grade ores. In addition, the source of fluids responsible for this style of mineralisation, their possible relationship with spatially associated porphyry systems, and the controls on to the development of extreme, 'nuggety' spatial gold grade gradients commonly encountered in these deposits are equivocal. We have therefore undertaken a study of the large, exceptionally high-grade (up to 41,582 g/tonne in 0.5 metre drill core intervals), Brucejack intermediate-sulphidation epithermal deposit to investigate the mechanisms of gold transport and deposition associated with formation of the deposit, and the chemical characteristics of its ore and associated hydrothermal alteration. Results from transmission electron microscopic imaging reveals the presence of abundant < 1 to 10 nm wide spherical nanocrystals of electrum within ore veins, providing definitive evidence that boiling-mediated nanoparticle suspensions (colloids) played a central role in ore formation. LA-ICP-MS and EMP-WDS trace element analyses of pyrite from phyllically-altered wallrock in the Valley of the Kings (VOK) and Eastern Promises zones show increasing enrichment of Co, Ni, Se and Cu with depth, documenting an otherwise cryptic transition to propylitic and potassic alteration and associated Cu-Mo mineralisation in deep drill core from the adjacent Flow Dome Zone. Strong positive shifts in $\delta 34S_{pyrite}$ values (> 20.0 ‰) from in situ SIMS analysis of VOK hydrothermal pyrite suggest that seawater mixed with hydrothermal fluids during the late stages of ore formation. Ongoing and future petrographic, mineral-chemistry, and fluid-inclusion studies will further test these interpretations and search for other insights into the physicochemical evolution of the Brucejack deposit. Ultimately, we aim address the fundamental question of whether the large, high-grade Brucejack resource can be formed using simple solubility considerations or whether non-solution (physical) gold transport models are required.

302 - Magmatic-hydrothermal history of the Klaza epithermal deposit in the Mt. Nansen district, Dawson Range, Yukon

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Understanding the magmatic-hydrothermal history of well-preserved Au-Ag-rich base metal sulfide veins from the Klaza epithermal deposit provides insight into Late Cretaceous porphyry-forming metallogenic events in the Mt Nansen district and the Dawson Range belt. The mid-Cretaceous (~107 Ma) granodiorite of the Whitehorse plutonic suite forms the host rock to mineralization and is first intruded by magnetite-bearing mafic composition dykes with an age of 78.0 ± 1 Ma. Stage 1 quartz-muscovite-pyrite sheeted veinlets cut this assemblage with a phyllic alteration halo dated at 79.02 ± 0.39 Ma (Ar-Ar sericite). Intermediate composition feldspar porphyry dykes with anhedral quartz phenocrysts cut this assemblage with a northwest, steeply dipping trend. CA-TIMS and LA-ICPMS dating of this generation of dykes reveals a bimodal age distribution of 76.568 ± 0.022 Ma and 71.37 ± 0.02 Ma, signifying two distinct pulses of magmatic activity. The Stage 2 base metal veins are only observed to crosscut the 76 Ma dyke suite. Stage 2a veins occur as massive fine-grained arsenopyrite-pyrite-sphalerite ± quartz veins, with electrum intergrown with arsenopyrite, pyrite and sphalerite. Stage 2b veins hydraulically fracture Stage 2a veins and are characterized by banded quartz-galena-acanthite-sphalerite-chalcopyrite ± sulfosalt assemblages. Stage 3 consists of multiple phases of carbonate veins (ankerite-dolomite-rhodochrosite±galena-sulfosalts) which brecciate Stage 2 veins at depth. Bladed barite and colloform carbonate-quartz textures occur in Stage 3 veins at shallow depths between 100-150 m below the current erosion surface. A similar vein paragenesis is observed in other epithermal systems in the Dawson Range such as Tinta Hill and Casino, suggesting a possible metallogenic event linking various Au-Cu porphyry-epithermal systems in the area.

303 - Geochronology and stable isotope of the Tiegelongnan porphyry-epithermal Cu deposit, Tibet, China

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The Tiegelongnan porphyry-epithermal Cu deposit is a recently discovery in the Duolong porphyry Cu-Au deposits district, within the Bangong-Nujiang belt in Tibet, China. It contains measured and indicated resources of around 2,000 Mt @ 0.53% Cu, which is characterized by high sulfidation epithermal Cu mineralization telescoping on porphyry Cu mineralization. There are mainly five alteration stages with dominant mineral assemblages are: sericite-quartz (stage 1), chlorite-epidote (stage 2), dickite-pyrophyllite (stage 3), alunite (stage 4) and kaolinite-dickite (stage 5). Mineralization events include porphyry stage : chalcopyrite-molybdenite (sulfide 1), chalcopyrite-bornite-pyrite (sulfide 2), and epithermal stage (sulfide 3) contains mainly tennantite-enargite-pyrite with some bornite, chalcopyrite, digenite, covellite, glena, sphalerite etc. It is formed during several discrete pulses of magma

emplacement and magmatic-hydrothermal fluid intrusion. Absolute zircon U-Pb dated porphyritic magma intrusions emplaced at 123Ma, 121Ma, 119.9Ma, 119.1Ma and 116Ma respectively, molybedenite Re-Os ages are 121Ma and 119Ma, meanwhile, biotite, muscovite, and alunite 40Ar-39Ar dating yielded hydrothermal events ages at 121Ma (biotite and muscovite1), 116 and 112Ma (alunite), and 109Ma (muscovite2). It indicates porphyry mineralization and alteration took place between 123Ma and 119Ma, while epithermal aluntie-sulfide events came later between 116Ma and 112Ma. The geochronology data suggests this Tiegelongnan deposit had experienced an extremely long magmatic-hydrothermal life span, which is corresponding to the long time active tectonic and magmatic activities in the Bangong-Nujiang suture zone, central Tibet. Oxygen and hydrogen stable isotope of gangue minerals and their stable isotopic equilibrium water composition indicate biotite and sericite (muscovite) are magmatic origin, alunite and kaolinite are results of mixing of meteoric water and magmatic fluid, and some meteoric water are trapped in quartz fluid inclusions showing depleted δD value. Sulfur isotope of porphyry mineralization stage sulfides (sulfide 1 and sulfide 2) are mostly between -4.4‰ and 0.8‰, originated from magmatic sulfur. The fluid composition of these stages is H2S dominant suggesting relatively reduced environment, because few oxide minerals or simultaneously deposited sulfate occurred. Sulfur isotope geothermometry of Δ34Salunite-pyrite gives epithermal temperature between 204 and 256 ℃. Enargite in alunite veins are out of S isotopic equilibrium with alunite suggesting probably they did not deposit at same time. Varying sulfide δ34S value range (-32.2 to -9.5‰) and low-variance alunite δ34S value range (+11 to +15.8‰) suggesting a SO42- dominant and relatively oxidized environment during epithermal mineralization stage.

304 - Characterization of ammonium bearing alteration associated with epithermal gold mineralization in southern Kyushu and northeastern Hokkaido, Japan

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Ammonium produces absorption of shortwave infrared (SWIR) spectrum and can be easily detected using a core scanner and a portable infrared spectrometer in the field. Furthermore, it is common in and around epithermal precious metal deposits and this provides the potential use of ammonium as a vector for deposits. However, minerals hosting ammonium and its precise concentrations are not well understood. This study addresses these questions by examining samples from two districts (southern Kyushu and northeastern Hokkaido, Japan) which host many epithermal Au mines. Southern Kyushu samples include auriferous veins and alteration halos around the low sulphidation Au deposits at Hishikari (>440t Au, 400 ppm) suggesting the substitution of potassium (ionic radius of 1.52 A) by ammonium (1.69 A). Ammonium concentrations are high with values up to 4920 ppm NH4 in samples from the Kitami area, Hokkaido, whereas samples from both Hishikari and Kasuga mines in southern Kyushu exhibit moderately high values. Samples from the Fuke and Tobaru deposits in Kyushu show high average ammonium contents (1562 ppm NH4) compared to those from the nearby Hishikari deposit (av. 565ppm NH4) whose veins occur mostly in shale. Considering the occurrence of sedimentary rocks as wall rocks and in the basement in all study areas, these sedimentary rocks likely contributed ammonium to auriferous fluids, but proximal host rocks appear to not be the major source of ammonium.

305 - Ammonium alteration associated with epithermal silver mineralization in Mexico

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Ammonium-bearing minerals are common in alteration associated with epithermal silver deposits in Mexico and the ammonium halo is used as a guide in exploration for deposits. Since ammonium produces absorption in shortwave infrared (SWIR), a portable SWIR spectrometer is extensively used in exploration. The quantity of ammonium to produce the absorption in the spectrum is unknown. This study was initiated to quantify the ammonium contents in rocks, identify minerals hosting it, and evaluate its source. Samples were collected in the El Zapote prospect of the Tizapa mining district in the Sierra Madre Occidental of Mexico. The Ag mineralization forms quartz veins spatially associated with Tertiary rhyolitic igneous rocks, which overlie a Mesozoic metasedimentary basement of phyllite and limestone. Rhyolite contains phenocrysts of quartz and K-feldspar in the pervasively altered groundmass of fine-grained quartz, illite, muscovite and kaolinite. K-feldspar phenocrysts are commonly replaced by illite. The occurrence of scorodite and acanthite in alteration halos suggests the enrichment of As with the Ag mineralization. Illite shows two types; coarse-grained (1-2 mm) and fine-grained (~200 um) Mg-rich (up to 1.28 wt% MgO) illite. Ammonium contents range from 330ppm to 1750ppm, but no ammonium mineral is detected with x-ray diffraction. High ammonium samples (> 1330 ppm) contain abundant fine-grained illite (~20 wt%), suggesting that ammonium mostly resides in the K site of fine-grained illite. A correlation of N vs K2O, (~0.08 wt% N is ~ 3 wt%K2O) suggests that approximately 9% of potassium is replaced by ammonium. The relationship between ammonium content and absorption in SWIR spectrum is not apparent. Samples with no absorption of ammonium in SWIR spectrum yielded ammonium from 330 ppm to 1020 ppm, whereas samples with 540 ppm and 830 ppm ammonium show strong absorption feature in the SWIR spectrum. The δ15Nair(‰) range from +1.1 to +6.1 independent of the ammonium concentrations, suggesting a significant contribution of ammonium from sedimentary rocks to mineralizing fluids. The signature may be related to the metasedimentary basement of the region.

306 - Thallium mineralogy of the Taron epithermal Cesium deposit: Implications for economics, mining, metallurgy and the environment

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The Taron Project (Cascadero Copper Corporation) is a Miocene epithermal cesium deposit situated in a graben-like structure composed of late Tertiary sedimentary and volcanic rocks (graben fill) straddling the contact between the Eastern Cordilleran Ranges and the Altiplano-Puna volcanic complex in the eastern central Andes. The deposit is dominated by cryptocrystalline silica, manganates, arsenates, and oxides. Cesium is predominantly hosted in pharmacosiderite; which can contain up to 12% Cs. Assay results have identified intervals of drill core with up to 0.5 wt% thallium over 2m. Due to the high toxicity of thallium, a potential association with the Cs ore minerals could impact the project economics. Analysis of the assay

data of 2m intervals from three drill holes show positive correlations of Tl to Mo, Cu, Mn, Ba, Co, Zn, U, Sr, As, Ag, P and Rb. fp-XRF spot analysis identified a dull earthy black mineral with up to 5 wt% Tl. fp-XRF data show a positive correlation of Tl to Hg, Mn, Ba, S, K, Te, Sr and Cu and negative correlations with As, Ca, Fe and Ti. XRD indicates the thallium rich material comprises the manganates, cryptomelane, hollandite, and the Mn-bearing arsenate sailaufite. XRD also reconfirmed pharmacosiderite as the principal arsenate. Hence whilst thallium is not found in the same minerals as cesium, the two elements are however, spatially associated within the 2-meter drill core intervals. Analysis of the manganate and arsenate minerals is in progress using microscopy, SEM and electron microprobe to confirm the Tl mineralogy.

400 - Intrusion-related Deposits

401 - White mica geochemistry as a vectoring tool applied to exploration of porphyry systems

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Over the last decade, significant advances have been made in the research of alteration mineral geochemistry relative to the targeting of poorly exposed porphyry copper deposits. This work provides new constraints on the identification of signatures and distance indicators for mineralized porphyry ore bodies based on geochemical variations present in white micas within the phyllic alteration zone. This is the first systematic study of the white mica vectoring tool grounded in the differentiation of distinct phyllic alteration events. Careful analyses using petrographic, short-wave infrared spectroscopy, electron microprobe, and laser ablation-inductively coupled plasma-mass spectrometry methods of white micas from early and late phyllic alteration assemblages were undertaken to unravel exploration potential in two porphyry systems in Montana, USA. Analytical data indicate that white micas from the early phyllic events display long-wavelength Al-OH absorption features, which are correlated with higher content of Fe and Mg, and lower content of V and Sc. In contrast, white micas from the late phyllic events are characterized by short-wavelength Al-OH absorption features, with lower Fe and Mg, and enrichment in V and Sc. Variations of trace element concentrations in white micas from the distinct phyllic events show clear patterns in relationship with distance from the hydrothermal center, and are suggested to be dominantly thermally controlled. At the Copper Cliff porphyry system, Cu concentrations decrease with distance from the deposit center, in contrast to B, Sr, and Zn that show an exponential concentration increase with distance from the deposit center. The application of the Cu/Zn ratio of white micas in a manner analogous to the chlorite proximitor equation of Wilkinson et al. (2015) provide an indicator of distance to the center of the hydrothermal system within approximately 710 m in samples of the early phyllic alteration event, and within approximately 1,300 m in samples of the late phyllic alteration phase. At the Grasshopper prospect, increases with proximity toward the center of the system were observed in elements including, V, Cu, Sc, Sn, W, and Zn, whereas increasing trends with distance from the deposit center are observed in Li and Cs. Comparison of the trace element concentrations of white micas from the early phyllic style from the poorly mineralized system of Grasshopper, and the mineralized system of Copper Cliff indicates significant differences in Zn, Cr, B, Tl, Sn, and Cs.

402 - Sulfur mobility in arc magma systems: Implications for porphyry ore deposits

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Porphyry ore deposits supply two-thirds of the world's Cu and nearly all of its Mo, as well as significant amounts of Au, Ag, and critical elements such as Re, Se and Te. These deposits form as a result of arc-related volcanism, when partial melts generated by dehydration melting of the subducting basaltic ocean crust percolate upwards through the mantle wedge and accumulate at the base of the crust in a process called underplating. As these mafic magmas fractionate, felsic melts segregate and ascend to the middle and upper crust where they form magma chambers that are thought to be the source of ore fluids in porphyry systems. However, a major problem with sourcing porphyry fluids from intermediate to felsic magmas is that mass balance calculations indicate that such silicic magmas cannot supply all of the S in porphyry ore deposits. The most plausible explanation for the excess S in porphyry deposits is underplating of middle to upper crustal silicic magma chambers by decompressing, volatile-saturated mafic magma that delivers volatiles such as S, H2O, and Cl, and possibly metals into the overlying felsic magma. This study explores the effects of underplating on volatile exchange between a mafic recharge magma and felsic host magma by simulating an underplating scenario. Diffusion-couple experiments were performed wherein a cylinder of mafic magma (basaltic andesite) was juxtaposed beneath a cylinder of felsic magma (dacite) and run under a range of pressure-temperature-composition-redox conditions relevant for upper crustal arc magma (porphyry) systems. The most intriguing finding is the development of a redox gradient of ~1.8 log units fO2 at the mafic-felsic interface of the most oxidizing (FMQ+4) experiments, where the mafic melt is oxidized and the felsic melt is reduced. Sulfur x-ray absorption near-edge structure (S-XANES) analyses also indicate complex S-speciation near the mafic-felsic interface in the most reducing (FMQ+1) experiment. Such a gradient affects the speciation of redox-sensitive elements such as S and moderates mass transfer from mafic to felsic melt, as well as affecting the metal-scavenging potential of an exsolved magmatic-hydrothermal volatile phase. Studying the effects of underplating in arc systems is paramount to understanding the source(s) and mechanisms responsible for the titration of volatiles and metals into ore forming environments and could help reconcile the excess sulfur problem in volcanic systems.

403 - Analysis of K-Feldspar from NYF-Type Rare-Element Pegmatites

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Rare-element pegmatites are subdivided into Niobium-Yttrium-Fluorine (NYF) and Lithium-Cesium-Tantalum (LCT)-types. This study examines the texture and composition of blocky K-feldspar samples from thirteen different NYF-type pegmatites related to anorogenic magmatism. Optical microscopy and backscatter imaging shows that all samples display perthitic textures and variable degrees of sericitization. Major and trace element data, obtained by electron microprobe analysis (EMPA) and laser-ablation inductively coupled mass spectrometry (LA-ICPMS), respectively, show that the composition of K-feldspar

reflects the degree of fractionation attained by the pegmatite. The K/Rb values, which range from 8.5 to 380.2 ppm, decrease with increasing Tl (0.98 to 59.70 ppm), Cs (1.53 to 517.67 ppm), and Ga (20.35 to 90.73 ppm). In contrast, Sr decreases with increasing fractionation. A comparison of these data with K-feldspar compositions from LCT-type pegmatites, indicate that NYF and LCT rare-element pegmatites can be easily distinguished using rare-alkali versus Ga discrimination diagrams. Relatively low Rb/Ga ratios, which is characteristic of K-feldspar from NYF-type pegmatites, most likely implies derivation from Ga-enriched source rocks. These results provide a basis for ongoing stable and radiogenic isotopic investigations of the sources of rare element granitic pegmatites.

404 - Geochemical characterization of K-feldspar from LCT-type granitic pegmatites

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The major and trace element composition of K-feldspar (a common rock-forming mineral) from different Lithium-Cesium-Tantalum (LCT)-type granitic pegmatites was determined in order to define the chemical characteristics of K-feldspar indicative of rare-element enriched pegmatite groups. LCT-type pegmatites are of economic interest because they are an important source of minerals used for ceramics (feldspars), glass (quartz), batteries (lithium), gems (beryl, tourmaline) and electronic components (Ta-oxides). Polished thin sections of K-feldspar from 11 major LCT-type pegmatites were examined using optical microscopy and electron backscattering imaging in order to describe subsolidus textures. Major and trace element concentrations were obtained using electron microprobe analysis (EMPA), and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), respectively. The results reaffirm known pegmatite fractionation trends, which show an increase in Li, P, Rb, Cs, Tl, Ga and Ge with increasing fractionation. K-feldspar from the Kamativi tin mine, Zimbabwe, was unique because of its anomalous concentrations of Sn (10-30 ppm). A comparison of K-feldspar compositions from LCT-type pegmatites (this study) and Niobium-Yttrium-Fluorine (NYF)-type pegmatites (Pushie 2019) reveals separate and distinct fractionation trends that are readily distinguished using rare-alkali versus Ga discrimination plots. The distinct geochemical character of K-feldspar from these rare-element pegmatites implies different source reservoirs. The data collected in this study facilitates identification of pegmatite groups of economic interest and provides a foundation for future stable and radiogenic isotopes investigations aimed at determining the source and evolution of mineralized pegmatite systems.

405 - An integrated stable isotopic and textural study of the Little Nahanni LCT-type rare-metal pegmatite system, NWT

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Understanding the origin and distribution of the increasingly more important strategic metals is paramount for both their exploration and exploitation. Here we present results of our ongoing work on the LCT-type, rare-metal (RM) rich (Li-Ta-Sn), Cretaceous (82 Ma) Little Nahanni Pegmatite Group in the Northwest Territories, Canada. Although previously studied, its origin and internal evolution remain

poorly understood. As with other LCT pegmatites, its RM (Ta-Sn±Nb) mineralization occurs in albite(-lepidolite) zones associated with sodium metasomatism. By integrating petrographic and textural observations with a set of stable isotopes (i.e. δ18O, δD), this study aims to address the following issues: (1) source of the pegmatite-forming melt; (2) internal evolution of the pegmatite; and (3) nature and origin of the Na-metasomatism and associated RM mineralization. The stable isotopes reveal a strong local isotopic disequilibrium reflecting the influence of meteoric fluids and wall rock contamination during its evolution; earlier fluid inclusion work supports both processes. Additionally, δ18Oquartz values are consistent with magma originating from a crustal reservoir (i.e., +8 to +15‰). Petrographic and SEM-EDS studies focused on the mineralogy and textures established the following significant observations: (1) absence of graphic and granophyric textures but extensive skeletal growth of primary K-feldspar and spodumene, which suggests the pegmatitic melt underwent a particularly high degree of undercooling (ΔT); (2) the co-spatial association of Sn-mineralization with F-rich muscovite and quartz intergrowth that reflects an episode of weak greisenization during Sn-mineralization; (3) absence of wall-rock xenoliths in the outer zones of the pegmatites suggest pegmatite-wall rock interaction was fluid-mediated; and (4) the presence of rims of SQUI texture around spodumene, combined with the presence of layered aplitic-pegmatitic dikes, is interpreted as reflecting fluctuations between lithostatic and hydrostatic pressure (e.g. open system) which is further supported by earlier fluid inclusion work.

406 - Lithium Isotope Signature and Gold Mineralization at the Dryberry Batholith, Western Wabigoon, Ontario

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In Canada, most orogenic gold deposits are found in greenstone belts from the Wawa-Abitibi Subprovince, but many important deposits were also found in those from the Western Wabigoon Subprovince, northwest of the Wawa-Abitibi and Quetico subprovinces. Like for Wawa-Abitibi, the Western Wabigoon Subprovince consists of large batholithic suites of so-called “tonalite-trondhjemite-granodiorite” (TTG) interlaced by greenstone volcanosedimentary belts. The batholiths are usually younger than the surrounding greenstone belts and thus often intrude the existing supracrustal rocks. These subprovinces are interpreted to have been microcontinents that sequentially accreted and collided from north to south during the Archean, therefore forming one of the first proto-continents, i.e., the Superior Province, a process which was intimately related with the genesis of economically important orogenic gold deposits. Although the tectonomagmatic processes through which the microcontinents were themselves amalgamated into interlaced TTG suites and greenstone belts remain contentious (e.g., vertical and/or horizontal tectonics), the metasomatic alteration found at all scales in greenstone belts has also affected the related TTG suites, and hence contributed to the genesis of the first microcontinents. The objective of this research is twofold and includes: (1) study the lithium isotope signature of this continental-scale metasomatism in the Dryberry batholith; and (2) use the δ7Li values to vector-in gold mineralization. Indeed, preliminary research by the same group at Kirkland Lake Gold Inc.’s Macassa and Goldcorp Inc.’s Hemlo world-class gold deposits has shown that δ7Li may correlate with gold concentration in hydrothermal alteration shells surrounding gold deposits and ongoing research at Goldcorp Inc.’s Red Lake world-class gold mine is aimed at adapting this isotopic tool for orogenic gold exploration.

407 - Raiders of the Lost Lake: New perspective for intrusion-related gold exploration in the western Wabigoon subprovince, Ontario

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Orogenic gold systems have been broadly explored in the western Wabigoon subprovince and account for the majority of the historical gold production. In contrast, intrusion-related gold systems have been relatively under-investigated in the area. This work aims to document the structural setting and alteration pattern proximal to syn-volcanic and syn-tectonic intrusions associated with gold occurrences to understand their spatial and genetic relationships and to provide a new perspective for gold exploration in the western Wabigoon subprovince. The Lost Lake area, located approximately 55 km SE of Dryden, Ontario via Snake Bay Road, represents a poorly documented domain with several recently reported gold occurrences that are spatially associated with felsic intrusions. Supracrustal exposures are dominated by mafic to intermediate metavolcanic rocks of the Boyer Lake and Kawashegamuk groups that are intruded by feldspar- and quartz-feldspar-phyric bodies. These intrusions display metre-scale dike-like shapes and are inferred to be genetically related to a km-size stock in the western portion of the area. The meta-volcanic rocks and intrusions are offset by the Lost Lake deformation zone, a regional northeast-trending, brittle-ductile shear zone. This metres to tens of metres wide deformation zone is characterized by reverse and dextral components and a localized penetrative, steeply dipping foliation with subvertical lineations. The foliation is defined by hornblende, plagioclase, biotite, chlorite, and muscovite, with lineations defined by mafic minerals in high-strain zones and slickenfibres in brittle fault zones. The Lost Lake area also contains abundant sets of variably oriented fractures that typically occur near the contact between the volcanic and intrusive rocks. Extensive hydrothermal alteration, including chloritization, epidotization, and minor sericitization, is observed throughout the area. Wall-rock alteration is intense within several metres of intrusive contacts and is characterized by silicification, carbonatization, and the formation of iron-oxide minerals. Regional mapping constrains the extent of alteration, its spatial association with the intrusions, and the structural evolution of the area. Whole-rock lithogeochemical analyses and petrographic observations were used to determine the nature of the intrusive rocks, the paragenesis and characteristics of the hydrothermal assemblages, and the relative timing of the intrusions compared to volcanism, metamorphism and late regional deformation. Preliminary results indicate that the Lost Lake area shares many similarities with typical intrusion-related gold deposits of the Superior Province, including widespread hydrothermal alteration, proximity to large-scale regional fault systems, and localized alteration at the contact between felsic intrusions and mafic volcanic rocks.
CFREF Metal Earth Project Contribution MERC-ME-2019-118.

408 - Characterizing the magnetic responses of felsic-intermediate intrusions in the western Wabigoon subprovince

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Felsic-intermediate intrusions make up most of the Superior Province and are a key component of several mineral systems and potential sources of fluids. Understanding the mode of emplacement in the upper crust, the magmatic fabric and the deformation of these competent bodies could lead to a better identification of prospective settings for base or precious metal resources in Archean greenstone belts. This work integrates structural, lithogeochemical, mineralogical, petrophysical, and airborne magnetic data from several intrusions to identify and characterize their internal structures. The western Wabigoon subprovince hosts several Neoarchean felsic-intermediate intrusions that are spatially associated with mineral occurrences and prospects (e.g., Au, Mo, Li, REE). These intrusions are classified in 6 groups based on their magnetic textures and intensity on high resolution airborne magnetic maps. Homogeneous textures (no visible linear features, heterogeneities lower than 200 nT) and low to moderate magnetic intensity are typically associated with more felsic bodies. A magnetic aureole of higher magnetic intensity is commonly observed around these intrusions. Heterogeneous textures (relative variations around 500 nT) include mottled, banded and concentric magnetic responses that are more commonly associated with intermediate intrusive bodies. In order to understand the formation processes of these different magnetic textures, representative samples of each of the identified magnetic patterns have been collected for mineralogical and lithogeochemical investigations. Magnetic profiles over the intrusions will be correlated with the modal proportion of magnetic minerals, with geochemical variations, and petrophysical data (e.g., magnetic susceptibility, density. This approach will be used to establish criterion by which the airborne magnetic signal of similar felsic-intermediate intrusions elsewhere in the Superior Province can be interpreted.

409 - The Rundle Intrusive Complex: Investigating Oxidation Processes Related to Gold Mineralization in an Archean Alkaline Intrusive Setting

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Current research suggests a possible correlation exists among depleted δ34S values, high fO2 and Au distribution in alkaline intrusive settings. There are very few studies that have investigated these relationships, along with their mineralogical attributes, on the deposit scale. Such studies are key to elucidating the interplay among the numerous parameters that are responsible for the development of Au mineralization, including the relationship between ore-forming processes and oxidation. The current spatial relationship among these aspects represents one to the most complete deposit-scale datasets in existence. The Rundle intrusive complex, located in the southern Abitibi greenstone belt, represents a unique opportunity to examine redox controls on high-grade Au mineralization hosted in alkaline intrusive rocks. A total of 120 samples, comprised of mineralized and non-mineralized SiO2-undersaturated rocks along with mafic to ultramafic rocks, were collected in 2018 for host-rock identification, whole-rock geochemistry, and S-isotopic analyses, in order to assess the spatial and temporal relationships of Au

mineralization with oxidation. Gold is associated with both disseminated and fracture-controlled pyrite within several types of alkaline to calc-alkaline rocks that range from ultramafic to felsic. In-situ SIMS analysis of pyrite grains suggests a strong correlation between depleted δ34S values (-5 to -15 ‰) and high-grade gold zones (1 to 100 ppm). In addition, preliminary SEM-EDS analyses show gold inclusions (3 to 5 µm) hosted within hematite (goethite?) rims that have replaced pyrite, suggesting a strong positive relationship between development of Au mineralization and oxidation. The observations made in this current study have many important implications not only for ore forming processes, but also for targeting and exploring new gold deposits in oxidized settings.

410 - Metasomatic modification of structurally focused Archean alkaline intrusions, Larder Lake, Ontario

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In the gold-rich Archean Abitibi greenstone belt, there is a subset of gold deposits found proximal to intermediate- to felsic- intrusives. This subset of intrusions is related to disseminated and quartz vein associated gold mineralization, focused along the Lincoln–Nipissing shear zone (LNSZ) near Larder Lake. The intrusions were mapped in detail to investigate the nature of this magmatism. They are dominated by either interlayered hornblende diorite and leucodiorite with zones of mafic pegmatite or leucotonalites. In addition, rare lamprophyric dykes are present in addition to zones of carbonate enrichment. These intrusions are volumetrically small, <0.1 km2 and the tonalites are constrained by recent U-Pb zircon dating to 2672 Ma. As part of this work, detailed petrographic and SEM-EDS analysis was conducted to characterize these rock suites. This work revealed significant mineralogical modification of the rocks with textural preservation due to extensive fluid-rock interaction via coupled dissolution-re-precipitation (CDP) processes. The latter resulted in extreme sodic and lesser K-feldspar metasomatism, variable hematization, and localized carbonatization. Textural and mineralogical evidence supporting the CDP processes the presence of pervasive pitting in neomorphic sodic plagioclase accompanied by sericite and development of non-pitted K-feldspar in dissolution cavities and variable hematite staining. Furthermore, the presence of various secondary hydrothermal minerals such as barite, rutile, apatite and monazite were observed. A preliminary interpretation of these observations is that the tonalite and diorite-leucodiorite intrusive centres are texturally magmatic but that considerable modification of their mineral chemistry has occurred. In addition, much of the accessory mineralogy reflects ingress of a fluid that is likely orthomagmatic in origin. The relationship of this metasomatism to gold mineralization remains to be investigated and at present, can only be speculated upon.

411 - Characterization of an enriched Mg-Cr-Ni unit hosted in Timiskaming Group metasedimentary rocks: implications for subsidiary structures of the Cadillac-Larder Lake deformation zone, Rouyn-Noranda, Québec

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The Cadillac-Larder Lake Deformation Zone (CLLDZ) is an East-trending, trans-crustal, auriferous structure within the southern Abitibi Subprovince of the Archean Superior Province. In the Rouyn-Noranda area, the CLLDZ coincides with ~2710 Ma mafic-ultramafic volcanic rocks of the Piché Structural Complex (PSC), 2679-2669 Ma Timiskaming Group metasedimentary rocks, albitized dikes, intense carbonate alteration, high strain zones, and orogenic style quartz-carbonate-Au vein mineralisation. This study focuses on the petrogenesis of an anomalously enriched Mg-Cr-Ni unit ~300 m South of the CLLDZ in order to determine if it is part of the Timiskaming Group metasedimentary host rocks, a syn-sedimentary volcanic rock, a structurally emplaced part of the PSC, a late but pre- to syn-deformation intrusive rock, and its implications for mineralisation. Detailed mapping, petrography, whole rock geochemistry, and geochronology suggests that at least part of the Mg-Cr-Ni unit has an intrusive and/or extrusive igneous origin. However, it is still uncertain whether the unit is Timiskaming in age or later. The unit is elongated subparallel to the CLLDZ and is more strongly deformed than the host metasedimentary rocks. Furthermore, the main deformation features are similar to those observed along the CLLDZ. Thus, the Mg-Cr-Ni unit possibly represents the physical expression of a related structure, regardless of its emplacement history. Because many gold deposits are hosted in subsidiary structures of the CLLDZ, it is important to understand and locate such second- and third-order structures.

412 - Preliminary investigation of partial melting relationships to identify the behavior of metals during high-grade metamorphism, Kapuskasing Structural Zone, Ontario, Canada

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A goal of the Canada First Research Excellence Fund *Metal Earth* project is to identify fundamental processes leading to the formation of metal-endowed belts, and measurable criteria to distinguish them from belts with less potential for ore deposit formation. However, some of the processes (i.e., fluid behavior and partial melting of the lower-crust) are not directly observable and their composition and evolution may be critical factors in the interpretation of processes forming and modifying the continental crust. The Archean Kapuskasing Structural Zone (KSZ) exposes an intracontinental portion of the lower-crust that was uplifted and thrust eastward upon the metal-endowed Abitibi Subprovince. The KSZ exposes metamorphic rocks that show a gradational change from amphibolite to granulite facies metamorphism towards the east, and offers a unique opportunity to investigate partial melting processes and metal behavior in the middle to lower Archean crust. Field-based observations indicate that mafic gneisses in the study area contain the widespread assemblage Hbl + Pl + Qz ± Cpx ± Grt ± Ttn and the presence of disseminated sulphides (i.e., Ccp ± Py ±Sph), where migmatitic mafic gneisses are

characterized by a variation in modal mineralogy at outcrop scale. Variation of layers ranging from Hbl-Pl-rich to Pl-Cpx-Grt-rich are interpreted as melanosome, while Pl-Qz-rich layers are interpreted leucosomes. The variety of migmatitic textures observed at the outcrop scale suggests that melt was not only generated in-situ (i.e., leucosome with margins of melanosome it) but also migrated (i.e., leucosome networks). In addition, preliminary petrographic observations revealed anhedral Pl ± Qz interstitial grains with low dihedral angles against the surrounding granoblastic Hbl grains, suggesting they crystallized from a silicate melt. The association of Grt with the development of leucosomes suggests that garnet locally formed during partial melting (i.e., peritectic). Some of these Grt porphyroblasts have metamorphic calcite inclusions near their rims, suggesting a metamorphic environment of reduced a_{H2O}. Future work will concentrate on reconstructing the metamorphic reaction history and P-T-t conditions of metamorphism to elucidate the tectonothermal history of portions of the KSZ, as well as investigate the behavior of metals in the formation of leucosome-melanasome pairs to understand the behavior of metals during high-grade metamorphism of the middle-lower crust.

413 - Identifying the source of the ca. 2.2 Ga Nipissing Diabase sills using geochronology and geochemistry with insights into their Ni-Cu-PGE potential

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The ca. 2.22 Ga Nipissing Diabase sills are an extensive mafic magmatic province within the southern margin of the Superior craton and its cover. Nipissing sills host Ni-Cu±PGE mineralization such as the Shakespeare deposit and may have contributed to the metal endowment of the Sudbury Igneous Complex. The sills are thought to have been fed by the Senneterre (2216 Ma) and Maguire (ca. 2230 Ma) dykes—part of the Ungava large igneous province (LIP)—based on matching ages and paleomagnetic data. Other dyke swarms belonging to the Ungava LIP include the Anuc (2220 Ma), Kogaluk Bay (2212 Ma), Klotz (2209 Ma) and Couture (2199 Ma) dykes, all of which are confined to the Ungava Peninsula. This study improves the understanding of the temporal and geochemical evolution of the Ungava magmatic system and tests the source of the Nipissing sills using geochemistry. We report a new U-Pb baddeleyite age for the Triangle Mountain sill at 2216.5±2.1 Ma and a previously obtained, precise, U-Pb zircon age for the Ni-Cu-PGE-mineralized Shakespeare intrusion at 2217.0 +1.7/-1.5 Ma. This refines the temporal evolution of the Nipissing sills. The proposed genetic link between Nipissing sills and Senneterre/Maguire dykes is tested using whole-rock major and trace element geochemistry and Nd isotopes. Five distinct geochemical groups are recognized within the Ungava LIP. These groups are distinguished by trace element ratios such as Tb/Yb, Nb/Yb and Th/Nb and each group corresponds to distinct ƐNd values (except one minor group for which Nd isotopes are not available). Two of these five groups include representatives of both Senneterre and Maguire, or Klotz dykes and Nipissing Diabase sills. This supports a genetic link between

the Nipissing sills and the Senneterre, Maguire and Klotz dykes. Sills with geochemistry matching the Senneterre, Maguire and Klotz dykes are prospective for Ni-Cu±PGE mineralization.

414 - A Mineralogical Study of Ni Distribution in an Atypical Pyrrhotite-rich, Cu-Ni Footwall Deposit, Norman Township, Ontario

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The Norman West Cu-Ni-PGE Main Footwall Zone is part of a multi-lens, contact-footwall environment located along the whistle offset trend in the northeast range of the Sudbury Igneous Complex (SIC). Mineralization in the footwall zone is hosted in pervasive breccia environment, similar to that at the Podolsky Deposit (Whistle Offset, KGHM). As is typical in footwall deposits, the ore body is dominated by chalcopyrite (Ccp), pentlandite (Pn), with trace magnetite (Mt). The ore body is highly unusual in that it shows a strong enrichment in pyrrhotite (Po), typically as alternating lenses with Ccp, that is not seen in other footwall Cu-Ni ore bodies. This study will seek to document the major- and minor-element chemistry, textural and modal abundances of the predominant Ni-bearing minerals (Po, Pn and Mt) via reflected-light microscopy, energy-dispersive spectrometry and powder X-ray diffraction. The data obtained will be used to investigate the distribution of Po polymorphs, evaluate the Ni content in the predominant minerals ore textures and will be augmented by drill-core and geochemical data provided by Glencore. The overriding goal of the study is to determine mineral paragenetic sequence for the sulfide minerals present and to evaluate the processes behind the formation of this unusual footwall deposit.

415 - The East-Sullivan Intrusion and its Associated Au, Ag, Cu, Mo Mineralization, Val d'Or District, Abitibi, Québec

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The gold-bearing district of Val d'Or (Lamaque, Sigma, Goldex) represents the archetype of "orogenic" gold mineralization, related to circulations of late-orogenic metamorphic fluids. However, near these well-known deposits and showing, several atypical gold mineralization has been discovered. These mineralizations are mainly concentrated at the southern edge of the East Sullivan pluton, immediately north of the Cadillac Break southeast of the town of Val d'Or. The area has been extensively explored since the 1930s and has allowed the discovery of Cu-Mo (Porphyre and Ducros Zone 1) and Cu-Au-Ag (Ducros Zone 2) showings on the southern edge of the East-Sullivan pluton. Chalcopyrite, molybdenite and pyrite mineralizations are hosted in porphyritic intrusive facies strongly altered (mainly epidotized and sericitized). During the 1960s, exploration campaign allowed to the discovery of Orenada zones 2 and 4, orogenic type deposits within the Cadillac break further South. In the East-Sullivan pluton area, the mafic volcanics interbedded with sills and gabbroic dykes of the Heva Formation are folded and metamorphosed to greenschist facies. The East Sullivan pluton is a large intrusive of calc-alkaline composition including

monzonites and trachytes that have affinities with the syn-Temiskaming sanukitoids family. South of the contact of the intrusion with the volcanoes, the first 200 meters are strongly affected by a contact metamorphism, and by many mineralized hydraulic breccias. These breccias are cemented by an assemblage with epidote, carbonates, magnetite, pyrite, pyrrhotite and chalcopyrite, localy enriched in gold. They were recorded at the Orenada Zone 5, Hogg and Jolin showing and up to 30 km east of the intrusion (Vaumont property, near Louvicourt). The most intense brecciation zones form sub-parallel corridors in contact with the intrusion with a dip at 60 ° and cuts through local stratigraphy. This style of mineralization is very similar to the Akasaba mine, located 10 km further east, and that have been interpreted as a skarn. The East Sullivan pluton sector is an exceptional case of coexistence of periplutonic (porphyry and skarn), volcanogenic (East-Sullivan mine) and orogenic gold and copper mineralization in the Abitibi belt indicating the protracted gold-copper metallogeny in the area.

416 - Mobilization of Ni-Cu-(PGE) mineralization at the Cubric showing in the La Motte-Vassan Formation, La Motte, Québec

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The Amos-Malartic transect across the Quebec segment of the Abitibi greenstone belt is one of several metal-endowed areas being studied by the Metal Earth project. The 2714 ± 2 Ma La Motte-Vassan Formation represents the oldest rocks of the Malartic group, which includes komatiites, basalts, and minor felsic-intermediate volcanic rocks. This group hosts the historical Marbridge Ni-Cu-(PGE) mine and the Cubric Ni-Cu-(PGE) showing, which are located 24 and 22 km north of Malartic, Quebec, respectively. The Cubric showing is exposed in a hydraulically stripped outcrop and in several diamond drill cores, making it an ideal area to study Ni-Cu-PGE mineralization in this district. The area surrounding the showing was mapped using a combination of airborne magnetics, bedrock mapping, and core logging. These data indicate that the Cubric showing occurs on the southern limb of a regional isoclinal fold that has been re-folded by north-south trending open folds. Nickel mineralization at the showing occurs as semi-massive sulfides within both oxide iron formation and along the margins of a hornblende gabbro. Sulfide mineralization consists of pyrite – pyrrhotite – violerite – magnetite – millerite – chalcopyrite – pentlandite ± nickelian pyrite ± galena ± spalerite with average grades of 2.5% Ni and 0.2% Cu at surface. The high-grade mineralized body was not intersected in drill core and is not interpreted to extend at depth. The high Ni/Cu ratio of the mineralization suggests that it formed from a komatiitic magma, as at Marbridge. Two endmember hypotheses are being considered for the mechanism for mobilization of the mineralization: 1) tectonic mobilization during deformation, and 2) mobilization by a metamorphic-hydrothermal fluid. The tectonized textures, high-S sulfide assemblage, minor Zn-Pb contents, and low Cr contents are more consistent with mobilization by a metamorphic-hydrothermal fluid.

417 - Evaluation of iron formation and mafic-ultramafic intrusions for economic potential: Results from new regional bedrock mapping, Northwestern Baffin Island

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Baffin Island is known for its economic potential through iron formation and diamonds, but large sections of Baffin Island have been largely overlooked for potential deposits. North of the Fury and Hecla Strait on Baffin Island shows prosperity in potential deposits. The Fury and Hecla 2018 field area displayed numerous areas of large magnetic high anomalies throughout the study area. These areas were comprised of large igneous mafic-ultramafic intrusions, banded meta-ironstone and kimerblites. These areas were investigate and are currently still being investigated on platinum group element potential, iron potential and diamond potential. These three aspects to the area have not been largely investigated and are unknown for potential metal endowment and possible mineralization. Through petrographical analysis of the mafic-ultramafic intrusions, the pyroxenite to hornblende gabbroic rocks are rich in sulphides containing pyrite, chalcopyrite, arsenopyrite, pentlandite and other sulphide minerals. Along with this, there are associations showing prosperity of PGE as they are commonly associated in large mafic-ultramafic bodies. On the latter side, large bands of iron formation and meta-ironstone were observed in the field area. This is expected as the study area is located to the west of the Mary River fm. which host the Mary River Mine own by Baffin Land. Three dominate locations showed volcanic meta-ironstone in contact with intrusive Rae craton basement and contained typical banding of hematite and magnetite and white bands coarse quartz. These meta-ironstone sections typically were capped with a metamorphosed fuchsitic quartzite. This area was overlooked for metal endowment and economic potential, but is showing signs of both Ni-Cu-PGE and iron deposits. These new mineralization potentials allow more studies on Archean aged deposits and allow insight in potential factors that allowed mineralization to occur in the Rae craton during this time. In the latter stages when geochemical data is available and interpreted, a greater understanding of the mineralization and types of mineral deposits may be more concise. Along with this, a greater understanding of tectonothermal history and possible metamorphic and metasomatic influence on metal endowment, coeval and geochemical relationships between magmatic intrusions and volcanogenic and sedimentation history of the area will also allow a greater understanding of the economic potential found in the Fury and Hecla 2018 field area and northwestern Baffin Island.

418 - Behaviour of ore-forming elements in the subcontinental lithospheric mantle below the slave craton

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Ore deposits represent exceptional concentrations of metals that are becoming more difficult to find. Metal enrichment likely begins in the mantle source regions for some ore deposit types. However, the fertility of the subcontinental lithospheric mantle as source region for metal-rich magmas remains poorly understood. Herein we report new major (EPMA), minor and trace element (LA-ICPMS) results for olivine mantle xenocrysts sourced from the Jericho, Muskox and Voyageur kimberlites. The kimberlite bodies are located in western Nunavut in the Slave Craton approximately 30 km north of the Lupin gold mine and are Middle Jurassic in age. Target elements include a suite of ore-forming elements that are unconventional

for mantle petrology studies, but may represent important geochemical tracers for metal metasomatism at depth. Using single-grain aluminum-in-olivine thermometry, formation temperatures for the olivine grains were calculated and projected on to a mantle geotherm to estimate PT conditions. The suite of xenocrysts corresponds to mantle sampling between 100–190 km depth. The range in their Mg# [MgO/(MgO + FeO) = 90–93] indicates that all 3 kimberlites sampled variably depleted mantle peridotite . The patterns of trace element enrichments found in this study agree with those documented previously for mantle olivine xenocryst samples from the lithosphere below the Superior Craton in Kirkland Lake, Ontario. In both studies, some ore-forming elements of interests were found to partition into mantle silicates at high PT, notably copper, with concentrations varying from ≤ 1 ppm in shallow samples up to 11 ppm at the maximum depth sampled. Because the concentration of copper and other metals in melt-depleted lithospheric peridotite melted to sulfide-out is expected to be low (≤ 20 ppm Cu), mantle silicates likely become a significant host for some ore elements at depth. Precious metals (e.g., Au, Pt) do not show any consistent PT dependencies and maintain low concentrations at depth (≤2.5 ppb Au). High field strength elements, which are highly incompatible within olivine, yield decreasing concentrations with depth, possibly the result of mantle metasomatic processes. Fluid metasomatized mantle peridotite domains are also inferred from olivine xenocrysts that yield unexpected trace element concentrations (ppb to ppm) for other highly incompatible ore-elements (e.g., As, Mo, Sb, Se). We expect that some of these fluid-mobile and highly incompatible ore-elements represent trapped fluid and/or melt inclusions. Further work includes in situ analysis of four phase lherzolites from the same source kimberlites.

419 - Ni isotopic fractionation associated with Ni mineralization in the Zambales ophiolite complex and Palawan ophiolite complex, Philippines

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Do Nickel isotope ratios reflect weathering and leaching processes in laterite profiles in a systematic way that can be used to understand these processes? The Zambales Ophiolite Complex (ZOC) and Palawan Ophiolite Complex (POC) are hosts to several Ni laterite deposits in the west-central Philippines. ZOC is a combination of island arc and back arc, while the POC is the result of subduction along the Asian continental margin. Nickel stable isotopes may be useful as tracers of weathering and lateritization processes of ultramafic rocks in tropical areas. Nickel is primarily hosted in olivine and olivine-derived serpentine before leaching into the groundwater during weathering processes. During the formation of weathering products (e.g., Fe-Mn oxides, goethite), Ni is incorporated into the newly-formed minerals. We report here Ni isotopic compositions for 22 river/groundwater, bedrock, weathered samples including laterite, saprolite, soil and 4 mineralized samples. X-ray diffraction analyses at the University of Minnesota Duluth indicate that least-altered bedrock is made up primarily of pyroxene, plagioclase and olivine while the weathered samples contain mostly goethite. Ni was purified from sample matrices at Western and isotopic compositions analyzed using a Nu Plasma II Multicollector ICP-MS at Indiana University. Mineral and rock standards were measured for inter-laboratory comparison. Results show (2SD relative to NIST

SRM 986 standard) δ^{60}Ni of 0.23 ± 0.07‰ for San Carlos Olivine, which overlaps with the published value of 0.17 ± 0.06‰. For other rock standards, -0.08 ± 0.03‰ for DTS-1 (published value from -0.08‰ to -0.07‰) were obtained, 0.04 ± 0.06‰ for BHVO-1 (published value of 0.08 ± 0.03‰) and 0.17 ± 0.02‰ for BIR-1 (published values from 0.12‰ to 0.19‰). Bulk chemical compositions analyzed by Quadrupole ICP-MS at Western indicate that the Ni content decreases in sequence from saprolite to laterite, soil, bedrock, and river/groundwater. Results show up to 1.3‰ variations in δ^{60}Ni (2SD) from 0.95 ± 0.11‰ for water (n=1), 0.22 ±0.57‰ (n=4) for mineralized samples, -0.03 ± 0.99‰ (n=6) for bedrock, -0.17 ± 0.01‰ for a limonite soil (n=1), -0.19 ± 0.75‰ for saprolites (n=6), and -0.22 ± 0.34‰ for laterites (n=7). We find that heavy Ni isotopes are preferentially leached into groundwater and incorporated into mineralization (e.g., garnierite and goethite), leaving saprolites and soils with lighter isotopic signatures. Ni isotopes can thus be used to trace weathering and mineralization processes of ultramafic rocks in tropical areas and to determine fractionation factors.

420 - Tin (SnO_2) occurrences of Mwanza region and related Alterations and Rocks, Democratic Republic of the Congo, Central Africa

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The present work presents the geology of the Democratic Republic of Congo, in the meridional portion of Katanga Province within Paleo-Mesoproterozoic formation to which Au, SnO_2 (Tin) are associated to. Mwanza region is localized through the Kibaran belt that is a Mesoproterozoic belt carrying a range of various mineral type (Li, Au, Tin, REE…). Two types of vein mineralization have been identified in the Mwanza region. The primary mineralization is vein type and associated with pegmatite veins as well as quartz greisen. Secondary or superficial mineralization, is resulting from weathering of the primary ones. The granitic domes exhibit differentiation marked by the Mwanza petrofabrics (mineral foliation and schlierens) with a mineralogy characterized by both mica and omnipresence of muscovite. Petrogenesis and geodynamic terms show that Mwanza granites are essentially hyper alkaline and aluminous refer to the Winter diagram that was used or this survey. The network of pegmatite dykes (simple) are dilatory in type and this explained by the continuity of a mineral foliation (gneissosity) on either side of the pegmatitic dykes walls. In consideration of the late and post magmatic transformations, they have been grouped into two kinds: – transformation related to magmatic fluids circulation in contact with the host and – Meteoric transformations. The albitisation is the most significant alteration phenomenon of supergene transformations. It has affected certain Mwanza granitoids. This transformation is related to the circulation of meteoric water favored by mechanical disintegration that led to the alteration and resulted in a white powder of kaolin. The tourmalinisation is the last alteration phase, it has affected the entire granitoids including the network of veins that over appearing capping the granitoids. This hydrothermal event marks the last pneumatolytic phase in the Mwanza region according to our new observation. The pegmatites of Mwanza seem to be developed at a depth of 10 to 20 m (wide observation in SEGMAL excavations wells) and the horizontal extension from 100 to 1000 m. These lenses are inclined 50 ° to the SW in the east of the study area and the same angle value to the NNW in the western portion of the study area. The next research will be focused on the mineral associated to SnO_2 especially the REE elements.

421 - Mineral chemistry of major sulfides: application to the understanding of PGE mineralisation in the Northern Limb of the Bushveld Igneous Complex

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The Platreef is a rock unit (ranging from about 50 m to up to 400 m in thickness) characterized by interaction of Bushveld magmas with underlying Transvaal meta-sediments or Archean granite basement. The Platreef is of interest because it contains intervals with significant PGE mineralization (e.g. averages of up to 4.5 g/t PGE over 90 m of drill core). Previous studies have suggested that footwall assimilation may have been involved in the mineralization process, whereas other studies indicated that PGE mineralization is mostly magmatic and unrelated to footwall assimilation. Whole-rock PGE content does not correlate with sulfide abundance (e.g. some sections with relatively high S content have low PGE grades). This study focuses on drill core showing (from whole rock data) that there are at least two different populations: One with relatively low sulfur and high Ni, Cu, PGE content; the other with higher sulfur content but lower and Ni, Cu, PGE (and associated with footwall assimilation). The working hypothesis is that if the differences identified in whole rock data are a consequence of different geochemical processes then the composition of major sulfides (pyrrhotite, pentlandite, chalcopyrite) is likely to keep a record of such differences. To test the hypothesis, major and trace element content in sulfides were acquired (using EPMA and LA-ICP-MS). The results are consistent with the hypothesis and show that: (a) selenium content in all sulfides associated with mineralization is higher than in sulfides associated with footwall assimilation and in intervals with lower grades; (b) other trace elements, such as Co content in pyrrhotite and pentlandite, and Cd content in chalcopyrite are also useful in distinguishing between sulfides associated with PGE mineralization vs. sulfides associated mostly with footwall assimilation (and will lower grades). On-going work aims to apply the results to other drill core for which whole rock data is largely inconclusive.

500 - Iron oxide copper-gold (IOCG) Deposits

501 - A new magmatic-hydrothermal genetic model for the world-class El Laco magnetite-apatite deposit, northern Chile

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The Plio-Pleistocene El Laco volcanic complex, located in the Chilean Altiplano in the Central Andes, hosts the youngest and best preserved Kiruna-type (IOA) mineralization style registered on Earth. Large iron oxide ore bodies with remarkable volcanic features have stimulated a challenging debate for the last fifty years, where two significantly contrasting hypotheses have been proposed to explain their origin. A magmatic hypothesis invokes precipitation of an erupting iron oxide melt formed as a result of liquid immiscibility, whereas the hydrothermal model involves precipitation of magnetite by metasomatic replacement of volcanic host rocks and direct precipitation of magnetite from an aqueous hydrothermal fluid. Such long-standing debate has endured due to the fact that the aforementioned models were

constructed based almost exclusively on the outcropping and most altered portions of the deposit, which are characterized by massive magnetite with hydrothermal geochemical signatures and lava-like field textures. We combined field observations with a comprehensive study of samples retrieved from the seven outcropping orebodies and twelve drill cores distributed throughout of the volcanic complex to gain a better understanding of the deposit from its roots to surficial portions. Detailed mineralogical, textural and geochemical investigations of magnetite grains sampled at different depths reveal complex vertical zonation, showing variations at both the macro- and micro-scale, which are characterized by magmatic-like features and a systematic Ti increase with depth. Such variations account for an evolving system that records a transition from purely magmatic to magmatic-hydrothermal conditions. We propose a new genetic model for El Laco IOA orebodies that consistently explains its geochemical and textural features as the product of a synergistic combination of common subaerial volcanic processes that led to efficient magnetite segregation from magma reservoir, followed by a late stage of iron remobilization and enrichment driven by late hydrothermal fluids.

502 - ATLAS 5 large-area and nano-scale imaging of iron ore from the El Laco volcano, Chile

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The El Laco iron deposit, located in the Chilean Andes, has more than 1.1 Gt (resources and reserves) of massive iron ore dominantly in the form of magnetite. It formed in the late Cenozoic (Pliocene-Pleistocene) at very shallow depths (<100 m) and relatively high temperatures, possibly above 1000°C. Texturally, the massive iron oxide rocks are vuggy and locally macrospherulitic, and resemble extrusive rocks of magmatic origin. However, this interpretation has been controversial and some investigators suggest a purely hydrothermal mode of origin. The goal of this research is to shed light on the debate, by providing new observations in the form of a full suite of novel imaging datasets of El Laco ore samples. These include macro- to nano-scale Zeiss ATLAS 5 imaging datasets (LM, FIB-SEM, EDS, 3D Nanotomography and 3D EBSD) and tools to assist in the visualization of quantitative information. Samples of unconsolidated tephra and of coherent lava have been examined using a novel workflow of optical and electron microscope images in a correlative workspace. Targets have been selected for closer examination by FIB-SEM to elucidate the composition and mineralogy of very small composite mineral inclusions suspected of being melt inclusions. This suite of techniques allows a seamless correlation of large sample surfaces from the macro- to nano-scale, which subsequently enables the observation and interpretation of features that were previously inaccessible. These observations, at a higher resolution than previously available, will help to constrain whether the mineralizing fluid from which magnetite was deposited was a hydrothermal fluid or a melt.

503 - Evidence for the IOCG - IOA Continuum from Fe-O Stable Isotopes and Trace Element Chemistry of Magnetite from the Candelaria Iron Oxide-Copper-Gold and the Quince Iron Oxide-Apatite Deposits, Chile

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Iron oxide-copper-gold (IOCG) and iron oxide-apatite (IOA) deposits are major sources of Fe, Cu and Au, and are enriched in many other metals. Both deposit types contain abundant Fe-oxides and are structurally controlled. It is generally accepted that IOCG deposits form by hydrothermal processes; however, for IOA deposits competing hypothesis range from a purely magmatic to a purely hydrothermal origin. In the Chilean Iron Belt (CIB), the spatial and temporal association of IOCG and IOA deposits has led some to suggest a genetic connection between both types, where S-Cu-Au-poor magnetite-dominated IOA deposits represent the barren, deeper levels of S-Cu-Au-rich magnetite- and hematite-dominated IOCG deposits. We geochemically characterize samples of magnetite from the Candelaria IOCG deposit and the Quince IOA prospect in the CIB. Back scattered electron imaging reveals textures of igneous and magmatic-hydrothermal affinities, and documents exsolved Mn-ilmenite in Quince and in the deep portion of Candelaria. Electron probe microanalyzer data show that trace element concentrations systematically increase with depth, and decrease from core to rim within individual magnetite grains in shallow samples from Candelaria, which indicate a cooling trend for magnetite growth. Iron isotope values (δ56Fe ± 2σ) yielding an average value of 0.13 ± 0.05‰ (n=3) for Quince and of 0.23 ± 0.05‰ (n=13) for Candelaria, paired with oxygen values (δ18O ± 2σ) yielding an average of 3.04 ± 0.07‰ (n=3) for Quince and of 3.52 ± 0.18‰ (n=12) for Candelaria, support a magmatic magmatic-hydrothermal source for the magnetite. Deuterium isotope values from cogenetic actinolite (δD ± 2σ) averaging -40.4 ± 2.10‰ (n=2) for Quince and -67.3 ± 2.10‰ (n=4) for Candelaria, coupled with their oxygen values (δ18O ± 2σ) yielding an average of 5.96 ± 0.23‰ (n=2) for Quince and of 7.57 ± 0.23‰ (n=3) for Candelaria, further support the high-temperature, magmatic magmatic-hydrothermal nature of the mineralization. Temperature estimations based on the Fe number of actinolite (755°C-770°C for Quince and 795°C for deep Candelaria), and on the oxygen isotope fractionation factor between actinolite and magnetite (830°C-850°C for Quince and 595°C-665°C for Candelaria) agree with the high-temperature source suggested by the isotope results. The combined chemical and textural data are consistent with an igneous magmatic-hydrothermal origin for Quince and Candelaria, where the deeper portion of Candelaria corresponds to a transitional phase between the shallower IOCG deposit and a deeper IOA mineralization analogous to the Quince IOA prospect.

600 - Orogenic Gold Deposits

601 - Petrographic and geochemical analysis of host rocks to auriferous quartz veins, Fisher property, Seabee Gold Operation, Saskatchewan

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The Seabee Gold Operation includes the Santoy mine, the only active gold mine in Saskatchewan, and the recently decommissioned Seabee mine. These Paleoproterozoic orogenic gold deposits are hosted by shear zones in the Pine Lake greenstone belt of the Glennie Domain, which has a complex geological and structural history related to accretionary and collisional events during the development of the Reindeer Zone of the larger Trans-Hudson Orogen. The Fisher property, located to the southeast of the Santoy mine, is an area of active exploration based on interpretations of the trends of structures in the region and the presence of rocks that are considered to be similar to those that host the Santoy and Seabee deposits. There are a number of auriferous quartz veins that have already been identified by prospecting, and recent targeted drilling. This study investigates the petrographic and geochemical characteristics of 38 representative drillcore samples, selected from 8 drillholes, of metamorphosed felsic to mafic volcanic units and various plutonic suites. Volcanic and intrusive units exhibit variably strong chlorite, epidote, K-feldspar, diopside, carbonate and albite alteration. Quartz veins, up to 1.5m thick, crosscut these units and host minor pyrite, chalcopyrite and pyrrhotite mineralization, favorable for gold mineralization. Petrographic analysis will identify the relict primary igneous minerals and textures, and the overprinting metamorphic and alteration mineral assemblages. The major and trace element compositions of the rocks will be used for classification and to provide constraints on their petrogenesis and tectonic setting at the time of formation. The objective of this work will be to determine whether the host rocks to auriferous veins on the Fisher property are similar to those that host the Santoy and Seabee deposits. Upcoming work during the summer 2019 will include geological mapping of key locations in the Fisher property to determine the stratigraphic and structural relationship between rock units, and their association with quartz veins.

602 - Hydrothermal Alteration Footprint of the Monument Bay Gold Deposit, Stull Lake Greenstone Belt, Manitoba, Canada

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Greenstone belts in the Superior Province are known for having important gold prospective areas. For this reason, there are several mining companies working and prospecting in the area. The area of this study, is located approximately 570 km north of Winnipeg. Manitoba. This research is part of the Monument Bay project, owned by Yamana Gold Inc, which has three distinct prospective areas: Twin Lakes, AZ Zone and Mideast Zone. The Monument Bay Project is located within the Stull Lake Greenstone Belt in the Superior Province. The objective of this work is to help Yamana Gold Inc. gain a better understanding of the

mineralization in those zones in order to advance the project from an exploration program to an operating mine. This will help make the future mine site more profitable by improving understanding of the distribution of gold within the deposit. To achieve these objectives the hydrothermal footprint of the ore body located in the Monument Bay area will be characterized. This research will encompass the delineation of the mineralogical and geochemical footprint of the hydrothermal alteration of these zones. In addition, as the association of gold and sulphide minerals in the deposit is still not clear, a sulphide-mineralogy study will also be conducted. In order to do this, techniques such as synchrotron radiation X-ray diffraction, synchrotron radiation X-ray fluorescence, and electron microprobe analyses, are going to be used to better understand how the alteration of the deposit is related to the Au associations in different zones. Moreover, the techniques are going to be used to determine the sequences of sulfide mineralization and the nature of the ore fluid. The final goal of this project is to understand if the Twin Lakes located in the center of Monument Bay is a single big deposit that occurred as a single event, or if it is part of a sequence of small systems together with AZ Zone and Mideast Zone that was formed as multiple deposits from multiple events. It is important to understand the correlation between the deposits because they can provide indicators of undiscovered mineralized areas. In addition, understanding the footprint is important because it helps provide exploration geologists with tools to help detect an ore system on a district scale, and to determine proximity to the most profitable mineralized area.

603 - Gold Mineralization at the Monument Bay Deposit, Stull Lake Greenstone Belt, Manitoba, Canada

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The research area of the project is the Monument Bay Deposit, which occurs in the Archean Stull Lake Greenstone Belt, located in Northern Manitoba, Canada. The Stull Lake Greenstone Belt is a prospective area for gold mineralization which hosts a number of high-grade orogenic gold deposits. Previous research in this area with Yamana Gold Inc. determined the initial relationship among lithology, alteration, geochemistry and gold mineralization. But further academic work is needed to build a reasonable gold mineralization model and determine proper exploration methods to support future gold exploration and production. Traditional microscopy will be used in combination with geochemical and mineralogical analytical techniques (X-ray diffraction (XRD), ICP + XRF geochemical data analysis and X-ray absorption near edge structure (XANES) spectroscopy) and geochemical mapping techniques (synchrotron micro X-ray fluorescence (μXRF) mapping). The specific objectives of our research over the next two years are to: 1) build the relationship between generations of sulfide minerals and gold distribution using optical microscopy and XRD, 2) confirm the relationship between alteration and sulfide mineral assemblages using altered drill core samples, existing inductively coupled plasma-optical emission spectroscopy (ICP-OES) data provided by Yamana Gold Inc., and XRF mapping, 3) determine the temporal and spatial relationship between mineralization stages and gold distribution, 4) investigate remobilization of gold by analyzing textural and geochemical properties of arsenopyrite, 5) identify the valence state of arsenic using XANES and verify whether arsenic plays a key role through substitution during the ore-forming processes. The result of this research will lead to a better understanding of the mineralogical expression of gold mineralization in a portion of the Stull Lake Greenstone Belt and lay the foundation for building a

reasonable gold mineralization model. Furthermore, the gold mineralization model will help Yamana Gold Inc. locate new high-grade gold deposits in this region more precisely and apply this knowledge to discover and explore other greenstone-hosted gold deposits in northern Canada.

604 - Linking Metamorphism and Orogenic Gold in the Proterozoic Lynn Lake Greenstone Belt, northern Manitoba

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Proterozoic greenstone belts represent complex assemblages of lithotectonic units whose ancient histories frequently comprise multiple overprinting deformational and metamorphic events. The timing of gold deposition within this complex geologic history often remains uncertain, which limits our current understanding of orogenic gold-style mineralization. The Lynn Lake Greenstone Belt (LLGB) located in northern Manitoba represents a complex assemblage of Paleoproterozoic supracrustal rocks deposited in a variety of tectonic settings during the 1.9–1.8 Ga Trans-Hudson Orogen (THO). An important metallogenic belt containing several historically productive Ni (orthomagmatic), Cu-Zn (volcanogenic massive sulphide) and Au (orogenic) deposits, the LLGB continues to be a major target for mineral exploration. This study employs in-situ dating of metamorphic and/or hydrothermal xenotime, monazite and apatite in concert with biotite-garnet thermometry to quantify the thermal and temporal evolution of the LLGB. Preliminary biotite-garnet thermometry data obtained in meta-sedimentary and -volcanic rock samples indicate a systematic increase in temperature from the east to west across the LLGB (535-560, 680-610, 685-690 °C at MacLellan Mine, Dunphy Lake and Fox Mine, respectively), consistent with an increase in grade of the metamorphic mineral assemblages following the same trend. New monazite and xenotime SHRIMP U-Pb ages measured at the MacLellan deposit yield multiple, temporally distinct metamorphic and/or hydrothermal ages at 1.83, 1.81-1.76 and 1.75 Ga. The youngest xenotime age is interpreted as the lower limit for the timing of gold and west-trending, regional shear zones (e.g. Johnson and MacLellan Shears) that provide fluid pathways and structural traps for auriferous fluids. However, xenotime associated with a garnet-hosted sulphide- and Au-bearing veinlet yield an age of 1.83 Ga, representing a potential early phase of Au mineralization that is coeval with the onset of collisional orogenesis. Forthcoming biotite-garnet thermometry and LA-ICP-MS U-Pb geochronology of metamorphic apatite are aimed at resolving the timing and conditions of metamorphism throughout the LLGB with the goal of further elucidating the link between tectonic events in the THO and the timing of gold deposition.

605 - Mapping the Hydrothermal Footprint of the MacLellan Au Deposit by Handheld Laser-Induced Breakdown Spectroscopy (LIBS)

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Geochemical mapping of rocks and minerals represents an important approach for tracing the complex geologic history of rock and minerals. However, most of the available mapping methods require sample preparation, are timing consuming and must be conducted in a laboratory setting. Recent advances in handheld Laser-Induced Breakdown Spectroscopy (LIBS) represents a new technique for generating rapid, qualitative geochemical maps in the field. LIBS is a form of atomic emission spectroscopy where characteristic spectra are emitted from a plasma, which is generated by a high-energy laser striking a solid, liquid, and/or gas. Each spectrum represents a geochemical fingerprint, which can be used for tasks such as mineral identification and/or geochemical vectoring. Herein we apply the LIBS method to unravel the complex hydrothermal footprint of the MacLellan gold deposit (Lynn Lake greenstone belt, Manitoba), which comprises multiple generations of veins and hydrothermal alteration mineral assemblages. Maps were generated in the field on the sawed surface of drill core samples with the handheld SciAps Z-300 analyzer. Analyses were conducted in an argon environment to improve LIBS signal intensity and for the detection of minor to trace elements. Signal processing and mapping was completed using new code written with free and open source software. Preliminary mapping results for coarse native gold yield its three characteristic element emission lines, suggesting that hand-held LIBS can detect gold on sawed rock surfaces without sample preparation. Mapping results for barren and ore-related hydrothermal alteration mineral assemblages (e.g., chamosite versus clinochlore) yield distinct spectral fingerprints, which further suggests that LIBS maps can be used to characterize the geochemical footprint of auriferous fluids. Future work will focus on applying machine tools to classify each alteration type and apply LIBS mapping results as vectoring tool for gold exploration.

606 - Preliminary results from regional mapping and petrographic analyses of mineralized and barren deformation zones in the western Wabigoon subprovince, Ontario

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Regional, crustal-scale deformation zones are the primary host for orogenic gold deposits in Archean greenstone belts of the Superior Province. However, many deformation zones do not contain significant gold mineralization. In order to guide exploration efforts, it is important to understand the geological controls associated with mineralized and barren structures. This study investigates two crustal-scale structures in the Dryden area of the western Wabigoon subprovince: the gold-bearing Manitou-Dinorwic (MDdz) and the barren Wabigoon (Wdz) deformation zones. Although these deformation zones have been previously mapped, their temporal and kinematic relationships with one another have yet to be described in the perspective of regional tectonic and metallogenic evolution. This work presents preliminary regional

to outcrop scale mapping, as well as petrographic and microstructural observations of representative samples in order to constrain and compare the kinematic and alteration histories of the deformation zones. An approximately 270m^2 outcrop that preserves key structural relationships along the Wdz was mapped at the 1:200 scale. Three deformation events (D_1 – D_3) are recorded along the Wdz: D_1 is represented by F_1 isoclinal folding with an associated axial planar foliation (S_1) defined by biotite and chlorite; D_2 is represented by asymmetric F_2 z-folds that affect S_0/S_1, asymmetric σ-clasts indicative of dextral shear, and a weakly developed S_2 fabric defined by biotite; D_3 is recorded by locally preserved, small-scale faults that display sinistral offsets and a weak S_3 crenulation of the earlier fabrics. The MDdz is a >60 km long, NE-trending deformation zone characterized by intense fabric development, σ-clasts indicative of sinistral shear, and heterogeneous zones of silicification, chloritization, and iron carbonate alteration. Locally, where the MDdz transects the Wdz, its NE-trending fabric crosscuts the E-trending fabric associated with the Wdz. Thus, three major deformation events are recognized in the study area. Early deformation is inferred to reflect progressive regional N-S shortening to dextral shear localization (D_1-D_2). This was followed by sinistral shear (D_3) related to the formation of the MDdz, which, based on the observed cross-cutting relationships, postdates deformation along the Wdz. Since gold occurrences are preferentially associated with the MDdz and not the Wdz, we suggest that gold deposition is late relative to terrane accretion and major D_1-D_2 deformation, which may partly explain the low gold endowment of the western Wabigoon subprovince. Furthermore, these results suggest that gold exploration in the area should focus on late NE-trending deformation zones such as the MDdz.
CFREF Metal Earth Project Contribution MERC-ME-2019-122.

607 - Kinematic analysis of the Manitou-Dinorwic deformation zone and its implications for mineral exploration in the Western Wabigoon subprovince

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Crustal-scale fault systems are key targets for orogenic gold deposits in the Superior Province. The NE-trending Manitou-Dinorwic deformation zone (MDdz) hosts 95% of the historical gold production in the Dryden area of the otherwise poorly endowed Western Wabigoon subprovince. The structural development, alteration, and kinematic history of the MDdz during orogenic gold mineralization are documented through detailed 1:100 scale mapping of rock types, alteration, veins and structural fabrics, followed by petrographic analyses of microstructures and parageneses from thin sections. These data can be used to target areas with similar structural setting and potential gold mineralization. The MDdz cross-cuts intermediate metavolcanic rocks and quartz-feldspar porphyry dikes and is associated with quartz-carbonate vein systems. Three main deformation events are documented. A penetrative NNE-striking, steeply ESE-dipping continuous S_1 schistosity defined by chlorite has been attributed to a D_1 WNW-ESE shortening event that resulted in kilometer-scale isoclinal folding. A near vertical NE-striking chlorite-sericite S_2 foliation crosscuts S_1 and is related to a D_2 NW-SE main shortening event that developed the MDdz as a sinistral transpressional shear zone spanning over 60 km along strike and approximately 3 km in width. Shear-sense indicators, including C-S fabrics and pyrite with quartz-carbonate-chlorite pressure shadows, are consistent with NW over SE movement combined with strike-slip sinistral displacement

during D_2. A subtle asymmetric crenulation of the S_1 and S_2 fabrics and brittle fracturing of all rock units have been attributed to a late and minor D_3 NNW-SSE shortening event. Gold mineralization manifested in disseminated pyrite in the metavolcanic host rock and felsic dikes and as visible gold within fracture-filling quartz-carbonate veins appears to be spatially associated with iron carbonate-altered felsic dikes along the MDdz. The felsic dikes are interpreted, based on cross-cutting relationships, to have intruded post-D_1 to early-D_2 and accommodated strain through brittle fracturing. Brittle strain in the dikes created dilational zones that acted as depositional sites for syn-D_2 gold-bearing hydrothermal fluids. This competency contrast was observed as jointing and a spaced foliation within the felsic dikes compared to the penetrative foliation in the host metavolcanic units. We suggest that carbonate-silica-sulfur rich fluids produced three generations of veins displaying variability in composition and relative timing of formation as well as disseminated sulfide minerals (e.g. pyrite) proximal to these veins. Thus, felsic dikes within the MDdz may be used as a vector to mineralization and may help guide exploration within the Western Wabigoon subprovince.

CFREF Metal Earth Project Contribution MERC-ME-2019-110.

608 - Archean gold mineralization in the Wawa Gold Corridor, Wawa, Ontario

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The Wawa Gold Corridor (WGC) is hosted by intermediate igneous rocks of the ca. 2750 Ma Jubilee Stock in the Michipicoten greenstone belt. It consists of auriferous shear zones formed during a protracted deformation event with quartz+carbonate±tourmaline veins and disseminated arsenopyrite and pyrite; the principle shear zones are the Jubilee (JSZ) and Minto Shear Zone (MSZ). Fieldwork and drill core observations indicate that: (1) the MSZ formed during late JSZ deformation; (2) similar sulfide assemblages are present in auriferous quartz+carbonate±tourmaline veins of both shear zones; and (3) a pre- to syn-kinematic Au-arsenopyrite event likely affected the JSZ. To investigate the timing and nature of this Au mineralization, a thorough petrographic study was undertaken, the results of which will serve as the foundation for forthcoming sulfide chemistry, S isotope, and quartz-carbonate cathodoluminescence analysis. Observations made by optical microscopy and scanning-electron microscope backscatter electron imaging indicate: (1) native Au on the margins of, and as inclusions in, porous, syn-kinematic arsenopyrite; (2) native Au associated with chalcopyrite and Bi-minerals in post-kinematic carbonate stringers which cross-cut quartz veins and sheared muscovite-carbonate-quartz rocks; and (3) curvilinear boundaries between native Au and native Bi and bismuthinite. Observations (1) and (2) suggest that at least two Au events affected the WGC, the first of which was restricted to the JSZ and the second of which overprinted multiple shear zones. Observation (2) and (3) suggest that some Au was probably transported in a Bi-rich melt during the second mineralizing event. Future mineral-chemical analyses will help determine whether the latter interpretation represents scavenging of Au from auriferous pyrite in the WGC, or new Au introduced by a post-kinematic Cu-Bi bearing carbonic fluid. This work highlights the importance of a petrographic and micro-analytical approach to understanding complex mineralization histories in shear-zone-hosted gold systems.

609 - Lithium Isotopes for Gold Exploration at Red Lake/Cochenour Mine, Ontario, Canada

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Archean orogenic gold deposits are commonly hosted within/around quartz-carbonate veins or as selective replacement of specific minerals within hydrothermally altered rocks. Justifiably, exploration for such deposits in Archean subprovinces of the Superior, and particularly in Wawa-Abitibi, was conducted extensively over the years around- and along strike from known deposits, near and within translithospheric shear zones and their secondary splays. Economic concentrations of the precious metal are notoriously difficult to find and the mining industry, in collaboration with academia, keep improving and exploration strategies by developing refined genetic models and efficient exploration models. Preliminary research by the same group at Kirkland Lake Gold Inc.'s Macassa and Goldcorp Inc.'s Hemlo world class gold deposits has shown that the lithium isotopic ratio may correlate with gold concentration in hydrothermal alteration shells surrounding gold deposits at the local and regional scales. A clear understanding of why δ7Li correlated with Au was complicated by the presence of multiple types of lithologies hosting numerous generations of magmatic, metamorphic, hydrothermal and meteoric alterations. The objectives of the present research are: (1) to systematically study the δ7Li signature of hydrothermally altered rock along segments ranging from outside to inside the ore zones, in vein-style and replacement-style auriferous mineralization, at the Cochenour extension of Goldcorp Inc.'s Red Lake gold mine; and (2) to study the distribution of Li among the different minerals present in alteration paragenesis and thus explain why δ7Li correlates with gold in Archean orogenic gold deposits.

610 - Metavolcanic evolution of the Swayze area of the Abitibi Greenstone Belt – Preliminary interpretations

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The Swayze area of the Abitibi Greenstone Belt (AGB) has long been considered the 'poor cousin' to the subjacent eastern AGB. Consequently, it has not received as much attention nor exploration expenditures. However, a regional scale compilation and mapping project in the mid-1990s, which had a significant U-Pb zircon geochronology component, demonstrated that the Swayze area has the same assemblages and major faults as those within the metal endowed eastern AGB. The Swayze area is now regarded as the westward continuation of the eastern AGB and may potentially host significant gold and base metal deposits. Exploration in the Swayze area, has relied on the same exploration models that were successfully utilized within the eastern AGB; however, fewer deposits have been discovered, most of which are auriferous and small in comparison to those of the eastern AGB. To increase our understanding of differential metal endowment, Metal Earth and the Ontario Geological Survey have undertaken detailed lithostratigraphic and structural mapping, seismic and magneto-telluric geophysical surveys, and targeted lithogeochemistry and geochronology to unravel the base metal metallogeny of

the Swayze area. Preliminary interpretations of new data suggest significant differences in the distribution of volcanic epidodes and that regional folding and shearing events are more complicated than originally portrayed.

611 - Structural architecture and gold mineralization of a metasedimentary basin located along the Larder Lake–Cadillac deformation zone in the Abitibi greenstone belt, Québec

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The Larder Lake–Cadillac deformation zone is a major structure along the contact between the Abitibi greenstone belt and the Pontiac subprovince in the Archean Superior Province. Near Malartic, Quebec, it forms the southwestern boundary of a metasedimentary basin comprised of older turbiditic sandstone with minor iron formation of the Cadillac Group (<2686 Ma) and younger polymictic conglomerate and sandstone of the Timiskaming Group (ca. 2677–2672 Ma). Multiple deformation events have affected the basin. Early shortening resulted in the formation of west-northwest striking isoclinal folds plunging moderately to the east-southeast. An axial planar cleavage, expressed as a continuous slaty cleavage in mudstone, a spaced disjunctive cleavage in sandstone, and flattened and elongated clasts in conglomerate, is oriented anticlockwise to north-younging beds and clockwise to south-younging beds. A mineral stretching lineation, defined by biotite porphyroblasts in turbidite and sandstone, and by elongated clasts in conglomerate, plunges moderately to the east-southeast, parallel to the regional fold axes. The folds, cleavage, and lineation are overprinted by gold-bearing quartz veins. These veins are tightly S-shaped folded, oriented at a low angle anticlockwise to bedding on both limbs of regional folds. Their geometry and orientation suggests that they were emplaced during sinistral shearing either late during or after the regional folding. An alteration halo of white mica, arsenopyrite, carbonate, tourmaline and biotite extends over 5 to 10 cm on both sides of the veins. Mass balance calculations, comparing an altered and least-altered homogeneous sandstone, show mass gains in S, C and K_20 and mass losses in Na_2O and CaO, which corresponds to sulphidation, carbonatization and sericitization of the host rocks. Late dextral bedding-parallel shearing produced dextral shear bands, boudinaged structures, dextral drag folds, all of which overprint the gold-bearing quartz veins. At the nearby Canadian Malartic gold deposit, gold mineralization is controlled by structures that formed during regional sinistral folding of the Pontiac metasedimentary rocks. As gold mineralization in the basin is also associated with sinistral structures, its emplacement could be structurally coeval or slightly later than that of gold mineralization at the Canadian Malartic deposit.

612 - Structural and geochemical analysis of a mineralized exposure from the Cadillac - Larder Lake deformation zone, western Abitibi subprovince, Ontario: implications for gold mineralization

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The Abitibi subprovince, located within the southern Superior province, is an Archean greenstone belt that comprises multiple volcanic rock assemblages and latter successor basins, which have undergone sub-greenschist to greenschist facies regional metamorphism. The Cadillac-Larder Lake deformation zone (CLLDZ), is a major crustal scale structure that has an east-west strike length of 250 km across the Abitibi subprovince, and is spatially associated with numerous economic gold deposits. There are three major deformation events (D_1-D_3) in the study area. D_1 is pre to syn- formation of the CLLDZ, defined by a south-east to east foliation. D_2 hosts the main mineralizing event that formed during north – south shortening and is defined by regional folding, an east - west trending foliation and an easterly plunging down dip lineation. D_3 is a dextral reactivation of the deformation zone during northwest – southeast shortening, resulting in folding and a north-east axial planar S_4 foliation. In this study we investigate the structure, alteration and mineralization of a mineralized exposure within the CLLDZ at the Agnico Eagle Mines Ltd property in proximity to the Queenston number 1 shaft. Structural analysis and alteration mapping from field work defined a relative sequence of deformational events and timing of gold mineralization, consistent with a syn-late D_2 mineralization event. This has been further constrained through preliminary petrographical and geochemical analysis. The study will assist in further understanding the controls of gold mineralization along the CLLDZ, potentially aiding in future potential for gold exploration.
CFREF Metal Earth Project Contribution MERC-ME-2019-114.

613 - Geology of the Windfall Lake gold deposit, Québec, Canada

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Windfall Lake is an Archean greenstone-hosted gold deposit located in the Urban-Barry greenstone belt of the Abitibi subprovince in Québec, Canada. The deposit which has been extensively drilled (~650,000 m) since 2016 has a combined indicated and inferred resource of 2.88 Moz Au (12.9 Mt at 6.84 g/t Au). The gold mineralisation is hosted in mafic to felsic volcanic rocks of the 2718 Ma Macho Formation that records greenschist facies metamorphism. These volcanic rocks are cross-cut by several generations of calc-alkaline quartz-feldspar porphyry (QFP) dikes that trend towards the NE and parallel the fold axes and dominant cleavage fabric in the area. The QFP dikes are separated into two groups based on cross-cutting relationships and zircon U-Pb TIMS dating: 1) a pre-ore (2698 ± 3 Ma) type which hosts the gold mineralisation and associated hydrothermal alteration; and 2) a post-ore (2697.6 ± 0.4 Ma) type which

truncates the former, as observed in drill core. The auriferous zones occur as thin, sub-vertical and elongate lensoids that plunge moderately towards the NE. These zones are coincident with the contacts between some pre-ore QFP dikes and host volcanic rocks. Three styles of gold mineralisation are observed: 1) early crustiform-colloform carbonate ± quartz veins; 2) grey quartz veins and stockworks with subordinate ankerite-pyrite-tourmaline; and 3) pervasive to patchy sericite-ankerite ± silica, fuchsite alteration with disseminated pyrite-tourmaline. Sulphides consists predominantly of pyrite with traces of chalcopyrite, sphalerite, tennantite, arsenopyrite, pyrrhotite and galena with the related gold as free gold, inclusions in pyrite, and invisible gold in pyrite. The spatial and temporal association of the QFP intrusions and gold mineralisation at the Windfall Lake gold deposit provides a unique opportunity to assess the relationship between Archean felsic magmatism and gold mineralisation and the current intrusion-related model for the deposit. The latter will be done by using a variety of methods: 1) field relationships, 2) petrography and supporting SEM-EDS analysis and CL imaging, 3) fluid inclusion microthermometry and geochemistry, 4) in situ SIMS isotopic measurements (O, C, S), and 5) pyrite geochemistry (LA-ICP-MS).

614 - Metallogeny and Geological Setting of the Pierre Showing in the La Grande Subprovince, Superior Craton, Québec

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The Menarik property is located in the Archean La Grande Subprovince of the Superior Craton, in the James Bay area of northern Quebec, 120 km to the northwest of the Eleonore mine. The property, owned by Harfang Exploration, hosts numerous gold showings, including the Pierre showing, which comprises a vein network returning up to 0.9 g/t Au over 68m in drill core. The property shows polymictic conglomerate, wacke and siltstone of the Ekomiak Formation (<2735 Ma), which is cut by porphyritic quartz monzodiorite dated at 2712.4 ± 1.4 Ma, and unconformably overlies Neoarchean volcanic rocks of the Yasinski Group. The conglomerate is clast-supported, shows graded bedding and is interbedded with sandstone showing metric crossbedding suggesting a fluvial-alluvial origin. Two metamorphic domains are documented on the property, one at the greenschist facies and the other at the amphibolite facies. The transition between both domains is abrupt and interpreted to be marked by the W-trending Menarik fault. The sedimentary rocks are affected by moderately to steeply plunging (~60°) tight to isoclinal folds with a steeply dipping (70-90°) axial-planar slaty cleavage. The Pierre showing is developed in carbonatized (calcite+ankerite) quartz monzodiorite, which is cut by auriferous quartz±carbonate-pyrite veins. These veins mostly occur as stockworks and laminated fault-fill veins, with local sericitized selvages. Although auriferous veins are present throughout the Menarik property, it is on the Pierre showing that they are best developed due to rheological contrasts and location of the quartz monzodiorite in a fold hinge zone. The geology of the Menarik property is reminiscent of well-documented stratigraphic relationships exposed in the southern Abitibi greenstone belt, where gold deposits are associated with fluvial-alluvial sedimentary basins and contemporaneous alkaline to sub-alkaline porphyritic intrusions, mainly distributed in the vicinity of major faults. We suggest that a similar favourable context for gold may thus be extrapolated to the La Grande Subprovince.

615 - The controls of Gold Mineralization at The Orenada Zone 4 Deposit, Val d'Or, Québec

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The Orenada Zone 4 deposit, owned by Alexandria Minerals Corporation, is situated approximately 8 km southeast of Val d'Or, Québec in the southeastern Abitibi Greenstone Belt. Orenada is an orogenic vein hosted gold deposit that occurs directly within the Cadillac Larder Lake Deformation Zone (CLLDZ). Gold is hosted by a volcanoclastic tuff that overlies Piché Group ultramafics and is interlayered with and below the Cadillac Group metasediments. It is unlike most other deposits in the Abitibi because of its structural positioning, host lithology and association with arsenopyrite. To understand the controls of mineralization and the deportment of gold, a petrographic and geochemical study was undertaken. Petrographic observations have documented two types of tuff within the mineralized tuffaceous unit. The first, is characterized by medium-grained, sub-round, smoky-quartz phenocrysts, within a muscovite-sercite-quartz±chlorite±carbonate groundmass. The second, is characterized by medium-grained, subhedral feldspar phenocrysts in a quartz-carbonate-sericite±chlorite groundmass. Both types are distributed throughout the deposit and share the same alteration styles. Tourmaline-sericite-chlorite-carbonate alteration of variable intensity is widespread. However, the tourmaline alteration is dominant in highly mineralized zones as haloes around gold-bearing quartz-carbonate-arsenopyrite veins. Three main styles of mineralization are identified: gold along thin fractures with quartz-muscovite-carbonate in arsenopyrite, fine-grained (1-10µm) sub-rounded gold inclusions within arsenopyrite, and as free gold mineralized adjacent to anhedral arsenopyrite associated with tourmaline-quartz-muscovite in the altered wallrock. Lithogeochemical analysis from 65 tuff samples show a strong correlation between Au, S, As and B. Samples with greater than 0.5ppm Au have elevated S, As and B values, which implies that gold mineralization is associated with sulphidation and tourmalinization. Gold mineralization is associated with both fine to medium-grained euhedral arsenopyrite and, medium to coarse-grained, anhedral to corroded arsenopyrite. Electron probe microanalysis on both textural styles of arsenopyrite were used to distinguish their chemical differences and their association with the different styles of gold mineralization. Analyzes were conducted on thirty grains from seven drill holes situated at spatially different locations on a longitudinal section of the deposit and from differing depths of each drill hole. All four styles of gold mineralization are present in anhedral arsenopyrite whereas, only micron-sized gold inclusions are observed with the euhedral grains. The strong association of Au and the anhedral arsenopyrite can be used as a useful exploration tool, as petrography can be applied to drill core logging where more-favorable arsenopyrites can be identified.

616 - New interpretation and relative chronology of gold mineralization in the Upper Eastmain Greenstone Belt, Québec, Canada

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Subprovince of the Superior Craton, in Quebec. The UERB comprises Meso- to Neoarchean amphibolite facies bimodal volcanic rocks and clastic sedimentary rocks that host numerous gold and base metal showings, as well as the Eastmain mine gold deposit, from which were produced 40 Koz of Au from high-grade auriferous zones (10.58 g/t Au and 0.3% Cu) in 1994-1995. A new stripped outcrop on the Hillhouse gold showing, located approximately 1 km northwest of the former Eastmain Mine mine, shows a mineralized horizon at the base of a felsic volcaniclastic rock horizon (2800 ± 6 Ma), in contact with transitional to calc-alkaline pillow basalt. The main mineralized horizon is 5m thick and composed of disseminated to semi-massive pyrrhotite and chalcopyrite, with up to 55 g/t Au over 0.7 m. Gold occurs as electrum and contains tellurobismuthite inclusions. The distribution and composition of the semi-massive to massive sulfide zone, as well as the field relationships, suggest a volcanogenic origin for this style of gold mineralization. Logging of four new holes in the Eastmain mine deposit (B zone) revealed that gold is stratabound and controlled by the presence of a stratigraphic package (< 6m) containing magnetite-amphibole-garnet chert interlayered with an amphibole-garnet rock (iron formation?) and biotite-quartz-garnet metasedimentary rocks. The presence of semi-massive to massive sulfide is common in the mineralized zone with pyrrhotite, chalcopyrite, euhedral pyrite porphyroblasts and local sphalerite stringers. This stratigraphic package is highly strained and contains quartz-tourmaline-amphibole gold-rich veins cutting the chert. Although the stratabound nature of the gold zones and association with massive sulfides and felsic volcanics may indicate the presence of early syngenetic gold, the preferential association of gold with the magnetite chert, a layer with favorable chemistry and rheology for gold deposition and vein formation, instead suggest a syn-deformation timing of high-grade gold mineralization for the B zone. These preliminary results indicate that the UERB has potential for volcanogenic gold and that the superimposition of syn-deformational mineralization onto a volcanogenic auriferous system could be an essential element in the gold budget of the former Eastmain mine deposit and its host rocks.

617 - Understanding the geology and gold distribution in the Archean Mistumis pluton, James Bay, Québec

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The James Bay area (Superior Province) comprises numerous gold showings that are hosted within Archean plutonic rocks and remain poorly understood in terms of classification and genesis. The Mistumis pluton is a large polyphased TTG intrusive suite located in the Lower Eastmain Greenstone Belt (La Grande Subprovince) and is host to a variety of gold showings. The purpose of this study is to characterize the Mistumis pluton and to interpret the gold showings according to its petrogenesis and to the tectonic

evolution of the La Grande Subprovince. This pluton is emplaced into 2723 ± 2.2 Ma bimodal volcanic rocks of the Anatacau-Pivert Formation, which were metamorphosed from upper greenschist to lower amphibolite facies. It is composed of a predominant 2716 ± 13 Ma biotite tonalite (U-Pb zircon; LA-ICP-MS this study) that is crosscuted by subordinate granodiorite and an intrusive breccia facies. The geochemical analyses for both tonalite and granodiorite suggest a similar calc-alkaline affinity and derivation from a low-K basaltic source. Gold occurs as 1- anomalous concentrations in a late magmatic breccia pipe and 2- mineralized high-strain zones comprising disseminated sulfides and veins. Anomalous gold in the magmatic breccia pipe is restricted to the breccia and is associated with sericitic alteration and disseminated euhedral pyrite in a porphyritic to an equigranular felsic matrix. The mineralized ductile-brittle high-strain zones (up to 1.15 g/t Au over 64 m) belong to the E-W trending D2 phase of regional deformation, to which most of the gold deposits in the area is related. These zones comprise mylonites and fracture zones affecting both the tonalite and granodiorite, as well as low-sulfide shear, extensional and sheeted quartz vein arrays. Hydrothermal alteration is present as sericitization and chloritization. Gold is associated with disseminated chalcopyrite and pyrite (< 2 %), and occurs as subspherical to spherical polymetallic inclusions in pyrite or more rarely as free gold. Polymetallic inclusions are composed of chalcopyrite, pyrrhotite and/or Bi ± Ag ± Au tellurides. Overall, the size, shape and paragenesis of gold grains varies little and may indicate a single main-phase mineralization event. The structural setting of the veins and alteration as well as the geochemical footprint suggest an orogenic model for the gold mineralization within the Mistumis pluton. Nevertheless, the presence of anomalous gold concentrations in a magmatic breccia pipe indicates an early phase of magmatic-hydrothermal alteration that predates regional deformation.

618 - Geology of the Tiriganiaq gold deposit, Meliadine district, Nunavut

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The Meliadine gold district is located within the Archean (>2.66 Ga) Rankin Inlet greenstone belt in Nunavut. The district comprises numerous gold deposits and prospects that are spatially associated with the crustal-scale Pyke Fault and its splays. Many of these gold deposits are partially to dominantly hosted within banded iron formation (BIF) units, including at the Tiriganiaq mine where a large part of the ore is hosted within BIF-associated zones that have been complexly folded and sheared. The Tiriganiaq deposit is hosted in the structural hanging wall of the Lower Fault, a W-trending splay of the Pyke Fault located further to the South. The Lower Fault marks a break between a mafic volcanic dominated sequence in the footwall (South) and a turbiditic dominated sequence in the hanging wall (North). The hanging wall units host the ore-bearing, dm- to m-wide laminated quartz-ankerite shear vein and associated shallowly North-dipping extensional veins referred to as the 1000 lode. A large part of the ore at Tiriganiaq is hosted within the Upper Oxide Formation, a sequence of iron-rich sedimentary rocks and BIF units. The southernmost ore zone (1100 "lode") consists of a geometrically planar mineralized corridor associated with the transposed long limb of the folded BIF. There are other, more geometrically and structurally complex ore zones in the Upper Oxide Formation, which are referred to as the 1150 and 1250 "lode series". These ore

zones are controlled by Lower Fault-parallel, narrow north-dipping reverse shear zones that overprint the slightly steeper, north-dipping S_2 foliation that is axial planar to tight F_2 folds affecting the BIF units. Shallowly South-dipping extensional veins, associated with the shear zones and related fault-fill veins, are preferentially developed in tightly folded dm- to m- thick BIF layers around the moderately north-dipping reverse shear zones. The objective of this study is to define the main structural and lithological controls on gold distribution and determine the relative timing of events at ore zone to deposit scale. Preliminary interpretations are in agreement with a protracted Paleoproterozoic compressional deformation (D_2) that started with F_2-folding of the host succession, followed by preferential strain partitioning along fold hinges, relatively less competent units, and lithological contacts by development of syn- to late-D_2 reverse shear zones. These reverse shear zones controlled the development of shear-hosted ore-bearing veins and associated ore-bearing extensional veins, that have been progressively deformed.

619 - Hydrothermal alteration of the gabbro-hosted orogenic Au mineralization in the Argyle deposit, Baie Verte, Newfoundland: Preliminary results

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The Argyle gold deposit (543,000 t @2.19 g/t Au indicated and 517,000 t @1.82 g/t Au inferred resources), Baie Verte Peninsula, Newfoundland is hosted within Lower Ordovician Snooks Arm Group. Gold mineralization is hosted within a 40-50 m thick, E-W striking, gently (22°) north-dipping tholeiitic gabbro sill, which intruded the Snooks Arm Group volcaniclastic rocks. This study is focused on examining the hydrothermal footprint of the strongly metasomatized gabbro-hosted gold deposits on the Baie Verte Peninsula, including the Argyle deposit. Preliminary results illustrate that the deposit contains three distinct alteration assemblages: (i) distal – chlorite-calcite ± rutile, epidote or siderite; (ii) intermediate – chlorite-ankerite-epidote-albite ± rutile, muscovite or pyrite and, (iii) proximal – albite-chlorite-ankerite-muscovite ± quartz veining, rutile, pyrite and gold. There were at least two separate hydrothermal events with early epidote-albite alteration overprinted by the above assemblages more proximal to mineralization. Mass balance calculations associated with albite-chlorite-ankerite-muscovite show significant mass gains in LOI, CO_2, SiO_2, Fe_2O_3, K_2O, S, P_2O_5, Zr, As, REEs, Rb and Au with mass losses in Na2O, V and Sc with increasing proximity to mineralization. Short wave infrared spectroscopy (SWIR) illustrates that muscovite and Fe-chlorite are most abundant proximal to mineralization, whereas phengite and Fe-Mg chlorite define the distal zone, implying that there were higher temperature and more acidic hydrothermal fluids proximal to mineralization. The host gabbros to mineralization are tholeiitic and Fe-Ti-rich in composition. Petrography shows titanomagnetite being partially to completely replaced by pyrite and gold mineralization, with gold occurring as inclusions within pyrite, at pyrite grain-boundaries and in fractures proximal to rutile, or other Fe-Ti-rich phases. This suggests that gold precipitated due to wall-rock sulfidation. Furthermore, gabbro grain size influenced the localization of mineralization as coarse-grained and pegmatitic gabbros were preferentially metasomatized, likely due to a greater permeability relative to their finer-grained counterparts, and were preferentially faulted, creating wide damage zones in secondary faults within 300m of the Scrape Thrust. The coincidence of structure-related fluid flow associated with regional tectonism, coupled with the textural and

compositional character of host gabbros was critical for the localization of mineralization in the Argyle deposit.

620 - Origins of the Black Hills terrane in the eastern Wyoming craton: An atypical supergiant orogenic gold province within supercontinent Nuna

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The Black Hills Terrane (BHT) marks the eastern margin of the Archean Wyoming craton and contains the largest Paleoproterozoic orogenic gold province in North America, including a supergiant deposit at Homestake that contains >62 Moz Au in known resources. Despite this phenomenal gold endowment the BHT remains remarkably unstudied and stands out as the only significant orogenic gold province formed during the terminal stages of the Nuna supercontinent assembly. This study presents a tectonic synthesis of the Precambrian evolution of the BHT based on U-Pb geochronology and paired Lu-Hf analyses of detrital zircons within 72 metasedimentary units. The exposed portion of the BHT is dominated by Paleoproterozoic passive margin miogeoclinal sequences deposited between 2.15-1.96 Ga that were subsequently overthrust by 1860-1820 Ma parautochthonous greywacke successions transposed over the margin during arc collision and ocean closure <1820 Ma. A flexural foreland accommodated thick greywacke sedimentation shed from the adjoining thrust highlands. With our expanded dataset, the gold resources of the BHT can be placed in a proper Paleoproterozoic tectonic framework. From 1.9 to 1.82 Ga the Wyoming craton was rapidly rotated during oroclinal development initiated by the failed subduction of the Dakota block beneath the Superior craton, culminating in a soft collision of the Wyoming and Superior cratons at 1.82 Ga in a dominantly strike-slip setting that trapped the intervening Dakota block and extruded Paleoproterozoic arc crust south of the Wyoming craton to form the controversial Central Plains orogen. This event placed the Black Hills on the margin of a mega-subduction system extending across the entire southern boundary of Laurentia after 1.8 Ga associated with Yavapai accretionary orogenesis. Tectonic readjustments after 1.75 Ga produced an environment favorable for the development of orogenic gold deposits in the BHT, including a switch from dextral to sinistral transpression, differential block uplift, dilation of mantle-tapping transverse basement faults and large-scale hydrothermal fluid release within the passive margin sequences. We view the BHT as an atypical orogenic gold province where deposits are hosted in miogeoclinal successions deposited several hundred m.y. before deposit formation and underlain by ancient attenuated lithosphere along a long-lived plate margin that experienced repeated gold refertilization through subduction modification. The remarkable first-order similarities with the Paleozoic tectonic history of both the Altaids and the Great Basin argue that the BHT may mark a transitional form of gold province linking classic Archean greenstone orogenic gold deposits with the sediment-hosted deposits that dominant the Phanerozoic.

621 - Reverse shear, horizontal shortening and lode-gold mineralisation along the Mougooderra Shear Zone, Western Australia

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The Yilgarn Craton of Western Australia is recognised as one of the best endowed geological terranes on Earth, hosting a diverse array of world-class orogenic-lode gold deposits. These deposits share a range of common characteristics including a spatial association with regional structures and a distinct structural control upon mineralisation. The 2.95-2.8 Ga Yalgoo-Singleton Greenstone Belt in the west of the craton contains less discovered gold resources than the well-renowned Eastern Goldfields, likely due to minimal (<5%) outcrop, thick transported cover and thus a more difficult exploration environment. In such areas, structural logging of drillcore is the only means of deciphering the style, geometry and kinematics of the potential mineralisation and associated structures present. This study has employed detailed structural logging of core drilled along the unexposed Mougooderra Shear Zone, primarily from the 400koz Silverstone deposit. Our pit mapping and structural analyses at Silverstone reveal predominantly reverse kinematics of a steep (~65°) west-dipping shear zone, with associated veining of two principal types: foliation-parallel shear veins and extensional flat veins. This vein geometry, along with reverse kinematics, conforms to the fault-valve model, requiring high pore fluid pressures to facilitate movement. Cross-cutting relationships show a progression from early, foliation-parallel quartz-carbonate veins, to flat quartz-carbonate-sulphide veins and late calcite veinlets. Some sulphide crystals are deformed into the foliation, whereas others are euhedral and relatively undeformed, consistent with mineralisation occurring in the late stages of shearing to post-shearing. Similar structural analysis at the ~100koz Windinne Well deposit, situated on a splay off the Mougooderra Shear Zone, also demonstrates reverse kinematics with foliation parallel veins and extensional flat veins. Further, our paragenetic study reveals at least two discrete gold-bearing phases at Silverstone, comprising an early phase of arsenopyrite and subsequent phase of antimony sulphides. Gold occurs both as inclusions and as free gold, with textural features suggesting that the two gold phases were formed as part of the same sustained mineralising event, rather than two overprinting episodes. Reverse shear and fault-valve mineralization are consistent with an episode of horizontal shortening. This is compatible with intrusion-related strain, such as diapirism/ballooning of surrounding granitoids, or alternatively, a subsequent shortening event. Similar kinematics are demonstrated by deposits along the main shear zone and those on second-order structures, suggesting they formed as part of the same contractional episode. There is currently little evidence for strike-slip/transpressional strains commonly associated with shear-hosted lode-gold mineralisation elsewhere in the Yilgarn Craton.

622 - Stable Isotope (H, O, C, Si, He, Ar) Systematics of the Turbidite-Hosted Shangxu Gold Deposits in the Bangong-Nujiang suture belt, Central Tibet, China: Implications for ore genesis

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In recent ten years, an increasing number of gold deposits have been found in the Bangong-Nujiang Suture zone, central Tibet, China, due to the increase of gold prospecting work. To understand their geological characteristics, ore features and genesis is a key point to promote the regional exploration. The Shangxu gold deposit is a newfound gold deposit, whose mineralization is hosted by the Jurassic turbidite sedimentary rocks of the Mugagangri Group and tectonically controlled by the regional fault system. A set of sequential quartz-carbonate-sulfide vein system is well developed in this area, which provides an opportunity for the stable isotope and ore genesis study. According to our investigation, during the early quartz-pyrite hydrothermal stage, defined as massive quartz with minor disseminated euhedral pyrite and gold, fluids in quartz have a $\delta^{18}O_{fluids}$ of 6.1~6.4‰, δD of -74.2~-116.2‰, $\delta^{13}C_{CO2}$ of -5.4~-7.6‰, and $\delta^{30}Si$ of -0.1‰; in the middle quartz-pyrite-sulfides hydrothermal stage, featured by saccharoidal quartz, granular and vein pyrite, with minor chalcopyrite, galena, sphalerite and gold, fluids in quartz have a $\delta^{18}O_{fluids}$ of 7~8.2‰, δD of -109.1~-120.4‰, $\delta^{13}C_{CO2}$ of -9.6‰ and $\delta^{30}Si$ of -0.1‰~-0.2‰; in the late carbonate-sulfides hydrothermal stage, characterized by plentiful ankerite, calcite and various sulfides with minor quartz and gold, fluids in quartz have a $\delta^{18}O_{fluids}$ of 5.3~6.4‰, δD of -112.6~-125.3‰, $\delta^{13}C_{CO2}$ of -7.4~-12.4‰ and $\delta^{30}Si$ of -0.1‰, whereas fluids in calcite have a $\delta^{18}O_{fluids}$ of 5.5~9‰, $\delta^{13}C_{carbonate}$ of -0.1~-2.4‰, $\delta^{13}C_{CO2}$ of -0.5~-2.8‰, and in ankerite have a $\delta^{18}O_{fluids}$ of 4.9‰, $\delta^{13}C_{carbonate}$ of -1.3‰ and $\delta^{13}C_{CO2}$ of -2.8‰. Fluids inclusions in ore-related pyrite have $^{3}He/^{4}He$ ratios of 0.27~0.42 Ra and $^{40}Ar/^{36}Ar$ ratios of 313.3~372.4. Generally, the stable isotope compositions of the ore-forming fluid from the Shangxu gold deposit are consistent with those of the typical orogenic lode gold deposits. Moreover, an ore genesis model can be outlined: ore-forming fluids were likely to be generated at the mid-crust through devolatilization of hydrous minerals in sediments of the Mugagangri Group, as triggered by metamorphism. Sulfur (gold, by inference), originated from sedimentary/diagenetic pyrite in sediments (Pei et al., 2016; Liu et al., 2018), was migrated by metamorphic fluids flowing by. During transportation to the site of deposition, gold-bearing fluids were variably influenced by interaction with organic matters in host rocks. Reduction of ore fluids is thus considered to be an important mechanism of gold precipitation as well as depressurization.

700 - Geophysics

701 - Are magnetic susceptibilities derived from aeromagnetic data consistent with measurements on outcrop?

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Magnetic susceptibility is a physical rock property commonly collected by field mappers in industry and government geological surveys. One use of this type of data is assisting with the interpretation of aeromagnetic data as outcrop-scale magnetic susceptibility readings can be assigned to the various rock types. This allows the modeller to eliminate a degree of freedom and focus on fine-tuning the geometry of their model. This interpretation process assumes a simple relationship between outcrop-scale magnetic susceptibility measurements and those that generate the measured aeromagnetic data, but it is unclear if a useful relationship exists. One way to test this is to produce an apparent (derived) magnetic susceptibility from the magnetic data to compare with the measured magnetic susceptibilities. Apparent magnetic susceptibility can be produced from a total magnetic intensity grid. A high pass filter is applied and a downward continuation is performed in order to remove noise due to regional effects and deeper rocks. Then this data is transformed to the magnetic north pole and converted to apparent magnetic susceptibility. Regional and deep rock effects are not relevant when estimating the near-surface susceptibilities. The apparent susceptibility values are then plotted against the mean of the measured values in a similar area. A bimodal distribution can be identified, with those in the mode below 10-3 SI showing no correlation. This is understandable, since rocks with a low magnetic susceptibility have an insignificant effect on the total field aeromagnetic data. Values in the mode above 10-3 SI, show a weak correlation with estimates frequently differing by an order of magnitude. This means that using the field-measured values to model magnetic data could result in incorrect models. There are several possible explanations for these discrepancies: different measurement scales, sampling procedures that do not capture magnetically susceptible features (near surface weathering), simplifications during calculation of apparent magnetic susceptibility, ignoring remanent magnetization effects, and the various filters' abilities to remove noise. For these reasons when modelling the aeromagnetic data in some cases the outcrop-scale magnetic susceptibility values will be useful, but in other cases they should be treated with a higher level of caution.

702 - UAV-borne Aeromagnetic Survey Delineates Structural Controls in Greenstone Gold Exploration

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Mineral exploration practices have been advanced by integrating unmanned aerial vehicle (UAV) platforms with high-resolution magnetometer payloads. UAV-borne aeromagnetic surveys have two distinct technical advantages when compared to conventional manned airborne and terrestrial magnetic

surveys: (1) UAV platforms are able to safely carry a magnetic payload at flight elevations closer to the ground than manned airborne surveys, increasing the resolution and amplitude of the measured total magnetic intensity (TMI) and (2) UAV platforms can provide a higher rate of coverage than terrestrial surveys, increasing efficiency and decreasing cost. As such, UAV-borne aeromagnetic surveys are favourable for smaller scale target areas up to 10 km2, providing a more desirable balance between the two end-members of resolution and coverage attained using manned airborne and terrestrial magnetic surveys. To demonstrate this, a UAV-borne aeromagnetic survey was conducted within the Shebandowan Greenstone Belt, northwest of Thunder Bay, Ontario, Canada in July 2017. The objective of the survey was to aid in resolving structural controls related to gold mineralization within the study area. A 2-D grid (~500m by ~700m) was flown at an approximate elevation of 35m above the ground with a DJI-S900 multi-rotor UAV and a GEM Systems Potassium Vapour Magnetometer (GSMP-35U). In total, over 16 line-km's of UAV-borne aeromagnetic data were flown with a line spacing of 25m, resulting in approximately 100,000 TMI observation points. Historical datasets related to the site were correlated with the UAV-borne magnetic observations. In doing this, the UAV-borne TMI and calculated 1st vertical derivative data provided an enhanced interpretation, aiding in delineating structural controls and potential hydrothermal fluid migration pathways (a pair of adjacent shear zones) related to gold mineralization on site. These structural controls sensed with the UAV-borne aeromagnetic data, were not clearly resolved in the regional manned airborne magnetic data, demonstrating the utility of applying UAV-borne aeromagnetic surveys to localized mineral exploration targets. The conclusions and interpretations drawn from the UAV-borne aeromagnetic data, coupled with historical datasets, where applied to make a new gold mineralization discovery on the site, assayed at 15 g/t. Thus, this case study highlights the potential impact of integrating both modern and historical geophysical and geological data on discovery. The overall acquisition, management, analysis and interpretation of UAV-borne aeromagnetic datasets applied to mineral exploration targets is discussed with a particular focus on the improvements made possible by surveying in closer proximity to the targets.

703 - Potential field data modelling along Metal Earth's Chibougamau transect using geophysical and geological constraints

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The Metal Earth (ME) project aims to understand the underlying geological mechanisms differentiating well endowed and less endowed mineralized zones in Precambrian greenstone belts of the Canadian Shield. ME acquires and collates various geological observations and geophysical data (i.e. seismic, magnetotelluric, gravity, magnetic and petrophysical properties) along 13 selected transects across the Abitibi and Wabigoon sub-provinces within the Superior Craton. The ME objective is to create valid 2D and 3D models of subsurface features, so as to identify components that contribute to mineralization processes. Thus far, the project has acquired a total of 2974 gravity readings with an average spacing of 300 m along ~822 line kilometers along 10 transects. The acquired data were checked for quality,

processed to calculate the complete Bouguer anomaly and combined with the existing gravity data provided by the Geological Survey of Canada throughout the areas of interest. In this paper, data along the Chibougamau transect (570 gravity observation along ~128 line kilometers oriented SW-NE) located in the northeastern part of the Abitibi sub-province is considered. The Chibougamau area is one of the well-endowed transects where the geology consists of several synclinorium and anticlinorium of volcanic and sedimentary rocks, with tonalitic gneisses cores. Gravity and compiled high-resolution magnetic data along this transect were modelled using an initial petrophysical modelling constrained by geological observations made at the surface, seismic sections at depth and measured petrophysical properties. Potential field data modelling requires adjusting the shape, densities and magnetic susceptibilities of features at depth and can resolve the geometry of some features which are transparent in seismic sections. For example, the model provides an improvement in estimating the size, shape, and depth of plutonic bodies such as the Barlow and Chibougamau plutons across the Lac Doré Complex. The new modified model is consistent with the known structural geology (the synclinorium and anticlinorium of volcanic and sedimentary rocks). The improved understanding of subsurface features will potentially help to identify components contributing to mineralising processes in the Chibougamau area.

704 - Multi-Focusing stacking technique: A robust method of improving subsurface seismic imaging

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Imaging the complex subsurface geological structures is one of the challenging tasks in the geophysical prospecting methods. Seismic data processing methods play an important role in constructing an accurate subsurface image from reflection seismic surveys. Seismic reflection method provides the highest lateral and vertical resolution among geophysical remote sensing methods and maintains the desired precision to depths of several kilometers. However, the application of seismic methods in hard rock environment encounters difficulties due to the complex geologic structures, complicated surface conditions, low fold, noisy data, and numerous steeply dipping interfaces and heterogeneities (faults, fracture zones, etc.). Conventional seismic data analysis could not deal with these issues because it uses relatively a low fold single common midpoint gather (CMP) and simplified velocity models that limit the S/N improvement. Recently, some attempts have been made to improve stacking procedures by utilizing Non-CMP based imaging methods to obtain the zero-offset stack sections. The Multi-Focusing approach proposed by Berkovitch et. al. (1994) is based on the homeomorphic imaging theory. Multi-Focusing (MF) is a highly effective multi-coverage zero-offset stacking algorithm that can address many of these issues and be used to generate high-resolution images for comprehensive geological interpretation. This method does not require any knowledge of the subsurface model and can produce an accurate zero-offset section for seismic data with arbitrary source-receiver distribution according to a new local double-square-root moveout correction formula. This method enhances time-migrated seismic sections drastically by increasing the fold of MF super-gathers that leads to a higher signal-to-noise ratio. Other advantages of MF method are stretch-free stacking, Non-hyperbolic moveout correction, automatic estimation of MF parameters, and determination of dip-independent velocities. This study presents the practical feasibility of the MF method and compares MF and conventional seismic sections. Application of the MF algorithm

to synthetic and real data examples indicates its advantages compared to conventional CMP processing. This research aims to demonstrate the potential of the robust and coherent MF algorithm in generating high-resolution seismic images from Metal Earth's data with a significant impact on the ability to interpret near-surface and deep geological structures. In general, therefore, the results of applying MF on Metal Earth's data show this method greatly improves the quality of time imaging and alignment of reflection events.

705 - 3D magnetic data inversion using a Lanczos bidiagonalization algorithm with the choice of the regularization parameter based on the normalized cumulative periodogram

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The importance of identifying buried mineral deposits is increasing due to increased demand associated with global industrialization. The magnetic method is an important tool, so interpretation and hence inversion of magnetic data to yield a 3D model is important. Inversion of magnetic data provides a means to determine the depth, geometry, size and location of the anomaly source. For magnetic data inversion techniques this requires solving for an approximate susceptibility distribution in the subsurface that is consistent with the observed data. One of the critical issues in solving inverse problems is the determination of the optimal value of the regularization parameter, which controls the balance between the data misfit and some other criteria that makes to model more realistic. In this study, normalized cumulative periodogram (NCP) is used to select an appropriate value. Inversion methods require an inversion of a large matrix. This can be done using direct matrix inversion methods, which have greater precision, but are inefficient. Instead, we used an iterative Lanczos bidiagonalization algorithm, which does not require a matrix inversion, but instead uses a number of efficient matrix multiplications that use less computer resources. A geological model of the Larder Lake, Northern Ontario, was used to generate synthetic data in order to validate our algorithm. Then real data from Larder Lake was inverted and the results show a reasonable approximation of the magnetic distribution and subsurface mineral configurations.

706 - A Study of Seafloor Massive Sulphide Deposit Systems through Magnetic Inversion; East Manus Basin

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Seafloor massive sulphide (SMS) deposits are hydrothermally formed mineral deposits located on the ocean floor. These modern equivalents to volcanogenic massive sulphide deposits are rich in copper, gold, silver, and lead, leading them to be viewed as future economic resources. An efficient way of forming resource estimates of SMS deposits and understanding their general geometry, despite their native

remote environments, is through the inverse modelling of magnetic data collected by autonomous or remotely operated underwater vehicles. At present, the default method for studying SMS deposits in the sub-surface is through drilling, which is difficult and expensive on the seafloor. The collected magnetic data can be inverted using a voxel-mesh modelling program to determine the regional characteristics of the hydrothermal system in three dimensions, and the effective magnetic susceptibilities of the deposit and host rock. A surface geometry inversion method can then be used to model the massive sulphide lenses as discrete volumes, allowing for their tonnage estimates. This surface geometry inversion method functions by modelling the Cartesian position of the vertices of a wireframe surface mesh, with the magnetic susceptibility values of all enclosed regions in the model remaining constant. The data specific to this study was gathered over the Solwara 1 SMS deposit, located in the East Manus Basin. Additionally, regional deep-tow magnetic data has been used to map the hydrothermal alteration surrounding Solwara 1, increasing our understanding of these felsic-rock hosted deposits.

707 - Geophysical Signature of Camel Back and Flat Landing Brook VMS deposits, Bathurst, NB

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The Bathurst Mining Camp (BMC) in New Brunswick is an area rich in base metal deposits, containing over thirty massive sulphide deposits, and the target areas for this study. These sulphide deposits are important due to the economic viability of precious metals such as gold, silver, platinum, copper and other industry important base metals. Geophysics has been widely utilized in Bathurst and other mining camps, mostly to detect the high conductivity anomalies associated with large massive sulphide concentrations. A vast concentration of geophysical surveys were conducted over the entire Bathurst camp during the federal program Exploration Science and Technology (EXTECH-2, 1994-1996) and Targeted Geoscience Initiatives 3 and 4 (TGI3 and TGI4, 2007-2013). The Bathurst Mining Camp is comprised of felsic volcanic rocks from the Middle Ordovician, interlaid with sequences of Middle to Upper Ordovician sedimentary and felsic volcanic rocks. This study focuses on the Camel Back and Flat Landing Brook deposits. Both deposits are confined within the Tetagouche Group and were discovered using airborne geophysical surveys. The Tetagouche Group forms most of the Camp, with 4 major formations (in ascending stratigraphic order): Nepisiguit Falls Fm., Flat Landing Brook Fm., Little River Fm., Tomogonops Fm. Regional thrusting sequences have created a complex tectono-stratigraphy. Both the Camel Back and Flat Landing Brook deposits have iron formations which are important indicators of pyrite and other possible accessory minerals, and have a particular geophysical signature that can be used as a marker when analyzing geophysical data. This study shows new modelling results using existing gravity and magnetic data, and other ancillary data (EM, IP/Resistivity, drilling information) to provide additional constraints. Rather than focusing on direct detection, it is shown that we can provide additional constraints on the structure and stratigraphy associated to both mineralized bodies, and subsequently use these criteria to determine possible future exploration sites.

708 - Massive Sulphide Exploration with the use of Geophysics: Key Anacon and Orvan Brook, Bathurst, New Brunswick

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Base (non-precious) metals are a very important economic industry around the world, placing a large focus on the identification and extraction of economically viable deposits. Within Canada a very important tool is the use of airborne geophysical methods to observed subsurface features over a large area. The Bathurst Mining Camp (BMC) in New Brunswick contains large deposits of both disseminated and massive sulphides as well as traces of Au, and Ag. It is comprised of felsic volcanic rocks from the Middle Ordovician, interlaid with sequences of Middle to Upper Ordovician sedimentary and felsic volcanic rocks. A vast concentration of geophysical surveys was conducted over the entire Bathurst camp during the federal programs Exploration Science and Technology (EXTECH-2, 1994-1996) and Targeted Geoscience Initiatives 3 and 4 (TGI3 and TGI4, 2007-2013). The goal of this study is the interpretation of existing geophysical data in attempts to identify signatures that can point to areas of interest for further study. For this, we analyze two deposits: Key Anacon and Orvan Brook. Both consist of stratiform deposits with base metal lenses of potential economic value. Iron formations have been identified at both locations, which corresponds with past and present mined deposits in the area. Key Anacon is located at the contact between the Nepisiguit Falls Formation and overlying the Little River Formation. It is defined by a Foot wall composed of felsic ash and crystal tuffs with a Hanging wall compromising of mafic volcanic flows interbedded with volcanoclastic siltstone, sandstone and shale. Orvan Brook is located within the Tetagouche Antiform, and is hosted by feldspar-phyric to aphyric micaceous sericite tuff and dark grey graphitic shale. We show new modelling results based on the existing gravity and magnetic data, aided by additional information (airborne EM, IP/Resistivity sections, drilling information, petrophysics) to provide additional constraints. These results point to the determination of augmented structural and stratigraphical control on both mineralized bodies, rather than a direct detection of geophysical anomalies, which has been the standard use of geophysical data for the BMC in the past.

709 - Removal of Severe Noise from Airborne Time-Domain Electromagnetic Data Acquired Across a Devonian Rift Basin in New Brunswick, Canada

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The study area of this project is a 40 km^2 area northwest of Bathurst Mining Camp where there is great interest for base metal (Zn, Pb, Ag) exploration. Due to dense vegetation and swamps covering the land in certain parts, airborne Time-Domain Electromagnetic (TDEM) systems have been employed to survey the area. One survey, flown in April 2004, collected 272 kilometers of vertical (Z) and horizontal (H) component TDEM data. Substantial complications in the data set arose from unconventional pole-mounted powerline transmitters used to carry large voltages into isolated areas. The noise response from these transformers overpowers the geological background response resulting in contamination of derived products such as the energy envelope and decay times maps as well as conductivity depth imaging (CDI) products making it impossible to identify true targets of interest. The unusual spatial distribution of these

transformers (single, cluster and in-line arrangements) poses a need for unique data processing of the airborne TDEM data. For removal, we use a time-series approach to analyze the unique stationary noise pattern and quantify the amplitude and phase response of the noise in order to design a prediction deconvolution to remove the powerful noise. The reprocessed airborne TDEM data are then used to compute contamination-free decay constant and conductivity maps of the base metal exploration area.

710 - Calculating the terrain correction for gravity gradiometry data using 3D forward modelling and unstructured tetrahedral meshes

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Gravity gradiometry method gives the gradients in the three orthogonal directions of the three components of the acceleration due to gravity. Gravity gradiometry data can be strongly affected by topography. To remove this effect leaving only the contributions from density variations in the subsurface, a terrain correction can be calculated and subtracted from the observed data. The terrain correction is typically computed using a Fourier-based technique. Such approaches can be efficient. Here, we investigate the use of 3D forward modelling that incorporates accurate topography as a means of more accurately computing the terrain correction. For this purpose, the components of the gravity gradiometry tensor are synthetized using forward modelling for a model of the Millennium area in the Athabasca Basin. A uniform density of 1 g/cc is used in the modelling, and the gravity gradient data computed for this density model at the same locations as the real data (HeliFALCON). The forward modelling is done using an unstructured tetrahedral mesh, the advantage of which is that it can honour the topography to as fine a resolution as the topography is known. The model uses a 10x10 m dense, refined topography of the study area. These synthetized gravity gradiometry data can be considered as the terrain effect. The synthetized data are compared with the terrain effect calculated using a Fourier-based technique by CGG also using a terrain density of 1 g/cc. The results show some differences (up to 8%) for the components. In order to apply the terrain correction, the terrain effects calculated for a density of 1 g/cc can be multiplied by a chosen appropriate density and then subtracted from the real data. In this research, the glacial sediments (overburden) of the Millennium area have a density of 2 g/cc. Thus, synthetized data are multiplied by 2. The resulting terrain effects are subtracted from the real data in order to obtain the terrain-corrected data. The results are compared with CGG's terrain-corrected data. The data corrected using the forward modelling approach have less of a remnant topography signature that the data corrected using the Fourier-based approach.
NSERC-CMIC-Footprints Publication #202.

800 - Other

801 - 3D Fault Network in the Western Wabigoon Subprovince: Implications for Orogenic Gold Prospectivity

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Three-dimensional (3D) modelling has become prevalent in the geological community as it provides a visual and comprehensive means to interpret geological data. With regard to understanding, measuring, and interpreting relationships between geological features, 3D modelling helps visualize and interpret data that could otherwise be missed in plan view. In this study, a geological modelling approach is applied to the western Wabigoon subprovince (WWS), part of the Superior Craton in northwestern Ontario, where the weak gold endowment is not sufficiently understood. To provide insight into the relationship between regionally significant geological features such as faults and intrusion to gold endowment, this study will quantify the spatial association between orogenic gold occurrences and crustal-scale geological structures. The WWS consists of greenschist facies metamorphosed Archean volcanic and sedimentary rocks intruded by intermediate to felsic plutons. Structural domains within the WWS are bounded by regional-scale deformation zones that locally host gold-rich quartz-carbonate-pyrite veins. Implicit modelling tools were used to build a 3D interpretation of the main lithologic packages, intrusive bodies, and fault network, constructed based on field structural data, airborne magnetic survey, reflection seismic transects and a database of historic maps and gold occurrences. Euclidean distance calculations are used for investigating the spatial relationship between faults, intrusions, and gold occurrences. Preliminary interpretations indicate a strong spatial between the gold occurrences and the deformation zones while the link with the plutonic bodies is much weaker but requires farther analysis. Ultimately, this work will help to understand the 3D geometry of the WWS, identify possible regional controls on orogenic gold mineralization, and offer some contributions towards proposing new hypothesis for prospectivity modelling of the area. CFREF Metal Earth Project Contribution MERC-ME-2019-119.

802 - Optimization of GIS-based lithology and structural variability analysis for Archean greenstone belts: A case study in the western Wabigoon subprovince, Ontario

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In the early stages of mineral exploration, ground selection tools are commonly applied to narrow search regions to prospective areas in order to focus exploration efforts. Selecting an appropriate method that is both effective and efficient is key to the success of an exploration program because choosing the wrong area or producing overly-complex results may negatively impact the program. An appropriate tool should identify geologic features and relationships that are interpreted to be significant in a given deposit model and setting. For orogenic gold exploration, understanding geological the characteristics of regional

structures are critical as they play a fundamental role in controlling the location of deposits since they act as both conduits and traps for mineralizing fluids. Therefore, structural variability has the potential to be used as a proxy for prospectivity of major structural zones. In the western Wabigoon subprovince, an Archean greenstone belt of the Superior Province, near Dryden, Ontario, a new geological and structural map was interpreted using aeromagnetic data, legacy GIS compilations, and new field observations. The map area includes hundreds of orogenic gold occurrences and several prospects, suggesting a potential for further exploration. The spatial variabilities of lithologies, strike and dip of bedding as well as foliation, and azimuth of segmented linear magnetic anomalies were calculated at different scales, gridded and visually interpreted. Grids were constructed using a range of cell-sized, from 50 m to 500 m, and a neighbourhood of 100 m to 10 km, to investigate the optimal resolution and sensitivity to detect prospective targets and characterize geological domains. The resulting maps highlight areas of lithological variability and structural complexity, where strikes of features vary from folding or faulting. These provide insight for map interpretation, defining boundaries and may indicate favourable domains for targeted orogenic gold exploration. The preliminary application of this variability method suggests that it may be an effective tool for green and brownfields exploration in orogenic belts of any age, worldwide. Tools such as lithologic and structural variability with integrated geophysics and structural measurements provide the geoscientific community with a means to confidently narrow search areas in geographically extensive exploration programs, better characterize geological domains, and effectively focus later exploration efforts. CFREF Metal Earth Project Contribution MERC-ME-2019-112.

803 - Random Forest Classification and Principal Component Analysis in Geochemical Data of a Sulfide and Silicate Base Metal Mineralization in Vazante District, Brazil

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As mineral exploration activities tend to aim at deeper targets, costs per discoveries are getting higher. Therefore, effective utilization of all the available data is becoming critical in the decision-making process. In recent years, several different machine learning algorithms (MLA) have emerged and have been adopted by the mineral explorers because of their ability to identify the multidimensional relationship between evidential features. The Random Forests (RF) algorithm is an MLA which is presented by many studies as a practicable technique for classification mostly because of its simplicity in terms of understanding the internal decision-making criteria, i.e. identification of feature importance, ability to handle with missing data and to overcome overfitting. RF is an assembly of decision trees and supposedly perform better or at least equal than the conventional decision trees according to several studies. This study uses rock geochemistry from Vazante-Paracatu District in Brazil and in which several zinc-sulfide and zinc-silicate deposits are known, to scrutinize the sensitivity of the RF prediction accuracy to changes in different conditions. In addition, a principal component analysis (PCA) is also performed to gain insights on the geochemical process by identifying the vectors which are oriented in a way that they are able to capture the variability of the data most effectively and summarize the related features of the associated vector. In the algorithm, sensitivities are performed in the sample amount by conducting bagging (bootstrap aggregating), as well as in the number of trees in the forest, number of features to split the samples in each decision nodes and in the data by removing some portion of the data, transforming the

data into log ratios with different methods and replacing the original chemical analysis results with principal components as input variables. A simple decision tree (DT) predictor which has less user-defined parameter was used as a benchmark to test the improvements of the RF results. Preliminary results show that RF outperforms the DT even before constraining the data with any domain knowledge. Further results and implications of them in mineral exploration are discussed to provide insights for future studies.

804 - Mineralogical reaction modelling of partial extractions in geochemical exploration samples

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Geochemical exploration using partial extractions, targeting specific phases in soil samples for analysis, allows for detection of nuanced signals from mineralization under transported soils non-native to the area being explored. These deposits make up a large portion of mineral resources in areas that have experienced recent glaciation, such as Canada. This chemical signal is typically composed of labile elements that have weakly sorbed to the surfaces of various soil components, with specific associations being unique to the elements of interest. Manipulation of pH, temperature, and reagent used in a partial extraction influences what phases of the soil are removed, affecting what elements appear anomalous and the interpretation of potential mineral sources in a survey. However, interpretation of extraction data is challenging due to the uncertainty of targeted phases and chemical reactions occurring under various extraction conditions. Here, we show that additional soil components are affected by partial extractions than what is previously hypothesized, and that consideration of several chemical reactions occurring during the extractions is required for more accurate interpretation of the results in a traditional geochemical exploration survey. Partial extractions of increasing strength, ranging from room temperature deionized water to high temperature hydroxylamine hydrochloride, were performed on fresh soil samples. By retaining and analyzing the residual material, it was observed that additional dissolution of untargeted phases, precipitation of new minerals, and readsorption of elements onto different mineral phases all complicate the interpretation of element concentrations and their abnormality relative to background. Our results provide further insight into the reactions that occur during a partial extraction that have thus far been hypothesized based on the leachate that has been analyzed. This work is intended to provide a starting point for further investigation into partial extraction chemistry and more robust modelling of mineralogical reactions that occur. This provides more confidence in the use of partial extractions as a mineral exploration tool and improves their accuracy.

805 - Magnetite geochemistry as a tool for exploration in Guyana

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Magnetite is a common mineral in geologic and ore environments, and the chemistry of magnetite in these environments varies. In this study, we investigate the geochemistry of magnetite from various mining districts in Guyana — a very under-explored country owing to thick jungle cover, and limited road

access. The aim of this study is to use magnetite geochemistry to complement existing geochemical, and geophysical data in order to identify locations for more targeted exploration. We investigate the geochemistry of detrital magnetite grains and magnetite grains from rock samples by using field emission scanning electron microscopy (FE-SEM), electron-probe micro-analysis (EPMA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). SEM analyses revealed the presence of sulfides – chalcopyrite, chalcocite, bornite, pyrrhotite – in detrital magnetite grains. We also observe mineral assemblages that contain varying amounts of bornite, magnetite, chalcopyrite, pyrrhotite and Co-enriched pentlandite in rock samples analyzed. The chemistry of magnetite grains collected from stream sediment is variable and most streams contain magnetite grains of different compositions. Analyses of magnetite yielded chemistry that is similar to magnetite from Ni-Cu-PGE, VMS, and igneous and hydrothermal ore deposits. The presence of sulfides and other inclusions in detrital magnetite grains may indicate the presence of mineralization types and/or alteration halos in the catchment areas being sampled.

806 - Direct discovery of buried mineralization through microbial community-fingerprinting

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Canadian mineral exploration is becoming increasingly complex as many undiscovered deposits are likely buried beneath significant glacial overburden. The modernization of genetic sequencing and big-data evaluation allows for efficient and cost effective microbial characterization of soil profiles, with the potential to penetrate glacial cover. Microbial communities are sensitive to subtle fluctuations in surrounding soil chemistry, reflecting these changes on very short timescales. Shifts in microbial community profiles induced by nearby chemical alteration, are detectable and can be used to vector toward different geological features. The development of innovative exploration protocols and techniques is imperative to the continuation of discovery success within the Canadian mineral exploration industry. Preliminary experimentation has demonstrated the viability of microbial fingerprinting to directly identify the projected sub-crop of mineralization in addition to more distal entrained geochemical signatures in till. Soils above two copper-porphyries in southern British Columbia, and two kimberlites in the Northwest Territories, have undergone microbial community profiling. These community-genome derived data-sets have been integrated with trace metal chemistry, mineralogy, surface geology, and other environmental variables including Eh and pH. Analyses show significant microbial community shifts, correlated with subsurface mineralization, with a distinct community response at the species directly over known deposits. The relationship between microbial profiles and mineralization can lead to the application of microbial fingerprinting as a method to accurately delineate ore deposits in glacially covered terrain. The integration of microbial community information with soil chemistry and landscape development coupled with geology and geophysics propagates the development of an improved decision process in mineral exploration. As databases are developed, there is potential for application as a field-based technique, as sequencing technology is progressively developed into portable platforms.

807 - Brazil and Canada: A Comparative Study on the Mining Industry towards the Indigenous Peoples

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This research will conduct a comparative legal analysis of the mining industry as it relates to Indigenous communities in Canada and Brazil. In Canada, for example, ongoing discussions and challenges about the importance of land to Indigenous Communities, their culture and traditions (e.g., Ring of Fire) are commonplace, but in Brazil, legal precedents and policies do not appear as well developed. Land claims decisions at the countries' top courts are of critical importance to both nations given that mining development impacts upon the social, economic, and cultural aspects of Indigenous, First Nations, Inuit, and Metis peoples in both countries. This research will target Supreme Court decisions in Canada and Brazil relating to land and the mining industry, with emphasis on Constitutional law, to compare aspects of land claims and Constitutional rulings and how they have influenced social policy on Indigenous lives. Hopefully, there will be lessons learned emerging from the comparison.

808 - Taking rocks for granite: An integrated mineralogical, textural, and petrographic baseline of curling stones used in international-level competition

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Currently, only two quarries in the world produce curling stones suitable for international competition: Ailsa Craig, Scotland (Common Green and Blue Hone varieties) and Trefor, Wales (Red Trefor and Blue Trefor varieties). Despite this, there is a paucity of scientific data regarding the geological and mineralogical features that characterise these materials. Such data are critical to understanding the desirable properties of curling stones: without a firm, scientific baseline, no definitive forward-looking studies can objectively assess current or prospective materials. Curling stones are structured around two key components: (1) the striking band (contact area between stones during collisions), which must withstand intermittent-stress impacts, and (2) the running surface (ring-like interface between stone and ice surface), which is responsible for the curling behavior of the stone. Both rely on the physical properties of the stone, and therefore are directly related to the types of minerals present, their grain-size distribution, the textures in which they occur, etc. Company-supplied curling stone samples were analysed via optical microscopy to investigate their geological and mineralogical features. All samples are intrusive, with three of four rock types exhibiting hiatal to phenocrystic textures (i.e., showing significant ranges in grain size). Ailsa Craig samples are alkali feldspar granites to alkali feldspar quartz syenites, whereas Trefor samples are quartz gabbronorites to tonalites: all lithologies are dominated by feldspars (although both feldspars are not necessarily present) with lesser quartz and minor mafic minerals. Feldspars are variably altered between rock types and occasionally display weak to moderate primary preferential fabrics. Quartz is present as interstitial grains which do not show microstructural evidence of deformation (i.e., undulatory extinction and sub-grain boundaries are absent). Preliminary results provide several implications for the desirable properties of curling stones: (1) significant ranges in grain size may be favourable for striking bands, (2) the presence of quartz challenges the current belief of the undesirability

of quartz in striking bands, and (3) the influence of alteration and primary preferential fabrics on the properties of curling stones is unclear, although deformation is likely undesirable. Further work includes scanning electron microscopy-energy-dispersive spectrometry (to determine mineral chemistry, microporosity, and textures), and powder X-ray diffraction with Rietveld analysis (to determine mineralogy and mineral proportions).

809 - Till geochemistry as a tool to discover concealed kimberlites, NWT

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In regions where recent glaciation has buried kimberlites under glacial sediments, surface geochemical detection methods are best interpreted when coupled with a comprehension of the landscape formation processes. The glacial, post-glacial, and cryoturbation processes that have affected the landscape have, in turn, affected the dispersal of geochemical signatures in the till that can be detected and exploited by detailed surface mapping, sampling, and geochemical analysis. This soil sampling method is designed to proximally and directly detect the presence of a kimberlite using surface sampling and inexpensive and accessible analytical techniques. Results from sampling b-horizon soils above the kimberlite, up-ice, and up to 1 km in the down-ice direction indicate the presence of subtle Ni-Cr-Mg-Nb trains originating from the kimberlite subcrop location extending for >1km from source following two dominant recent ice directions. Kimberlite material was abraded and incorporated into basal till by recent glaciation, and in shallow till environments, is directly detectable at the surface using shallow sampling methods and commercial analysis. In order to better interpret the variation in the geochemistry of soils, the variation in sample material and parent material origin should be minimized; therefore an understanding of the surficial materials allows for sampling of the most effective medium. The practice of employing a soil sampling campaign to test multiple geophysical targets will introduce an additional layer of information for exploration geologists that can screen out false positive targets earlier in the exploration pathway while prioritizing certain targets for subsequent drilling campaign.

810 - Experimental study of reaction textures in volcaniclastic kimberlites

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Some of the most famous diamond deposits are associated with Kimberly-type volcaniclastic kimberlite facies (KPK) located within diatreme part of kimberlite pipes. The origin of this type of kimberlite is one of the most debatable topic in kimberlite geology. The two contemporary models suggest either 1) explosive pyroclastic eruption with subsequent welding of pyroclasts or 2) in-situ magma fragmentation without formation of a pyroclastic deposit. The later model suggests that a reaction between silicate fragments of the country rock and carbonatitic magma exsolves CO_2 causing the magma fragmentation and freezing. This experimental study tests the two hypotheses by examining the reaction of mafic (basalt) and felsic (granite, andesite, and rhyolite) xenoliths with synthetic analogues of evolved kimberlite magma. The

experiments are conducted using a box-furnace, and a piston-cylinder apparatus at the Experimental Petrology Laboratory, Dalhousie University, at 800-1100°C and pressure 0.1 MPa and ~500 MPa to explore the effect of temperature, CO_2 and H_2O on the textures and the sequence of the reaction minerals. First composition was modelled by removal of 50 vol% of olivine components and adding CO_2 to the composition of a hypabyssal kimberlite (Anaconda kimberlite, NWT). Second composition was Na-Ca-carbonate in equal proportions. Experiments at 0.1 MPa were in the absence of water, and at 500 MPa with 10wt% H_2O added. The experimental run-products were analyzed using the scanning electron microscope (SEM) to examine the textures, and energy-dispersive spectroscopy (EDS) was used to identify mineral phases. At 0.1 MPa and water-free conditions the reaction of kimberlite composition with mafic xenoliths at 1100°C showed reaction occurring along the rims leading to xenolith fragmentation, and with granitic xenolith reaction at 1000°C showed melting of sheet silicates and reactions occurring along the rims. Rhyolite xenoliths melted at 1100°C with no evidence of reaction to kimberlite mixture. The reaction of carbonate melt with both basalt and rhyolite xenoliths exsolved CO_2, which raptured both capsules due to the over pressure. At 500 MPa and 10wt% of H_2O the reaction of kimberlite composition and mafic xenoliths at 900°C showed no reaction, and with andesite xenoliths at 800°C melting and reactions along the rims were observed. Preliminary analysis shows dissolution occurring at a faster rate than the reaction between xenoliths and kimberlite mixture. The developed reaction mineral phases and their textures will be compared to the textures of natural BK1 KPK from Orapa kimberlite cluster, Botswana in order to better understand KPK emplacement processes.