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100 - Volcanogenic Massive Sulfide (VMS) Deposits

101 – Geology of the Central North Fiji Basin Triple Junction: A possible modern analogue for voluminous late Archean mafic volcanism

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The Central North Fiji Basin Triple Junction (CNFBTJ) is located at the center of the largest and most evolved interoceanic back-arc basin in the world, the North Fiji Basin (NFB). The NFB opened in the Miocene due to back-arc spreading behind the newly formed New Hebrides Arc. The CNFBTJ, a ridge-ridge-ridge type triple junction, is located at the intersection of the New Hebrides, Balmoral Reef and Conway Reef microplates and formed ~3 Ma. Because of their close link to plate formation and their complex architecture, triple junctions are a locus for high heat flow, faulting, crustal-scale permeability, hydrothermal convection and seafloor venting. This study presents the first detailed geological and structural map of the CNFBTJ. Ship-based bathymetry, covering 10,000 km^2, was combined with geophysical data, geological sampling, and seabed observations, to derive the geological units. In areas with limited data, units were extrapolated from well-documented units in adjacent regions. The CNFBTJ consists of a large oval shaped (25 km x 14 km) axial shield volcano located on the magmatically robust southern arm. The shield comprises several large coalesced volcanoes, with a combined volume exceeding 175 km^3. The shield's summit caldera (~2 km diameter) is the focus of the most recent eruptions and does not appear dissected by extensional structures. Just south of the caldera hosts the verified high-temperature hydrothermal systems with massive sulfide deposits (White Lady and Sonne99), and the low temperature Mussel Hill. The southern arm of the triple junction is actively spreading at 82 mm/yr and is bordered by older (~0.8 Ma), relict back-arc crust. Spreading fabrics in the relict crust are notably curved, possibly indicating that an overlapping spreading center formed in the earliest stages of the CNFBTJ. The northwestern arm is a tectonically controlled spreading center (46 mm/yr), characterized by a broad zone of normal faults with minor volcanism. The eastern arm contains a narrow central axial ridge within a 30 km-wide rift graben, superimposed by the axial volcano, and terminating ~47 km to the northeast. Abundant spreading centers in the NFB point to the long-term evolution of a microplate mosaic dominated by high regional heat flow. Associated with high magmatism, they suggest an anomalous hot upper mantle at the center of the NFB. The particular features of the CNFBTJ may be an indication of the dynamics associated with similar mafic magmatism in oceanic crust of Archean greenstone belts characterized by high heat flow, as previously noted by Lagabrielle et al. (1997). CFREF-Metal Earth Project Contribution MERC-ME-2020-022.

102 - Geochemical evolution of back-arc spreading regimes – a multivariate analysis of Lau Basin volcanic rocks

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Modern submarine volcanic systems, such as the Lau Basin of the western Pacific margin, provide the opportunity to observe the geochemical evolution of back-arc spreading regimes on a basin scale, with implications for the potential of forming large seafloor massive sulfide (SMS) deposits. These processes may be analogous to some ancient greenstone belts, including parts of the Archean Abitibi belt, which is host to world-class Cu-Zn volcanogenic massive sulfide (VMS) deposits and continues to be a primary exploration target. The discovery of the next generation of deposits will depend on improved models of the relationship between host-rock geochemistry and mineral potential.

Here, we present a study of active spreading regimes in the Lau Basin as an example of the diversity of lithogeochemical variations that may occur within a single volcanic belt and the possible geodynamic triggers of those differences. Principal components analysis (PCA) and machine learning (Random Forest classification) identify small- and large-scale mantle flow regimes and petrogenetic controls on whole-rock chemistry that reflect: i) degree of partial melting; ii) upwelling asthenosphere; iii) subduction related input; iv) and felsic magmatism. We focus on the geological evolution of rifting events and the initiation of back-arc spreading, with an emphasis on the magmatic products. This study illustrates the controls of spreading rates, dislocating spreading centers, mantle mixing and distance to the subduction zone and their implications for micro- and nanoplate architecture. We also identify a previously recognized influence of hot and enriched mantle material related to the Samoan mantle plume in the north. A new compilation of data collected in the Lau Basin since 1970 forms the basis of study. It includes more than 308 dredge locations and more than 450 analyses, including the major and trace elements and isotope ratios ($^{143}Nd/^{144}Nd$, $^{87}Sr/^{86}Sr$, $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$). The data includes all rift-related assemblages in the Lau Basin, including passive rifting, active spreading and propagating rifts proximal to and distant from the subduction environment.

This study provides further insights into the geochemical development of the Lau Basin, which is of significant interest for understanding processes that may lead to regional metal endowment and preservation in the geological record, such as early asthenospheric upwelling and the interaction of microplates. Signatures of mantle flow regimes and petrogenetic controls on melt composition in prospective and barren settings are seen in the Lau Basin data that may have important parallels in Archean greenstone belts. CFREF-Metal Earth Project Contribution MERC-ME-2020-019.

103 – Textural and geochemical analysis of pyrite from two Archean VMS systems in the Onaman Tashota Greenstone Belt, ON

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Volcanogenic massive sulfide (VMS) deposits are characterized by stratabound massive sulfide lenses overlying a pipe of discordant vein type sulfide mineralization. Most VMS deposits have alteration pipes consisting of chlorite and sericite reflecting a weakly acidic, reduced fluid. However, some VMS deposits are typified by advanced argillic alteration, indicating a strongly acidic, oxidized fluid, leading most workers to suggest a magmatic volatile component in their genesis. These VMS deposits are typified by pyrite-dominant sulfide assemblages, but may have additional high sulfidation minerals such as bornite and covellite prior to metamorphism. VMS with advanced argillic alteration typically have higher Au content than conventional VMS, a feature commonly attributed to Au input from magmatic volatiles. The Onaman-Tashota greenstone belt, within the Eastern Wabigoon Subprovince of the Superior contains several variably mineralized advanced argillic alteration-associated VMS systems, providing a natural laboratory to study Au-enrichment mechanisms. Two prospects in the belt will be examined: 1) The Vent, a ca. 2718 Ma Au-rich system; and 2) The Onaman, a ca. 2769 Ma composite hydrothermal system with a barren pyrite zone. Though advanced argillic alteration in VMS and epithermal systems commonly correlates with high Au values, this is not always the case, suggesting that simply having magmatic volatile input into the system is not alone sufficient to enrich Au. To address this problem, a study of the pyrite from each of these systems was conducted to reconstruct their hydrothermal fluid characteristics. Our results indicate multiple microscale pyrite textures present within mineralized samples from both occurrences, these include: inclusion rich cores, euhedral cores, polygonal mosaic, altered massive sulfide. Chemical zonation of As was observed through SEM-EDS mapping, indicating multiple distinct pyrite events with differing fluid chemistry. Texturally late HS minerals such as boulangerite have been identified at the Au-rich Vent system. Further work will focus on conducting in-situ LA-ICP-MS work on the various pyrite types in order to obtain semi-quantitative analysis for comparison. The information gained from this study is expected to shed light on the ability to assess magmatic volatile fluid input and its role in the formation of an auriferous HS VMS system. This study will shed light on the role of magmatic volatiles on Au-enrichment, and hopes to identify key characteristics of Au-rich vs Au-poor magmatic fluids in these systems to help guide further exploration for lucrative Au-rich VMS. CFREF-Metal Earth Project Contribution MERC-ME-2020-033.

104 - Geology of the Monowai volcanic centre, Kermadec-Tonga arc: Implications for the location of caldera-hosted submarine hydrothermal systems

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Large submarine calderas are important ore-forming environments, hosting a range of ore deposit types such as VMS, epithermal, polymetallic vein, and some porphyry Cu systems. The processes that form calderas also provide the heat, structural pathways for fluids, and sufficient host-rock permeability, required for the formation of the mineral deposits. Understanding how these processes evolve over the life cycle of a submarine caldera complex can provide important guides for mineral exploration. Many ancient ore-hosting submarine calderas are only partially preserved or highly deformed, which makes it difficult to study these processes. Therefore, modern submarine calderas, and especially large back-arc megacalderas where the key features can be mapped in their entirety are important analogs. One example is the giant Monowai volcanic centre situated along the Kermadec-Tonga arc in the SW Pacific. It comprises a large stratovolcano flanking two nested caldera-like structures approximately 14.5 km in diameter with a resurgent cone at the centre and surrounding parasitic cones. The innermost large Monowai caldera contains a significant, active hydrothermal system, with extensive diffuse venting sources (<60°C) and evidence of a large inactive sulfide deposit. The presence of oxidized massive sulphides on the resurgent cone suggests that higher-temperature venting also occurred in the past. We combined ship-based bathymetric data with geophysical data and camera surveys to make detailed structural and geological maps of the volcanic complex at the scale 1:1,000,000, highlighting the large-scale structures that were important in its formation. We also identify the lithological units (formations and members) which may have been key in focusing the hydrothermal system within the volcanic centre. Quantitative analysis of the major caldera structures, including orientations, strike lengths and throws, and volumes of magmatic products using GIS analytical tools reveals up to 9.9 km long NE-SW extensional faults with 130 m offsets adjacent to the Monowai caldera complex as well as an excess volume of 2.47 km^3 volcanic material in the surrounding parasitic cones. This data can be directly compared to other large, ore-hosting caldera structures in the oceans and on land, including some of the most important examples recognized in ancient greenstone belts (e.g., the Noranda cauldron). CFREF-Metal Earth Project Contribution MERC-ME-2020-021.

105 - Preliminary results from regional mapping and petrographic analysis and mineralization associated with the Canagau and Ehrhart properties of the Ben Nevis Volcanic Complex (Ontario, Canada)

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The Ben Nevis Volcanic Complex (BNVC), located in the Abitibi Subprovince of the Superior Province, Ontario, is part of the Blake River Group (2701 ± 3 - 2698.5 ± 2 Ma), which is considered a subaqueous megacaldera complex. The Blake River Group in Quebec is well documented as a result of excellent exposure and significant base and precious metal mineralization. This study focuses on the BNVC (2696 ± 1.3 Ma), which consists of basaltic-andesite to rhyolite coherent units and volcaniclastic rocks. Despite its similarities in age, lithology, geochemical characteristics and styles of synvolcanic mineralization, exploration activities in the BNVC has not yielded significant base or precious metal mineralization. The aim for this research project is to investigate the volcanic environment, alteration systematics, and structural architecture of the BNVC, and then compare with the Noranda area. Detailed mapping of the BNVC focused on volcanic facies, alteration assemblages and the distribution of mineralization at stripped outcrops in the Canagau and Ehrhart properties. Field relationships identified features of pyroclastic eruptions, with the presence of dark, wispy flattened fragments, interpreted as possible

pumice fragments, as well as large clasts and blocks grading to fine ash. Multiple injections of dykes into unconsolidated sediment were also identified, indicated by the presence of both blocky and fluidal peperite. Typical VMS alteration (i.e. chlorite, epidote, carbonate and sericite) was also observed locally with strong chlorite alteration overprinting pillowed basalts at the Ehrhart property. The Canagau property is characterized by disseminated sulfides, pyrite stringers and sulfide-rich veins (pyrite, chalcopyrite, galena and sphalerite). Samples were analyzed for major and trace element geochemistry to characterize the host rock and mass flux due to hydrothermal alteration. Future work will focus on the stratigraphic and structural controls of the mineralization surrounding the Canagau and Ehrhart properties and will use further detailed mapping, along with geochemistry. A comparison of the BNVC to the Noranda mining camp will aid in further developing a regional model of mineral endowment for the Blake River Group. CFREF-Metal Earth Project Contribution MERC-ME-2020-009.

106 - Chlorite element ratios as an indicator of alteration conditions: A case study of the LaRonde Penna Deposit

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The LaRonde Penna Deposit is an Au-Rich Volcanogenic Massive Sulphide (VMS) deposit in the Blake River Group of the Abitibi Greenstone belt (2703-2964 MA). The units of interest are the Hebecourt formation and Bousquet formation, which are composed of tholeiitic mafic rocks (basalt and gabbro sills) and calc-alkaline rocks. These units underwent two distinct episodes of metamorphism; a prograde phase to upper greenschist- lower amphibolite facies and a retrograde phase to greenschist facies. Previous studies have found chlorite in VMS deposits to have depleted Al, Fe, and Li ratios and enriched Ca, Sr, and Si ratios compared to metamorphic chlorite. Metamorphic chlorite contains discriminators such as enriched Ti ratios and depleted Mg, Zn, Sb, As, Ag, and U ratios, although the presence of these elements is not as consistently correlated as the VMS indicators. In this study, chlorite was investigated using petrography and electron microprobe analysis to determine the indicator element ratio of chlorite from the LaRonde Penna Deposit. The major, minor and trace elements ratios of chlorite were then compared to previously accepted ratios in order to determine if the chlorite was formed in a metamorphic or VMS environment. This study is an initial investigation to determine whether there is potential for chlorite chemistry to be a viable vector towards mineralization at the LaRonde Penna deposit. Before the results can be implemented in an exploration setting, a set of drill holes with a progressively longer distance from the mineralized horizon should be tested to see if there is a systematic change in chemistry. Indicator element geothermometry and element ratios could be utilized in industry to locate and grade VMS deposits.

107 - Chemostratigraphy and structural framework for gold mineralization at the Goliath Deposit, Wabigoon Subprovince, Ontario

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The Goliath gold deposit is one of the largest gold mineral systems within the Archean western Wabigoon Subprovince. The deposit is located north of the Wabigoon fault and is hosted in a volcano-sedimentary complex (2775 Ma -2700 Ma) of highly deformed felsic volcanic, and sedimentary rocks that contain metamorphic mineral assemblage reflecting upper greenschist to lower amphibolite conditions. Through initial field and core logging observations, gold mineralization at Goliath is interpreted to have formed early (pre deformation) which was subsequently remobilized into the penetrative deformation fabrics. Sphalerite, pyrite, and galena are associated with an increase in gold content. Field observations suggest that mineralization is primarily hosted by the volcanic rocks of the Thunder Lake assemblage, which are volcaniclastic rocks where primary textures are observed. The preliminary results of the geochemical data, petrographic sections, and 3D modeling will complement the fieldwork to aid in understanding what factors controlled gold endowment and how the deformation events affected the mineralization. Bulk rock geochemistry was analyzed to understand the chemostratigraphy of the deposit, in addition to, interpreting the overprinting relationships between the different hydrothermal alteration events. Mineral paragenesis and the relative timing between gold mineralization, sulphides and structural fabrics were examined through petrographic sections. A 3D geological model of Goliath was developed using Leapfrog to highlight potential spatial relationships between the gold deposits bodies, lithological facies, and distribution and spatial correlation of metal values. The modeled gold and base metals ore shoots are parallel to the regional foliation that supports that mineralization is structurally modified (consistent with observations of drill cores in which sulphide mineralization is mainly hosted in foliation planes). There is no apparent spatial correlation between gold and zinc. Future work includes additional geochemistry, petrographic sections, and 3D modeling of the deposit in addition to SEM and LA-ICP-MS for identifying textures and trace elements in mineralised samples. This research will provide a geological model for the genesis of the Goliath deposit, which will be beneficial to further exploration in the area. CFREF-Metal Earth Project Contribution MERC-ME-2020-012.

108 - Petrography, geochemistry, and Pb-Zn-Cu-As-Au mineralization in drill core from the Faribault Brook area, Western Cape Breton Island, Nova Scotia

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Mineral exploration has been ongoing in the Faribault Brook area of the western Cape Breton Highlands, Nova Scotia, since the 1890s when adits were dug in areas enriched in sphalerite, galena, chalcopyrite, and arsenopyrite. Since then at least 15 significant mineral occurrences have been reported and more than 50 exploration holes have been drilled. However, details of the age, structure, and tectonic setting of both the mineralization and its highly deformed metavolcanic and metasedimentary host rocks remain enigmatic. This study focuses on core from three holes drilled in 1978, 1990, and 2008 and archived at the Nova Scotia Department of Energy and Mines core library. Core logging included magnetic susceptibility measurements, petrographic study of 39 thin sections, and 120 portable X-ray fluorescence (PXRF) analyses. Whole-rock chemical analyses were obtained for 17 samples and assays for 6 mineralized samples. PXRF analyses facilitated recognition of rock types in these mainly fine-grained, deformed and metamorphosed rocks: Zr/TiO_2 ratios over 100 ppm characterize

metasedimentary rocks whereas ratios less than 100 characterize metavolcanic rocks. Hole AMC-06-78 (177.3 m) from near the Core Shack occurrence north of Faribault Brook consists of interlayered mafic metavolcanic, calc-silicate and garnet-rich metasedimentary rocks; the abundance of metavolcanic rocks increases with depth and metasandstone with blue detrital quartz clasts occurs at the top of the hole. Hole RB-90-01 (102.4 m) from near the Rocky Brook occurrence 7 km south of Faribault Brook also contains interlayered metasedimentary and metavolcanic rocks but metasedimentary units dominate in the upper and lower sections. Hole GM-09-08 (50 m) from near the Fisset Brook occurrence in the western part of the area consists of metasandstone with blue quartz clasts and interbedded mudstone with local gossan zones. All 3 holes contain much more mineralization than recognized in company assessment reports. Elevated Pb-Zn occur mainly as stratabound layers in metasedimentary rocks whereas Cu and As are hosted in quartz-carbonate veins. Anomalous Au was found in two holes, in both quartz veins with arsenopyrite (up to 6 ppm Au and >10 000 ppm As) and in metawacke with elevated Pb and Zn (e.g. 1236.3 ppb Au, 2464.7 ppm Pb, and 6086 ppm Zn). Although previous studies have suggested that the mineralization in the Faribault Brook area is VMS-style, most mineralization in the three drill holes are in metasedimentary rocks, suggesting sedimentary exhalative (SedEx)-type with related epithermal veins.

109 - Investigating growth of present-day oceanic back-arc crust as an analogue for ancient greenstone belts

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The Lau Basin is an active back-arc basin of the western Pacific margin that originated at ca. 6 Ma and is currently opening at rates of 91 mm/yr in the south and 159 mm/yr in the north. It is the location of some of the fastest-growing crust in the oceans and prolific magmatic and hydrothermal activity. Here we present the first comprehensive regional geological map of the Lau Basin at 1:1 million scale depicting assemblage- and formation-level lithostratigraphic units across the entire basin, including deep marine areas. The map was constructed using standard remote predictive mapping techniques, compiling formation-level units at 1:100,000 to 1:200,000 for specific geological features that were then extrapolated to areas with fewer data. The training sets integrate all available geological data (hydroacoustics, magnetics, gravity, and satellite altimetry converted to vertical gravity gradient) to establish a classification scheme and internally consistent legend that can be applied elsewhere. The 1:1 million compilation includes marine geophysical data from more than 50 research cruises that have investigated the region since 1970 together with the results of geological sampling, ocean drilling, seismic surveys, and direct seabed observations. An example of high-resolution mapping at 1:200,000 scale is presented from the Mangatolu Triple Junction (MTJ) in the northeast Lau Basin, which shows characteristic neo-volcanic, back-arc crust, rifted arc crust, and off-axis volcanic formations. These formations can also be recognized in other parts of the Lau Basin map where complementary data (e.g.,

magnetics, acoustic backscatter) are sparse. The cross-basin correlation of units is based on published geochronologic information and increasingly sophisticated models of basin opening from interpretation of the seafloor magnetization patterns and basin morphology. The newly compiled geological maps illustrate the diversity of assemblages within the basin and the complex geodynamic triggers that led to their formation. The spatial and temporal resolution is high enough to perform quantitative analysis of age-area relationships, thus tracking the growth of oceanic back-arc crust, which can be directly compared to ancient greenstone belts. For example, many of the most mineral-rich volcanic belts, such as the Abitibi greenstone belt, are thought to represent microplate mosaics developed in thin, hot oceanic crust where there is a close link between microplate evolution, crustal growth, and mineral endowment. Knowledge of present-day crustal growth and microplate evolution can improve understanding of greenstone belt construction and therefore improve exploration targeting. CFREF-Metal Earth Project Contribution MERC-ME-2020-023.

110 - A re-examination of the Joliet Breccia, Rouyn-Noranda, Quebec

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The Joliet Breccia (JB) is a historical Cu occurrence hosted by a breccia body at the margin of the Quemont feeder dike (QFD). It consists of disseminated to fracture controlled Cu-Zn mineralization associated with intense chlorite, sericite and spotted alteration. The JB had been interpreted as an extrusive steam explosion breccia, related to the emplacement of the QFD. The JB was re-examined to better understand the metallogeny of the Powell Block in the Rouyn-Noranda camp because cross-cutting relationships constrain the age of the Cu-Zn mineralization and associated alteration within the breccia. This might relate to a similar style of mineralization and alteration observed throughout the Powell Block. Six other Cu-Zn mineral occurrences in the Powell Block consist of veins along synvolcanic faults and are interpreted to be part of a VMS plumbing system. Despite differences in morphology and grade, the JB has similar mineralogy, metal proportions and alteration to these other mineral occurrences and thus may belong to the same hydrothermal system. Detailed mapping at a scale of 1:500 subdivided the breccia into three domains, a felsic dominated domain, a transitional domain and a mafic dominated domain. The boundary between the host QFD and the JB, as well as the internal contacts within the breccia are gradational. The felsic dominated domain is an in-situ, shattered zone that contains >70% quartz-phyric felsic clasts of the QFD, 1-70 cm in size, and local blocks 2-3 m in size, and <30% matrix (vuggy quartz, fine-grained chlorite ± pyrite ± chalcopyrite). The transitional domain is a clast-rotated, polymictic breccia with 50-70% chloritized mafic clasts, 5-14 cm in size, and ≤50% quartz-phyric felsic clasts, 2-30 cm. Poorly sorted, polymictic breccia of the mafic dominated domain consists of >70 % mafic clasts that range from 3-60 cm in size, and local blocks ≥2 m in diameter; the finer matrix comprises ≤10% of the breccia. An approximately 130 m diameter tonalite body occurs within the mafic dominated domain. It has a sharp brecciated contact, indicating that brecciation took place during, or continued after, emplacement of the tonalite. The field observations demonstrate that the breccia formed in the subsurface, and that the Cu-Zn mineralization and related alteration occurred late with respect to the formation of both the tonalite and the QFD. In addition, the overprinting cleavage, possibly folded nature of the outline of the breccia and asymmetric distribution of fractures surrounding

the breccia, suggest that it was emplaced prior to regional deformation. CFREF-Metal Earth Project Contribution MERC-ME-2020-010.

111 - Testing pyrrhotite trace element content as a vector towards the mineralization in the Sullivan Deposit, B.C.

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The Belt-Purcell Supergroup, which hosts the Sullivan deposit is one of the most important districts for SEDEX (sedimentary exhalative) style base metal mineralization. The Sullivan deposit is the largest producer within the Belt-Purcell Supergroup and produced 161.97 Mt of Zn (5.86%), Pb (6.08%), Ag (67.36 g/t). The Sullivan deposit is the most important mineral deposit in the Canadian portion of the Belt-Purcell Basin. The metal production capacity of the Sullivan deposit is over $20 billion at 2014 metal prices. The Sullivan deposit forms below the contact between the Lower and Middle Aldridge Formation. The top of the Middle Aldridge Formation consists of black laminated mudstone which is described as carbonaceous wacke laminite by Cominco. Rocks of the Sullivan deposit have experienced extensive hydrothermal alteration by a plethora of alteration processes. The most pervasive alteration mineral is sericite. It is heavily controlled by the disseminated, fragmental, coarse-grained sedimentary rocks at the Sullivan deposit. Sericite alteration can be observed as a typical pale yellowish grey-green colour because of the sulphidation of biotite which forms pyrrhotite and muscovite during metamorphism. Challenges in mining exploration are an important issue. Since exploration methods are expensive and time-consuming, new strategies must be developed on known deposits. In this project, we will be attempting to develop new tools to search for new SEDEX style deposits in the Belt-Purcell Basin, focusing on in situ analyses of individual phases. However, the base to building any good micro- or nano-analytical study is always detailed petrology. That petrology is the focus of this presentation. Here we present reflected light and SEM images of the samples from the host horizon of the Sullivan deposit with increasing distance from the deposit. Specifically, we highlight the different generations of the sulfide species that occur within the host horizon and how these change with proximity to the mineralizing source.

200 - Intrusion-related Deposits

201 - Mineralogical and geochemical study of the Ni-rich magmatic sulfides of the E&L mineral zones, Nickel Mountain Gabbro Complex, British Columbia

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The E&L Intrusion is a variable- to orbicular-textured olivine gabbro intrusion containing disseminated magmatic pyrrhotite, pentlandite, and chalcopyrite. The contact zones of the intrusion with silicified

Hazelton Group sedimentary rocks contain an unusually base- and precious metal-rich type of massive sulfide mineralization with grades of 8.29% Ni, 4.24% Cu, 0.19% Co, 1.96 g/t Pt, 4.47 g/t Pd, and 1.13 g/t Au over 16.75 m in the recently discovered Lower Discovery Zone. The massive sulfide mineralization occurs at the margin of the intrusion and within the adjacent sedimentary rocks; the sulfides comprise primary loop-textured sulfides where 1-10 cm grains of pyrrhotite are separated by chalcopyrite and granular pentlandite as well as weakly to strongly sheared massive sulfides which have a similar sulfide mineralogy, but where the primary loop textures are destroyed. Closer in to the contacts of the E&L Intrusion, the semi-massive sulfides contain segregations of gabbro, and locally grade through orbicular-textured semi-massive sulfide into disseminated sulfide mineralization.

A petrographic and geochemical study is in progress to understand the mechanism of formation of the mineralization. Drill core assays exhibit a strong bimodal distribution of Cu/Pd, Ni/Cu, and Ni/Pd between disseminated and massive sulfide mineralization which is not easily reconciled with a common paragenesis. A comparison of the Cu/(Cu+Ni) ratio of the disseminated sulfide with that of the contact and footwall style massive sulfide mineralization indicates that the latter are depleted in Cu. Understanding the cause of this depletion could have important implications for exploration. The massive sulfide footwall zones show systematic changes in the concentrations of Ni, Cu, Co, and precious metals from Ni-Co-rich at the base to Cu-Pd-Pt-rich at the top. Electron microprobe reveals the dominate PGMs and Au species are tellurides and Au-Ag alloy (electrum), respectively. Elevated IPGE (Ru, Rh, Os, Ir) grades within the footwall massive sulfides are associated with magnetite-chromite-clinopyroxene-bearing horizons. Pyrrhotite varies between monoclinic to hexagonal crystal structure throughout all massive sulfide zones and the relationships between the type of pyrrhotite, deformation and precious metal distribution is will help understand the relative roles of magmatic and post-magmatic processes in the genesis of the mineralization.

202 - Localization and genesis of breccia-hosted Ni-Cu-PGE mineralization in the Cryderman area, Sudbury Igneous Complex, Ontario

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The Sudbury Igneous Complex (SIC) hosts one of the world's largest known resources of Ni-Cu-PGE mineralization and has been interpreted to result from a 1.85 Ga impact event. Mineralization occurs in two distinct environments: 1) in magmatic breccias and brecciated footwall rocks along or near the basal contact of the SIC (contact-footwall systems) and 2) in radial and concentric dikes emplaced into the footwall rocks (offset systems). Although the geology of the SIC is reasonably well understood, the ore-forming mechanisms and controls are still debated and the mechanisms controlling the internal textures and fabrics of the contact ores have received little attention. Sublayer norite (SLNR) and footwall breccia (FWBX) occur discontinuously along the basal contact of the SIC and host a significant portion of the Ni-(Cu-PGE)-bearing contact ores. Both units are locally well developed on the North Range of the SIC, but FWBX appears to be less well developed on the South Range. Both are polymictic, matrix- to clast-supported breccias containing heterometric fragments of mostly local footwall lithologies and minor exotic lithologies, but SLNR is characterized by a noritic to sulfidic matrix and FWBX is characterized by

an anatectic to sulfidic matrix. The matrix of FWBX coarsens towards the contact with the SIC, and mineralogy and bulk composition vary with proximity to the footwall and to the sulfide mineralization. Drill core logging in the Cryderman area, located along the SE margin of the SIC, reveals that mineralization occurs dominantly in clast-supported brecciated metabasalts within intervals of inclusion massive sulfides that typically occur adjacent to weakly to non-brecciated metabasaltic-metasedimentary footwall rocks. However, it is not yet clear whether these rocks are magmatic SLNR, anatectic FWBX, or a hybrid involving structural and tectonic processes. Petrographic, textural, and mineralogical studies will aid in establishing the nature of the host breccias in the Cryderman area and will help to better constrain the mechanism of formation, timing, and spatial relationships between the different rock types in contact-ore environments in the SIC. CFREF-Metal Earth Project Contribution MERC-2020-004.

203 - Petrogenesis and mode of emplacement of the Neoarchean Round Lake Batholith, Kirkland Lake, Ontario

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Unravelling the petrogenesis of the Archean synvolcanic intrusions of the metal-endowed Abitibi Subprovince is essential to understand Archean mantle conditions, as well as the geodynamic and metallogenic evolution of greenstone belts The main period of magmatism (synvolcanic period), in the Abitibi Subprovince, formed tonalite-trondhjemite-granordiorite (TTG) batholiths that can be associated with Au and Cu-Au magmatic-hydrothermal mineralisation. This study focuses on the Round Lake Batholith, a synvolcanic TTG suite, to unravel the economic importance of these intrusions and to better constrain Archean mantle conditions. The aim for this research project is to develop a better knowledge of the petrogenesis of this intrusion, which will allow for a greater understanding of the magmatism associated to porphyry systems in the Abitibi Subprovince. Field relationships show that the studied part of the Round Lake Batholith consists of two magmatic phases, a more strongly foliated outer rim and a massive to weakly foliated inner section. In the outer rim the foliation is mostly defined by quartz, feldspar and ± amphibole ± biotite. The weak foliation in the inner part is defined by elongated mafic minerals, quartz and feldspar. Also, the inner and outer parts of the batholith have distinct chemistry (whole rock analyses), especially when considering the heavy rare earth elements. The outer rim shows a higher signature in the heavy rare earth elements when compared to the inner section. Geothermobarometry performed on amphibole grains is used to determine the pressure and temperature conditions and depth at which the batholith assembled. These results are combined with whole rock and isotopic analyses to determine the source and partial melting conditions and with geochronology to allowing for the development of a complete timeline of the formation, exhumation and subsequent deformation of the batholith. CFREF Metal Earth Project Contribution MERC-ME-2020-014.

204 - Textural and geochronological investigations into the Separation Rapids rare-metal pegmatites, northwestern Ontario

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The Separation Lake greenstone belt (SLgb) is host to a suite of potentially economic Neoarchean Lithium – Cesium – Tantalum (LCT) complex type, petalite subtype granitic pegmatites (Separation Rapids Lithium Deposit, Big Mack, Snowbank, Glitter and Marko's). Field observations on these pegmatites such as ptygmatic folds, boudins, strong fabrics and mullions have in the past led investigators to infer that the pegmatites experienced extensive post-emplacement deformation. In this study, we reinterpret the field relations between the pegmatites and country rock, incorporate pegmatite microtextures, and date, by the U-Pb method, the time of crystallization to reassess the role of regional-scale deformation in the distribution and morphology of these pegmatites. The dominant fabric in the country rock is defined by the alignment of hornblende and is cut by the pegmatite. Moreover, a metasomatic halo of biotite overprints the contact zone between pegmatite and country rock. Uranium-Pb ratios in monazite and titanite were measured, in-situ, by LA-ICP-MS to establish the timing of regional metamorphism and pegmatite intrusion. Monazite in the country rock yields the same age, within error, of ca. 2645 Ma as the Separation Rapids pluton suggesting that intrusion and metamorphism are coeval in the area. The U-Pb ages of ca. 2637 Ma, ca. 2617 Ma, and ca. 2602 Ma on monazite, zircon and wodginite, indicate that the pegmatites crystallized after metamorphism/deformation. Field relationships and microtextural data indicate that deformation is induced locally (i.e., not regional) and associated with emplacement mechanisms during pegmatite intrusion. Essentially, the pegmatites acted as viscous indenters into weakened, ductile country rock. Recognizing the fact that deformation is not associated with regional scale deformation has important implications for exploration including: 1) pegmatites need not intrude along structural corridors and 2) undiscovered LCT pegmatites may lie within other segments of metavolcanic rocks along the English River – Winnipeg River subprovincial boundary, as similar emplacement ages across the SLgb and Bird River belt of eastern Manitoba (ex. Big Mack at ca. 2637 Ma and Tanco at ca. 2640 Ma) may infer continuous mineralization along the boundary.

205 - Genesis and localization of komatiite-associated Ni-Cu-PGE and Cr mineralization in the Superior Province, Canada

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High-Mg basaltic and komatiitic rocks often host Ni-Cu-PGE (e.g., Alexo ON, Kambalda WA, Pechenga RU, Raglan QC, Thompson MB) or Cr (e.g., Inlaya-Rhonda and Peak-Railway Block ZI, Ipueira-Medrado BR, Sukinda IN) mineralization, but they less commonly host both Cr and Ni-Cu-PGE mineralization (e.g., McFaulds Lake and Shebandowan ON, Uitkomst SA). The objective of this research is to place constraints on the metallogenesis of associated Cr and Ni-Cu-PGE mineralization, focussing in the Superior Province, which includes domains containing only Ni-Cu-PGE mineralization (e.g., Abitibi Belt ON-QC), domains containing only Cr mineralization (e.g., Bird River Belt MB, Uchi Belt ON, La Grande and Eastmain QC), and domains containing both Ni-Cu-PGE and Cr mineralization (e.g., McFaulds Lake Belt and Wawa Belt ON). Both mineralization types have been interpreted to have formed by interaction of komatiitic magmas with upper crustal metasedimentary rocks: sulfidic argillites and sulfide-facies iron formation in the case of Ni-Cu-PGE and oxide-facies iron formation or oxide-rich gabbroic rocks in the case of Cr deposits, forming sulfide xenomelts or oxide xenocrysts that are dynamically upgraded in the lava channels/magma conduits. This project will test these models by compiling data from the Superior Province on the locations and parental compositions of komatiitic rocks, and the locations and facies of iron formation facies. Thus far, it appears that komatiite-associated Ni-Cu-PGE mineralization occurs in lava channels in volcanic settings and magma conduits in subvolcanic settings, whereas komatiite-associated Cr mineralization occurs only in magma conduits in subvolcanic settings. Ni-Cu-PGE mineralization is associated with a wide range of komatiite compositions, ranging from high-Mg komatiites (32-24% MgO) that are undersaturated in both sulfide and chromite to low-Mg komatiites (24-18% MgO) and komatiitic basalts (18-10% MgO) that are undersaturated in sulfide but saturated in chromite, whereas Cr mineralization is associated only with chromite-saturated low-Mg komatiites, komatiitic basalts, and high-Mg basalts. The results of this project will help constrain geological, genetic, and exploration models for co-associated Ni-Cu-PGE and Cr mineralization and will be applicable to greenstone/volcanic belts worldwide. CFREF-Metal Earth Project Contribution MERC-ME-2020-025.

206 - Magmas responsible for the porphyry Cu-Au mineralization at Dizon Mine in the ancestral Pinatubo volcano, Philippines

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The Dizon porphyry Cu-Au mine (0.67 Mt Cu, 174 t Au) is located within the ancestral Pinatubo volcano of the Luzon arc, Luzon Island, Philippines. Mineralization at Dizon is hosted in quartz diorite porphyry of 2.5 ± 0.2 Ma which intruded Late Miocene dacite-andesite eruption products of the volcano. Chalcopyrite and minor bornite occur predominantly in quartz-magnetite veins which are accompanied by biotite and chlorite alteration halo. This was overprinted by alteration forming white mica, chlorite and pyrite. The Dizon deposit shows abundant evidence for multiple injections of hot mafic magmas including destabilization of plagioclase, presence of basalt enclaves, and a pyroxene-rich diorite phase, which indicates the equilibrium at ~986°C and ~470 MPa. Composition of igneous amphibole in andesite and diorite yields high water contents of parental magmas (5.8 and 7.1 wt%), high fO_2 (FMQ +2.6 to +2.8 and FMQ +1.8 to +2.1), and temperatures of ~817°C and ~986°C, respectively. Fe-Ti oxides in the andesite confirm a highly oxidized parental magma, FMQ +3.0 to +3.3 with temperature ~830°C, both slightly higher than amphibole results. The magma conditions responsible for Cu-Au mineralization at Dizon are remarkably similar to those of the Pinatubo 1991 eruption products of dacite, which had fO_2 of FMQ +3.1 to +3.2. The data suggest supply of oxidised melt to the volcano for a period over ~3 m.y.

Furthermore, the oxidized magma conditions and temperatures at Pinatubo are similar to those associated with porphyry Cu deposits elsewhere, including the Bingham Canyon, El Salvador and Yerington deposits.

207 - The origin, age and hydrothermal alteration of Khak-Sorkh iron skarn deposit, Central Urumieh-Dokhtar arc, Iran: Insights into granitoids and magnetite geochemistry as exploratory indicators

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The Khak Sorkh iron deposit lies in the central Cenozoic Urumieh-Dokhtar magmatic arc (UDMA). The UDMA is an Andean-type magmatic arc resulting from Neotethyan oceanic lithosphere subduction beneath Iranian plate. This is the first documentation of Oligocene iron mineralization in the UDMA, and the age of iron mineralization range from 29.49 to 31.23 Ma based on ID-TIMS dating of zircon, monazite, xenotime, and titanite minerals. Magnetite trace elements geochemistry has been widely used as deposit type fingerprinting of different magnetite generations. Khak Sorkh magnetite EPMA results plotted on skarn-type iron deposit region in discriminating diagrams like TiO_2 versus V_2O_5 and Ca+Al+Mn versus Ti+V. Two main generation of magnetite identified based on magnetite chemistry results and SEM-BSE imaging, and it has been shown that primary magnetite suffered dissolution and reprecipitation process (DRP) which reflected in decreased MgO, TiO_2, Al_2O_3, and slight increased FeO contents in the second generation. The K_2O/MgO ratio of Khak Sorkh granitoid geochemistry results and their plotting on K_2O vs. SiO_2 show they are very similar to world class Au-Cu skarn deposits, and their Rb content are very close to those of Cu skarn associated granitoids. Overall chemistry of granitoids suggest a high potential of Cu and Au mineralization in the region which are supported by evidences like high contents of copper (3510 ppm) and As (616 ppm) in the ICP-AES results of magnetite separates, and the presence of arsenopyrite, and chalcopyrite in mineralography results. Based on microprobe results, presence of Ni-Co-As sulfides and chemical analysis of magnetite separates, this study suggests Zn, As, Co, Ni, and Mn as pathfinder elements for regional geochemical explorations of the same skarn Fe mineralizations. Lead isotope compositions obtained from epidote and calcite of endoskarn and exoskarn zones to investigate fluid/rock hydrothermal interactions (15.584–15.669) are identical, implying a common fluid source. This Pb isotope method could be applied to investigate the contribution of intrusive units to skarn formation in the presence of multiple magmatic units. Epidote Pb isotope data indicate an orogen environment with mixed mantle and crustal sources which is consistent with the petrogenesis of granitoids, and the presence of inherited cores in cathodoluminescence imaging of zircon crystals.

208 - Skarn mineralization at the Rau project

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Skarn deposits are a subset of intrusion related ore deposit that are characterized by a non-ore mineral assemblage dominated by calcsilicates, mainly garnet, pyroxene, tremolite and actinolite. Skarn deposits host a variety of economic minerals which are commonly zoned with distance away from an intrusive body. These include, proximal to distal, Mo, Cu, Au, Zn, Pb, and Ag mineralization. The Canadian cordillera hosts several economic skarn deposits which produce a variety of industrially and technologically significant minerals. Strengthening our understanding of these deposits will allow for more effective exploration and development of skarn systems as sources of base metals, precious metals, and rare earth elements. Understanding extent and conduits of fluid flow around a mineralizing system allows for better targeting of exploration. ATAC Resources operates the Rau project located in central Yukon, the site of the Tiger carbonate replacement gold deposit. This research is focused on several mineral targets in the vicinity of the Tiger deposit and aims to evaluate the potential for skarn formation around the Rackla pluton. Here we report preliminary geochemical and fluid inclusion analyses to define the style of mineralization and to further develop the working genetic model for the formation of this hydrothermal system. Previously, the Rackla pluton's known extent was limited, but the resulting fluid rock interactions in the area are far reaching and encompass underexplored mineral targets. There are several structural pathways in the area, which enable fluid flow and extend the range of metal bearing hydrothermal fluids. With a known mineral resource in the Tiger deposit, this research will better define the potential for adjacent mineralization at the Rau project.

209 - Geology and geochemistry of granitoid plutons in the Sturgeon Lake greenstone belts, Western Wabigoon Subprovince: Implications for base and precious metal metallogeny

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Felsic plutons often span the main petrogenetic and deformational history of granite-greenstone belts. The tectonic and crust-mantle dynamic processes these plutons recorded may provide important insights into the metallogeny of the associated greenstone belts that supracrustal assemblages cannot provide. Granitoid plutons within greenstone belts may vary geochemically and petrographically due to the origin of their melts, interaction between mantle and crust, and subsequent magmatic-hydrothermal activities. The granitoid plutons in the Sturgeon Lake greenstone belt are divided into three classes: pre-, syn-, and post-tectonic. The regional-scale field relationships between granitoid and supracrustal assemblages are relatively well constrained. This study contributes petrographic, geochemical, and geochronological data that better reveal the petrogenetic, tectonic, and metallogenic

evolution of the belt. Several Cu-Mo showings were observed in the field, which suggests the importance of magmatic-hydrothermal systems in this region. Preliminary petrographic observations reveal that the primary minerals of the syn- and post-tectonic plutons mostly lack post-crystallization metamorphic and/or hydrothermal modifications and will be used for thermobarometric determinations. However, many pre-tectonic plutons commonly have quartz ± pyrite veins that may be significant for the mineral deposition in the region. Preliminary observations also indicate that there are no obvious petrographic differences between mineralized and non-mineralized systems. Additional differences between these suites of plutons are highlighted by trace element geochemistry. Ongoing elemental and isotopic investigations aim to resolve differences between mineralized and un-mineralized plutons. CFREF-Metal Earth Project Contribution MERC-ME-2020-040.

210 - Platinum group element (PGE) mineralization at the New Afton Cu-Au alkalic porphyry deposit, Kamloops, British Columbia

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New Afton is an alkalic Cu-Au porphyry deposit situated 10 km west of Kamloops, British Columbia, within the Quesnel island arc terrane, a Late Paleozoic to Mesozoic arc complex that comprises the eastern part of the Intermontane Belt of the Canadian Cordillera. Mineralization at New Afton is associated with the Late Triassic Cherry Creek monzonite phase of the Iron Mask batholith and hosted by coeval, undifferentiated volcanic rocks of the Nicola Group. Bulk rock and sulfide minerals from New Afton were analyzed for Pd, Pt, and Au concentrations and the presence of platinum group minerals (PGM). Lead fire assays were conducted on 218 samples from 19 drill holes spanning the deposit. Fire assay data show a range concentration of Pd between 0.5 to 33600 ppb, Pt between 0.2 to 37800 ppb, and Au between 3 and 18600 ppb. The PGM temagamite, isomertieite, mertieite-II, and cooperite were identified in most samples with elevated Pt and Pd (> 400 ppb). PGM were found as either individual inclusions in chalcopyrite, along the grain boundaries of pyrite in contact with chalcopyrite, or as free crystals, and were up to 90 µm long. Chalcopyrite and pyrite were analyzed for platinum group elements (PGE) using LA-ICP-MS. In general, pyrite was moderately enriched in Pd and greatly enriched in Pt relative to chalcopyrite. Concentrations of Pd and Pt in pyrite ranged from below detection limit to 30.8 ppm and from below detection limit to 6.9 ppm, respectively. Chalcopyrite had modest enrichments in Pd, ranging from below detection limit to 13.4 ppm and Pt from below detection limit to 0.015 ppm. Precious metal ratios, particularly Pd/Au in the bulk rock samples, show that PGE mineralization may be grouped in three domains: (1) high Pd, low Pd/Au, (2) high Pd, high Pd/Au, and (3) low Pd, variable Pd/Au. These domains are interpreted as representing primary PGE mineralization, related to primary hypogene Cu-Au mineralization, secondary enrichment of PGE via hydrothermal redistribution, and the depleted source of the secondary enriched domains, respectively. In this scenario, domains (2) and (3) represent remobilization of PGE, leading to local depletion and local enrichment, with no net addition of PGE to the system. Consequently, initial PGE (Pd ± Pt) deposition at New Afton occurred during the primary hypogene mineralization event, but was susceptible to subsequent hydrothermal remobilization along new and pre-existing structural features.

211 - Genesis of offset dikes in the Sudbury Igneous Complex

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Radial and concentric offset dikes intruded from the Sudbury Igneous Complex (SIC) into the footwall rocks and contain approximately 50% of the total ore reserves and resources in the SIC. Their margins are interpreted to represent the initial impact melt composition modified by variable amounts of contamination by their wall rocks. Thus, they play an important part in understanding the formation of the SIC and represent highly prospective exploration targets. Despite the fact that some of these dikes have been studied in great detail and have been mined for over 130 years, their genesis is still debated. Two models have been proposed for their emplacement: 1) multi-stage injection of an initial phase of sulfide-poor, inclusion-poor quartz diorite melt (QD) followed by injection of a second core phase of sulfide-rich, inclusion-rich quartz diorite melt (MIQD) in the center of the dikes, and 2) single-stage injection of MIQD melt with flowage differentiation producing marginal QD and interior MIQD. Several syn- and post-impact processes – including crater excavation and modification (rebound), melt pressure increase, isostatic uplift, cooling, and tectonism – have been proposed to be mechanisms responsible for the dilation of fractures and subsequent emplacement of one or several melts. The timing and duration of these processes vary considerably, and each has very different implications for a) the timing and mechanism of offset dike emplacement within the evolution of the SIC, b) the timing of inclusion generation and sulfur saturation in the SIC, and c) exploration vectors for targeting mineralization in offset dikes. For example, most models advocating flowage differentiation have implicitly assumed laminar flow, but several of the most favoured emplacement mechanisms involve very rapid (hypersonic) injection and therefore turbulent flow. Regardless of the rate of emplacement, multi-stage injection is supported by the common presence of inclusions of QD within MIQD, sharp contacts between QD and MIQD, and the spatial relationship between marginal QD and interior MIQD. The objective of this research project is to more rigorously test models for the emplacement of the offset dikes in the SIC through detailed geological, petrographic, geochemical, and fluid dynamic studies.
CFREF-Metal Earth Project Contribution MERC-2020-005.

300 - Sedimentary Environments

301 - Application of boreholes redox mapping technique for sandstone type uranium exploration in Arlit, Niger

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The objective of the present research studies is the application of borehole redox mapping technique as a guide of uranium exploration in the sedimentary environment. The Tarat formation in the study area is The Tarat formation in Arlit area is divided into four units (U4, U3, U2, and U1) such as Tarat Unit4 (U4) consisting of reduced gray fine consolidated sandstone alternating clay-silt; Tarat Unit 3 (U3) composed of coarse to medium sandstone with increasing presence of micro-conglomerate towards the bottom; Tarat Unit 2 (U2) characterized by reduced fine gray sandstone with kaolinitic cement and Tarat Unit 1 (U1) consists of coarse to micro-conglomerate gray sandstone. The results of oxyhydroxides distribution maps show high radiometric accumulation in low oxyhydroxides zones of the Tarat Unit (U4) and Tarat Unit (U3) while the Tarat Unit (U2) and Tarat Unit (U1) show less radiometric accumulation in high oxyhydroxides zones. Therefore, the generalized oxyhydroxides distribution maps of the whole Tarat Formation show that zones with moderate to less oxidation are suitable for uranium mineralization while zones with intense oxidation are poorly mineralized.

302 - A combined multivariate approach analyzing the geochemical data for knowledge discovery: The Vazante – Paracatu Zinc District, Minas Gerais, Brazil

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The Vazante Group is a sequence of intercalated carbonate and siliciclastic rocks located in Minas Gerais, Brazil. It is the host of the Vazante-Paracatu Zinc District which comprises the largest hypogene zinc silicate deposits, in the southern part, and several Pb – Zn sulfide deposits in the northern part. A recent study revealed the occurrence of base metal sulfide mineralization that formed prior to the Brasiliano orogenic event in the siliciclastic rocks (Serra do Garrote Formation – SGF) that underlie these dolomite-hosted silicates and sulfide deposits. The siliciclastic rocks were considered as potential sources of elements for the hydrothermal fluids that formed the dolomite-hosted deposits although there is no consensus based mainly on mineralogical studies and preliminary statistical analysis of the

lithogeochemical data. In this study, we present an exploratory study, where Random Forest is applied in unsupervised mode along with t-distributed Stochastic Neighbor Embedding and principal component analysis over a dataset of lithogeochemical analyses, to provide insights about the processes related to the base metal mineralization in the Vazante District.

Multivariate analysis shows that SGF, which occurs throughout the basin, has a large number of samples with Zn, Cd, Cu, Hg, In, V, Sb, Se, Mo, Re commonly associated with organic matter-bearing rocks in positive PC1 (PC1+). This association resembles the geochemical signature of the known deposits located in stratigraphically upper carbonate units. PC analysis further distinguish the PC1+ group in various subsets, one where Zn and In are associated with total C (PC2+) and another in which most of the other elements are associated with organic C (PC2-), reflecting the occurrence of sphalerite with carbonate veins (In-rich) and organic-rich laminations, respectively. Moreover, the elements found in sphalerite Zn, In Cd (PC6-) in both styles of mineralization are clearly distinguished from the C-rich elemental association (As, Hg, Mo, Pb, Sb, Tl and U; PC6+). However, some of the subunits and/or some zones in the basin exhibit a distinct multivariate geochemical pattern, which is represented by an association of Ba, Bao, K_2O, Al_2O_3 (PC1-), reflecting their higher abundance white mica and lower content in ore-related elements. This distinct geochemical signature and mineralogy is interpreted to be related to the interaction of saline fluids, causing K-metasomatism, and removal of ore-related metals such as Cu, Pb, Zn, Cd, In. However further studies are required to better constrain the hypothesis of depletion, and the timing of the fluid-rock interaction related to the various elemental signatures.

303 – Major ore mineraloids, Grants Uranium Distict, New Mexico, USA

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The Grants Uranium District in northwestern New Mexico is host to some 400 million remaining pounds of uranium oxide resources, most of which are sandstone-hosted and associated with organic matter. The mineralogical characterization of the deposits has previously relied on X-ray analyses, which are of limited use when identifying amorphous (mineraloid) phases—the major reservoir of uranium in the Grants. In addition, it is not particularly sensitive to minor mineral content (<5%). This study used high-resolution electron microprobe element mapping to describe uranium host phases within select samples of important deposits within the region.

Our findings indicate that uranium-bearing materials within Grants Uranium District sandstone-hosted ores include cryptic mineral and mineraloid mixtures as well as uranium hosted by amorphous organic matter, interpreted as brine-fixed uraniferous humates. Humates are formed where humic acids' functional groups complex cations—in the case of the Grants deposits, where bumic acids from decaying organic matter encountered brines in groundwater. Distinct paragenetic episodes of brine-humate+/- uranium fixation are observed in electron microprobe element maps. Strong uranium fixation within organic matter is linked to a distinct high-potassium brine, likely from a deep regional source which carried uranium. Such occurrences may be armored by barren, low-potassium organic matter which probably precipitated from uranium-devoid shallower brines, e.g. playas. Redistributed-type ores' uranium appears to be sorbed to the surfaces of clay and oxide minerals.

304 – Pyrite classification and paragenesis at the Kamoa-Kakula sedimentary-rock-hosted copper deposit, Democratic Republic of Congo

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The Central African Copperbelt (CACB), the world's largest and most prolific sedimentary-rock-hosted copper-cobalt province, contains the Kamoa-Kakula sedimentary-rock-hosted copper deposit, independently ranked as the world's largest undeveloped high-grade copper discovery. Diamictites and siltstones at Kamoa-Kakula, whether mineralised or unmineralised, contain abundant pyrite, in particular syngenetic and early diagenetic framboidal pyrite. Pyrite types at Kamoa-Kakula, are classified as follows: (1) microcrystalline framboidal pyrite (py1); (2) anhedral to subhedral microcrystalline pyrite aggregations (py2); (3) very fine to finely crystalline euhedral pyrite (py3); (4) subhedral to euhedral inclusion-bearing pyrite clusters (py4); and (5) anhedral clast-rimming pyrite (py5). Study of Kamoa-Kakula pyrite, using optical and scanning-electron microscopy, yielded a paragenetic history of the various pyrite types, starting during diagenesis (and possibly before) and extending into the ore-forming event: py1 → py2 ± py3 → py4 → py5. Previous work at Kamoa-Kakula highlighted the critical importance of framboidal pyrite, as a sulphur source in the copper-mineralising event. Framboidal pyrite generally contains elevated trace element concentrations (Ni, Co, As, Se, Cu, Zn, Pb, Bi, Sb, Tl, Mo, Ag, Cd, Mn, Hg, Te and Au), and has been suggested as a metal source in mineralising systems. This ongoing study will evaluate the trace element content of Kamoa-Kakula pyrite types in unmineralised stratigraphic units distal to ore using laser-ablation inductively coupled mass spectrometry, and the sulphur-reduction mechanisms implicated in the formation of pyrite and base-metal sulphides using in-situ sulphur isotope analysis.

305 - The importance of pyrite to Ni tenor in the metasedimentary-hosted 1D ore body at the Thompson (T3) Mine, Northern Manitoba, Canada

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The Proterozoic (1.7 Ga) Thompson Nickel Belt (TNB) is the rifted collisional craton margin of the Archean Superior province in Northern Manitoba, Canada. The Ni tenor of sulfide in the 1D ore body at the T3 Mine is highly variable (4-16 wt%), and the majority of the sulfides are hosted by metasedimentary rather than ultramafic rocks. The Ni tenors in the 1D metasediment-hosted sulfides are greater than those of primary ultramafic associated mineralization like at the Birchtree deposit. The current research is designed to understand the process that controls tenor variations through geological, mineralogical and geochemical investigations. Mapping and petrographic data indicate five different styles of mineralization and various post deformation sulfide textures in the 1D ore body. The two most significant findings are that Ni and Co tenors are highest in shear-hosted massive sulfide and that there is a positive dependence of whole rock Ni and Co tenor on pyrite modal abundance. Seven different textural types of pyrite were identified. EDS/WDS elemental maps show heterogeneity in Ni and Co compositions of pyrite, and that Co is paragentically late. Average Ni and Co contents of pyrite are 1.10

wt% and 1.30 wt%, respectively. Petrographic analysis indicates that pyrite is genetically late and was formed during a late-stage high sulfur fugacity event, which is interpreted to have controlled the tenor of the mineralization. A primary magmatic process control on sulfide composition is unlikely owing to the late paragenesis of pyrite and the lack of precious metal variability within the deposit. Polymetallic sulfide melt inclusions in metamorphic quartz, and less commonly, garnet are observed, and these are likely products of post magmatic processes. Three hypotheses are discussed to explain the high sulfidation event; viz: 1. S2 release via oxidation of pyrrhotite along shear zones; this is not favored due to the minimal amount magnetite or Fe-oxides in the deposit; 2. Modification of sulfide composition by retrograde metamorphism; remobilization of late Ni- and Co-rich fluids is supported by the late paragenesis of pyrite; and 3. Localized melting of pre-existing massive sulfide. In the case of the third model, evidence of sulfide melt inclusions supports this hypothesis, and the abundance of graphite could have aided in lowering the temperatures needed to melt the sulfides. The diversity in Ni tenor of sulfide is not entirely explained, but it appears to be related to the abundance of pyrite, and the late tectonic-metamorphic history of the deposit.

306 - Styles of zinc mineralization in high-grade metamorphosed carbonate sequences of the Proterozoic Grenville Supergroup: Evidence from the Salerno Lake and Calumet-Sud occurrences in Ontario and southern Quebec, Canada

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The carbonate and volcano-sedimentary sequences of the southeastern Central Metasedimentary Belt (CMB) in the Grenville Province host several zinc deposits and occurrences (e.g., Balmat-Edwards, Franklin and Sterling Hill, Renprior/Cadieux, New Calumet, Calumet-Sud, Salerno Lake, Long Lake, Maniwaki). Most of the zinc mineralization is hosted in high-grade metamorphosed marbles of the Grenville Supergroup, and is regionally controlled by the basin-margin faults that border the CMB. The geological setting and processes that formed these styles of mineralization, however, are still poorly understood. This study describes the major stratigraphic controls and characteristics of the various styles of mineralization at the Calumet-Sud and Salerno Lake occurrences. At both locations, dolomitic (and locally calcitic) marble hosts zinc mineralization, grading to siliciclastic and quartz diopside rocks, and cut by basic to felsic intrusions. The host marble is coarse-grained, graphitic, and contains variable proportions of talc, tremolite, diopside, serpentine, quartz, and phlogopite. Pyrite, sphalerite (red and yellow), and pyrrhotite occur concentrated in bands or disseminated through the unit. At Salerno Lake, two distinct styles of mineralization were identified: Style 1 is associated with apatite, observed at an intersection of 4.3 meters grading 1.4% Zn, and is poor in Pb (<17 ppm); Style 2, observed at an intersection of 12.4 meters grading 3.8% Zn, is proximal to intrusive rocks and contains more diopside and amphibole, and lesser graphite and apatite than Style 1, with even less Pb (<7 ppm). Red sphalerite in style 1 contains 0.14-0.21 wt% Cd and 7.18-8.42 wt% Fe compared to that of style 2 with 0.11-0.19 wt% Cd and 5.33-9.68 wt% Fe. At Calumet-Sud, observations were made on an intersection of 6 meters grading 3.9% Zn, and 65.93±96.22 ppm Pb; other drill-hole and trench intercepts show higher grades. Sphalerite is associated with apatite and galena, and red sphalerite contains 0.05-0.27 wt% Cd, 2.87-9.85 wt% Fe, and 0-6.03 wt% Mn. Yellow sphalerite in both localities has lower Fe contents (0.063-5.631

wt%) and higher Cd contents (0.081-0.571 wt%) than red sphalerite. At Salerno Lake, apatite from both styles of mineralization contains more F, S, and Sr than at Calumet-Sud, where apatite contains more Ca and Cl. Moreover, style 2 apatite contains more Na, La, Ce, and As than the other zones. These results suggest that the processes by which the various styles of mineralization formed are more complex than previously thought and may have involved contribution of ore-forming basinal and magmatic fluids.

307- Investigation of ore elements relationship to REE geochemistry in hydrothermal fluids of the Jinding Pb-Zn deposit, southwestern China

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The Jinding Zn-Pb deposit, located in the Sanjiang Tethyan metallogenic domain of southwestern China, is one of the largest sandstone-hosted Zn-Pb deposits in the world. This deposit contains an ore reserve of ~220 Mt Pb and Zn with average grades of 6.1 wt.% Zn and 1.3 wt.% Pb. A large amount of gangue and their complex occurrence and ages (e.g., in calcite and pyrite) suggest that the Jinding deposit has experienced multiple periods of hydrothermal activities. This study uses cathodoluminescence images and LA-ICP-MS analysis in calcite textures to examine linkages between ore elements and REE geochemistry and to recognize the ore-related hydrothermal fluid information. The sample was selected mainly from representative hydrothermal calcite in the paragenetic sequence of the ore minerals in Beichang, Paomapingin, and Fengzishan ore blocks. Calcite show intra-crystal variations in trace element concentrations, and they show well-developed growth zoning that can be detected with CL. The core parts, middle parts, and the outer growth zones in the calcite grains of the three compositionally different calcite populations in the same sample have some different concentrations and REE patterns, which reflect formation from the compositionally different fluid types. Calcite in the Jinding deposit has precipitated at the pre-ore stage of crystal growth (period-1) has LREE enriched patterns, MREE enriched to irregular patterns at the ore stage (period-2), and flatter to LREE enriched patterns at the post-ore stage (period-2). The Zn and Pb content of period-2 calcite are very high compared to the pre or later periods, indicating that the major metal introduction event at Jinding was during period-2 hydrothermal fluid activities. In addition, a positive correlation between Pb and Zn contents and Tb/La ratios (an indicator of fractionation between LREE and MREE) in the calcite crystals based on in-situ analyses, implying similar partitioning behaviors between Pb, Zn, and MREE. This MREE enriched pattern in the ore-forming fluids may be related to the characteristic of high-salinity and acid basinal brines in the Jinding deposit. An alternative explanation is fluid-rock interaction had caused REE (especially LREE) depletion, which can lead to loss of LREEs because HREE complexation in the fluid is more effective than LREE complexation. Taken together, the calcites record signals from compositionally different fluid generations (different types of REE patterns and the covariation of Pb, Zn with the REE), reflects changes in fluid compositions, related to the successive influx of compositionally different fluid pulses.

400 - Epithermal Deposits

401 - Distribution of indium in xenothermal veins from the Andean Tin Belt: the Ánimas-Chocaya-Siete Suyos and Huari Huari Districts, SW Bolivia

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Indium is a high-tech metal that has been classified as a critical raw material by the European Commission. Important enrichments in indium have been reported in several xenothermal-type polymetallic-vein deposits along the so-called Andean Tin Belt. In this research we seek a better understanding of the mineralogical expression of indium and its temporal and spatial distribution in this type of deposits. To do so, we have studied ore samples from the Ánimas-Chocaya-Siete Suyos (ACSS) and Huari Huari (HH) mining districts, both located in the Bolivian Eastern Cordillera and genetically linked to Miocene S-type magmas. Electron probe micro-analyses reveal that the highest contents of indium occur in sphalerite (up to 9.66 wt. % in ACSS and up to 3.49 wt. % in HH) and stannite (up to 4.11 wt. % in ACSS and up to 2.64 wt. % in HH). Indium contents in cassiterite are lower (up to 0.25 wt. % In_2O_3 in ACSS). Cassiterite crystallized during a first paragenetic stage characterized by a low-sulfidation mineral assemblage including pyrrhotite, arsenopyrite and sphalerite with FeS>~21 mol%. Indium-rich sphalerite and stannite crystallized during a second stage characterized by a low-intermediate-sulfidation mineral assemblage including pyrite-marcasite. Stannite and sphalerite stoichiometry suggests that the incorporation of indium in these phases can be contextualized in the sphalerite-stannite-roquesite pseudoternary system. In sphalerite, the positive correlation between the atomic proportions of Cu and In at 1:1 ratio agrees with a [2Zn ↔ Cu + In] coupled substitution, which suggests a relatively high Cu activity during its crystallization unlike In-free sphalerite. The concentration of indium in sphalerite and stannite is much pronounced in the central parts of the studied districts. In ACSS, an increase in the concentration of indium in sphalerite at depth along single veins has been traced.

402 - Zone refining in an epithermal setting: A mechanism of gold liberation at the Klaza Epithermal Deposit, Yukon

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The Late Cretaceous (71 Ma) Klaza Au-Ag-Pb-Zn-(Cu) deposit is an intermediate sulphidation epithermal deposit in the southern Dawson Range gold belt, Yukon. Recent work suggests the epithermal veins

overprint earlier phyllic alteration related to a 76 Ma porphyry system (Kelly). The Klaza epithermal system reflects a thermal gradient from northwest (low-temperature Ag-Pb-Zn) to the southeast (high-temperature Au-Cu). However, specific locations in the deposit, such as the Western BRX zone, display significantly elevated Au grades and wider, highly brecciated (syn-to-post mineralization faulting) fault-veins. Detailed paragenetic studies of the Klaza veins from each zone in the deposit were conducted using macro- and micro-scale observations - drill core logging, optical petrography, and scanning electron microscopy (SEM). Three main vein stages (1 to 3) and three sub-stages (in Stage 2) were defined. Gold is correlated with Stage 2a and Stage 2b, whereas Ag is correlated with Stage 2c. Electrum (Au fineness 600 to 800) occurs as secondary inclusions and fracture-fill in pyrite and arsenopyrite. Pyrite and arsenopyrite grains lacking electrum inclusions display significant As-zonation and banding, whereas this feature is absent in electrum-bearing sulfides grains (abundant in Western BRX zone). Laser ablation inductively-coupled mass spectrometry (LA-ICP-MS) 2-D element mapping of pyrite (vein margin), sphalerite, and arsenopyrite grains from Stage 2b reveals: (1) porphyry-stage pyrite (elevated Ni-Co-Te) is overprinted by epithermal pyrite with elevated Au-Ag-As-Sb-Bi-Pb-Cu; (2) primary zones in arsenopyrite have elevated Au-Sb (Au = 46 to 400 ppm); (3) primary zones in in sphalerite in textural equilibrium with arsenopyrite have elevated Fe-Sn-In-Cu-Ga-Co; and (4) a late-stage overprint of elevated Cu-Pb-Ag-Sb-Bi-Ba in all three mapped sulfides as manifested by fractures enriched in the aforementioned elements. These observations suggest coupled dissolution precipitation (CDP) processes destroyed the primary zonation in arsenian pyrite and arsenopyrite, thereby contributing lattice-bound metals, including Au, to the mineralized system. The deep and highly active fault structures at the Western BRX zones likely formed a permeable conduit for ingress of this late fluid to interact with Au-bearing sulfide minerals on a large scale, which resulted in the observed elevated gold grades. The results of our coupled mineral paragenesis and LA-ICP-MS element mapping studies suggest a continually evolving hydrothermal environment accounts for Au enrichment through various forms of zone refining.

403 - Ammonium in alteration haloes of epithermal deposits in Southern Kyushu, Japan

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Ammonium is detected in alteration haloes of many epithermal gold-silver deposits and is considered to replace potassium in minerals like K-feldspars and illite. Since ammonium absorbs certain wave lengths of infrared, Short-Wave Infrared (SWIR) Spectroscopy is used for its detection. The study area was located at three mines: Hishikari (>440 t Au, 1.2-0.7 Ma), Kasuga and Iwato, on the southern part of Kyushu in Japan. Hishikari samples include quartz-adularia veins of the Sanjin and Yamada veins. The veins are hosted in shale and andesites, respectively. Iwato and Kasuga mines (9.3 ton Au) occur in highly silicified andesite of 4-5 Ma. Ammonium is high in shale (231 - 935 ppm) near the Sanjin vein and moderate in andesite (107-279 ppm) near the Yamada vein. Ammonium concentrations are low (< 100 ppm) proximally to the vein. Samples from Iwato and Kasuga contain low ammonium concentrations (<20 ppm). $\delta^{15}N$ values range from +2.0 to +3.3 ‰ (av. 2.6 ‰), suggesting that ammonium is predominantly derived from shale with a minor contribution of low ^{15}N. Only one sample, containing 440 ppm of ammonium, showed ammonium-related absorption in its SWIR spectrum despite other

samples having higher concentrations. This result demonstrates that the use of SWIR spectroscopy for ammonium detection remains difficult.

404 - Colloidal transport: The high-grade gold ore paradox & the search for a porphyry source for ultra-high-grade gold mineralisation at the Brucejack epithermal Au-Ag deposit, northwest BC

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The transport of gold as dissolved species in a hydrothermal liquid has long been the accepted means of gold mobilisation and epithermal ore formation. A major weakness of this hypothesis is that it cannot explain the formation of ultra-high-grade or bonanza gold veins. Gold concentrations in the fluids responsible for epithermal mineralisation are typically on the order of 10-30 ppb, which are far too low to explain concentrations of 10's of thousands grams per tonne Au in veins in some deposits. A potential solution to the paradox of ultra-high grade gold deposition, in geologically realistic time-frames, may be offered by colloidal transport. We have undertaken a study of high-grade gold mineralisation from the Valley of the Kings (VOK) and Eastern Promises (EP) zones at the Brucejack epithermal gold-silver deposit to evaluate this possibility. Images obtained using transmitted electron microscopy show that: (1) gold commonly occurs as < 1-10 nm spherical nanocrystals of electrum embedded within a calcite matrix; and (2) larger (100-500 nm) particles of electrum, also embedded in calcite, are composed of hundreds of nanoparticles, each displaying distinct crystal lattice plane orientations. These images provide compelling evidence for the formation of colloidal suspensions of electrum and their flocculation. Furthermore, LA-ICP-MS and EMP-WDS trace element analyses of pyrite from phyllically-altered wallrock in the VOK and EP zones show increasing enrichment of Co, Ni, Se and Cu with depth, documenting an otherwise cryptic transition to recently discovered propylitic and potassic alteration and associated Cu-Mo mineralisation in deep drill core from the adjacent Flow Dome Zone. Strong positive shifts in $\delta^{34}S_{pyrite}$ 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. We present a model in which high-grade epithermal gold mineralisation develops through boiling- and seawater-mixing-driven colloid suspension and flocculation of gold nanoparticles that were transported by a carbonate fluid from a porphyry source at depth. In addition to pyrite, sphalerite, apatite, chlorite, and epidote major and trace element mineral chemistry analyses from propylitic and potassic alteration zones at depth are being conducted to better understand the exact nature and location of the porphyry source. Our model offers a solution to the longstanding problem of high-grade gold transport and deposition in epithermal vein systems, as well as an explanation for the extraordinary and challenging grade variability often encountered during the mining of these deposits.

405 - Structural analysis of a sulphide bearing shear zone on Colin Lake, Northern Saskatchewan, Reindeer Zone

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In 2019, bedrock mapping of the Colin Lake area was conducted in the western Kisseynew domain of northern Saskatchewan by the Saskatchewan Geological Survey. A zone of rusty-weathered, sulphide-bearing rocks was identified along the southern shore of Colin Lake. This outcrop is thought to be formed through a fluid migration event that is utilizing the weaker bedding of a pre-existing shear zone which was formed as a splay of the Rattler Creek fault. To understand the controls of the sulphide mineralization, detailed mapping of an analogous outcrop was preformed to gather information related to the sulphide mineralization. This area is located 5 km north of the sulphide bearing outcrop on a large island in the center of Colin Lake. Mapping also focused on the measurement of structures related to the rusty-weathered exposure in order to better understand development of the sulphide mineralization. Petrographic analysis prepared from samples taken during the 2019 summer field season focused on the microstructures present in the rock as well as the mineralogy to determine if there are any economically viable minerals in the area. Preliminary results have shown that a series of leucosome and leucogranitic dykes have formed throughout the area to the north of the rusty weathered outcrop. Next, a minor amount of quartz veinlets formed which cross-cut the dykes and leucosome and have dextral apparent shear sense associated with them. These veinlets are cross-cut by three separate events which emplaced fractures and quartz veins and are determined to belong to conjugate sets. The first two conjugate sets have fractures related with them which have since been partially infilled with quartz veins and display no shear sense. The last conjugate set has only fractures associated with it and no quartz vein infilling or shear sense.

406 - Geology of the Vent Prospect, a 2718 Ma high sulfidation epithermal system?

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High sulfidation epithermal deposits are shallow-level hydrothermal ore systems in which highly acidic, sulfur-rich fluids leach their host volcanic rocks resulting in characteristic argillic and advanced argillic alteration assemblages. Epithermal deposits are formed in a subaerial environment, and thus are extremely susceptible to erosion, such that the majority of epithermal deposits are Tertiary in age or younger. No clear examples of high sulfidation epithermal deposits have been documented in the Archean rock record. The ca. 2722-2718 Ma Metcalfe-Venus assemblage, a portion of the Onaman-Tashota greenstone belt within the Eastern Wabigoon Subprovince of the Superior in Ontario contains a gold-silver occurrence named “The Vent” which contains metamorphosed mineral associations consistent with advanced argillic alteration, and discordant Au-Ag bearing pyrite-dominated sulfide

mineralisation that shares many of the characteristics of high sulfidation epithermal systems. A detailed study of the lithofacies, mineralisation, and metamorphosed alteration associations was undertaken to assess of the origins of this hydrothermal system. This study's results show that the Vent is hosted by a series of aphyric, and quartz ± feldspar-phyric aphanitic dacitic flows and high level porphyry intrusions with minor coarse heterolithic felsic volcaniclastic rocks. The dacitic flows show spine-like structures and contain blocky flow top breccia facies that lack visible hyaloclastite, consistent with derivation in a shallow-water or subaerial setting. Cutting these units is a swarm of pebble dikes bodies containing heterolithic, rounded (milled) fragments in a finer, altered, rock flour matrix. The Vent consists of a decimeter scale, zoned, discordant, metamorphosed alteration system consisting of a) pods of residual quartz-pyrite; b) kyanite-quartz-pyrite; c) kyanite-sericite-quartz; d) sericite with minor kyanite; and e) sericite without kyanite. Mineralisation occurs dominantly as Au- and Ag-bearing pyrite and arsenopyrite as distinctly replacement and stringer styles. These lithofacies, alteration associations, and mineralisation styles, are consistent with a subaerial or shallow subaqueous volcanic edifice into which hot, acidic hydrothermal fluids were pumped, periodically over pressuring and brecciating the edifice. We propose that this setting is consistent with modern high sulfidation systems, and that the Vent may represent one of the oldest identified high sulfidation epithermal deposits on the planet. CFREF-Metal Earth Project Contribution MERC-ME-2020-041.

500 - Orogenic Gold Deposits

501 - Gold mineralization at the Vertigo Target White Gold District, West-Central Yukon Territory, Canada

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The Vertigo target in the west-central Yukon Territory White Gold District is a gold mineralized zone that exhibits morphological characteristics similar to structurally controlled "orogenic" deposits. Au mineralization at the Vertigo target is hosted in a series of moderate-to-high angle, east-southeast striking, south-southwest dipping structures associated with polyphase quartz veining, fracturing, magnetite-destructive quartz-sericite+/-carbonate alteration, and brecciation. These structures transect 3 lithological packages including (1) upper mafic hornblende schist and fine-grained felsic biotite-quartz-feldspar gneiss, (2) middle intermediate schist, intercalated pelite-siltstone-sandstone layers, quartz muscovite schist, intermediate plagioclase-quartz-biotite gneiss, and (3) lower coarse-grained biotite-quartz-feldspar gneiss. Significant gold mineralization occurs preferentially in the upper felsic biotite-quartz-feldspar gneiss within intersecting altered quartz vein contacts and thin fracture sets. A petrographic and geochemical study is in progress to understand the mineralizing controls, where petrography, used in conjunction with electron probe micro-analysis (EPMA) and synchrotron X-ray powder diffraction (XRD) analysis is being used to assess the characteristic signatures of gold mineralization to help define the genesis of ore formation at the Vertigo discovery. Preliminary sample examination through optical microscopy (transmitted and reflected light) and EPMA from energy

dispersive spectroscopic (EDS) and wavelength dispersive spectroscopic (WDS) analyses has established preliminary textural relationships. XRD data collected using integrated synchrotron analysis is being used for quantified mineral phase identification. Based on the results of this phase of the research, mineral paragenesis will be established for different ore mineral assemblages to guide the subsequent stages of this study. Au mineralized zones exhibit a strong geochemical correlation with Ag-Bi-Pb-As-Te. Coarse visible gold occurs along fractures and in quartz veins with sulphide associations consisting of semi-massive to subhedral-euhedral arsenopyrite, galena and pyrite. Petrographic examination and EPMA of Au grains suggest a tentative mineral association with arsenopyrite, galena, and possibly beudantite, although XRD from synchrotron analysis will serve to effectively characterize the minerals present. Observed geochemical associations with gold discovered at the Vertigo target are unlike any other prospects discovered in the White Gold District to date.

502 - Sedimentology of a potential Timiskaming-type assemblage in the Sturgeon Lake greenstone belt, Northwestern Ontario: Implications for gold exploration

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Timiskaming-type assemblages are known to be spatially associated with gold deposits in the Abitibi Subprovince. At typical localities, volcaniclastic conglomerate units were deposited in narrow, transtensional “pull-apart” basins and are often associated with calc-alkalic to alkalic magmas that likely promote circulation of the mineralizing fluids. Sedimentary and structural observations of the Ament Bay Assemblage of the Sturgeon Lake greenstone belt reveal alluvial-fluvial sedimentary facies that form a molasse-type basin bound by a disconformity on the northern margin. Sedimentological data shows normal grading that becomes nearly matrix supported as it youngs to the South. This indicates deposition in an alluvial-fluvial setting. Clasts are dominated by chloritized mafic volcanic fragments with lesser chert pebbles and sulphide clasts. Stratigraphic variations include appearances of felsic intrusive clasts as well as anhedral blue volcanic quartz phenocrysts within a greywacke matrix. The penetrative subvertical foliations, stretching lineations, and inclusions of pre-deposition deformed clasts are consistent with post-D1 events associated with gold-bearing, Timiskaming-type structures elsewhere in the Superior Province. Additionally, the Ament Bay features a linear distribution, has a half-graben architecture, and is spatially associated with the Sturgeon Narrows Alkalic Complex. Further mapping of the Ament Bay and interpretation of sedimentary and intrusive characteristics of the Timiskaming-type basin at Sturgeon Lake is vital to understanding the relationship between precious metal endowment and syn- to late tectonic geodynamic evolution of the belt. CFREF-Metal Earth Project Contribution MERC-ME-2020-038.

503 - Hydrothermal alteration footprint of the Monument Bay Gold Deposit, Stull Lake Greenstone Belt, Manitoba, Canada - New results

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Gold deposits in Greenstone Belts in the Superior Province are well known for their importance in Canada's economy, hundreds of large-scale gold deposits have already been discovered in the country. Monument Bay is a Gold Greenstone Belt hosted deposit located 570 km NE of Winnipeg with approximately 5 km width. The deposit is composed of sedimentary, mafic, ultramafic and intrusive rocks located inside the Stull Lake Greenstone Belt in the NW of the Superior Province. A significant E-W fault (Twin Lakes Shear Zone) crosscuts the deposit and it is known as the possible mineralization conductor. Previous analytical studies show significant gold grades in the area. The Au grades are distributed in the deposit with similar alteration characteristics in different lithologies. In this study, Monument Bay is divided into six targets: Twin Lakes Zone, AZ Zone, South Limb Shear Zone, Mideast Zone, and the Fence Zone. This work aims to characterize the hydrothermal alteration through the development of a mineralogical and geochemical footprint in those targets. This will help to understand the relationship between the mineralization and the alteration to master the deposit genesis, and then give support to Yamana Gold to advance the exploration program. In order to do this, techniques such as optical petrography, synchrotron radiation X-ray diffraction, synchrotron radiation X-ray fluorescence, and energy dispersive X-ray spectroscopy analyses, were used to enhance the understanding of the alteration of the deposit and its relationship with the Au mineralization in the different zones. Analyses of previous responses demonstrated that the observed alteration characteristics, such as the amount and type of alteration are varying only with the different lithological groups (intrusive, metavolcanic and metasedimentary rocks) and do not have a significant relation with the geographical distribution of the samples. Au is found to be related to the sericite and carbonate alteration with distinct textural and compositional characteristics in different targets, but all associated with arsenopyrite. Energy-dispersive X-ray spectroscopy and Scanning electron microscope analyses show different relationships between Au and different generations of sulphides in the different targets. Further work will be done to improve the identification of the most profitable mineralization areas of the deposit. This will include mineral chemistry to understand how the alteration chemistry changes in the different targets, besides cluster X-ray diffraction analyses will be created to improve the knowledge of the mineralogical distribution of the fine-grained alteration.

504 - Multivariate analysis on major and trace elements at the Monument Bay Gold Deposit, Manitoba, Canada

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Greenstone Belts in Canada contain a large number of Archean shear-hosted gold deposits. The Monument Bay project, located in northeastern Manitoba, is an economically promising Au deposit that consists of three main exploration targets: Twin Lake, Mid-east and AZ zones. Various exploration techniques including geological, geophysical and geochemical methods have been used in the study area over the past 70 years. Biogeochemical techniques have been recently employed to determine the presence and character of concealed mineralization using chemical analysis of black spruce (*Picea mariana*). This project aims to firstly, describe the biogeochemical response in black spruce (*Picea mariana*) associated with mineralization, and secondly, extrapolate biogeochemical data to wider surveys across the Monument Bay property to create a vector towards new mineralized sources. Statistical analysis including probability plot, scatter plot, principle component analysis (PCA) and factor analysis (FA) are used to interpret the complex relationship between different elements and interrelation among samples. Multivariate statistical analysis is carried out using ioGAS 7.1 and SPSS 25.0 to group elements according to their similarities. Differences in element distribution between various tissues of black spruce including bark vs. needles vs. twigs are observed. Statistical regression clearly illustrates a positive correlation between gold and arsenic which confirms the presence of arsenic as an indicator of gold at Monument Bay. PCA and FA are the dimension reduction methods that reveal the similar distribution between precious metals (Au, Ag and W) and base metals (Fe, Pb, and Cu) in different plant tissues (e.g., bark, twigs, needles). Micro-nutrients (Ca, K, Mg, P and S) are generally present in needles which is a metabolically active organ. In contrast, toxic elements (Pb and Cd) and precious metals (Au, Ag and W) prefer to accumulate in woody parts of plants (i.e., the bark). The present study is the first detailed statistical study on the distribution of gold and different elements in black spruce at the Monument Bay project.

505 - Geometallurgy and gold mineralization of 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. Further academic work is focusing on the geometallurgy and gold mineralization of the Monument Bay Deposit, and a reasonable gold mineralization model will be built for future gold exploration and production. Traditional microscopy is used in combination with geochemical and mineralogical analytical techniques (Electron Probe Microanalysis (EPMA) and Energy-dispersive X-ray Spectroscopy (EDS) element map) and synchrotron geochemical techniques (X-ray Diffraction (XRD), synchrotron micro X-ray fluorescence (μXRF) mapping, X-ray Absorption Near-edge Structure Spectroscopy (XANES)). The study preliminary results show: 1) most of the high gold-grade samples (>1 ppm) are hosted in Quartz Feldspar Porphyry (QFP) and Feldspar Porphyry Flow (FP) and are from Twin Lakes and Twin Lakes West, and a few are metasandstone from the South Limb Shear; 2) metallic gold (Au^0) exists in Monument Bay as free gold and inclusion gold, and no refractory gold (Au^{+1}) has been found yet; 3) microscopic gold distribution is

related to sulfide morphology; 4) there is possible evidence for 3 fluid events observed in preliminary EDS Element maps: i) euhedral arsenopyrite formed; ii) corroded needle pyrite formed; iii) gold formed in the fracture of pyrite. This research is helpful to get more information about the gold type and distribution and multi-episodic fluid history in the Monument Bay Deposit and 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.

506 - Application of dendrochemistry in biogeochemical exploration at the Borden Gold Mine, Ontario

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Biogeochemistry involves biological, geological, and chemical processes and reactions, and how they interact in the environment. Dendrochemistry is a branch of biogeochemistry that studies trace element and mineral uptake in tree rings. Dendrochemical studies have demonstrated that trees absorb non-essential elements and minerals through the tree roots and retain these elements in the heartwood of many tree species. Commonly, the retained elements reflects the underlying geochemistry of bedrock geology. Dendrochemistry applied to mineral exploration involves the chemical analysis of tree cores to assess the underlying bedrock and potential mineralization. Dendrochemical studies have been useful in base metal exploration programs, but they have yet to be applied to gold exploration programs. This study examined the tree ring chemistry of Black Spruce (*Picea mariana*) above a gold deposit and active mine in the Kapuskasing Structural Zone in northern Ontario. Two primary aims of this project are to: 1) assess the applicability of dendrochemical studies to lode gold deposits, and 2) determine if additional mineralization exists along strike of the Borden Lake Deposit using dendrochemistry. As tree ring chemistry can reflect local anthropogenic activity, the years 1985-1990 and 1990-1995 were sampled in the tree cores, in order to avoid a time period where there was drilling in the area. The five year time periods gave an average sample weight of 100 mg. Archean gold deposits typically have anomalous pathfinder elements of Au, B, Mo, and heavy metals (As, Sb, Te) with background, or slightly anomalous, contents of base metals. It is anticipated that there will be anomalous concentrations of pathfinder elements that readily uptake into plants. Because Mo, B, and base metals are known micronutrients commonly absorbed by plants regardless of underlying mineralization, it is unlikely anticipated that anomalous concentrations of these elements will be significant for this study. Gold does not readily uptake into plants, however, it has been recently recorded in leaves of eucalyptus species. Additionally metals such as As, Sb, and Te are readily absorbed by plants and are also anticipated within our analyses of Black Spruce core samples collected from the Borden Gold Mine property.

507 - Investigation of sulphide-poor gold mineralization of Kiena Deep A Zone at the Kiena Complex, Val d'Or

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The Kiena Complex, owned by Wesdome Gold Mines Ltd., is located between Val d'Or and Malartic, Québec, in the southern Abitibi Greenstone belt. Recent exploration drilling at the lower levels in the Kiena Deep A Zone intersect unusual sulphide-poor quartz vein hosted gold-rich mineralization that contrasts with the sulfide-rich mineralization in the upper Kiena Complex, particularly the S50 Zone. The gold mineralization, characterized by visible gold, is hosted by quartz veins that cut deformed ultramafic and basaltic rocks. Two distinct groups of basalt with different sources have been distinguished using lithogeochemical analyses and the distinctive basalt chemistry has the potential to be used as a marker for structural analysis. The mechanism of gold deposition, potential vectors for mineralization, and a more detailed understanding of the genesis of the mineralization are the main objectives of this study. Observations of drill core throughout the mineralized zones show that gold grade does not correlate with quartz colour, or vein thickness. Flecks of visible gold are mostly along fractures within the veins, and to a lesser extent as free gold at vein contacts or within the wall rock. A “degree of complexity” factor that considers the degree of deformation, fractures, complex mineralogy, and quartz types was generated for barren, poorly mineralized, and strongly mineralized veins. The results show that gold grades increase with an increasing degree of complexity within the veins. In addition, preliminary lithogeochemical results suggest that the mineralized zones are associated with cryptic sodic alteration, i.e., the alteration is not observable in hand samples. This sodium alteration may be related to the albitization observed with gold mineralization in the upper Kiena Complex, where visible grains of albite are reported. Results from this study will be used to differentiate between barren, poorly mineralized, and strongly mineralized quartz veins, aiding in mineral exploration at the Kiena Complex and other orogenic gold camps. Next steps for this project include petrographic analysis of vein and wall rock samples, as well as lithogeochemical analysis of least altered wall rock to quantify alteration proximal and distal to gold mineralization. Understanding the genesis of sulphide-poor orogenic gold mineralization is needed to better understand local gold deposition, to generate new exploration targets at the Kiena Complex and at other gold exploration properties.

508 - A fluid inclusion study of auriferous quartz veins in the Archean Hardrock orogenic gold deposit, Geraldton, Ontario

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Hardrock is an Archean orogenic gold deposit situated in the Beardmore-Geraldton Belt (BGB), of northern Ontario. Hosted in greenschist facies metasedimentary rocks, including oxide iron formation, it occurs along the boundary between the Wabigoon and Quetico subprovinces of the Superior craton. Gold occurs in three different quartz vein generations associated to early-D1 veins (V1) and syn-D2 veins (V2 and V3), in the multi-deformed (D1-D3), highly strained host rocks of the one km-wide Bankfield-

Tombill deformation zone near the southern boundary of the BGB. This study focuses on using fluid inclusions to define the PTX conditions of the different mineralized veins at Hardrock and contrasting them with other quartz veins along strike, contiguous stratigraphy, and at the Brookbank deposit along the Paint Lake shear zone that marks the northern boundary of the BGB. Well-characterized vein samples from previously studied outcrops at Hardrock and Brookbank will be studied using the fluid inclusion assemblage (FIA) approach to identify and classify different fluid types (e.g., H_2O versus CO_2) and identify fluid trapping events. These FIAs will be used for thermometric studies to define homogenization temperature, fluid salinity and volatile chemistry (XCO_2, XCH_4). This data will then be used to constrain PT of entrapment of different vein generations and thus assess gold mineralizing conditions. Further chemical characterization of fluid chemistry, which can be used to infer possible fluid reservoirs, will be done using evaporative salt mound analysis via SEM-EDS, in situ SIMS δ^{18}Oquartz and δ13C on inclusion extracts. These results will be compared to those of other fluid inclusion studies in other similar orogenic systems to assess similarities and differences. CFREF-Metal Earth Project Contribution MERC-ME-2020-035.

509 - Predictive analysis of gold mineral prospectivity using Deep Neural Networks (DNN)

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Machine learning has recently gained popularity in the geoscience community with applications including predictive analytics, cluster identification and data characterization. Vast amounts of research and applications of machine learning is being done to help make predictions for prospective regions that may contain valuable mineral resources around the world, however; some of the drawbacks of using machine learning is that the models tend to overfit to the training data thus making them incapable of making accurate data predictions. There is a need for better algorithms and machine learning models that are capable of handling complex geoscience data and able to distinguish between prospective and non-prospective regions. This study evaluates the mineral system and key ingredients responsible for the distribution of gold in the form of evidential layers (i.e. geoscience maps) and uses Deep Neural networks (DNN) to evaluate the mineral potential for mesothermal gold deposits over the Swayze greenstone belt. DNN as implemented in Google's Tensorflow are a sophisticated type of neural network technique that consist of a layer of input nodes, multiple hidden layers and an output layer. There are various activation functions, optimization, and regularization techniques that exist to help compute the training and validation accuracies and losses – thus helping data-science geoscientists mitigate model overfitting during training and to ensure high accuracy of model predictions. The model losses show how well the training data fit to the target, low loss values indicate that the model had a good understanding of the training data and was able to perform well when tested on unseen validation datasets. The results obtained from a deep learning model generated over the SGB using 11 input evidential layers show a training and validation accuracies of 93% and 90% respectively and the model's training and validation losses are 0.1 and 0.23 respectively. Overall, the deep learning models trained on geoscience data show an overall high training and validation accuracies with capabilities to make new predictions from learned input information.

510 - Structural setting and kinematic history related to vein emplacement and shear localization at the Van Horne prospect in Dryden, Ontario

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Archean metavolcanic rocks that are spatially associated with high strain zones commonly host orogenic gold deposits in the Superior Province. The western Wabigoon subprovince contains several crustal-scale fault systems, making the area prospective for gold exploration. This work takes an in-depth look at the kinematic relationship between deformation and gold mineralization of the Van Horne prospect, a property located along the E-W striking Wabigoon deformation zone. Rock types, structures, timing of vein emplacement and shear localization are documented in 1:400 scale maps of two key outcrops: Glatz West and Glatz East. The study area is primarily comprised of intermediate metavolcanic rocks, including mafic dikes, pillow basalt, feldspar-phyric flow, and volcaniclastic units. Using field observations and microstructuctural analysis, two main brittle-ductile deformation events and three major vein sets are identified. D1 generated isoclinal F1 folds, an axial planar S1 cleavage, and thrust faults, are interpreted to be related to an early phase of N-S shortening. A first generation (V1) of fracture-filling quartz-carbonate-tourmaline veins, sub-parallel to the S1 fabric, formed during D1. Syn-late D1 quartz-feldspar porphyry dikes were subsequently affected by D2 deformation. The S1 fabric got wrapped into S2, which can be seen as a chlorite foliation that trends E-W. D2 is characterized by strike-slip transpressional shearing, which generated dextral C-S fabrics and quartz-chlorite-biotite pressure shadows surrounding pyrite crystals seen at the microscale, as well as asymmetrical Z-folds (F2) seen at the outcrop-scale. D2 is also associated with multiple E-W striking high-strain zones located within highly iron-carbonate altered metavolcaniclastic units. D2 structure offsets V1 veins and caused the emplacement and folding of the second generation (V2) quartz-carbonate veins. A third generation (V3) of quartz veins was observed that cross-cut the older vein generations and are oriented N-S. Gold mineralization is primarily seen within the pyrite that is disseminated in the host metavolcanic rock and less frequently within the V2 quartz-carbonate veins as visible gold. Thus, gold-bearing hydrothermal fluids filled dilational fractures synchronous with late D2. Characterizing the structural evolution of the Van Horne prospect and the relative timing of orogenic gold mineralization will contribute to defining a favorable structural setting along the Wabigoon deformation zone, and aid exploration in the western Wabigoon subprovince. CFREF-Metal Earth Project Contribution MERC-ME-2020-016.

511 - Alteration geochemistry and petrogenesis of gold-mineralized metavolcanic rocks at the Van Horne Prospect, Dryden, Ontario

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Greenstone belts have been recognized as highly prospective settings for high grade gold mineralization and are host to most of the world-class quartz-carbonate vein deposits, so-called orogenic gold deposits. Orogenic gold systems have been broadly explored in the western Wabigoon subprovince and account for the majority of the historical gold production in the Dryden area, Ontario (~37,000 ounces Au). Greenstone-hosted quartz-carbonate vein deposits correspond to structurally controlled networks of gold-bearing, quartz-carbonate fault-fill or extensional veins. However, lithogeochemistry of protoliths, alteration geochemistry, ore mineralogy, and paragenesis are yet to be characterized in the area. This project documented the alteration mineralogy and geochemistry of altered and gold-mineralized metavolcanic rocks at the Van Horne property, located approximately 8 km southwest of Dryden, Ontario. Three main assemblages occur on the property, identified as the: 1) Eagle Lake volcanics, 2) Lower Wabigoon volcanics, a mixed assemblage of tholeiitic and calc-alkaline mafic to felsic volcanic flows and syn-volcanic intrusions, and 3) Upper Wabigoon volcanics, an iron-rich tholeiitic basalt. All metavolcanic rocks have been strongly sheared and hydrothermally altered along the Wabigoon deformation zone, which truncates these units to the north. Mapping (1:400 scale) of the Van Horne property was used to constrain the extent and intensity of alteration, and the spatial association with shear zones and quartz-carbonate veins. Whole-rock lithogeochemical analysis and petrographic observations are being used to characterize the nature and composition of host rocks and their paragenesis, and to determine how the intensity of the alteration vary with proximity to shear zones, and near quartz-carbonate veins. Preliminary results show that gold mineralization appears to be largely confined to quartz-carbonate vein networks, but may also be present within iron-rich sulfide bearing wall-rock, proximal to veining. Wall rock alteration is intense within metres of the main NW-SE trending shear zone and is characterized by intense carbonatization and the formation of iron-oxide, chlorite, biotite, and sulfide minerals. Mass balance calculations, comparing altered to least altered metavolcanic host rocks will show the mass gains and losses in elemental abundances, allowing for a geochemical characterization of the alteration at the Van Horne prospect. Comparing the Van Horne prospect with other greenstone-hosted orogenic gold systems, this work will contribute to identify favorable lithological traps, and discuss possible fluid sources for gold mineralization along the Wabigoon deformation zone, which will ultimately assist mineral exploration in the western Wabigoon subprovince. CFREF-Metal Earth Project Contribution MERC-ME-2020-015.

512 - Chemometric Strategies for the qualitative comparison of biotite and chlorite from an orogenic gold deposit using LIBS

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Laser-induced breakdown spectroscopy (LIBS) is an analytical technique that records the atomic emission spectrum following the decay of a laser -generated plasma on a sample surface. Recently, field-portable LIBS technologies have become commercially available, which allows rapid, in situ analyses of geological materials with minimal sample preparation. One of the advantages of LIBS over other field-portable techniques is the ability to rapidly determine the relative abundance of most elements in the periodic table. These spectral "fingerprints" can be used to identify the relative abundance of major to minor element compositions in rocks and minerals. Here we apply the LIBS method to a suite of metamorphic and hydrothermal mineral assemblages on the sawed surfaces of drill core at the MacLellan gold deposit (Lynn Lake greenstone belt, Manitoba). Field relationships (e.g., varying alteration mineral assemblages, degrees of alteration intensity and distance to mineralization) and statistical analysis of the qualitative LIBS spectral fingerprints are used to distinguish multiple generations of biotite and chlorite. Due to the fine-grained nature of the MacLellan deposit, it is necessary to first employ discriminant techniques to isolate specific minerals of interest prior to further statistical analysis. One of these approaches, discriminant function analysis (DFA), assigns spectra to two or more categories based on observed quantitative variables. Categories are defined using unique combinations of single emission line intensities as well as emission line sums and ratios that are designed to maximize the variance between known reference data sets. Selected emission lines are summed and divided by sum of emission line intensities to allow for comparison across multiple mineral samples in addition to minimizing the shot-to-shot variability inherent in the LIBS technique. The filtered LIBS datasets can then be used to discriminate multiple generations of the mineral of interest. One example following this approach, is to distinguish biotite from barren versus mineralized alteration zones using a combination of principal component and linear discriminant analysis. We demonstrate that biotite associated with gold-bearing veins yield a distinct spectral fingerprint, which has the potential to be used as a guide during core logging and/or regional mineral exploration.

513 - Assessing the potential spectrum between Carlin-type and classic magmatic-hydrothermal mineral deposits: a case study in the Battle Mountain mining district, Nevada, USA

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Although Carlin-type gold deposits in Nevada have produced nearly 200 Moz since 1965, better understanding of mineralizing processes would help refine exploration efforts. The critical question is whether these deposits formed from magmatic hydrothermal fluids or circulating meteoric/metamorphic fluids. While difficult to test directly, geochronology and (U-Th)/He thermochronology allow us to determine the timing of magmatism and thermal events such as hydrothermal fluid flow, respectively. If thermal events in mineralized zones and magmatism are consistently contemporaneous, this implies magmatism is a necessary control on Carlin-type deposit formation. The Battle Mountain mining district provides an ideal area in which to test this relationship, as the district contains deposits that display characteristics of distal-disseminated, skarn, and Carlin systems.

Rhyolite dikes dated at Lone Tree yielded zircon U-Pb CA-TIMS ages of 40.95 ± 0.06 Ma and 40.94 ± 0.05 Ma. Zircon and apatite (U-Th)/He dates generally fall between 31 and 39 Ma, suggestive of the cooling magmatic system and the accompanying hydrothermal fluids. At the Brooks deposit, our zircon (U-Th)/He dates are Cretaceous (96.58 ± 1.39 Ma to 80.84 ± 1.69 Ma), contradicting mine site interpretations that the intrusions were contemporaneous with those at Lone Tree. Two granodiorite intrusions at Marigold Mine yielded Cretaceous zircon U-Pb CA-TIMS ages as well (96.59 ± 0.07 Ma, 92.22 ± 0.08 Ma). Textural evidence at Marigold suggests a Cretaceous-base metal event was overprinted by a younger Au event, hypothesized to be Eocene. Apatite and zircon (U-Th)/He dates from the margins of Au-mineralized intrusions at the Marigold and Valmy deposits support Eocene hydrothermal fluid flow. One granodiorite intrusion in the transition zone between the Marigold-Valmy deposits and Trenton Canyon, along the Oyarbide fault, has preliminary zircon U-Pb LA-ICP-MS dates that indicate Cretaceous emplacement, yet again the apatite (U-Th)/He dates indicate younger heating (42.92 ± 1.98 to 21.57 ± 2.31 Ma). We report the first zircon U-Pb LA-ICP-MS analyses from Trenton Canyon Au here, which support Eocene emplacement of granodiorite intrusions. Zircon (U-Th)/He dates are contemporaneous, however, the apatite (U-Th)/He dates predate the zircon U-Pb dates, despite the lower closure temperature of the apatite system. Apatite and zircon (U-Th)/He dates from the margins of the Cretaceous Trenton Canyon stock are also reported here to identify if the stock served as a major crustal conduit for Eocene fluids.

514 - Identifying magmatic overprint in Archean orogenic gold deposits: An example from Wawa, Ontario

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The Wawa Gold Corridor (WGC), located in the Michipicoten greenstone belt of the Superior Province, Canada, comprises gold-bearing shear zones that resulted from protracted deformation (D1-D3) of intermediate igneous rocks of the 2.75 Ga Jubilee Stock. The shear zones are cross-cut by 1.0 Ga lamprophyre dikes that imparted a distinct riebeckite-carbonate alteration assemblage. D1 and D2 ore mineralization consists of disseminated arsenopyrite and pyrite in quartz + muscovite + carbonate schists, whereas D3 ore mineralization comprises pyrrhotite and pyrite in quartz + tourmaline shear veins. These veins are cut by carbonate ± riebeckite veinlets. Investigation of gold-bearing samples by optical and SEM microscopy divides gold mineralization into two principal events: syn-kinematic (AuI);

and post-kinematic (AuII). AuI is associated with arsenopyrite and pyrite in D1-D2 structures and occurs as inclusions in, along fractures in, or on the margins of these minerals. AuII is hosted by the carbonate veinlets that cross-cut D3 veins and occurs with chalcopyrite, pyrite, bismuth, maldonite, and a variety of Bi-Te minerals. AuII and Bi-Te minerals have mutual curvilinear boundaries and often present as trails of globular grains in quartz. Analysis of sulfide chemistry by LA-ICP-MS reveals that: (1) syn-kinematic arsenopyrite is Au rich (x0– x000 ppm); (2) syn-kinematic pyrite is As rich (x00 – x0000 ppm) and Au rich (x – x0 ppm); and (3) post-kinematic pyrite is As poor (x – x00 ppm) and Au poor (< 1 ppm). The textural, mineralogical, and geochemical features of the syn-kinematic gold event are consistent with typical orogenic mineralization (i.e., invisible gold in Fe-As sulfides, native gold bordering these phases, and an Au-As association); such features of the post-kinematic gold event are not (i.e., gold with Bi-Te minerals and chalcopyrite and an Au-Bi-Te-Cu association). The mineral assemblages and textural nature of the latter indicate precipitation from Bi-rich polymetallic melts. Based on mineralogical similarities (in particular, the observation of gold in carbonate-riebeckite veinlets), the hydrothermal fluids that drove this process were probably related to emplacement of the lamprophyre dikes and re-distributed gold on a deposit scale; the WGC can therefore be described as an orogenic deposit that experienced magmatic-hydrothermal overprint. The AuII event in the WGC shares similarities to gold mineralization in magmatic systems (e.g., skarn, IOCG) and identification of such features (e.g., gold with Bi-Te phases and the Au-Bi-Te-Cu association) in other orogenic deposits may serve as evidence for magmatic contribution.

515 - Possible ore-controlling structures for the Woxi Au/Sb/W deposit in Tanghuping Mining Section, Hunan Province, South China

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The Woxi Mining District in Hunan Province, South China, hosts numerous high tonnage gold, stibnite, and tungsten strata-bound deposits. The mining district is located in the Xuefeng Orogen, an essential component of the Neoproterozoic Jiangnan Orogen, which is the result of a continent-arc-continental collision between Yangtze block and Cathaysia block in the South China Craton. Our research focuses on the geological characteristics of the Tanghuping and Xintianwan faults in the Tanghuping Mining Section, within the Woxi Mining District. The Woxi Mining District comprises mainly slate, with interbedded quartz sandstone and clastic rocks, cut by three east-west to northeast-trending faults: the Tanghuping, Xintianwan, and Woxi faults. The Tanghuping and Xintianwan faults join the regional Woxi fault in the northeast part of the district. Regionally significant altered fracture zones and bedding-parallel quartz veins are found parallel to the Tanghuping and Xintianwan faults. The ore zones defined in other mining sections around Tanghuping are closely related to alterations in surrounding rocks of the fracture zones and quartz veins. We test the hypothesis that the mineralization in Woxi Mining District is structurally controlled, related to motion along these faults. While the presence of Tanghuping and Xintianwan faults in the Tanghuping Mining Section has not been confirmed, the proposed faults are interpreted to be intimately related to mineralization. Previous field mapping and cross-section construction have corroborated the location of the Tanghuping and Xintianwan faults. Through the observation of

outcrops and trenching, high strain zones coincide with the mapped faults, but new core logging data do not show evidence of fracture zones at expected depth. It is therefore still unclear if the high strain is related to the presence of the faults or if it is the result of local interlayer flexural slip. Additional microstructural analysis is underway to further characterize strain-induced recrystallization textures and sense of shear near and within the interpreted fault zones. Understanding this relationship is important as it facilitates exploration tasks to help detect ore systems on a regional scale and identify areas with the most profitable mineralization.

600 - Geophysics

601 - Exploration for podiform chromite in the Quesnel Terrane, British Columbia

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The Quesnel and Stikine Terranes in Central British Columbia is comprised of two Mezozoic aged volcanic arcs extending parallel to the Canadian Cordillera, which hosts significant Cu-Au ± Ag-Mo mineralization. Along the margins of these terranes there are obducted ophiolite complexes which have demonstrated potential for podiform chromite and associated commodities. This study presents the results and interpretations of geological and geophysical surveys completed in the summer of 2019, which aimed to map the structure of an ophiolite complex located in the Quesnel Terrane, near Kelowna, BC. Additional geological and structural knowledge acquired during these surveys has led to improved constraints for exploring chromite pods hosted within this complex. Historical exploration in relied extensively on airborne magnetic methods which successfully delineated the trend of the larger scale formation, but generally failed to resolve the internal structure. Using ground magnetic surveys combined with geological observations in the field, we were able to refine the geological and structural model of the ophiolite with the highest level of precision to date and propose new guidelines for exploration. The ground magnetic survey was highly effective at mapping the extent of the ultramafic units, even with significant glacial till cover, which infilled the valleys between outcropping ridges to an unknown and variable depth. This is due to the effect of serpentinization and the associated formation of magnetite. With this effective mapping tool, we were able to constrain the extent of the serpentinized ophiolite as well as the identification of a conjugate fault set, previously unknown in the area, which provided information about the regional stress field and potential fluid pathways for nearby hydrothermal systems. Three distinct alteration patterns were identified: (i) serpentinization associated with the deformed chromite-bearing zones, (ii) formation of ferrian chromite and magnetite under oxidizing conditions, and (iii) antimony anomalies associated with fault zones. These results aid in further constraining future exploration for podiform chromite deposits, as well as to establish the structural controls of the antimony anomalies reported in the area. Based on these results, Further exploration for the chromite pods within the complex are recommended and planned for 2020 including an unmanned aerial vehicle magnetic survey to better refine the geological model in areas inaccessible to the ground survey and additional rock and soil geochemical assays along the trend of the complex.

602 - High-resolution multi-focusing seismic imaging of Metal Earth's Larder Lake transect

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A recently introduced Multi-focusing (MF) time imaging method can considerably improve the quality of seismic imaging in the complex geologic areas with the poor signal-to-noise ratio. This method is a sophisticated alternative method for conventional stacking and provides very detailed and high-resolution images based on a transformation of multi-coverage pre-stack data into a zero-offset stack section. The implementation of Multi-focusing is technically challenging, computationally expensive, and comprises several isolated steps and lacks an efficient optimization component. In a two-dimensional case, the MF time correction operator depends on three wavefront parameters. The main problem of this approach is the simultaneous determination of these parameters optimally for each image point and time location. In this research, we address the optimization problem using multidimensional constrained Very Fast Simulated Annealing (VFSA) global optimization algorithms. We have also designed an efficient signal processing sequence for pre-stack data enhancement. We examined our developed algorithm and codes on both 2D complex synthetic and Metal Earth seismic data. The results indicate that mentioned optimization algorithm is computationally cost-effective and accurate. The MF method focuses the sub-vertical faults and steeply dipping reflections at their right location and images them clearly compared to the conventional method. Also, This algorithm brings new reflection to focus that were not appeared in the conventional results. Our approach leads to high-resolution seismic images with a significant impact on interpretation ability for the seismic section. CFREF-Metal Earth Project Contribution MERC-ME-2020-028.

603 - Monitoring groundwater dynamics with time-lapse gravity gradiometry: Forward modelling

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The feasibility of monitoring the depletion/recharge of ground- and surface water reservoirs using gravimetry is presented. This is important because many industrial processes are water-intensive and therefore the use of sustainable and proximate water resources is preferred. Changes and depletion of water reservoirs must be observed with adequate water monitoring systems, such as networks of monitoring wells. Water extraction or injection operations are regulated and require mandatory

monitoring. Groundwater dynamics are controlled by reservoir boundary conditions and several parameters, including, but not limited to, pumping rate, hydraulic conductivity, water level/drawdown, and required monitoring intervals. Monitoring water reservoirs with gravity gradiometry is inexpensive compared to drilling a network of monitoring wells. Therefore, gravity and gravity gradient signals are forward modeled to estimate signal strength and spatio-temporal distribution of water reservoir dynamics. The required sensitivity of the gravimeters, the time intervals between measurements, and the number/density of gravity stations, are evaluated. Groundwater models for a water extraction site using ModFlow are used and the outputs are transformed to test a range of gravity parameters at the surface, including, vertical gravity, vertical gravity gradient and horizontal gravity gradient. Time-lapse gravimetry for small-scale reservoirs poses two obstacles, namely, i) a microgal sensitivity requirement, and ii) noise from environmental or anthropogenic sources in the vicinity of the reservoir. In principle, the use of two gravimeters in tandem could compensate for environmental noise and improve the gravity gradient measurements. Examples of reservoir models are presented to illuminate the resolvability of groundwater dynamics from surface gravity gradiometry.

604 - Seismic refraction tomography of the Western Superior Province

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Seismic refraction tomography is a powerful tool to constrain lateral variations in elastic rock properties of the crust. It utilizes the arrival times of compressional waves refracting off of interfaces, where the maximum resolvable depth is proportional to the offset of the survey. This study reprocessed and analyzed a pair of wide-angle refraction surveys that were collected by the Lithoprobe National Research Project in the Western Superior (WS) province. In these surveys, seismic sources included 23 dynamite shots with 1000 kg charges placed into 50-meter boreholes. These were arranged into two profiles of 500 km and 600 km in length, trending N/S and E/W, respectively. The intersect point of each line lies centrally and both lines were re-evaluated individually using a non-linear tomographic inversion software. For each line, the processing sequence began by sorting the seismograms into shot gathers and interactively picking the first arrivals of the pP and pMP waveforms. Subsequently, a three-layer initial tomographic velocity model was calculated by considering the gradients and intercepts of those arrival times. The challenging sparsity of the dataset was overcome with rectangular gridding of the model space and minimizing the trade-off of norm to data misfit. Optimal parameterization of the inversions was achieved, and the models converged to acceptable levels of misfit. Finally, depictions of the calculated ray paths were used to de-emphasize the sparser, less reliable, regions of the final velocity models. Two interpretable P-wave velocity models were generated down to a depth of 50 km which gives a fence model of the WS province. The resulting depths and gradients of velocity layers of the two models at the intersection point are consistent. Furthermore, overlaying these models onto legacy seismic reflection data shows that the interfaces are comparable with major structures, particularly with the Mohorovičić discontinuity imaged at depths of approximately 36 km. Major lateral variations are in proximity to known geological sub-provincial boundaries thought to represent Archean continental accretion. This is particularly evident in the N/S line beneath the contact of the North Caribou and Uchi sub-provinces where a well-constrained, North-dipping, high-velocity anomaly appears to extend into the upper crust. A co-located regional magnetotelluric (MT) inversion model reveals this anomaly to be resistive, consistent with unweathered igneous rocks. The results of this study, integrated

with reflection and MT data, give evidence to suggest that this anomaly is a subducted Archean greenstone slab. CFREF-Metal Earth Project Contribution MERC-ME-2020-034.

605 – Characterizing magnetometer swing noise with an inertial measurement unit in UAV total magnetic intensity surveys

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Mineral exploration has advanced by integrating multi-rotor unmanned aerial vehicles (UAVs) with high-resolution magnetometer payloads. Directly integrating a high-resolution optically pumped magnetometer onto the frame of a multi-rotor UAV will compromise the integrity of the total magnetic field measurements due to the platform generated electromagnetic interference. One solution to this problem involves physically suspending the high-resolution magnetometer below the resolvability limit of the electromagnetic interference via a semi-rigid mount. However, the swinging motions of the high-resolution magnetometer while suspended below the UAV can introduce periodic signal variations in the collected total magnetic intensity (TMI) data. In this study, a UAV aeromagnetic survey was conducted over a mineral exploration target within the Shebandowan Greenstone Belt, northwest of Thunder Bay, Ontario, Canada, to assess the impact of magnetometer swing on collected UAV-borne TMI data. A DJI-S900 multi-rotor UAV and a GEM Systems Potassium Vapour Magnetometer (GSMP-35U) were used to fly a 500 m by 700 m grid, with a 25 m line spacing and a 35 m flight elevation above the ground. The optically pumped magnetometer was suspended outside the resolvability limit of the electromagnetic interference below the UAV via a semi-rigid mount. A nine degrees of freedom inertial measurement unit (IMU) was fixed to the semi-rigid mount and a Kalman filter was applied to calculate the positional variations (pitch, yaw and roll) of the magnetometer throughout flight. Spectral analysis was applied to the TMI measurements and the IMU data to assess the contributions to the TMI signal from the swinging, semi-rigidly mounted magnetometer. The amplitude of the periodic TMI variations was variable (< 1 nT – 5 nT) throughout the survey and depended on the horizontal gradient of the ambient magnetic field and the arc length of the magnetometer swing. Periodic signals were observed within the recorded TMI data directly relating to the swinging frequency of the magnetometer throughout flight. The wavelength of the swing-related TMI variations was characterized with the IMU measurements, determined to be spectrally unique, and low-pass filtered from the longer wavelength signals of the susceptible sub-surface targets. The design factors controlling the wavelengths of the geological target signals (flight speed) and the magnetometer swing signals (suspension length) must be considered when integrating high-resolution magnetometers on multi-rotor UAVs. This is to ensure that these signal wavelengths do not spectrally overlap and make filtering of the unwanted signals unnecessarily challenging.

606 – Aeromagnetic interpretation of the Matheson area in the northwestern end of the Abitibi greenstone belt of the Superior province, Ontario, Canada

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The Matheson area is located northeast of Timmins Township in Ontario, near the northwestern end of the Archean Abitibi greenstone belt of the Superior province. The area is of great exploration interest as it includes the Porcupine-Destor deformation zone, a major structure related to gold mineralization. Many of Canada's major gold deposits are located proximal to this deformation zone. The main objective of the research is to use aeromagnetic data to identify linear structures such as deformation zones, faults and dykes in the area and to identify and interpret magneto-lithological contacts. The results obtained from the aeromagnetic interpretation will be compared to the geological maps to identify overlaps and differences. The existing geological map can then be modified by incorporating the aeromagnetic interpretation. The identifications, interpretations and comparisons will be done using ArcGIS. Preliminary interpretation of the aeromagnetic data set shows that the northern part of the study area is dominated by north south striking linear features interpreted to be a dyke swarm. There are two north east-south west striking linear features which may be dykes filling faults. The area has a generally low magnetic susceptibility, so identification of magneto-lithology is difficult.

607 - Integrated quantitative seismic interpretation of Larder Lake area, ON

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The Larder Lake area is characterized by a series of complex meta-volcanic and sedimentary rocks which are intruded by granitic plutons and batholiths, which makes the area to be referred to as hardrock environment. These stratigraphic units are truncated by two major breaks, the Lincoln Nipissing Shear Zone (LNSZ) and Cadillac-Larder Lake Deformation Zone (CLLDZ) which are trending NE-SW and E-W, respectively. Seismic imaging and interpretation in hardrock environment is challenging due to lack of continuity of reflections which is mostly due to high dips and also small difference between acoustic impedance of stratigraphic units. This study aims to determine the structural architecture and evolution of the area using seismic data and other depth resolving geophysical methods for quantitative interpretation. Inverted models of Gravity and Magnetotulloric data will be used cooperatively with seismic data to overcome pitfalls from seismic data. Crossplot interpretation will be used to find correlations between all the geophysical methods using statistical methods. General interpretation in the area will be based on the Lithoprobe and Metal Earth's seismic data sets to better understand the structural controls of the reflections. Three Lithoprobe transects will be used in conjunction with the Metal Earth's transect for the interpretation. Seismic data in the area shows steeply dipping reflections on the upper crust which corresponds to the structural orientation of rock units on the surface geology. However, the middle to lower crust is characterized by subhorizontal reflections which are "preliminary" interpreted to be intrusive or tectonic contacts. CFREF-Metal Earth Project Contribution MERC-ME-2020-032.

608 - Integrating multi-parameter geophysical data to analyze, delineate and visualization bedrock geology beneath glacial cover

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A large geophysical and petrophysical dataset has been collected and compiled over many years in the Nash Creek area, northern New Brunswick. The area has inadequate outcrop exposure and is covered with dense vegetation and swamps, which results in poor geologic knowledge. Due to this, various geophysical methods have been employed to aid in the mapping of the area. These methods consist of various airborne and ground geophysical techniques such as chargeability, induced polarization, resistivity, magnetics, electromagnetics, radiometric, LIDAR, seismic, self-potential. Petrophysical data has also been collected to supplement and verify the geophysical data. Gaps in the petrophysical data and spatial sampling of geophysical data pose a severe challenge. This work shows some innovative multi-parameter visualization maps that will help with the definition of subsurface geology and structure.

609 - Modeling and processing magnetotelluric measurements in Mono Basin, California

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The Inyo-Mono Crater chain is result of an active volcano system that lies on the east side of the Sierra Nevada mountains. At the northern end of these craters lies Mono Lake, a 20-kilometer by 15-kilometer saline lake containing notable geologic features such as tufa towers and Paoha Island, a volcanic island formed in the 17th century. Because it's an area of active volcanism, there are possible environmental threats posed to nearby communities and popular tourist destinations such as Mammoth Lakes. The US Geological Survey has used magnetotelluric surveying to better understand the magmatic and hydrothermal systems in the area. Magnetotellurics is a passive method using natural electric and magnetic field variations to recover the electrical resistivity of the subsurface. This method is particularly useful in volcanic settings because of the contrast between resistive host rock and electrically conductive targets such as fluids and heat sources. A 3D inversion of the data collected by the USGS showed a large conductor on the edge of the survey towards the shores of the lake on the south side. Scripps scientists and the USGS then conducted two surveys in 2018 including deployments in the lake and on land to the north. Both the lake-bottom data and land data from these surveys were processed using a multi-station processing code, which incorporates a continuous remote magnetic reference site to improve the quality of the responses. A preliminary 2D inversion shows the large conductor extending under the lake and to the north, which is likely a hydrothermal system as it is not deep enough to be magmatic. In order to do a 3D inversion with this data the bathymetry must be ignored due to restrictions in the code. The theoretical one-dimensional MT recurrence relation can be used to

calculate the “lake-effect” and applied to the data so that the receivers may be placed on the surface in the model.

610 - Integrated interpretation of geophysical data for the Metal Earth’s Rouyn-Noranda transect

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Rouyn-Noranda is located in the southern part of the Abitibi greenstone belt of the Superior province. We have utilized Seismic reflection, Gravity and Magnetotelluric (MT) data for a detailed interpretation of the subsurface structures along and around the transect. The interpretation is carried out by enhancing and integrating the data sets in order to find correlations and relationship between seismic reflections, density and electrical resistivity. The seismic reflection character of the upper crust (~10 km) is poor, characterized by weak scattered reflections, marked by the base of the Blake River Group (BRG). Gravity data shows low- and high-density zones of which the high-density zones correlate with strong reflections interpreted to be volcanic rocks BRG and the low-density zones correlate with zones of poor reflections, interpreted to be plutonic bodies along transect. The middle crust (~10 – 24 km) is characterized by continuous, sub-horizontal reflections, which cross-cut with east-ward dipping reflections, interpreted to be of tectonic origin. This part of the crust comprises the most complex reflection character and high conductivity based on the MT data. The high reflectivity is attributed to have possibly caused by several geologic factors such as underplating, gneisses, mafic sills, etc. Reflections of the middle crust are predominantly of regional extend. The deeper crust (~24 – 36 km) is characterized by laterally discontinuous, subparallel reflections. The major break of reflections in the lower crust suggest possible mantle penetrating fault zones. The geophysical data complement each other where other data sets perform poor and details about crustal structure have been properly revealed by integration with legacy geophysical data sets. CFREF-Metal Earth Project Contribution MERC-ME-2020-036.

611 - 3D modelling and inversion of airborne gravity gradiometry data from Budgell’s Harbour Stock, Newfoundland

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Airborne gravity surveys have developed and become a popular tool for mineral exploration in the past three decades, mostly because of considerable improvements in equipment. Airborne methods make the data acquisition process rapid, more straightforward as no direct ground access is required, and hence potentially cheaper than ground gravity surveys. Also, the data coverage can often be much denser than for a ground survey. Here, 3D modelling and inversion of a gravity gradiometry data-set from Budgell’s Harbour, located in north-central Newfoundland, is carried out. Reef-type platinum

group mineralization is present in the area, as well as a large scale, deep igneous intrusion (the Budgell's Harbour Stock). The intrusion is thought to be related to the same tectonic activity that resulted in the formation of the basins off-shore Newfoundland that is now being actively explored for hydrocarbons. The gravity gradiometry survey was performed by Bell Geospace using their Air-FTG system. Line spacing was 200 m, covering a total of 407 km, with an 80 m altitude. The topography of the survey area is moderate. 3D forward modelling and inversion, specifically taking into account topography, were done on this data set. The inversions were typical unconstrained, minimum-structure inversions. The Earth model was parameterized in terms of an unstructured tetrahedral mesh, which allowed the topography to be modelled to the same accuracy with which it is known. The goal is to develop a 3D density model of the area, thus further assessing the mineral potential of the area and better delineating the Budgell's Harbour Stock.

612 – Magnetic and bathymetric surveys in lakes using an autonomous unmanned surface vessel

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Current methods of acquiring total magnetic field data and bathymetry data in lakes often relies on the use of inhabited vessels towing a magnetometer and sonar device through the water. The use of inhabited vessels often limits the surveyable region to large bodies of water, can result in irregular survey line orientations, and can create a large source of magnetic noise. Autonomous vessels are capable of following a strict survey grid, using on-board control systems to navigate from the current location to the next desired location or along a desired path, thus reducing survey path drift. The lightweight design of some autonomous vessels allows the vessel to be propelled through the water via small electric motors that require a much lower voltage to operate, thus generating a smaller magnetic field than is seen in industrial vessels. In this poster, the configuration of sensors and data outputs required to record high quality total magnetic intensity and bathymetric data are presented. The configuration discussed throughout consists of a Seafloor Systems EchoBoat autonomous unmanned surface vessel, HydroLite Echosounder and Marine Magnetics Explorer Magnetometer. Results show that an unmanned surface vessel is capable of autonomously acquiring total magnetic field and bathymetric data with centimeter level positional accuracy (via RTK) and total magnetic field intensity records with a noise level of ~1 nanotesla (nT). Three case studies have been conducted with a survey speed of 1m/s and a sampling frequency of 0.3 Hz with a constant survey depth of approximately 2 meters below the water surface of three lakes in Ontario, Canada - Lake Ontario (Downtown Kingston shoreline), Opinicon Lake (South Frontenac), and Surprise Lake (North of Thunder Bay). This study has identified that the high sensitivity Overhauser total field magnetometer can be used to record data with survey lines in any heading direction, with no dead zones. To reduce magnetic noise and improve data resolution, the following survey parameters must be considered; survey turning radius, in line sampling rates, vessel speed, vessel – sensor separation, cross line separation, base station preparation, and lake bottom clearance. Survey guidelines intended to maximize the signal-to-noise ratio of each survey, while resulting in improved magnetic body resolvability and resolution as compared to pre-existing local or regional aeromagnetic surveys of the area are discussed. Further application of this configuration and

survey guidelines can potentially be extended to tailings facilities and shoreline monitoring for hydrographic or engineering projects.

613 - Towards measuring density with pXRF spectra

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For successful mineral exploration, efficient mining and accurate reclamation, it is important to properly establish geophysical and geochemical features throughout the stages of a mining project. Density is one of these fundamental parameters that require consistent acquisition. From the gravimetric modeling of a deposit to the dimensioning of mining and residue handling, an error in density measurement can have consequences on the feasibility of a project. The importance of density acquisition is often understated. Density commonly receives less attention than other geochemical and other geophysical analysis. Local density distributions are usually based on fewer data points and measured with less controlled practices when compared to other physical and chemical parameters. Current instruments on the market that can measure this parameter are limited. Volume density measurements obtained through the Archimedes principle are often costly and time-consuming. This type of density acquisition is often done on competent core samples. This technique over-represents the more competent portions of the rock mass leading to a biased estimate of local density distributions. For borehole logging, the density probe available is commonly known as gamma-gamma. This technique provides better spatial coverage by characterizing lithology continuously but requires the use of a nuclear source. Potential radiation hazards restrict this instrument operation since the loss of the source in a borehole can have financial and environmental consequences. Its recovery can be costly which deters companies from using this type of instrumentation. As an alternative, this project evaluates the feasibility of using portable X-ray fluorescence (pXRF) to obtain density for borehole exploration. Scatter responses of X-ray radiation interacting with different geological samples have shown that there is a direct correlation with density values. This report quantifies the contribution of heavy elements and light elements on the observed scattering effects known as Compton and Rayleigh. This feasibility study evaluates pXRF as a potential density logging tool. We look at different technical obstacles that could impede its use for downhole density logging and show that they appear to be surmountable. Continuous density logging with pXRF could provide fast and continuous results increasing the efficiency for its acquisition. Having consistent data points on a large scale will improve the quality of data sets for multivariate models to characterize local geology.

614 - Unsupervised machine learning for continuous classification of borehole images into rock textural classes

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Conventional diamond drilling is a significant development cost of mineral exploration projects. As we attempt to reach ever deeper, the financial viability of projects is being challenged. In order to control the cost of drilling for these projects, we propose to extract more information from the boreholes that are already drilled and reduce the overall number of boreholes required for a discovery. The new generation of Optical televiewers (OTV) provides unsurpassed image quality that makes it possible to generate a continuous oriented image that is suitable for mineralogical and structural analysis. These images provide an unbiased representation of the rock mass that was encountered and can eventually be coupled to other physical properties measured in the hole. The digital nature of these images makes them suitable for use with machine learning algorithms that allow rapid and unbiased characterization of the material. After appropriate segmentation and image enhancements, meaningful features of the rock can be extracted (e.g. mineralogy, relative abundance of minerals, fracturation, etc.). As an example, we present in this work the spectral and textural features that were calculated from OTV images acquired at the Kipawa deposit, Quebec, Canada. These features are obtained from the gray level co-occurrence matrix (GLCM), gray level run length matrix (GLRLM), statistical descriptors, and values computed from the pseudo-mineral map. Altogether, a database of 35 parameters were extracted from the color and the gray-scale images. These parameters were fed into the Expectation-Maximization (EM)-Gaussian Mixture Model (GMM) algorithm to classify the OTV images into rock textural classes. Results show that the application of the EM-GMM algorithm allows the identification of major lithological intervals based on their textural similarities. This automated interpretation along the entire length of the borehole helps the geologists concentrate on important geological mechanisms and integrate the results in the best possible earth model.

700 – Other

701 - District-scale hydrogeochemical mineral exploration in Mumbwa district, Zambia using metal stable isotopes

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Metal stable isotopes can trace post-mineral dispersive processes and their incorporation into hydrogeochemical studies potentially offers a powerful geochemical tool for mineral exploration in areas of post-mineral cover. Hydrogeochemistry is cheaper than drilling exploratory holes and provides a larger anomaly target than regolith geochemistry, yet few studies have investigated metal stable isotopic compositions in groundwater as a vector for mineralisation. To further assess the potential of hydrogeochemistry as an exploration tool, we present physiochemical data (Eh, pH, TDS, conductivity),

major and trace element concentrations, and isotopic compositions ($\delta^{98}Mo$, $^{87}Sr/^{86}Sr$, and $\delta^{65}Cu$) from groundwaters interacting with the Kitumba iron oxide copper gold deposit and surrounding prospects. The Kitumba deposit is located in west-central Zambia, roughly 200 kilometres west of Lusaka, near the town of Mumbwa. Mineralisation is hosted within metasedimentary rocks of the Katangan Supergroup (540 Ma to 512 Ma) and associated with syenite intrusions of the Hook granitoid (550 Ma to 540 Ma). A significant hydrogeochemical footprint of As, Mo, Fe, Mn, U, Zn, and SO_4 is evident up to 5 kilometres from the deposit. We report a fractionation of 1.34‰ to 1.65‰ ($\Delta^{65}Cu_{solid-solution}$) between primary chalcopyrite and proximal groundwater. Strontium concentrations plotted against $^{87}Sr/^{86}Sr$ in groundwaters and rocks from the Mumbwa district indicate three isotopically distinct populations, suggesting mixing and a lithological control on groundwater compositions. Proximal to the known mineralisation, $\delta^{98}Mo_{3134}$ values are low (-1.08 ± 0.18‰ 2SE to 0.64 ± 0.08‰ 2SE) but increase distally to 2.08 ± 0.12‰ (2SE). This pattern of Mo isotopic fractionation is interpreted to result from a change in Mo coordination from MoO_4^{2-} to polymolybdate species during adsorption to abundant Fe- and Mn-oxides. Metal stable isotopes trace post-mineral dispersive processes and their incorporation into the exploration toolkit will provide greater confidence when determining drilling locations than would otherwise be achieved with groundwater metal abundances alone.

702 - The suitability of mine waste rock for road construction

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In trying to obtain alternative construction material for use as chippings in road construction works, this project sought to ascertain the suitability or otherwise of the mining waste from the Ghana Manganese Company, (GMC) Nsuta mine. Field sampling of rocks aggregates from Pit C Central West, subsection of Pit C of the mine site was done considering the volume of aggregates required to conduct the various tests. The geotechnical properties investigated were the flakiness index (FI), elongation index (EI), aggregate impact value (AIV), aggregate crushing value (ACV), Los Angeles abrasion (LAA) value, water Absorption of the material, 10% fines value, the material specific gravity and its grading characteristics. The results obtained from these tests were analysed and discussed and they showed that the FI for metatuff and greenstone gave average values of 31.36% and 28.25% respectively. EI for both aggregates thus greenstone and the metatuff were 38.5% and 33.28% respectively. On the basis of the results obtained from conducting the mechanical property tests on the greenstone and metatuff respectively, i.e the ACV (13.47% and 9.77%), AIV (7.27% and 6.61%) and LAA (17.48% and 15.76%). average water Absorption test resulted in values of 0.26% and 0.13% for the greenstone metatuff respectively and specific gravity values of 2.566 and 2.344. The Load required for the production of 10% fines was 320KN and 330KN for greenstone and metatuff respectively. The results obtained were compared to the standard given by the “Standard specification for road and bridge works” by the Ministry of Transportation, Republic of Ghana and this showed the material to be competent for use as chippings in surface dressing road works.

703 - Petrogenesis and chemostratigraphy of the Central Sturgeon assemblage, Sturgeon Lake greenstone belt, Ontario

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Greenstone belts throughout the Superior Province are dominated by mafic volcanic rocks that can provide critical information regarding tectonic and geodynamic setting. Understanding geodynamic settings is important as it provides context for mineral deposit formation and metal endowment. Mafic-dominated volcanic strata can host an array of mineral deposits, such as volcanogenic massive sulphides (VMS), but also can be metal poor. Extensional submarine environments with hydrothermal activity is great for forming VMS deposits while dry igneous environments, such as subaerial volcanic arcs, are not. Once the right metal-forming environment is confirmed, then finding potentially metal-endowed horizons can be difficult because the mafic-dominated strata is relatively homogenous in the field. This study uses transect mapping and chemostratigraphy to identify geodynamic settings within the mafic-dominated Central Sturgeon assemblage of the Sturgeon Lake greenstone belt. Spatial variation of geochemical characteristics helps identify different tectonic environments and potentially link these to potential metal forming events. Preliminary field results show that iron formation horizons represent the most prospective stratigraphic horizons as they are a result of hydrothermal events and can be associated with Archean VMS deposits. Pairing these with hydrothermal alterations within mafic rocks, such as the presence of quartz epidote alteration, in the field is key to recognizing an ancient extensional submarine environment. Geochemical proxies for geodynamic setting, such as Nb/Th, La/Yb, or Th/La ratios, will help identify prospective horizons that are not marked by obvious lithologic horizons. CFREF-Metal Earth Project Contribution MERC-ME-2020-037.

704 - Petrographic and paragenetic study of uranium mineralization along the Midwest Trend, Northeastern Athabasca Basin, Saskatchewan, Canada

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The Athabasca Basin in Northern Saskatchewan is host to many world-class uranium deposits associated with the unconformity between the Paleoproterozoic sandstone of the basin and the underlying crystalline basement. While the style and tonnage of these deposits vary, the current genetic model for unconformity-related uranium deposits has been a practical tool for exploration in the Athabasca Basin. However, the factors which control the location and formation of these deposits is still not fully understood. A paragenetic and petrographic study of mineralization along the Midwest Trend, located on the northeastern margin of the Athabasca Basin, aims to refine the current model and to address the general problem: What are the factors which control mineralization and non-mineralization? The

Midwest Trend will be used as a "modèle réduit" for uranium mineralization, as it displays many features characteristic of unconformity type deposits. The Midwest Trend comprises three mineral leases which encompass two uranium deposits, the Midwest Main deposit and Midwest A deposit. Mineralization occurs along a NE trending graphitic structure, and is hosted by sandstone, at the unconformity, and in much lesser amounts in the underlying basement rocks. Petrographic observations aided by the use of RAMAN spectroscopy and SEM-EDS, have been used to create a paragenetic sequence of mineralization. Future work will focus on fluid inclusion studies using microthermometry, LA-ICP-MS, and volatile mass spectrometry.

705 - Reaction processes and element mobilization in aluminous slags from the St. Lawrence Columbium Mine, Oka, Quebec

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The former St. Lawrence Columbium Mine (Oka, Quebec) used an aluminothermic reduction of pyrochlore-group minerals by adding iron oxide, aluminium and accessory fluxes (CaO, CaF_2, $NaClO_3$, BaO) to produce ferroniobium. A byproduct of this process were aluminous slags, whose composition reflects the remaining pyrochlore components (Ca, REE, Na, Ti, Ta, Zr, U, Th) and the additional compounds used during smelting (Ca, Al, F, Cl, Na, Ba). Such slags were discarded in waste piles and exposed to natural weathering processes. Alteration of primary phases present within these slags (i.e. grossite [$CaAl_4O_7$], hibonite [$(Ca,Ce)(Al,Ti,Mg)_{12}O_{19}$], REE- and Zr-bearing perovskite [$(Ca,REE)(Ti,Zr)O_3$], fluorite [CaF_2], anorthite [$CaAl_2Si_2O_8$], several unidentified phases and glass) by chemical weathering leads to the formation of hydrated secondary minerals and mobilization of elements, some of which may be hazardous to the environment. However, the key processes which control the generation of these secondary phases are poorly understood. The aim of this study is to shed more light on these processes. Primary and secondary phases in slag particles previously immersed in simulated rainwater (for ca. 200 days) were examined using transmitted and reflected light microscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD) to determine phases and their composition. The differences in composition between primary and secondary phases are key to understanding the reaction processes occurring within these slags, which can be used to trace the potential mobilization of various elements during weathering and alteration. Hydration alteration of primary phases results in the mobilization of elements such as Ca, Si, LREE, and HFSE (Ti, Zr, Nb, U, Th), leading to the generation of secondary hydrous phases of heterogeneous composition. Glass, grossite, and anorthite are observed to alter more readily than more resistant phases like hibonite and perovskite. The findings of this study should provide a better understanding of the alteration processes in aluminous slags, and provide valuable information on the environmental impact should mobilized elements be leached from the slag.

706 - Use of offshore geophysical data to target mineral resources on land

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Mapping of geological structures on islands and coastal areas is restricted to the small exposed footprint of these localities. However, these regions have an abundance of offshore geophysical data, often acquired as part of petroleum exploration. These datasets provide a broader image of the geological and structural background when coupled with onshore mapping. This project presents a test case from the Fiji Platform in the Southwest Pacific. Fiji is host to numerous mineral deposits, including the 14.7 Mt, 8.1g/t Au Emperor alkaline-epithermal deposit and the Namosi porphyry-Cu district. Fiji was originally formed in the middle Eocene as part of the Vitiaz arc, along the Pacific and Indo-Australian convergent margin. Late Oligocene collision of the Ontong-Java Plateau resulted in cessation of volcanism, compression, and synorogenic plutonism. Continued convergence produced a reversal in arc polarity, followed by back-arc rifting and counter clockwise rotation of Fiji. Peak rotation at 5.5 Ma coincides with a transition to shoshonitic volcanism. Major alkaline epithermal gold deposits in the region have been found proximal to late shoshonitic and high-K volcanic centres. However, much less is known of the spatial and genetic relationship between the mineral deposits and major regional structures. Current metallogenic maps and models are based on subaerially exposed crust, which represents only 20% of the area of the Fiji Platform. Preliminary results from a compilation of offshore data with structures mapped on land show that mineralized volcanic centres, represented by gravity highs, as well as major faults throughout the Fiji Islands, form a linear ENE-WSW trend parallel to extensional structures bounding the Bligh Water Basin north of Viti Levu. These structures are also parallel to the Fiji Fracture Zone, a major transform boundary located on the northern boundary of the Fiji Platform with short spreading-centre segments northwest of Vanua Levu. The new structural map highlights new areas with a greater potential for mineral endowment south of Vanua Levu. This proof-of-concept demonstrates a new approach to data integration in areas where offshore petroleum data can be incorporated into land-based mineral exploration. CFREF-Metal Earth Project Contribution MERC-ME-2020-020.

707 - Hotspots analysis of trace elements in areas affected by illegal mining activities: A case study at Mpatoam at Amansie West District of Ghana

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Elements distributions and concentration levels in surface environments are able to reveal spatially terrains enriched in disease-causing-elements and essential elements deficiency areas. Both scenarios of elements toxicities and deficiencies have health implications to humans. The study area has seen numerous illegal mining operations that will influence elements mobility and concentrations, but how far this has gone is unknown. The study's results show from samples collected at the alluvial plain areas with control samples from elevated area embankments that some elements including As were elevated while others like Zn were depleted. The results processed using multivariate factor analysis indicated that PCA 1 representing As-group has relationship to the underlying geology. It thus suggested that As and Cr toxic in kind have their source link to the geology whose spread are facilitated by mining activities. PCA 2 contains essential elements whose sources are from the local geology. The results of the surface geochemistry in comparison with the continental crustal averages (Bn) showed the toxicity of As, Cr, V, Zr, Ni and Mo from the CF and PLI analysis. These also showed Cu, Zn, Pb, Rb, Sr, Ba and Nb were deficient. Igeo value for As indicated moderate pollution while the 12 other elements were marked as unpolluted to moderately polluted. The spatial maps for As transformed data indicated Hotspots for

As and Cr at all points with highest values from active points for As. Zn generally indicated cold-spots. These results demonstrate that the disease-causing elements and essential elements based on their distribution and levels in the area will affect the health of the people around. This opens up a call for further investigation on water and food crops on which the people depend in the area.

708 - Trace element mobility in framboidal pyrite using the 3D imaging technique of atom probe tomography

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Pyrite is of interest to many researchers in the field of economic geology because it is closely related to several ore deposit types, including: porphyry deposits, epithermal deposits, volcanogenic massive sulfide (VMS) mineral deposits, sediment-hosted gold deposits, and orogenic gold deposits. Trace element composition in pyrite is used to interpret paleoenvironmental conditions, determine the origin, timing, and conditions of ore forming fluids, and as a vectoring tool for mineral exploration. The samples that are analyzed in this study are pyrite framboids from the Cariaco Basin (Early Miocene-Holocene) and Demerara Rise (Cretaceous). These samples are unmetamorphosed and from euxinically deposited sediments at two times (modern and proto-Atlantic) when the ocean conditions are relatively well understood and sampled. In this study we utilize atom probe tomography (APT) to determine how trace elements are held within pyrite when formed in the ocean. Previous studies that investigated this problem utilized analytical techniques such as laser ablation-induced coupled plasma- mass spectrometer (LA-ICP-MS); however, the results of these studies cannot conclusively determine between pyrite lattice substitution or evenly distributed nano-inclusions. With the use of the unique 3D, atomic scale imaging technique of the atom probe, this study reveals with more accuracy which trace elements are incorporated into the pyrite lattice and which are evenly distributed as nano-inclusions. Our results reveal the heterogeneous distribution of trace elements throughout pyrite framboids as well as the association of trace elements with each other. The results of my research will further the knowledge of trace element incorporation into framboidal pyrite and will advance our understanding of the evolution of the paleo-ocean chemistry in these basins.

709 - Evaluating muscovite as an indicator mineral in lithium bearing pegmatites, Wekusko Lake, central Manitoba

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The increased focus on renewable energies and battery technologies have led to an increased use of lithium (Li) batteries. As a result, there is an increased demand for high grade Li. The two dominate sources of Li are currently pegmatites (i.e. Greenbushes, Australia) and brines (i.e. Salar de Atacama, Chile). In Canada, the main source of Li is Li-Cs-Ta (LCT) pegmatites such as the world-class Tanco deposit in Manitoba and the Whabouchi pegmatite in Quebec. These pegmatites are also enriched in rare metals such as Niobium, Tantalum, Rubidium, Tin and Cesium. Lithium can be obtained from different minerals, including spodumene, petalite and Li-bearing micas. This project investigates the potential use of muscovite as an indicator mineral within Li-bearing pegmatites and the potential of field portable techniques, such as Raman spectroscopy and Laser Induced Breakdown Spectroscopy (LIBS), and real-time result in exploration. The studied pegmatite swarm, in Wekusko Lake, Manitoba, Canada, displayed five zones of varying mineralization. The muscovites analysed using Laser Ablation Induction coupled Plasma Mass Spectroscopy (LA-ICP-MS) and Electron Microprobe Analysis (EMPA) show a strong correlation in Li-content to the whole rock LiO_2 obtained from the assays of drill core. The K/Rb vs Cs of the muscovites show a range of from highly to minor chemical evolution. The most prospective dikes are moderate to highly evolved. Muscovite also have a high concentration of Nb (250-1000 ppm) and Ta (100-400 ppm). This range has a strong correlation to rare metal concentrations of the micas. The use of portable Raman spectrometry, while useful for mineral identification, was not able to detect a significant Li signature at the concentrations tested (1500-6000 ppm). The use of portable LIBS to detect Li contents within muscovite is a promising technique. It is being used successfully in Australia to map the Li concentrations of spodumene in pegmatites. The use of field portable techniques and real-time results in exploration will provide geologists with powerful tool for more effective drilling and field exploration.

710 - A study of thallium isotopes from the Leeville Carlin-type gold deposit, Nevada, USA

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Carlin type gold deposits are commonly associated with a suite of pathfinder elements consisting of arsenic (As), mercury (Hg), antimony (Sb), and thallium (Tl). These elements typically form broad anomalies around these deposits but provide little information about proximity to, or the tenor of gold mineralisation. This study presents thallium isotope data collected from 205 samples collected from the Leeville Carlin-type gold deposit. These data exhibit a range of ε205Tl values ranging from -17.4 to +7.2. Samples exhibiting heavier ε205Tl isotope values correlate with samples with highest Au, Tl, Sb, As and Hg. Samples exhibiting the lightest ε205Tl isotope values correlate with samples with highest potassium, rubidium and caesium. These results support that Tl isotopes in Carlin type gold deposits fractionate based on paleo-redox state as reduced monovalent Tl^{+1} or oxidized trivalent Tl^{+3}. Reduced Tl^{+1} has similar bonding behavior as potassium, and oxidized Tl^{+3} has a chalcophile behavior. Results from this study suggests that Tl isotopes can be used as an exploration tool to discriminate reduced Tl associated with distal potassic alteration from that of oxidized Tl associated with sulphide minerals proximal to mineralization.

711 - Bioleaching potential of Co from alkaline tailings in Northeastern Ontario

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Bioleaching is a green, efficient, and cost-effective technique to extract metals from low-grade mine waste. Most research on improving bioleaching extraction methods for mine waste has focused primarily on acidic rather than neutral to alkaline mine tailings, such as those found at a legacy mine camp in Northeastern Ontario, which are characterized by Co and Ag-bearing carbonate veins. Sixteen tailings sites were generated, as a result of mining, comprising high concentrations of metal(loid)s such as arsenic (As), cobalt (Co) and antimony (Sb). Three tailings sites were chosen for this particular study (sites A-C), for their elevated concentrations of the metal(loid)s of interest. Within these tailings, As and Co are in close association in the form of arsenates, arsenides, and sulpharsenides. Secondary Co-As-bearing minerals are the result of various weathering processes occurring within the tailings material. Here, we present data on the microbial, chemical, and mineralogical composition of the tailings and how these might impact re-processing through bioleaching. The microbial composition of the tailings is dominated by Proteobacteria and Actinobacteria, with several metal-cycling, neutrophilic genera (e.g. Sphingomonas and Gaiella). Interestingly, less abundant Acidobacteria are also present, although they do not have optimal growth conditions above a pH of 5.5. In site C, a higher proportion of Acidobacteria along with neutrophilic sulfur-oxidizing bacteria (e.g. Sulfurifustis sp.) occur within layers that have a higher abundance of secondary arsenates over primary arsenides. The former layers have a higher chemical index of alteration (CIA), which correlates with a higher As concentration and lower iron concentration. In site C, samples having a higher CIA results in a higher average As valence, therefore a higher proportion of secondary arsenates to primary arsenides is observed. The opposite is seen in sites A and B where a higher CIA corresponds to a lower average As valence, thereby showing a higher proportion of primary arsenides to secondary arsenates. Samples from each tailings profile, with the highest concentrations of the metal(loid)s of interest will be chosen for bench-scale bioleaching experiments. The tailings indigenous bacteria will be used in the bioleaching experiments in media that supports either arsenide-oxidation or arsenate-reduction. The chemical results of the leaching experiments will be presented. This project hopes to contribute to “green” mining methods by producing an economically feasible method of metal extraction from these types of non-acid generating tailings materials, while simultaneously cleaning up the environment.

712 - Developing a foundational metamorphic model for the Onaman-Tashota greenstone belt, eastern Wabigoon Subprovince, Ontario

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The Onaman-Tashota greenstone belt (OTGB) of the eastern Wabigoon subprovince dominantly consists of Meso- to Neoarchean tholeiitic to calc-alkalic mafic to felsic volcanic rocks, and minor unconformably

overlying metasedimentary rocks. The assemblages vary in metamorphic grade from mainly greenschist to locally lower, middle, and possibly upper amphibolite facies. Previous mapping of the belt focused on its general geology and styles of mineralization, but key uncertainties remain in the nature and timing of metamorphism with respect to regional deformation, pluton injection, and shear zone activity, limiting our knowledge of the events that lead to its present day architecture. This study aims to unveil the detailed metamorphic history of the OTGB by differentiating between regional and contact metamorphism, and relating these events to deformation. To accomplish this task, a series of traverses across mafic metavolcanic and minor metasedimentary packages towards several plutons were completed across the belt in order to observe changes in metamorphic mineral assemblages and to identify the loci of metamorphic isograds. Three preliminary trends were observed in the metamorphic conditions of the belt: 1) Local garnet-in isograds surround major plutons within the mafic metavolcanic rocks. 2) Seemingly regional-scale garnet+hornblende-in and garnet+staurolite-in isograds occur within mafic metavolcanic and metasedimentary rocks in the northernmost part of the belt, respectively. 3) Garnet-in and/or hornblende-in isograds occur westward along strike of a major, predominantly lower greenschist facies shear zone within metasedimentary, mafic metavolcanic, and felsic to intermediate pyroclastic rocks. The mafic metavolcanic rocks develop into gneisses in the westernmost part of the shear zone. Detailed petrography will help to refine mineral assemblage changes and mineral-fabric relationships to determine the relative timing of metamorphism in these areas. Where applicable, U-Pb geochronology of accessory minerals such as monazite, titanite, zircon or xenotime will establish the radiogenic age of metamorphic and deformation events. Additionally, P-T phase equilibrium modelling using pseudosections will aim to differentiate between regional and contact metamorphic events, and contribute to our understanding of the metamorphic history of the greenstone belt. CFREF-Metal Earth Project Contribution MERC-ME-2020-013.

713 - Deformation bands and their relationship to faults associated with unconformity-related uranium deposits; a case study and comparison of the C1 and WS fault zones in the eastern Athabasca Basin

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In northern Saskatchewan, world-class uranium deposits are associated with the unconformity between the Proterozoic Athabasca Basin and underlying Archean-Paleoproterozoic basement rocks. Many deposits exhibit a strong spatial association with post-Athabasca faults formed by reactivation of basement-rooted structures. Deformation bands are products of localized strain in highly porous sediments and are commonly associated with fault damage zones; they can modify porosity due to grain rotation and granular flow and can act as fluid baffles or conduits. In this study we investigate deformation bands in the sandstones of the basal Manitou Falls Group in eight drill-hole fences transecting two prominent fault corridors in the eastern Athabasca Basin: the NNE-trending (025°–035°) C1 fault corridor, which comprises three main faults (Offset, G, and Basal) and hosts the Gryphon deposit; and the WS shear zone, one of several faults defining a 055°–060°-trending splay of the main C1 trend, and which hosts the Phoenix deposit. Our results indicate that compaction and cataclastic bands increase in abundance close to projected damage zones, and are especially evident in the hanging wall

of the faults. The proportion of cataclastic bands also increases with depth. Paleostress analysis performed using orientation data from basement and sandstone-hosted brittle structures from respective corridors identified two major stress regimes. In the first case (Stress regime A) σ1 and σ3 lie in the horizontal plane, consistent with strike-slip faulting, and σ1 is perpendicular to the strike of the corridor. For this regime, σ1 shifts in orientation from the C1 to WS corridors, in each case maintaining a roughly perpendicular relationship to the fault. The second case (Stress regime B) is also compatible with strike slip motion, but in this case σ1 lies close to parallel to the fault; a similar adjustment in stresses to the local fault orientation is also observed. While theoretically strike-slip, the first of these regimes (A) would have been favourable for reverse/thrust reactivation of pre-existing basement-rooted structures, and this is independently corroborated by reverse offset of the unconformity, especially along the C1 corridor. Stress regime B may have been associated with younger sinsitral strike-slip motion but supporting evidence is lacking. Under a given regional stress regime, it thus appears that pre-existing basement-rooted faults exerted a strong influence on the local stresses encountered in each corridor and controlled deformation. Further work aims to improve understanding of deformation band genesis its relationship to faulting and fluid movement associated with uranium mineralization.

714 - The Structural Evolution and Controls on Gold Mineralization in the Tashota Shear Zone, Northern Onaman-Tashota Greenstone Belt

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The Tashota Shear Zone (TSZ) is a north-striking, ductile geological structure within the eastern Wabigoon subprovince of the Archean Superior Province in northwestern Ontario, Canada. The TSZ has never been studied in detail, despite its location along a Mesoarchean-Neoarchean assemblage boundary, its north trend in a belt where most shear zones trend east-west, and the presence of gold mineralization. The objectives of this study are to determine the nature of the Mesoarchean-Neoarchean assemblage boundary and its relationship to the TSZ, and to unravel the sequence of deformation events overprinting this contact. Furthermore, we aim to determine the relative timing and structural controls on gold mineralization and characterize its alteration mineral signature and geochemical footprint. The TSZ underwent 3 deformation events. The D_1 deformation event resulted in the formation of tight to isoclinal F_1 folds defined by folded dikes and veins, a continuous, axial planar S_1 cleavage expressed by amphibole, chlorite and micas, and the flattening of pillows and clasts.The S_1 foliation appears to wrap around a nearby granitoid intrusion, and an L_1 stretching lineation, which is defined by elongate clasts and phenocrysts, typically plunges in a radial pattern away from the intrusion. During the D_2 deformation event, F_1 folds and S_1 cleavage were folded by tight, asymmetrical S-shaped F_2 folds with a continuous, axial planar S_2 cleavage defined by amphibole, chlorite and micas. The D_2 deformation event also resulted in the formation of an L_2 mineral amphibole lineation. The D_3 deformation event is manifested by an S_3 crenulation cleavage. Gold mineralization is associated with V_1 quartz-ankerite-sericite--chlorite-tourmaline-pyrite-chalcopyrite-gold veins.. V_1 veins are intensely deformed, boudinaged, tightly to isoclinally folded by F1 folds, and locally refolded by F2 folds, suggesting that they formed prior to or early during the initial formation of the TSZ during the D_1 deformation event. CFREF-Metal Earth Project Contribution MERC-ME-2020-011.

715 - 3D geological modelling of the northern Swayze greenstone belt: Assisting mineral exploration by mapping controls on gold (Au) deposits

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With the recent development of computer technology, geological modelling software has evolved from flat 2D mapping to enhanced 3D representations, vastly improving data visualization. 3D modelling facilitates the integration and interpretation of multi-disciplinary data and their extension through surface tessellations, allowing unprecedented visualization of subsurface geology. Specifically, 3D geological modelling can be described as the reconstruction of a volumetric model comprising a collection of geological objects (faults, lithologies, contacts, others) and their topological relationships that define the subsurface geology. This study aims to integrate lithology, structural orientations and seismic interpretations in 3D to produce detailed geological models that will assist in elucidating the structural and geological aspects of the northern Swayze area (interpreted as a plausible extension of the Abitibi Greenstone Belt) and their statistical correlation with known gold mineralization. The modelling can unravel the 3D multiscale controls on mineralization such as dependency on fault distribution, geometry, and represented lithological contrasts and geochemical trends. The northern Swayze area is one of the oldest Neoarchean granitoid-greenstone terranes that developed between 2.8 and 2.6 Ga. It represents the westward extension of the mineral-rich Abitibi Greenstone Belt of the Superior Province, which comprises mafic-felsic intrusive and extrusive rocks as well as clastic and chemical sedimentary rocks. The belt is composed of precious and base metal deposits hosted within the mafic-felsic rocks, with gold (Au) deposits being the widely explored deposits. Despite the Abitibi link, the Northern Swayze economic viability is questionable due to the greenstone-hosted deposits being mostly low-grade, large-tonnage types. Mineralization is localized in epigenetic vein systems, closely associated with ductile deformation zones. To provide insight into the relationship between these geological features and gold endowment in the area, 3D implicit geological modelling software such as Leapfrog Geo is being used to simulate a variety of structural scenarios allowing for the rapid construction of multiple geological models in 3D. Implicit modelling uses a single mathematical function such as radial basis function to construct surfaces and volumes. The preliminary correlation analysis of the gold mineralization in respect to a spatial association to the regional faults indicates that gold occurrence points occur within the range of 0-500 m, with minor exceptions, occurring at ranges of 2000-2500 m. A closer observation between the intersecting faults indicates strong control over the distributed gold mineralization. Such observations and analysis are critical in unravelling the complexity of the northern Swayze area in order to produce a reliable geological model. CFREF-Metal Earth Project Contribution MERC-ME-2019-142.

716 - Geostatistical analysis and integration of soil chemistry data with remote sensing information in the Greater Sudbury area, Ontario

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Soil contamination by trace elements is one of the most prominent environmental problems in the Greater Sudbury area, owing to the historical mining of Ni, Cu and secondary PGEs concentrated in the Sudbury Igneous Complex. Ni and Cu are the primary metallic contaminants in the Sudbury soils, with anomalous concentrations (Ni: 5.3-2149.0 mg kg^{-1} and Cu: 11.4-1891.0 mg kg^{-1}) as compared to the worldwide averages of uncontaminated soils, at background levels (Ni: 25 mg kg^{-1} and Cu: 12 mg kg^{-1}). This study presents ordinary kriging (OK) prediction maps of soil samples produced using the 2001 Sudbury Soils Survey data, to re-evaluate the spatial distribution of trace metals. We implemented trend analysis to assess how kriging interpolations assist with the unraveling of natural processes, influencing geochemical patterns. Estimating trends and geospatial distributions of metal contamination can be challenging due to the sparsity of information, making classical statistics inadequate as it only focuses on the sampled sub-population. A kriging geostatistical approach addressed this problem, by considering the distance separation between samples and predicting the distribution of values regionally, to fill data gaps. As expected, results showed an anomalous distribution of metals centered on historic smelters. A series of trends were depicted and interpreted as being the result of processes operating at different scales. Some trends support atmospheric deposition as the main driving force, as observed by previous studies, with geology having little effect. Satellite (multispectral and multitemporal Landsat 8 imagery) data is being compared with the results of the geostatistical analysis (OK) to assess the relationship of vegetation regrowth or change with variable degrees of soil contamination. The approach considered a spectral index referred to as Normalized Difference Vegetation Index (NDVI) to represent vegetation change at different times yearly (from 2013 to 2019, analyses compared the same months to account seasonality). Around the vicinity of the significant smelters, visible semi-barren areas indicate a definite trend of increasing NDVI values suggesting vegetation recovery; however, the vegetation is denser elsewhere (this can be attributed to liming and reforestation practices). Increasing NDVI values with moving distance from the smelter regions suggests a correlation of vegetation patterns with those depicted using OK predictions. Re-evaluation of the regional, geospatial distribution of the measured trace element concentrations will assist the monitoring and improved understanding of soil contamination trends and their impact on vegetation and other aspects of the biosphere in the Greater Sudbury area.

717 - Origin of mafic-ultramafic volcanic rocks in the northern Pontiac subprovince, Quebec, Canada

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The Pontiac subprovince is an Archean sedimentary terrane located south of the Abitibi subprovince in Quebec, comprising ~2682 Ma turbidites, felsic to intermediate plutons, and thin, but laterally extensive units of mafic and ultramafic volcanic rocks. The sedimentary successions comprise muddy sandstones to siltstones with minor conglomerates and graphitic argillites. The volcanic succession successions consist of flows and sills that exhibit a bimodal lithogeochemical profile with Fe-rich, NMORB-type basalts [La/Sm ≈ 1.1] and Al-undepleted (Munro-type) komatiites [Al/Ti = 6.8 to 20.7]. Previously, these successions were interpreted as allochthonous slices, emplaced through south-verging thrust faults and genetically unrelated to the Pontiac Group sediments. Detailed mapping of the area around Bellecombe, Quebec, identified peperite in the contact zone between the volcanic and sedimentary packages. The

peperite comprises fluidal and blocky clasts of mafic-ultramafic igneous rock within bedded and massive sedimentary rocks. This texture suggests that mafic-ultramafic magma intruded into wet, unconsolidated sediments, and is inconsistent with a syntectonic origin. Interlayered basaltic flows and sedimentary beds were also observed at the margins of the volcanic package. The volcanic-sedimentary contact zones that lack these features display, for the most part, no localized shearing and are interpreted as primary contacts. These field relationships, supported by whole-rock geochemistry and petrographical observations, suggest that volcanism was contemporaneous with Pontiac sedimentation, marking a previously unrecognized episode of extensional volcanism around 2682 Ma. This interpretation is compatible tectonic models where the Pontiac subprovince formed as an exotic arc terrane that subsequently underthrusted the Abitibi subprovince or, formed between two ribbon-like microcontinents (i.e. the Abitibi subprovince and an unknown arc terrane) followed by rapid underthrusting during a mantle-overturn event. The findings presented here may also provide insight into the origins of other analogous, but mostly understudied Archean sedimentary terranes such as the Quetico and English River subprovinces in Northern Ontario. CFREF-Metal Earth Project Contribution MERC-2020-042.

718 - Tracing the origin of metals and fluids in the enigmatic Ag-Co-Ni-As-Bi deposits of Cobalt, Ontario

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Cobalt, Ontario, is Canada's premiere Ag producing district with over 460 Moz of Ag produced (1904-1989; peak in 1911) from deposits of the enigmatic five-element association (Ag-Ni-Co-As± (Bi, U)). The recent emergence of Co as a critical metal needed for a variety of high-technology industries (e.g., high quality batteries) has refocused exploration on this deposit type globally, including the Cobalt area. Previous work at Cobalt emphasized Ag, but here we focus on the nature and distribution of the Co ore. This project aims to constrain the timing and physio-chemical characteristics of the mineralizing fluids and the mineral paragenesis of ore samples by: 1) investigating regional metal zonation using metal assay values across the Cobalt camp; 2) extending fluid inclusion and stable isotopes (C, O) studies across the area; 3) assessing the spatial and temporal relationships between mineralization and altered host rock; 4) and determining the absolute age of fluid flow. Preliminary results from detailed petrography, and SEM-EDS imaging and analysis, suggest re-interpretation of mineral paragenesis of the five-metal-association type deposits is required. This implies modification of our current understanding of the geochemical evolution of mineralization. In-situ secondary ion mass spectrometry (SIMS) isotopic analyses (S, O) of mineral phases, in addition to conventional methods, will complement earlier studies, but with the greater spatial resolution offered by SIMS this may better constrain fluid reservoirs and temperatures. Detailed fluid inclusion studies using samples from numerous vein systems will be carried out to assess possible regional PT trends of the hydrothermal fluids and how these trends might relate to regional metal zonation. Preliminary petrography revealed the local presence of low-density fluids suggestive of fluid unmixing. The absolute age of mineralization will possibly be constrained using in situ LA ICP-MS U-Pb dating of syn-mineralization carbonates. These data will collectively be used to re-evaluate both the deposit type and Cobalt specific ore deposit models to aid in further exploration of the district. CFREF-Metal Earth Project Contribution MERC-ME-2020-026.

719 - Characterization of Co-Ni bearing polymetallic vein occurrences in Meguma Terrane metasediments, Nova Scotia

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Three unique polymetallic vein hosted occurrences have been identified in Nova Scotia's Meguma Terrane featuring various combinations of the elements Co-Ni-As-Sb-Pb-Zn-Cu-Bi-Ag-Au. Current research is aiming to understand the source of metals and fluids in these occurrences to provide a mechanism for mineralization within a regional context. Mineralization is hosted within quartz or quartz-carbonate vein stockworks, often with notable proximity to mafic dykes and sills. Field work has identified these mineralized zones and further petrographical and microanalytical techniques have provided a working paragenesis and characterization for each of the occurrences. There has yet to be a concerted exploration effort in Nova Scotia directed at the potential for deposits of this unique elemental association, but this project aims to direct these efforts forward.

720 - The Proterozoic Morro Agudo Pb-Zn District, Minas Gerais, Brazil: Stratigraphic, mineralogical and lithogeochemical constraints

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The Morro Agudo sulfide Pb-Zn district comprises the Morro Agudo Mine and three occurrences (Bento Carmelo, Sucuri, and Morro do Capão). The mineralization is hosted by Mesoproterozoic carbonate rocks of the Vazante Group in the northern part of the Vazante-Paracatu district in Minas Gerais, central Brazil. The processes related to the formation of the Morro Agudo deposit is controversial (coeval with sedimentation or with the Neoproterozoic Brasiliano Orogeny) and little is known about the other occurrences. This study reports the main stratigraphic, mineralogical and lithogeochemical controls on the various styles of mineralization in the Morro Agudo district. The primary ore minerals throughout the district are sphalerite and galena with hydrothermal dolomite, quartz, and pyrite. Throughout the district, mineralization is hosted mainly in dolarenite, brecciated dolomite, and locally in brecciated dolarenite and impure dolomites. The majority of ore in the lower orebodies at Morro Agudo occur as massive lenses, replacement, brecciated, disseminated or veins. However, mineralization in the upper-most orebody, N, is laminated with red chert and pyrite in an intercalated shale-dolomite sequence. Bento Carmelo and Morro do Capão contain sphalerite ± galena in quartz-carbonate ± pyrite veinlets dissecting the host rock; ore at Sucuri resembles Morro Agudo with coarse veins, replacement, and disseminated textures hosted predominantly by dolarenitic rocks. The molar Ca:Mg ratio of the dolomitic host rocks varies subtly between occurrences; Bento Carmelo has purest dolomite signature (mean Ca:Mg = 1.00), whereas, the other occurrences, especially at Morro Agudo (mean Ca:Mg = 1.13),

are magnesium-poor. The occurrences display varying degrees of silicification and pyritization prior to mineralization. Morro Agudo has greater concentrations of typical ore related elements Zn, Pb, Cd, Hg compared to the other occurrences. Sucuri has higher concentrations of As, Co, Cr, Cu, Ni, In, and Zr, which is a similar signature to the upper N orebody of Morro Agudo, which are related to pre-ore processes. Bento Carmelo typically has the lowest metal contents, and the host rocks are the least altered. The development of stratigraphic and lithogeochemical controls can be used to aid targeted exploration in similar base metal settings and assist in the reconstruction of the paleo-environment at the time of deposition. Further geochronological and provenance isotopic studies will help constrain basinal evolution and the timing of mineralization.

721 - Evidence for a new architectural interpretation of the Swayze area, Abitibi greenstone belt and its significance

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The Swayze area of the western Abitibi greenstone belt has the same lithostratigraphic metavolcanic episodes as the metal-endowed eastern Abitibi greenstone belt and should therefore, have the potential to host significant gold and base metal deposits. However, few deposits have been discovered, most of which are auriferous and small in comparison to the world class deposits of the eastern Abitibi. The reasons for this differential endowment have not been identified. New detailed bedrock and structural mapping, lithogeochemical and geochronological data, in conjunction with Metal Earth seismic and magneto-telluric geophysical surveys, has resulted in a new interpretation of the architecture of the Swayze area based on significant differences in the distribution of lithostratigraphic metavolcanics episodes. The most significant differences include: 1) an absence of Tisdale (2710-2704 Ma) aged metavolcanics rocks (which host many of the Timmins gold deposits) which indicates a prolonged hiatus in volcanism (6 Ma) not represented in the eastern Abitibi and therefore a different volcanic evolution; 2) an abundance of Pacaud (2750-2735 Ma) and Blake River (2704-2695 Ma) aged metavolcanic rocks. Although the abundance of the Blake River episode is favourable (357 Mt of VMS deposits in the eastern Abitibi), the absence of associated synvolcanic, subvolcanic intrusions that define magmatic/volcanic centres, a key component of VMS ore systems, is an important difference. 3) The continuation of the PDF and CLB transcrustal structures cross the Swayze belt, but do not, as yet, host a significant orogenic Au deposit. The 7.3 M oz Cote Au deposit, the only significant Au deposit in the Swayze area, is synvolcanic and occurs within the subvolcanic Chester intrusive complex (Pacaud) adjacent to the transcrustal Ridout Deformation Zone; 4) In eastern Abitibi, all volcanic episodes, except the Blake River, are floored by ultramafic rocks indicative of mantle plume interaction, crustal thinning due to extension and high heat flow, all favourable for VMS deposit formation, but , lacking in the Swayze area. The occurrence of ultramafic volcanic rocks in the Blake River episode attests to mantle plume activity, but late in the formation of the greenstone belt, and 5) the occurrence of volcanic episode bounding iron formations that are thick (up to 200 m with possible artificial thickening), extensive along strike (up to 20 km), continuous to depth of at least 3 km and that host significant, anomalous base metal mineralization, unlike those of the eastern Abitibi. These differences reflect a constructional volcanic history that was characterized by long volcanic hiatuses (+6 Ma), late plume interaction, lesser heat flow and cross strata structural permeability afforded by extensional faults, and lesser development of

volcanic/magmatic centres which, collectively, are detrimental to the formation of VMS base metal deposits. CFREF-Metal Earth Project Contribution MERC-ME-2020-031.

722 - Composition, origin, and history of regional fluid system responsible for Zn+Pb showings in the Cornwallis (Polaris) Zn-Pb district, Arctic Canada

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The Cornwallis district of Canada's Arctic archipelago hosts numerous carbonate-rock-hosted Zn+Pb showings with isolated anomalous Cu showings within its 450 km by 130 km area. Centrally located in the district is the past-producing, world-class Polaris Zn+Pb deposit (20 MT at 17% Zn+Pb). Like most districts with showings surrounding a large deposit, a relationship between the (large) deposit and the surrounding showings has been assumed. This study uses a multi-analytical approach with in-situ analyses, to determine the relationship among the mineralised areas with regards to the mineralising fluid's composition, origin, and history within the district. Petrography, fluid inclusion microthermometry, LA ICP-MS, SIMS, and evaporate mound analysis were done on sphalerite and dolomite gangue from representative samples of selected showings from throughout the district. Mineralisation throughout the district is not limited to specific strata or to faults, although the majority is hosted by the organic-rich Thumb Mountain Formation adjacent to faults. Fluid temperatures, salinity, composition, and oxygen isotopic composition are shared throughout the district; sulphur isotopes, conversely, are varied throughout the district, but consistent within each showing. Results indicate that a regional, marine-sourced fluid dissolved subsurface evaporites and transported metals and sulphate to sites of mineralisation. The different sulphur isotopes indicate mixing of sulphur sources between the regional fluid's sulphate and local accumulation of reduced sulphur. Mixing caused initial mineralisation with isotopically lower sulphur values and acted as an impetus for the initiation of TSR processes, which became the dominant sulphur source for mineralisation with heavier S isotopes. The volume of mineralisation is a function of the accumulation of pre-ore reduced sulphur, the ability to sustain TSR at a sufficient rate (i.e., supplying a reductant), and fluid flux. Polaris was successful because it was hosted by the organic (reductant)-rich Thumb Mountain Formation that is overlain by an impermeable seal to accommodate successful TSR, and being located at dilational faults with a high fluid-flux capacity.

723 - Assessing structural variability from geological and geophysical data in the western Wabigoon subprovince, Ontario, Canada

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In the early stages of mineral exploration, ground selection tools are applied to narrow search regions to prospective areas. Traditionally, exploration has relied heavily on manual, time-expensive, human

interpretation and the success or failure of a project depends on the experience of current geoscientist. Therefore, applying methods that are efficient in identifying geologic features while minimizing human bias from interpretation can increase the success of an exploration program. For orogenic gold deposits, integrating geological observations and geophysical datasets highlights structurally complex zones that may have acted as fluid pathways or traps and provides insight into regional-scale structural features. This study investigates the use of combined structural variability analysis in an Archean greenstone belt of the Superior Province, near Dryden, Ontario. Spatial variability of lithologies, strike and dip of bedding, and the trend of automatically detected linear magnetic anomalies were calculated. The resulting grids show regions of structural complexity where fluids may have been trapped, identify major deformation zones, and define regional fold traces. These results can be used to improve geological maps, characterize structural domains, and indicate favourable targets for base and/or precious metal exploration. Future work will include defining optimal grid resolution and search radius for variance calculations to identify targets and characterize regional structures accurately. CFREF-Metal Earth Project Contribution MERC-ME-2020-029.

724 - Genesis and localization of Ni-Cu-PGE mineralization in the North Range of the Sudbury Structure, Ontario

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The Sudbury Igneous Complex (SIC) hosts some of the world's largest Ni-Cu-PGE sulfide deposits. The ores occur primarily within magmatic breccias and brecciated footwall rocks along or near the basal contact of the structure or in radial and concentric offset dykes that extend into underlying footwall lithologies. Despite 135 years of research, the exact mechanisms of ore formation are still debated. Most current models explain the genesis of the ores by the exsolution of immiscible sulfides from the impact melt sheet, followed by gravitational settling and transportation into topographic embayments at the base by convective currents. However, this process cannot account for the strongly heterogeneous Pb-S-Os isotopic composition of the ores, nor can it explain the apparent discrepancy between observed metal tenors and metal depletion trends in the overlying igneous rocks. The aim of this project is to better understand the parameters responsible for the generation of contact-type Ni-Cu-PGE mineralization on the North Range of the SIC, large segments of which are well exposed on surface and in abundant diamond drill cores. We are testing an alternative model that includes 1) syn-impact devolatilization of S, Pb and other volatile elements from the impact melt, 2) post-impact thermomechanical erosion of footwall rocks to form embayments and troughs and to assimilate S from underlying footwall rocks and 3) formation of local sulfide and inclusion-rich xenomelts that continued to interact with the overlying melt sheet. Detailed sampling of drill core and outcrop sections through the Main Mass of the SIC on the North Range will help constrain metal mass balances in order to better understand the metal depletion and sulfide saturation history of the SIC. Detailed geological, petrographic and geochemical studies of Sublayer and Footwall Breccia will aid in determining their relationship to the sulfide mineralization and the mode and extent of thermomechanical erosion in forming ore-localizing footwall embayments and troughs, as well as in creating sulfide-inclusion-rich xenomelts at the base of the SIC. Ultimately, a better understanding of the processes involved in the

formation of the sulfide ores associated with the SIC will help to define better constrained vectors to mineralization, which will aid in discovering new deposits. MERC-2020-006.

725 - Mine-community relationships in north-eastern Ontario: A rigorous and critical review of literature

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This paper presents a rigorous literature review identifying and critically examining the characteristics of decision-making processes in the mining sector that empower or disempower Indigenous communities in north-eastern Ontario, specifically Treaty no. 9 territory. The conclusions drawn from this review aim to inform future research throughout my doctoral program and other researchers and practitioners within the mining sector. The Ring of Fire is a controversial but lucrative mineral cache in north-eastern Ontario worth an estimated $60 billion that may position nearby rural and remote communities for economic growth. However, critics caution that proposed mineral exploration and extraction in the region may threaten the sustainability of First Nations communities. Fifty secondary sources, academic and grey literature produced by both Indigenous and non-Indigenous authors, were reviewed and I propose three "myths" surrounding relations between the mining sector and Indigenous communities in Ontario. I position the synthesis of literature in response to these myths to provide insight into false assumptions that may form the basis of community-mine relations. First, critical examination of the signing of Treaty 9 in the early twentieth century shows that Indigenous communities in northern Ontario did not unilaterally cede and surrender title rights to their traditional territories. Second, the literature falsifies the notion that Indigenous communities are inherently anti-development and show that Indigenous communities do not always unilaterally refute opportunities for resource development. Third, the literature debunks the idea that the duty to consult and accommodate is always triggered before proponents infringe on Indigenous and treaty rights on traditional territory. The duty to consult and accommodate, triggered by the fiduciary duty of the Crown to protect aboriginal and treaty rights outlined in the Constitution Act of 1982, attempts to address the exclusion of Indigenous perspectives in decision-making processes within the mining sector. However, current consultation standards do not ensure an "effective" or "meaningful" decision-making process. Narrowing in on some false assumptions surrounding relations built between mining operations and Indigenous communities, this rigorous literature review can support researchers and practitioners working with Indigenous communities in the mining sector to generate novel approaches to community-mine relations in the future.

726 - The sources of Ediacaran phosphorite in South China: evidence from LA-ICP-MS

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Studies of Ediacaran marine sedimentary phosphorite in South China have lasted decades, scholars proposed some standpoints about ore-forming process. However, the sources of phosphorite were still unknown. The EMPA and LA-ICP-MS studies of Weng'an phosphorite in Central Guizhou were conducted to reveal the sources of phosphorus and other elements. We found that the P_2O_5 of phosphorite in lower layer (16.64%) is lower than that of upper layer (36.46%). LA-ICP-MS analysis indicate that in the francolite, the average content of P_2O_5, F and CaO were 41.97%, 54.11% and 3.70%, respectively. Both Sr and Ba contents of francolite are higher in upper layer (average 1414.32 ppm, 187.09 ppm, respectively) than that of the lower layer (average 790.44 ppm, 268.07 ppm, respectively). The Y/Ho of francolite in lower layer (average 39.42) are lower than that of upper layer (average 45.82). The ∑REY of francolite in lower layer have an average of 235.41 ppm, and the REE distribution is characterized by "left-inclining" shape. Whereas the ∑REY of francolite in the upper layer have an extensive range, majority of samples have an average of 20.39 ppm, minority of samples have an average of 240.60 ppm, and the REE distribution is characterized by "hat-shaped" shape. In addition, the P_2O_5 content of the phosphorite have positive correlations with the ∑REY of francolite, and both P_2O_5 and REE have little rangeability in lower layer, whereas have conspicuous rangeability in different samples of upper layer. Our results demonstrate that the Sr and Ba directly derived from the hydrothermal fluids, Y/Ho indicated the deep seawater contribution to sources. The transgressions were stable and remarkable during the earlier Ediacaran and invaded the shallow water environment, while during the later Ediacaran, the transgressions weakened, there might be weathering materials inputting leading to high REE in seawater and minor francolite. What's more, the consistent correlations between the Sr, Ba, REE and P_2O_5 indicate they shared same origin. So, we conclude that the mix of deep seawater and hydrothermal fluids served as main source of phosphorite, weathering materials have also been considered another source of later Ediacaran phosphorite. The study and results provide the evidence for the sources of metallogenic materials which is unsolved yet, with great theoretical significance. More studies should be conducted and more evidences should be given to put forward a complete metallogenic model in further research.

727 - Assessing the behavior of metals (Au-Ag-Cu-Zn-Pb) in mafic rocks during lower crustal metamorphism, Kapuskasing Structural Zone, Ontario, Canada

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Whole rock geochemistry of different migmatite components in granulite facies mafic rocks from the Kapuskasing Structural Zone (KSZ) suggests that partial melting of lower mafic crust can be an effective mechanism for economic metal recycling during crustal evolution processes. The KSZ is interpreted to be an uplifted portion of the intracontinental lower crust that exposes a transition from amphibolite to granulite facies towards the northeast, with a wide range of metamorphic mineral assemblages preserved. A variation in modal mineralogy at the outcrop scale defines different migmatite components: 1) *melanosome* composed of predominantly retrograde amphibole + garnet + clinopyroxene + plagioclase ± orthopyroxene ± quartz, 2) l*eucosome* composed of plagioclase + quartz ± garnet ± clino/orthopyroxene, where three different types are described in terms of the degree of separation from the melt production site (in-situ, in-source and leucocratic vein), and 3) *mesosome* composed of clinopyroxene + garnet + plagioclase + quartz ± orthopyroxene ± amphibole. Separation of

mesosome, melanasome, and in-source leucosome from granulite facies outcrops and whole rock analysis indicates that in-source leucosomes have higher Au-Cu and lower Zn (Au: 0.013 to 0.022 ppm, Cu: 470 to 620 ppm, Zn: 50 to 80 ppm) than the associated mesosome/melanosome, which contain lower Au-Cu and higher Zn (Au: 0.001 to 0.004 ppm, Cu: 10 to 50 ppm, Zn: 80 to 90 ppm). Previous studies have postulated that metamorphic devolatilization at the greenschist-amphibolite transition can explain the enrichment, segregation, timing, distribution and character of many mineralized Archean greenstone belts. However, this model accounts for liberation of metals at a lower metamorphic grade than that observed in the northern part of the KSZ. The preliminary results presented here suggest that economic metals are still available to be liberated during partial melting of the lower crust. Understanding such processes (i.e. partial melting and sub-solidus devolatilization) is critical for the interpretation of continental crustal evolution and the formation of some Precambrian ore deposits. Lower crustal processes need further evaluation to determine if metal recycling from the lower crust played a significant role in the formation of major orogenic gold deposits hosted in the upper crustal rocks of Archean greenstone belts. MERC-ME-2020-018.

728 - Mineralogical Implications of Sapphire from the Old Pressley Sapphire Mine, Canton, North Carolina

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The Old Pressley Deposit is an unusual syenitic pegmatite near Canton, North Carolina. The pegmatite is extremely aluminum-rich, with the main minerals consisting of 77.2% sodic plagioclase, 13.1% muscovite, 7.8% annitic biotite, and 1.9% corundum[1] with other accessory minerals including apatite, zircon, and microscopic sulfides and REE minerals. Here, we test the hypothesis that the pegmatite formed in the mid Ordovician era as a result of partial melting of metapelitic rock at around 8 kbar and ~850°C during peak metamorphism of the Taconic orogeny[1,2]. Further we are interested in understanding the behavior of incompatible elements during partial melting and their potential record in corundum minerals. The samples were analyzed through slab scale petrography, elemental mapping using a micro-XRF mineral analyzer (Bruker M4 Tornado), LA-ICP-MS, and SEM. Four sapphire samples with different colors, color hues, and/or those with the asterism effect required for cutting a star sapphire were analyzed in detail. Petrographic slab scale observations revealed parting in corundum, the presence of opaque and transparent mineral inclusions in corundum and a reaction rim of muscovite around corundum minerals. Trace elemental mapping of sapphire revealed zoning of Fe, Ti, and Ga, and an unknown Ba-Sr-bearing mineral phase that crosscuts sapphire. The LA-ICP-MS analyses of sapphire show minor concentrations of Fe (1147-1833 ppm), Ti (4.9-101 ppm, Ga (60-78 ppm), Mn (0.7-5.9ppm), Mg (0.6-4.7 ppm), and V (0.6-1.6 ppm) and trace amounts of Nb (0.04-2.4 ppm), Ce (0.01-0.27 ppm), Y (0.01-0.2 ppm), and La (0.01-0.2 ppm). The Ga/Mg ratios measured in Old Pressley Sapphire are similar to geochemical signatures of corundum formed through magmatic processes as opposed to corundum formed through metamorphic processes, that characteristically shows lower Ga/Mg ratios[3]. The SEM analysis identified various interesting trace microscopic minerals within the corundum, including pyrite, chalcocite, zircon, monazite, and a REE mineral (Nb-Ce-rich phase). Further analyses will involve XRD analyses of the unknown Ba-Sr-bearing mineral and U-Pb dating of zircon and monazite mineral inclusions in corundum.