16th Annual

PDAC - SEG Student Minerals Colloquium

POSTER EXHIBIT

March 2-5 2025

PROSPECTORS & DEVELOPERS ASSOCIATION OF CANADA

SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

Meet students and discuss their research!

Tuesday, March 4 • 10 a.m. - 12 p.m.
Trade Show North, Hall B

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Trade Show North, Northern Lights Learning Hub

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

METAL EARTH

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

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

The Colloquium highlights student research focused on innovative projects essential for the evolution of mining and mineral exploration. Since 2009, this event has featured more than a thousand presentations from BSc, MSc, and PhD students studying mineral deposits and related disciplines such as mineralogy, geophysics, geochemistry, hydrogeology, and sedimentology, to name a few. It provides a unique opportunity for industry professionals to discover and support student research related to the mining industry.

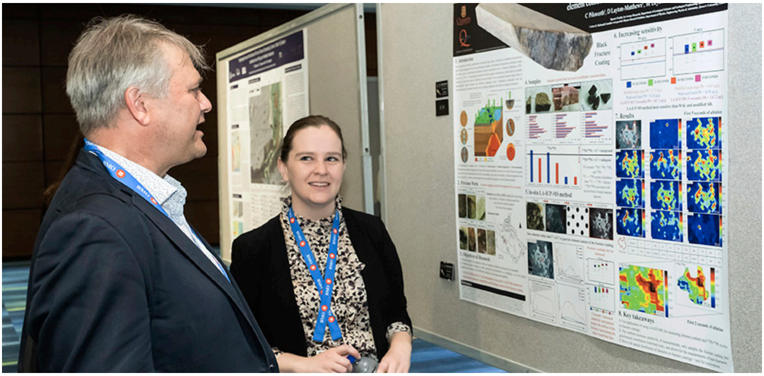
This would not be possible without continued support from our volunteer judges and generous funding from our named sponsors, the Prospectors & Developers Association of Canada (PDAC) and the Society of Economic Geologists (SEG). We also would like to thank past sponsors and volunteers who have contributed to our success, as well as this year's sponsors and student organizers from the Mineral Exploration Research Centre, Metal Earth, and the Harquail School of Earth Sciences at Laurentian University.

This year, we are pleased to showcase 80 participants from 29 universities across 13 countries.

All of the Abstracts are listed in this booklet and can also be viewed in the online Abstract & Poster Directory at this link:
pdac.ca/convention-2025/exhibits-2025/pdac-seg-student-minerals-colloquium-2025

Poster judging for the PDAC-SEG Student Minerals Colloquium will take place from **10:00 am - 12:00 pm on Tuesday, March 4,** followed by an **awards ceremony and reception** from **3:30 pm - 5:00 pm** at the **Northern Lights Learning Hub in Trade Show North, Hall B.**

Judges will select nine winners (1st, 2nd, and 3rd) from participants at the BSc, MSc, and PhD Levels. For details about this year's event, news and announcements, past winners, and more, visit ***merc.laurentian.ca/seg-smc****.*



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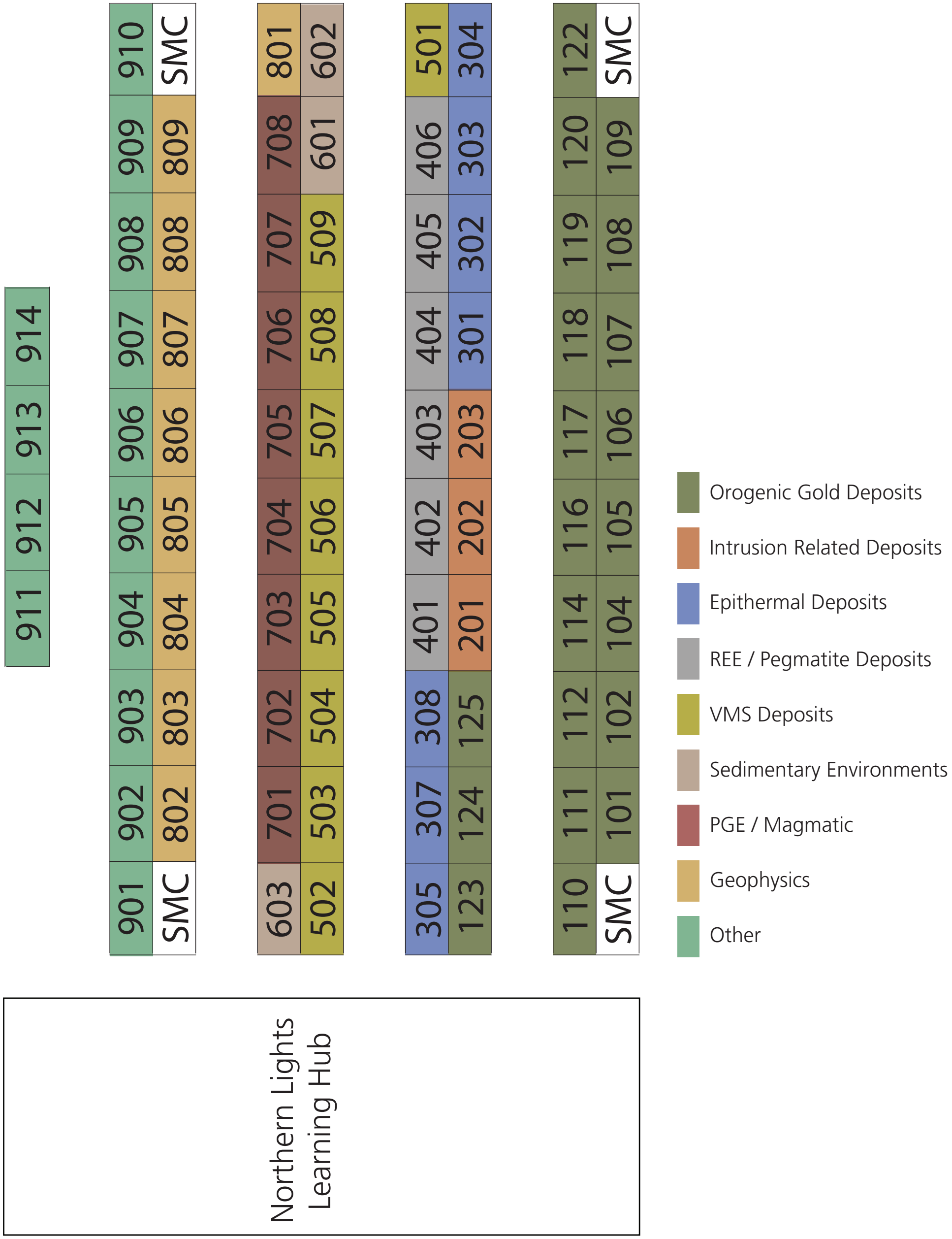

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Abstracts

MARCH 2-5, 2025
Metro Toronto Convention Centre (MTCC)

100 Orogenic Gold Deposits

101 **Oya Ak Kaykun - PhD**
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The Formation of the Young-Davidson Orogenic Gold Deposit

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The Archean Superior Province of the Canadian Shield is a key gold producer, accounting for approximately 88% of Canada's gold output. A significant area within this region is the Cadillac-Larder Lake Deformation Zone, located in the southern Abitibi greenstone belt in Northern Ontario. The Young-Davidson (YD) Mine, located in Matachewan, Ontario, represents the westernmost deposit in this zone. Gold at YD is primarily hosted in syenite, surrounded by a broad hydrothermal alteration halo. The main gold production targets are suphidized quartz-carbonate veins and sulphidized syenite veins associated with strong hematite alteration in the syenite. This study aims to refine the genetic model of the YD deposit and identify key evidence for gold precipitation through analyses at macro to micro scales.

This presentation highlights findings from the summer 2024 fieldwork, which included core logging and short wavelength infrared (SWIR) analysis of 17 drill holes across various sections of the ore zone. The samples represent diverse lithologies, mineralization types, and alteration zones. Preliminary analysis revealed that pyrite is the primary mineral associated with gold. Notably, high-grade gold is observed as inclusions within disseminated pyrite, particularly in areas with increased quartz veining. Additionally, assay results from the drill holes demonstrate a significant correlation between higher gold grades and increased pyrite mineralization. To identify controls on the formation and evolution of the Young-Davidson gold deposit, we performed a detailed investigation of pyrite textures (reflected light microscopy) and compared whole rock geochemical analysis and SWIR results.

The next steps will involve analyzing trace element content using LA-ICP-MS and sulfur isotopes (^{32}S, ^{33}S, ^{34}S) to identify the source of the gold and determine which pyrite generations are linked to gold mineralization. These investigations aim to enhance the understanding of gold precipitation from hydrothermal fluids in the region and to develop predictive tools for estimating gold grades before mining.

102 **Joleen Belanger - MSc**
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Tracking metamorphic P-T-t fluid evolution at the Great Bear deposit, Red Lake, ON, Canada

J. Belanger[1], D. Tinkham[1], B. Lafrance[1], S. Brueckner[1], J. Simmons[1], M. Laverge[1], W. Boehme[1], J. Ordonez-Calderon[2]

[1]Mineral Exploration Research Centre, Harquail School of Earth Sciences, Laurentian University, Sudbury, Ontario, Canada, [2]Kinross Gold Corporation, Toronto, Ontario, Canada

The Great Bear deposit, located ~25 km SE of Red Lake, Ontario, lies within the Uchi Subprovince of the NW Superior craton. It is host to Au mineralization in polydeformed Archean volcanic and sedimentary rocks previously suggested to have reached greenschist to lower amphibolite facies metamorphic conditions. The property is divided into a distinct northern felsic domain and southern mafic domain that are separated by a SE-striking crustal scale LP Fault. A ~500m wide,

NW-SE trending high strain zone, termed the LP Fault Zone (LPFZ), sits within the felsic hanging wall of the fault. This project focusses on constraining the metamorphic evolution across the property by: (1) calculating the P-T conditions of observed mineral assemblage development; (2) discerning any metamorphic discontinuities across interpreted structures; (3) documenting and modelling metamorphic fluid production or infiltration, and (4) determining if the rocks experienced polymetamorphism (overprinting metamorphic events).

Core logging and petrographic analysis of metamorphic mineral assemblages and reaction textures across the deposit were performed to determine relationships between the variability of metamorphic conditions and fluid production, deformation fabrics, and alteration. Low variance metamorphic mineral assemblages in the felsic domain are characterized by a quartz + white mica + biotite matrix with intertectonic garnet ± staurolite ± andalusite porphyroblasts, indicative of middle amphibolite facies metamorphism. Staurolite porphyroblasts locally contain inclusions of garnet, and andalusite porphyroblasts overgrow both staurolite and garnet. These middle amphibolite facies assemblages and paragenesis in the felsic domain indicate metamorphism reached temperatures where andalusite forms after staurolite and indicate a high temperature-low pressure metamorphic P-T path. These low variance assemblages are concentrated within the zone of high strain along the LPFZ, and the number of observed porphyroblast phases co-existing and abundance of andalusite decreases towards the NW and SE. This assemblage variability suggests a decrease in metamorphic grade towards the northwest and southeast regions of the property, and phase equilibria modelling will be used to confirm this interpretation.

Mafic domain metamorphic assemblages contain calcic amphibole, quartz, plagioclase, and biotite, with local prograde chlorite parallel to the dominant foliation, widespread retrograde chlorite, and local discontinuous intervals containing garnet porphyroblasts. Facies identification and determination of peak metamorphic temperatures in the mafic domain will be determined using mineral chemistry of amphibole and feldspar coupled with phase equilibria modelling of individual samples. These results will be compared to the P-T constraints of the felsic domain to determine if there is a metamorphic discontinuity across the LPFZ.

104 **Wieland H. Boehme - PhD**
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Host lithology, mineralogy and ore textures of gold mineralization in the LP Zone at the Archean Great Bear deposit, NW Ontario, Canada

W.H. Boehme[1], S.M. Brueckner[1], B. Lafrance[1], M. Laverge[1], J. Simmons[1], D. Tinkham[1], J.C. Ordóñez Calderón[2]

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The Great Bear deposit is a new world-class gold deposit, in the Red Lake greenstone belt of the Mesoarchean to Neoarchean Uchi sub-province, Superior Craton (measured + indicated resource of 2.7 Moz at 2.81 g/t Au). Gold mineralization principally occurs in the LP Zone, a strongly foliated, up to 400 m wide zone at the contact between a northeastern felsic domain and a southwestern mafic domain. Stratigraphic and petrographic analyses of mineralized intervals were conducted to characterize the host lithology, ore assemblages and textures in the LP Zone and to constrain gold mineralization and remobilization processes.

The volcano-sedimentary host rocks in the LP Zone consists mainly of strongly foliated metasedimentary and felsic metavolcanic rocks. Massive coherent volcanic flows or intrusions dominate the stratigraphy and consist of a porphyritic unit containing coarse, rounded quartz and blocky plagioclase phenocrysts (<15 %) in a dark grey, fine-grained quartz-plagioclase-biotite matrix and an altered porphyritic unit with a very fine-grained to aphanitic quartz-plagioclase-biotite matrix. The metasedimentary lithologies are dominated by a dark grey, very fine-graine, massive to thinly bedded, biotite-rich groundmass with locally occurring garnet and staurolite porphyroblasts. Gold mineralization is associated with quartz ± carbonate veins that crosscut and are aligned parallel to the host strata. Mineralized intervals also correlate with varying degrees of silica, albite, and sericite alteration as well as moderate carbonate and minor chlorite alteration.

The ore assemblage consists predominantly of disseminated pyrite, arsenopyrite, and pyrrhotite, with minor chalcopyrite, sphalerite, galena, and magnetite, as well as trace Bi±Ag-Te minerals, scheelite, and gold. A local enrichment in gold occurs in the central and southeastern LP Zone and correlates with higher sulfide abundance, stronger alteration and elevated strain. The gold enrichment is characterized by pyrite-arsenopyrite (central LP Zone) and pyrite-pyrrhotite (southeastern LP Zone) dominated ore assemblages.

Native gold occurs primarily as round, disseminated blebs within and close to quartz ± carbonate veins. Gold occurs as interstitial grains along coarse recrystallized grain boundaries within the veins and is locally intergrown with altered, foliation-parallel biotite within the host strata. Further, gold shows close spatial and textural relationships with Bi±Ag±Pb tellurides, galena, and coarse, deformed pyrite. These preliminary observations suggest a pre- to syndeformational emplacement of gold and a potential syndeformational remobilization accompanied by pyrite recrystallization.

105 **François-Xavier Bonin - MSc**
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Evidence of multi-stage orogenic gold mineralization at the Bonnefond deposit, Val-d'Or, Québec

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Most of the gold mined in Canada today comes from quartz veins in orogenic-type deposits. In the Abitibi greenstone belt, the gold-bearing quartz veins are commonly described as late orogenic with regard to the N-S D2 shortening event (~ 2669 - 2643 Ma). However, not only are the quartz-carbonate veins reported over a large time period overlapping with D2 (2665 - 2640 Ma) but several younger post-D2 ages have also been identified in those veins (~ 2705 - 2360 Ma). These dates thus need better constraints to isolate the different events responsible for gold mineralization.

The Bonnefond gold deposit is located within the Val-d'Or vein field. Mineralization is associated with quartz-tourmaline-carbonate (QTC) veins. Gold is hosted mostly in pyrite as Au ± Te inclusions or in pyrite micro-fractures and at grain margins. Near-infrared imaging and LA-ICPMS trace elements mapping of pyrite show textural and chemical zoning. An inclusion-rich core domain is commonly overgrown by a hydrothermal oscillatory-zoned gold-hosting pyrite domain. A dissolution-reprecipitation front delineates the border with the next generation, showing as a barren, silicate inclusion-rich pyrite. This dissolution-reprecipitation texture supports a two-stage mineralization process. In situ LA-ICPMS U-Pb xenotime geochronology provides us with texturally-controlled temporal constraints on gold mineralization. These analyses yield a syn-D2 hydrothermal event associated with QTC veins at ca. 2662 Ma and a second post-D2 hydrothermal event at ca. 2607 Ma. Both hydrothermal episodes must therefore have contributed to local high gold grades at the Bonnefond deposit via its remobilization. Our work not only highlights the early- to syn-D2 timing of gold introduction in the system within QTC veins locally but is also consistent with a documented district-scale post-D2 gold remobilization event.

106 Jennifer Cann - MSc
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The trace element content of pyrite from the orogenic gold deposits of the Abitibi belt

J. Cann[1], D. Gregory[1], E. Hastie[2]

[1]University of Toronto, Toronto, Ontario, Canada, [2]Ontario Geological Survey, Sudbury, Ontario, Canada

Northeastern Ontario hosts some of the world's largest orogenic gold deposits within the Porcupine-Destor and Larder Lake-Cadillac deformation zones which crosscut the Abitibi greenstone belt. Despite the importance of these deposits, their mechanisms of formation and fluid sources are not fully understood. Both magmatic and metamorphic fluids have been proposed as potential gold sources, with some studies suggesting that metamorphic fluids can be derived from devolatilization of multiple rock types including carbonaceous shales, komatiites and basalts during greenschist-amphibolite facies metamorphism.

In this project, we investigate pyrite morphology of gold bearing samples from gold camps in the Abitibi region to better understand their paragenesis. Pyrite morphology from these samples will be examined using reflected light microscopy and scanning electron microscopy to determine how many generations are present in the mineralized samples. This data will provide the basis for later parts of the project that will investigate the trace element content of these pyrite generations using laser ablation inductively coupled plasma mass spectrometry. The trace element contents will be used to collect information regarding the oxidation state, pH, salinity and temperature of ore forming fluids. In addition, some of the trace elements to be examined are critical metals, including cobalt, nickel, antimony and tellurium which are vital for the transition from hydrocarbon-based energy to green energy sources. By creating associations between various trace elements, their depositional mechanisms and fluid sources, we can better predict which gold deposits may also have potential as critical metal sources.

107 Matteo Clemente - BSc
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Utilizing trace element content of pyrite to interpret fluid chemistry of five historic Au deposits in SE Ontario

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The Grenville Province is a northeast-southwest trending orogenic belt comprising granitoids, greenstones, and metasediments that extend through Ontario and Quebec in Southern Canada.

It hosts Au mineralization that was among the first gold deposits mined in Ontario. In this study, samples from five of these historic gold deposits in the Elzevir and Manizaw Terrane in the Central Metasedimentary Belt were analyzed by a combination of reflected light microscopy and laser ablation-inductively coupled plasma mass spectrometer (LA-ICPMS) to examine trace element content of different generations of pyrite. Understanding the trace element chemistry of pyrite contributes to the understanding of gold deposits in Ontario by interpreting past fluid chemistry and providing evidence of potential significant orogenic gold mineralization events. The study also highlights the potential for Proterozoic gold in Ontario, which is poorly constrained and understood. Twelve Au and pyrite-bearing samples were examined from five historic deposits including Ore Chimney, Dillman-Chard (Black River), Cordova, Dingman, and Bannockburn.

108 **Ella Curtis - BSc**
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Analyzing the Alteration Halos of Young-Davidson Orogenic Gold Deposit Using Short Wavelength Infrared (SWIR)

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Young-Davidson's (YD) mine at Matachewan offers an interesting opportunity to explore how we utilize technology around alteration haloes and better our understanding of orogenic gold deposits. Situated in Northern Ontario YD is located in the southwest of the Abitibi greenstone belt, part of the Superior province. More specifically, the site is located on the western limb of the Larder Lake Cadillac deformation zone (LLCdz) and hosts a series of deformation and vein formation events. On-site gold mineralization is primarily hosted in a large syenite intrusion with an extensive hydrothermal alteration halo. The primary target for gold production is quartz veins with a strong hematite alteration. This study focuses on the use of shortwave infrared (SWIR) analyses to identify major alteration minerals and thus enhance the understanding of the deposit, particularly the distinctive features of the alteration halo. SWIR identifies the composition of a sample by recording the wavelengths reflected off the samples. Due to its structure, each mineral will return a different combination of wavelength and intensity that can be compared to a stored mineral library. The use of SWIR improves the efficiency and accuracy of identifying alteration haloes made during in-core logging. We also present a comparison of SWIR and results from whole-rock geochemical analysis to create a comprehensive model of alteration halos around the YD orogenic gold deposits. Through the use of this technology this study will enhance understanding of site geology as well as build on techniques to identify alteration halos of orogenic gold deposits.

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Structures, alteration, and mineralization along a newly exposed segment of the Larder Lake-Cadillac Deformation Zone, southern Abitibi subprovince, Ontario, Canada

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The aim of this project is to characterize the lithologies, structures, and alteration mineral assemblages along a newly exposed segment of the Larder Lake-Cadillac Deformation Zone

(LLCDZ) along strike and within the footprint of the world-class Kerr-Addison gold mine in the southern Abitibi subprovince, Ontario, Canada. The LLCDZ straddles the contact between metavolcanic rocks of the ca. 2705 Ma Larder Lake Group and metasandstone of the ca. 2676 to ca. 2669 Ma Timiskaming assemblage. Structural mapping along this new segment suggests that folding of the Timiskaming metasandstone north of the LLCDZ is associated with the formation of a regional east-west striking cleavage. This cleavage is more pronounced and parallel to bedding adjacent to the LLCDZ and becomes the main structure within mafic and ultramafic metavolcanic rocks of the Larder Lake group along the LLCDZ, where it is parallel to lithological contacts. A steeply plunging (~65° to the east) mineral stretching lineation lies along the cleavage and formed during dip-slip movement along the deformation zone. Later dextral transcurrent reactivation of the LLCDZ produced narrow shear zones with a shallowly-plunging mineral lineation, S-C fabrics, and steeply-plunging Z-shaped folds. Mineralized quartz veins cut across the cleavage in the Timiskaming metasandstone but are also folded, suggesting that they were emplaced during deformation. This well-exposed segment of the LLCDZ is easily accessible and promises to become a regular stop during field trips across the Abitibi.

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AI-Driven Mineral Prospectivity Mapping to Detect Potential Gold Deposits in the Baie Verte Peninsula, Newfoundland

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Mineral prospectivity mapping (MPM) is an essential tool for identifying high-potential zones for mineralization, providing a data-driven approach to enhance exploration targeting. This study focuses on the Baie Verte Peninsula, Newfoundland, with its complex geological history and significant gold occurrences. The region hosts two primary gold deposits: orogenic vein-hosted gold and disseminated gold in ore zones, both associated with structural features and lithological controls. This research integrates diverse data into a unified analysis framework by leveraging open-source datasets from the Federal Government of Canada.

Using a support vector machine (SVM) algorithm, predictive modelling was performed on key features, including fault proximity, geochemical anomalies, geological unit interactions, etc., critical indicators of gold mineralization. The results yielded a prospectivity map for potential gold deposits and provided a reliable tool for exploration decision-making.

As part of this project, a new software solution tailored for mineral prospectivity mapping was developed, which supports two machine learning algorithms (SVM and Random Forest) and one deep learning algorithm (Convolutional Neural Networks, CNN). While this software offers flexibility in algorithm selection, the current study exclusively utilizes the SVM algorithm for its robustness and suitability to the dataset. This research demonstrates the effectiveness of combining AI-driven methods with public geoscientific data to improve the efficiency and precision of mineral exploration. This study contributes to the broader adoption of sustainable, data-driven practices in the mining industry and aligns with the goals of enhancing resource exploration in Canada.

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Chlorite chemistry in carbonated serpentinites from the Alleghany gold district, California, USA

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The Alleghany district, California, is located within the Sierra Nevada foothills and has historically produced 89 tons of gold. It is located adjacent to the Melones fault zone, which acts as the main pathway for mineralizing fluids in the region. When gold-bearing H_2O-CO^2-rich fluids interact with ultramafic country rocks, a distinct distal-to-proximal alteration profile is produced: talc-carbonate, talc-carbonate-quartz, and carbonate-quartz-muscovite mineral assemblages. Chlorite, which is present across the alteration profile, has been analysed in Neoarchean ultramafic hosted-gold settings (e.g., Kerr-Addison) and shows changes in chemistry attributable to distance from fluid pathways. Specifically, chlorite shows a proximal increase in Al^{3+}, suggesting that Tschermak substitution ([6]Mg + [4]Si ↔ [6]Al + [4]Al) is occurring. This study aims at testing if similar trends can be documented in the Phanerozoic ultramafic hosted-gold Alleghany district. Half-core and grab samples of altered ultramafic rocks from the Alleghany district (n = 20) will be analyzed using: (1) hyperspectral analysis (mineralogy and trends in mineral chemistry), (2) whole-rock geochemistry (protolith information and elemental gains and losses), (3) optical microscopy (modal mineralogy and textures), and (4) SEM-EDS (mineral chemistry and textures). Petrographic thin-section observations suggest that chlorite is present across the alteration profile. Early SEM results have shown that gold grains are only present in the most altered mineral assemblage (carbonate-quartz-muscovite), showing a direct link between fluid interaction and gold mineralization. Mineral chemistry variations will be documented by semi-quantitative SEM analyses and hyperspectral imaging of least altered and mineralized samples. Ultimately, this study will demonstrate if chlorite chemistry can vector towards gold mineralisation in ultramafic-hosted gold systems, using time and cost-effective hyperspectral analyses that can easily be implemented in exploration programs.

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Geochemical discrimination of IRG and ORG systems in the Mazaruni greenstone belt, Guiana Shield, South America

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The two dominant Au systems within Precambrian greenstone belts are orogenic (ORG) and intrusion related (IRG; i.e., magmatic-hydrothermal). Classification of gold deposits into one of these two types is still much disputed due to their similar features, and in some cases the overprinting of IRG by ORG systems, adding further complexity. This study differentiates these systems using the geochemical signature of pyrite grains, analysed through laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) traverses and maps. Samples were collected from gold deposits within the Mazaruni greenstone belt of the Guiana Shield, Guyana, South America. This include two IRG systems (Toroparu Au-Cu(-Ag) and Eagle Mountain

Audeposits) and several ORG systems (Aurora Gold Mine:Rory's Knoll, Mad Kiss and Alec Hilldeposits; Omai Gold Mines: Wenot deposit; Oko West gold deposit; and Sona Hill deposit). These deposits are hosted within Rhyacian-age mafic to felsic volcanic, volcaniclastic andintrusive host rocks metamorphosed to greenschist facies assemblages.

Time slice domain (TSD) data obtained from LA-ICP-MS maps and traverses, plotted on Au/Ag binary plots, revealed distinct patterns: IRG deposits exhibit randomly dispersed Au/Ag ratios, whereas ORG systems cluster at Au/Ag = 0.1, 1 or 100. Principal component analysis (PCA) onthe TSD (standardised using a centered log-ratio transformation) identified four significant components (PC1 – PC4) with eigenvalues greater than 1.29. K-means clustering analysis of these components subdivided the dataset into four groups. The analysis showed that IRG deposits are enriched in Cu, As, Se, Ag, Sb, Au, Pb and Bi, whereas ORG deposits are depleted in those elements and enriched in Co, Ni and Te. Notably, both IRG deposits have As-rich pyrite (As values between 1000 to 10000 ppm), with As causing lattice distortions that facilitate element substitution due to ionic radius, captured by PC1. This methodology determined that As, Se, Ag, Sb, Au, Pb and Bi are the discriminator elements for differentiating IRG and ORG deposits in the Mazaruni greenstone belt and these findings are broadly applicable to similarly aged greenstone belts worldwide.

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Structural Controls on Gold Mineralization at the Great Bear Property, Red Lake, ON

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The Great Bear property, located 25 km south of the productive Red Lake gold camp (>29 Moz gold) in the NW Superior craton, hosts a new world-class, structurally-controlled gold deposit with a combined resource estimate of 6.6 Moz Au. The property is bisected by the SE-striking LP fault, which straddles the contact between a mafic domain to the south and a felsic domain to the north. Mineralization is hosted within three distinct zones: the LP Zone, Hinge Zone, and Limb Zone. The LP Zone, which hosts the bulk of the known gold mineralization, sits within the felsic hanging wall of the LP fault, while the Hinge and Limb zones sit in the mafic footwall. Mineralization is characterized by gold-bearing deformed quartz veins oriented parallel and oblique to the foliation but also occurs disseminated in altered felsic volcanics.

The LP Fault Zone is expressed as a ~500m wide high-strain zone characterised by a penetrative, NW-striking, steeply NE-dipping foliation and transposed isoclinal folds. A mineral stretching lineation plunges steeply (~79°) to the N along the foliation. Later Z-shaped folds strike E-W and are associated with steeply dipping dextral shear bands. Several lines of evidence suggest that the development of these structures occurred during a single long-lived dextral transpressional event. First, deformed quartz phenocrysts with dextral asymmetrical strain shadows on horizontal outcrop surfaces are stretched vertically on vertical outcrop surfaces. Second, the fold axes of both early isoclinal and later Z-shaped folds and the mineral lineations are rotated into parallelism, likely during concurrent dextral shearing and oblique to near-vertical extension. Finally, the mineral stretching lineation is consistently steeper than the calculated slip direction.

Structures along the LP Fault Zone formed after 2712.3 ± 2.2 Ma, which is the age of the mylonitized and mineralized quartz-feldspar porphyry host rocks, and locally outlasted 2692.4 ± 4.5 Ma, which is the age of a weakly-deformed granitic intrusion. This indicates that deformation on the Great Bear Property is the local expression of the D3 deformation in the Red Lake Greenstone Belt, which resulted during the last increment of regional shortening associated with the Uchian Phase of the Kenoran Orogeny.

Gold-bearing quartz veins were deformed by both early and late-stage transpression, indicating pre- to early syn-deformation emplacement of mineralization, followed by subsequent reorientation during D3 deformation. This suggests that gold mineralization occurred during a pre-existing deformation event that has been overprinted by D3 deformation.

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Mineralogy of hydrothermal alteration in the Amalgamated Kirkland Gold Deposit, Ontario: Insights from Petrography, µXRF Mapping and Hyperspectral Imaging

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The Amalgamated Kirkland (AK) gold deposit, located in the Kirkland Lake camp in the southern Abitibi greenstone belt, is considered an orogenic-type gold deposit. It is hosted within the metamorphosed subalkaline to alkalic igneous rocks and clastic sedimentary rocks of the Neoarchean Timiskaming Group (<2679-<2669 Ma), which unconformably overlay older Larder Lake Group mafic metavolcanic flows (2710–2704 Ma) in proximity to the Larder Lake-Cadillac deformation zone. The gold zones primarily occur in sericite-carbonate-pyrite altered trachytes within the siltstone, sandstone and conglomerate beds of the sedimentary succession, and within cross-cutting dioritic intrusive rocks. Understanding the mineralogical changes associated with increased hydrothermal alteration and gold mineralization in this deposit is critical for improving exploration strategies in the Kirkland Lake camp and in similar settings globally. This study therefore aims to investigate the mineral chemistry variations across the AK gold deposit using various field-ready (µXRF, hyperspectral imaging) and laboratory-based (SEM/EPMA) spectroscopic techniques. To characterize mineralogical changes in response to increasing alteration and mineralization intensity, a suite of 24 representative drill core samples of each rock type of the AK deposit were collected from four drill holes. These samples were categorized into three groups using thin-section petrography: altered with gold mineralization, altered but non-mineralized, and least altered. A µXRF mapping approach will be employed to analyze the elemental distribution in thin-section blocks. SEM/EPMA analyses will be conducted to determine mineral chemistry and validate µXRF data. One of the principal objectives of this research is to test the applicability of µXRF element mapping and hyperspectral imaging techniques to document such alteration mineralogy trends across the AK deposit, and subsequently refine exploration methodologies to better target orogenic gold deposits in the Abitibi greenstone belt and beyond.

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Metal and trace element distributions in polymetamorphosed banded iron formation northeast of Rankin Inlet, NU with connections to orogenic gold exploration

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The Kivalliq region in Nunavut contains banded iron formation (BIF) -hosted gold deposits, including the Meliadine and Meadowbank mines, that are being actively studied. Units of BIF northeast of Rankin Inlet (east of Meliadine) have received less attention. Our aim is to characterize the pre-mineralization states of BIF in this region as a baseline to understand metal mobilization and concentration during regional Barrovian metamorphism. The study area is in a complex transition zone between the Rae and Hearne cratons, which is affected by regional Archean and localized Paleoproterozoic deformation at greenschist to amphibolite facies conditions. The goal of this project is to gain insight into the relative timing and paragenesis of minerals in BIF that are known to carry precious metals, along with any relationships between metal mobility and tectono-metamorphic processes that would inform exploration in the region. Element maps generated by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) on representative BIF samples show low Au contents in the interior of pyrite crystals, but elevated metal contents (Au, Ag, As, Cu, Te, Bi) as well as high Ba and Ce along grain boundaries of pyrite, indicating metal mobility related to late-stage hydrothermal alteration affecting both pyrite and magnetite. Moving from south to north, BIF samples were exposed to higher degrees of metamorphism, with the southern mica-rich BIF becoming more amphibole- and garnet-rich further north. The trace element chemistry of magnetite and pyrite across metamorphic grade will be presented along with the key geochemical signatures related to primary and secondary formation processes. This work will increase the understanding of the paragenesis of BIF-hosted metals in this previously unmapped area of a geologically complex region and will be combined with additional field data to provide a pre-mineralized analogue for future exploration projects.

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Structural Architecture of the Kirkland Lake Gold Camp, Northeastern, Ontario

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The Macassa mine, one of the world's highest grade gold mines, is located in the Kirkland Lake Gold Camp (>24 Moz gold) of northeastern Ontario within the southern Abitibi greenstone belt. Gold mineralization is hosted by orogen-parallel reverse brittle faults, which cut through siliciclastic sedimentary and alkalic volcanic rocks of the ca. 2676 Ma-2670 Ma Timiskaming assemblage and co-genetic intrusions. These rocks are separated from older mafic and komatiitic volcanic rocks of the ca. 2705 Ma Larder Lake Group by the Larder Lake-Cadillac deformation zone (LLCDZ), a 50 m-200 m wide ductile deformation zone hosting several world-class gold deposits over its 250 km strike length across eastern Ontario and western Quebec.

Current gold production is mainly from the South Mine Complex (SMC), a network of east-northeast trending, shallowly dipping faults filled with quartz veins, hydrothermal breccia, sericite and pyrite alteration. The SMC is bounded by the steeply south-dipping, south-side-up reverse, Main Break to the north and the steeply north-dipping, north-side-up reverse, Amalgamated Break to the south. This study focuses on a 2,300 m wide panel of Timiskaming volcanic and sedimentary rocks between the Amalgamated Break and the LLCDZ to the south. The Amalgamated Break overprints weakly deformed Timiskaming rocks, with ductile strain increasing towards the LLCDZ. Stratigraphy is folded and transitions from south-younging near the LLCDZ to east-younging further north. The earliest and most penetrative foliation is a steeply (70-90°) south dipping and east-northeast striking S2 foliation, which is axial planar to the folds. The S2 foliation becomes more pronounced along the LLCDZ where it is parallel to bedding. A steeply plunging stretching lineation and intense carbonate alteration further characterize the LLCDZ. The S2 foliation is locally overprinted by a northeast-striking, steeply (70-90°) south dipping, S3 cleavage, which is associated with Z-shaped F3 folds and formed due to dextral reactivation of the LLCDZ.

Preliminary results suggest that the Amalgamated Break evolved from a brittle fault to a ductile shear zone due to clay alteration during fluid flow along the fault. A mineralized zone within the panel, i.e. the AK zone, is controlled by brittle fractures and breccias, predating the regional S2 foliation. This suggests that mineralization is associated with a brittle deformation event that predates the formation of the LLCDZ. The project aims to further investigate the timing relationships between the mineralized brittle faults (Amalgamated Break and Main Break) and ductile LLCDZ and structural controls on gold mineralization.

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Characterization of Alteration and Mineralization of the Moss Gold Deposit, Shebandowan Greenstone Belt, Northwestern Ontario: Insights from SWIR and mineral chemistry of white mica and chlorite

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The Moss Au deposit is an orogenic-style gold deposit hosted in dacite and diorites of the western Shebandowan greenstone belt, with an inferred mineral resource estimate of 140.07 Mt of ore averaging 1.09 g/t Au, yielding 4.91 Moz. Mineralization is concentrated within shear zones and an array of quartz-carbonate-pyrite veins. A Re/Os age (2708 ± 12 Ma) from molybdenite from a quartz-carbonate-pyrite ± molybdenum vein is taken to be the age of mineralization based on the relationship of gold with sulfides. This age, when compared with the ages of the host rock from Skimpole Lake area (2721 ± 4 Ma) and the nearby Burchell Lake stock (2680 ± 3 Ma), constrains the gold mineralizing event between 2725 Ma–2694 Ma.

Alteration at Moss occurs in variable intensities and comprises albite, biotite, sericite, chlorite, carbonate, and epidote alteration. Sulfide minerals are dominated by pyrite with minor chalcopyrite, sphalerite, and molybdenite. Sulfide abundance is commonly 2–10% of the samples but can be up to 15% in sulfide-rich veins. Based on the observed textural and crosscutting relationships of the alteration, sulfides, and veins, a paragenetic sequence was developed; gold deposition is coeval with pyrite crystallization.

Alteration studies using hyperspectral Short Wave Infra-red (SWIR) data identified different species of white mica and chlorite at Moss. White mica with a spectral range of 2208–2216 nm is associated with high gold values and corresponds to a mixed phengite-muscovite composition. Chlorite with a spectral range between 2242–2249 nm is also associated with gold-bearing samples. The mineral chemistry of chlorite and white mica varies with proximity to the center of the deposit. This is characterized by an increase in Mg, Fe, Si, and a decrease in Al, in chlorite and white mica with increasing proximity to ore center. The variations in the Mg, Fe, Si, and Al contents are attributed to the Tschermak substitution reaction, where Al is replaced by Si in the tetrahedral sites, whereas Mg or Fe is incorporated into the octahedral sites; these variations can be used to distinguish hydrothermal and metamorphic chlorite and white mica species. The Tschermak reaction can be linked to temperature changes resulting from interaction with mineralizing fluids during deposit formation, hence can be used to track ore fluid pathways. Overall, mineral chemistry and spectral features of white mica and chlorite show a trend that can be used as a vector to ore.

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Au-Ag-Te mineralization in the Niou area, Goren district, Boromo-Goren greenstone belt, West African Craton

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The mineralization of gold, silver, and tellurium (Au-Ag-Te) in the orogenic Niou area is hosted by metamorphosed volcanic formations, such as metabasalts and metaandesites, in greenschist facies. These volcanic formations are cut by intermediate to basic intrusions, including metadiorites and metagabbro. The mineralization is an epigenetic type, exhibiting three stages of gold mineralization that are controlled by two episodes of shear deformation. These episodes have been described and documented in this deposit. Stage I is characterized by early pyrite mineralization, exhibiting chagrined, skeletal, and locally fractured grains ranging in size from 200 μm to 1 mm. These grains are disseminated along the S1Ni foliation, with low gold concentrations. This stage is associated with sericitic alteration and chloritization. Stage II is marked by remobilized mineralization invading Py1 pyrites, interpreted as Py2, exhibiting signs of partial dissolution at the margins. These pyrites display euhedral to sub euhedral textures. Notable inclusions of chalcopyrite have been identified in the cores and at the rim of theses pyrites, dispersed along the foliation plane structures and the S/C structures and micro-fold hinges. Stage III is characterized by the crystallization of Py3-type pyrite, which is concomitant with late silicification along the axes of the microfold axes. The distribution of gold within the sulfides can be categorized into the following forms: (i) Au, Au-Bi, Au-Te, and Au-Ag-Te present in the micropores of pyrites with a subhedral texture, (ii) as inclusions within large pyrite crystals in contact with chalcopyrite and pyrrhotite, and (iii) in fissural form in contact with pyrite and pyrrhotite.

Sulfides have been observed to absorb gold in their lattices up to 0.18% for pyrite, 0.15% for chalcopyrite, and 0.10% for pyrrhotite. Metabasites (metabasalts and metaandesites) have been interpreted as the source of gold in the NGD.

122 **Nelson Román - PhD**
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Gold alloy trace element composition at the Klondike gold district, Yukon

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Linking placer Au alloy (native gold, electrum) to specific vein Au occurrences is a fundamental exploration tool in Au districts. In the Klondike Au district, Yukon, this approach has been successfully implemented from a compositional and mineralogical viewpoint by previous studies, based on electron probe microanalyses (EPMA) of large sample populations combined with detailed petrographic mineral inclusion examination. However, this approach is limited due to the relatively high detection limits of EPMA which restricts the identification and quantification of additional trace elements, and by the scarcity of mineral inclusions in Au alloy grains. With the goal of enhancing the certainty of placer-vein relationships in the Klondike, here we report preliminary vein and placer Au alloy LA-ICP-MS trace element composition from the Klondike, focusing on the Lone Star area.

The most detected elements in Au alloy were Ag, Hg, Cu and Sb. Lead, Pd, Pt and Bi were detected in more than 40% of the analyzed spots. Vein Au alloy composition variation trends were observed. Mercury concentrations in vein Au systematically decrease from Lone Star to the southwest Au occurrences (Nugget-Buckland, Dysle-Gay Gulch and Violet), whereas Cu concentrations show the opposite trend. Gold alloy element ratios (Hg/Cu and Ag/Cu) discrimination diagrams highlight the relationship between placer and vein Au in the district.

Future work will use Au alloy Pb isotope data to reinforce the geochemical placer-vein Au link. The results of this study are expected to have direct application for exploration in the Klondike and elsewhere.

123 **Weeda Tiraei - BSc**
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Are the Tetrahedrite and Telegraph Prospects, in Kirkland Lake, ON, Orogenic or Intrusion Related?

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The Kirkland Lake-Larder Lake Gold district is one of world's largest gold (Au)-producing regions, with over 60 million ounces of historical production. The district is part of the Neoarchean Abitibi greenstone belt in northeastern Ontario and hosts a wide variety of Au deposits, including orogenic and intrusion-related systems. This part of the Abitibi consists of the Blake River assemblage (ca. 2704-2695 Ma), which consists of mafic-intermediate rocks and pillowed lavas/flow, and the Tisdale assemblage (ca. 2710-2704 Ma), which consists of mafic-ultramafic

volcanic rocks and intermediate calc alkaline volcanic rocks. Deposited later are sedimentary and volcanic rocks of the Timiskaming group (ca. 2676-2670 Ma), which consists of fluvial polymictic sandstone and conglomerate interlaced with trachyte and intruded by a calcalkalic to alkalic intrusions of the same age. The Larder Lake-Cadillac Fault Zone transects the region and serves as a locus for hydrothermal fluid flow and ore deposition. It controlled the deposition of orogenic deposits in the area. The Tetrahedrite and Telegraph prospects are located between the Upper Canada (orogenic) and Upper Beaver (intrusion-related) deposits, and this study investigates if their formation is more akin to orogenic or intrusion-related deposits. Fieldwork included geological mapping and sampling (n=23) at Telegraph and Tetrahedrite. Petrography, scanning electron microscopy, and whole rock/trace geochemistry helped understand the relationships among sulfide minerals, deformation, alteration, and metal associations. Sulfide minerals at these prospects include galena, sphalerite, tetrahedrite, and chalcopyrite. Preliminary results show that sulfide mineralization is aligned with a foliation that is defined by sericite rather than overprinted by the foliation. Further work will be completed to identify the location and textures associated with gold mineralization. Determining the type of gold mineralization at Telegraph and Tetrahedrite will aid future exploration, because exploration strategies differ for orogenic and intrusion-related gold deposits. Exploration for orogenic gold deposits focuses on the host structures (i.e. fold hinges and shear zones), whereas exploration for intrusion-related gold deposits focuses on the host intrusions and their footprint.

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Multiscale Structural Analysis of the Troilus Au-Cu Deposit of Northern Quebec and Applications to Deposit Metallogeny

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The Troilus deposit is hosted in the eastern Frotet-Troilus segment of the Frotet-Evans Greenstone Belt, part of the Opatica Subprovince of the Superior Province of Canada. Located approximately 120km north of the town of Chibougamau, Quebec, the deposit produced gold and copper as an open pit mining operation between 1996 and 2010. New ownership and revived exploration efforts led by Troilus Gold Corp, since 2018 has led to resource growth of over 12 Moz AuEq between 4 main mineralized zones. While the deposit is understood to be structurally controlled, observed structural features question the current deformation sequence for the deposit and the genesis and evolution of these features is poorly understood.

This research employs a traditional structural geology field mapping approach which integrates detailed structural analysis at regional, outcrop, and microscopic scales to establish a comprehensive structural framework. Through the integration of geometric and kinematic analysis of features observed at multiple scales, the geological history and structurally controlled nature of the Troilus deposit can be better constrained.

Field mapping has shown that the Troilus deposit is hosted within a broad mylonite zone characterized by a dominant WSW-ESE striking transposition foliation (S1) which is the earliest recognizable fabric in the study area and defines a major regional lineament. This mylonite zone is interpreted to have formed during regional dextral transpression and overprints an earlier mineralizing event, leading to reworking and zone refining. Features indicating a post-mineralization tectonic overprint include stretched semi-massive sulphide clasts and lenses within mylonites, and aggregate lineations of sulphide minerals on foliation surfaces in pit walls and around the deposit which control high grade ore shoots. Post-mylonite kinking, crenulations, shear zones, and veins are observed in the vicinity of the deposit.

Rocks are dominantly S-tectonites with poorly developed mineral lineations except in the vicinity of the deposit where lineations are more recognizable and are approximately down-dip. Mineral lineations shallow to approximately sub-horizontal away from the deposit towards the northeast. Similar metamorphic grades of upper greenschist to lower amphibolite are observed across the deposit and suggest a dominant horizontal shortening component. Shear sense indicators include asymmetric porphyroclasts, flanking folds and S/C fabrics on horizontal surfaces which are consistent with a dextral sense. Shear sense determinations from quartz LPO are currently ongoing.

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Gold Exploration Targeting Using Lineament Analysis in the Issett Lake Region of Northern Manitoba

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A structural analysis of the Northern Issett Lake region of northern Manitoba was carried out in order to define structural features that may host or be related to gold mineralization. The area is host to a recent discovery of a gold bearing structure plus other mineralization. The analysis was conducted by identifying and interpreting linear features derived from satellite imagery, digital elevation models, a variable time-domain electromagnetic survey (VTEM), and a magnetic survey. DEM and satellite lineaments define linear topographical features, which, in the Canadian Shield are known to have excellent correlations with structure, and to a lesser degree with stratigraphy. VTEM and magnetic lineaments define trends, breaks and offsets in linear conductive and magnetic bodies. Structural features derived from topographic lineaments reveal two dominant sets of orthogonal structures that suggest two unique orogenic tectonic events within the Trans Hudson Orogen, with different orientations. The most important structural features identified are those that correlate with, or are parallel to and nearby the VTEM and magnetic lineaments that are directly associated with the known gold-bearing trend. In particular, the intersections of orthogonal transverse structures with gold-bearing belt-parallel structures identify excellent potential target sites for the accumulation of significant gold mineralization. Many target sites were identified by this investigation. Some of the best sites occur where coincidence of multiple lineaments from the different surveys intersect the known gold-bearing trend, especially those in the vicinity of known mineralization. Overall, many interesting areas with mineral potential were identified within the project area, and it is highly recommended that further exploration be conducted on those sites.

200 Intrusion-Related Deposits

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Geology And Footprints Of The New Afton And Other Alkalic Porphyry Deposits In The Iron Mask Batholith District, British Columbia

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The late Triassic - early Jurassic Iron Mask Batholith (IMB) in southern British Columbia hosts several alkalic porphyry Cu-Au mineralized centers such as New Afton, Ajax, Copper King, and Python. This research identifies mineral and chemical footprints of the alkalic porphyry deposits in the IMB through fieldwork, petrography, geochronology, and geochemistry. Results were compared with the footprint of the nearby Nora and other BC calc-alkalic deposits.

Pathfinder elements in the studied alkalic porphyry deposits extend horizontally from a central core of Pd, Pt, Cu, and Au (~100m x 800m) to Te, Re, and Se (~700m x 1.5km) and further distal V, As, and Sb (>~1 km x >1.5km). Vertically, at New Afton, a higher concentration of Mo occurs at depth (~750m deep) along with depleted Zn and Mg. This is overlain by a zone of high concentrations of Cu, Au, Pd, and Pt. Near surface Te, V, As, and Sb have higher concentrations. K-feldspar-rich veins occur proximal to the mineralization, surrounded by calc-potassic (k-feldspar + epidote ± sulfides ± magnetite) and more distal calcic veins (epidote ± carbonates).

Results indicate that hydrothermal alteration in alkalic porphyry deposits is more cryptic than calc-alkalic deposits. Porphyry emplacement and alteration is typically asymmetric and structurally controlled. Similarly, anomalous values of pathfinder elements are typically less pronounced than those in the calc-alkalic porphyry deposits except locally for Te, Pd, As, Ag, and V, which have higher concentrations and display concentric zoning. These results help to identify the signature of the alkalic porphyry mineralization early during exploration and vector toward potential mineralization.

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Patchy Alteration Carapace and High-Grade Mineralization above the Valeriano Cu-Au Porphyry Deposit, Chile

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The Valeriano porphyry-epithermal deposit is located in the Atacama Region of northern Chile, between the El Indio and Vicuña belts at ~4500 m elevation in the Frontal Cordillera. ATEX Resources Inc. acquired access to the property in 2021, and is presently in the fifth drill campaign to identify the resources. The deposit is associated with Miocene porphyry and biotite-hornblende granodiorite dikes. Valeriano is capped by a north-trending advanced argillic lithocap with epithermal mineralization. At the base of the lithocap, patchy pyrophyllite-alunite alteration formed due to cooling from white mica stability. Drillcore logging indicates that this alteration occurs as a carapace ~800-1200 m above the early porphyry intrusions. The intrusion-hosted porphyry mineralization is overlain by a polymictic magmatic-hydrothermal breccia, ranging from clast- to matrix-supported, with abundant angular fragments of early A- and B-type

quartz veins as well as angular porphyry fragments; it is referred to as the Rock-Milled Breccia (RMB). The RMB is locally mineralized, but in the 2024 drilling program intercepted an interval of the RMB in drillhole ATXD26 that returned 122.0 m of 1.11 wt% Cu, 0.49 g/t Au, 2.7 g/t Ag and 348 g/t Mo, with anomalous concentrations of Te and Bi. Initial observations indicate that K-feldspar, biotite and magnetite is overprinted by white mica, chlorite, clay which occurs as halos to lavender quartz veins that cut the potassic alteration, and which is associated with high-grade mineralization. The highest-grade intervals within the ATXD26 RMB are associated with the destruction of magnetite by hematite-dominant alteration. Ongoing petrographic and mineralogical study (shortwave infrared spectroscopy, X-ray diffraction), and stable isotope analysis of S of coexisting sulfate-sulfide pairs for paleotemperature estimates, will characterize the alteration and mineralization of the high-grade interval of the RMB, to assist in targeting similar zones.

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Characterizing the lithostratigraphic and geochemical controls at the Bidgood gold deposit, Kirkland Lake, ON

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The Bidgood deposit is located 7 km east of Kirkland Lake, Ontario, and is part of the world-class Kirkland Lake-Larder Lake gold camp (>47 Moz) situated in the southern Abitibi greenstone belt of the Superior Province. Gold deposits in the camp are associated with faults and shear zones, such as the Larder Lake-Cadillac deformation zone, and are predominantly classified as orogenic (e.g., Kerr Addison-Chesterville, Omega, Cheminis) and, less commonly, intrusion-related (e.g. Upper Beaver deposit). The Bidgood deposit is hosted within intrusive units that cut across sedimentary and volcanic rocks of the Timiskaming assemblage, representing the youngest Archean supracrustal assemblage in the Abitibi greenstone belt. Due to the complex deformational history of the area and the presence of several intrusive units at Bidgood, the style and origin of the gold mineralization remain poorly understood. Furthermore, constraints on the composition and genesis of the intrusive host lithologies are lacking. This complicates the interpretation of Bidgood into a deposit type. This study therefore aims to identify the lithostratigraphic, geochemical, and alteration controls on mineralization at the Bidgood deposit, using field mapping, detailed core logging, petrographic descriptions, and whole rock geochemistry.

Sedimentary and volcaniclastic units at Bidgood include siltstone, greywacke, conglomerate, and trachytic tuff units of the Timiskaming assemblage (≤2679 – ≤2669 Ma). They are intruded by diorite, feldspar and quartz-feldspar porphyries, with diorite as the oldest unit. Thin syenite and bimodal quartz-feldspar porphyry dikes appear to be the youngest intrusive units. The diorite shows evidence of at least two stages of alteration: an early assemblage of chlorite-epidote-calcite-magnetite is overprinted by a sericite-ankerite-pyrite+/-quartz assemblage. The latter is weak to strong, pervasive and selectively pervasive (appearing as vein envelopes). This alteration type is also prominent in sedimentary rocks of the Timiskaming assemblage and later intrusive feldspar porphyry and quartz-feldspar porphyry.

Gold mineralized zones are mainly hosted by diorite and feldspar porphyries altered to sericite-ankerite+/-quartz and closely associated with pyrite within mm-thick veins of quartz+/-molybdenite, calcite, and pyrite only stringers. Visible gold is present in the pyrite-calcite vein, occurring as specks less than 1 mm in size.

Although it is too early to propose a deposit model for Bidgood, it likely formed as either an intrusion-related or orogenic deposit, both present in the camp. Ongoing and future work includes the alteration mineralogy and geochemistry of the intrusive units, and the age of the host rocks and mineralization will be determined using U-Pb zircon and Re-Os molybdenite dating, respectively, to identify the most applicable deposit model.

300 Epithermal Deposits

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Geological Features and Some Diagnostic Characteristics of the Gunung Akmil HSE Prospect in Menoreh Range, Central Java, Indonesia: Implication for Vectoring to the Concealed Porphyry System

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The Gunung Akmil high sulphidation epithermal (HSE) prospect, located within the Menoreh mountain range of southern Magelang, Central Java, presents a compelling geological setting for the potential occurrence of a concealed porphyry system. Numerous previous research studies have consistently pointed towards this possibility. This study is aimed to identify geological features and some diagnostic characteristics of HSE mineralization, to be utilized for vectoring to the possible presence of concealed porphyry system. The lithologies consist of andesite porphyry and diorite porphyry as host rock of the mineralization. The ore mineralization system is mainly controlled by ENE and NNW trending structures. To further achieve the objectives, we conducted systematic mapping and sampling from central to peripheral of the prospect. Petrography and X-ray Diffraction (XRD) to determine the type of mineral alteration and geochemical analysis using Fire Assay-Atomic Absorption Spectrometry (FA-AAS) to determine the Au content were employed. Four alteration zones were identified extending from periphery to center of the prospect including chlorite-epidote±pyrite (propyllitic), kaolinite±dickite (argillic), quartz-pyrophyllite-white mica-dickite (advanced argillic) and quartz-goethite (silicified). There is a systematic increase in silicification degree and stockwork density toward the central of the prospect. The result from five selected samples for petrography and XRD reveals the presence of several diagnostic minerals indicating acid fluid alteration such as pyrophyllite, dickite and white mica. The occurrence of alunite is relatively rare, which implies that the deposit has been deeply eroded. Previous geomagnetic survey conducted in the study area indicates a high magnetic susceptibility, which may imply the presence of secondary magnetite-enriched altered rock underneath, possibly associated with a concealed porphyry system. The result from FA-AAS analysis exhibits a systematic change of gold grade from distal (peripheral) (0.03 g/t Au), proximal (0.19 g/t Au), toward the center of the prospect (0.44 g/t Au). In summary, the systematic increase of the silicification degree and vein/veinlet stockwork density, as well as a systematic change in the alteration intensity from propylitic, argillic, advanced argillic to the silicification zones from the periphery toward the center of the prospect obviously suggests a vectoring to the ore i.e. central HSE and possible concealed porphyry system. This is supported by ground magnetic anomaly and systematic increase of gold grade toward the prospect center. The presence of pyrophyllite, dickite and white mica in the central part of the prospect indicates a transitional zone of the HSE prospect to the porphyry system.

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Metamorphic remobilization of precious metals and critical-metals as a function of pyrite texture and composition: Example from the epithermal Haile deposit, South Carolina, USA

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The Neoproterozoic, low-sulfidation Haile epithermal deposit in South Carolina has been metamorphosed to greenschist facies conditions and deformed during the Paleozoic Taconian and Alleghanian orogenies related to the formation of the Appalachians. The primary hosts for mineralization at Haile are late Proterozoic meta-sedimentary and meta-volcanic rocks of the Persimmon Fork Formation. The deposit has total estimated reserves of 45.4 Mt with 2.6 Moz Au @ 1.8g/t and 3.2 Moz Ag @ 2.2g/t. The complex deformational history and metamorphic conditions of the deposit yields questions about the degree and extent of epigenetic processes that led to the distribution and remobilization of the mineralization dominated by pyrite, minor sphalerite, arsenopyrite, galena, chalcopyrite, pyrrhotite, and traces of native gold ± silver ± lead tellurides.

In order to constrain the impact of metamorphism and deformation on the ore phases, detailed mineralogical, textural and compositional investigations were conducted on pyrite due to its known close association with precious metals. Petrographic and micro-structural results show three growth generations of pyrite that are from oldest to youngest: (1) syngenetic very fine to medium grained, idiomorphic to subhedral pyrite, denoted Py1a, that is concordant with foliation S2; (2) syngenetic fine-grained to medium-grained, anhedral pyrite (Py1b) with a spongy, open vugs texture that commonly has irregular grain boundaries; (3) syntectonic, coarse, euhedral, and inclusion-free pyrite (Py2) that forms either around Py1b or forms annealed aggregates with weakly convex-concave grain boundaries.

While gold generally occurs as “invisible gold” in pyrite, high-grade gold occurs either as native gold along cataclastic cracks in Py1b and Py2 or as inclusion in Py1b. Less abundant, gold also occurs with Ag ± Pb tellurides interstitially between Py2. Also, arsenic concentrations is, on average, highest in Py1a (0.30 wt.%, n=56) and Py1b (0.30 wt.%, n=59); however, As-rich zoning developed in Py2 can be enriched in As of up to 2.94 wt.%. Further, the trace elements Ag, Au, Bi, Sb, and Te are more enriched in Py1a and Py1b.

These textural and geochemical observations indicate a complex epigenetic history where precious and semi-metals were deposited syngenetically with pyrite. However, metamorphism and deformation, likely during the Taconic orogeny, resulted in the partial destruction of coarser Py1b by relatively reduced, acidic fluids, and the formation of Py2 by dissolution-reprecipitation around Py1b. Further, Ag, Au, Sb and Te were liberated from Py1b, remobilized and deposited along cataclastic cracks (native gold) or interstitially between Py2 by the metamorphic fluid and sulfide melts (tellurides).

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High-grade gold controls and spatial chemical zonation at the Snip North prospect of the Iskut project

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The Iskut project, located in northwestern British Columbia, Canada, is located in a tectonically active region within the Intermountain Belt, formed by the convergence of the Pacific and North American plates. This subduction environment has generated a complex geologic history, characterized by intense magmatic activity, faulting and folding. Lithological units in the area include a Triassic-Jurassic volcano-sedimentary sequence composed of shales, sandstones and basalts, intruded by Cretaceous monzodiorites and younger intrusive bodies related to hydrothermal events.

At the Snip North prospect, multiple vein systems intersecting all lithologies have been identified, defining at least three stages of mineralization. Stage 1 includes veinlets with pyrite, chalcopyrite and carbonates, representing the earliest stage. Stage 2, the most economically significant, is composed of quartz, chalcopyrite, pyrite, sphalerite, gold and carbonates. Finally, Stage 3 corresponds to late veinlets dominated by carbonates, quartz and pyrite, occasionally accompanied by chalcopyrite.

Spatially, Stage 2 veinlets with white mica halos (~20 cm wide) predominate at shallow levels and are associated with the highest gold grades. At greater depths, veinlets with secondary biotite halos are observed, linked to pervasive biotite alteration in the host rock, which is cut by vein-related alterations. Monzodiorite quartz intrusions present at depths greater than 1 km are associated with increased molybdenum concentrations, suggesting their connection to deep stages of mineralization.

Micro-XRF analysis and detailed observations have revealed that copper is not always associated with sulfides, as it also appears disseminated in the host rock, suggesting the presence of sulfosalts. In addition, high concentrations of magnetite have been identified distributed throughout the deposit, along with smaller zones of hematite, indicating local variations in oxidation conditions during hydrothermal events. These features highlight the complexity of the deposit and underscore the need for further analysis to understand the controls on mineralization.

This geological and mineralogical context provides a basis for developing more efficient exploration strategies, optimizing resource estimation and advancing the comprehensive understanding of the Snip North prospect within the Iskut project.

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Spectral Evaluation of Hydrothermal Fluids in Sedimentary Hosted Au Deposits, Marigold Mine, Battle Mountain District, Nevada.

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The northern extent of the Battle Mountain-Eureka trend contains porphyry, skarn, and distal disseminated deposits of known origin. Marigold, an active producer, and Trenton Canyon Au, which was in production between 1996 and 2001, are sedimentary rock-hosted Au deposits proximal to these magmatic-hydrothermal deposits. As of September 2023, Marigold has recovered 4.7 Moz of gold since 1989. Both deposits share characteristics with Carlin-type gold deposits (CTGDs), such as structural controls, Au deportment, and geochemical signatures of ore zones. However, the majority of mineralization at both deposits is hosted in the siliciclastic Valmy Formation of the Roberts Mountain Allochthon. The ore currently mined at Marigold is oxidized and consists of Au-bearing goethite and hematite. Despite the interpreted timing of the Au deposition as Eocene, the genetic relationship with Eocene hydrothermal activity is not well understood. Marigold's Cretaceous intrusions are mineralized where they intersect with NW-WNW structures, and no Eocene intrusions have been identified. Trenton Canyon, located two kilometers south of Marigold's southernmost deposit, hosts both Eocene and Cretaceous intrusions. The Trenton Canyon and Marigold deposits present an opportunity to compare the role of hydrothermal fluids in sedimentary-rock-hosted Au deposits by defining influential factors involved in fluid evolution and Au deposition. Alteration zonation, mineralogy, illite crystallinity, and the distribution of alteration relative to lithology aid in determining the parameters of Marigold alteration. This contribution presents field data and results of spectral analysis across five fluid conduits located on the primary mineralized trend at Marigold.

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Distinguishing Late Neoproterozic hydrothermal alteration from metamorphic overprint: a study case of Bonavista Peninsula (Newfoundland)

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Two epithermal-style Au mineralization belts are hosted in the Late Neoproterozoic volcanic and sedimentary sequences of the Avalon terrane in Newfoundland. The pervasive epidote and titanite early replacement of mafic minerals from volcanic and plutonic rocks reflects the protracted latest Edicaran hydrothermal alteration. Oxygen isotope data and hydrothermal zircon U-Pb ages link this event to the Avalonian volcanic arc-back arc magmatism before ca. 550 Ma. However, widespread epidote-allanite cement replacement in clastic sedimentary successions cast doubt on the duration and extension of hydrothermal activity and the effects of the Acadian orogeny. This study presents data on heavy minerals, U-Pb calcite, and epidote-allanite from Ediacaran sedimentary units in the Bonavista Peninsula of Newfoundland. The heavy mineral assemblage is dominated by epidote-allanite-clinozoisite, titanite, biotite-muscovite, and garnet,

which corroborate the enrichment in hydrothermal/metamorphic minerals at the expense of primary magmatic mafic phases. Early calcite cement yield 415 – 390 Ma U-Pb ages associated with a low-grade metamorphic thermal resetting. Allanite results disclose different ca. 698 Ma, 587 Ma, and 430 Ma populations. The first two are interpreted as magmatic/hydrothermal, whereas the latter suggests a metamorphic overprint of sedimentary cover. Similarly, epidotes are divided into three groups based on texture and rare earth elements (REE), from which patchy REE-rich epidote yields a metamorphic age ca. 390 Ma. These new findings agree with previous detrital titanite and apatite geochronological and geochemical data from the same units, indicating hydrothermal and magmatic crystallization during Cryogenian-Edicaran, later affected by a regional metamorphic event between 430 – 370 Ma along the Avalon zone margin related to the Acadian Orogeny.

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Adularia in High-Grade Epithermal Au-Ag Veins, Russian Far East

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K-feldspar is common in igneous rocks, wall rocks and in mineral deposits. Hydrothermal K-feldspar (adularia) is one of the essential components of epithermal gold veins. This study examines the occurrence and compositions of adularia from several mines and prospects in the Russian Far East region to evaluate the usefulness of adularia as a vector for mineralization. Samples are from the Kupol (180.7 t Au, 1986 t Ag), Dukat (40 t Au, 17 kt Ag), Dvoinoye (36.3t Au, 50.5t Ag) Kubaka (>100t Au, >100t Au), and Karamken mines, as well as satellite and prospective deposits. Cretaceous Okhotsk-Chukotka volcanic belt hosts these deposits except for the ~ 300 Ma Kubaka deposit in the Omolon massif.

All samples show banded Qz-adularia, with adularia occurring as coarse (>2mm) sub-rhombic to fine rhombic crystals (<50µm), crystal aggregates and cementations, in crustiform, colloform and brecciated veins as well as in wall rock replacing plagioclase. Adularia observed compositionally close to the end member orthoclase. Adularia often creamy to pale white is easily identified by cobaltinitrite staining. Fine rhombic adularia grains were the predominant style of adularia in samples and are commonly Ba-bearing (0.3-2.9wt% Ba), adjacent to bands of microcrystalline quartz and observed in close spatial association with electrum, Ag-tellurides, Ag-sulfosalts and sulphides, suggesting contemporaneous formation of adularia and precious metals. Coarse sub-rhombic adularia contains various minerals including earlier albite, calcite, sulphides, sulfates and oxides. Pyrite has variably zoned compositions including arsenian pyrite (4.9-3.2 wt% As) and Co-bearing pyrite (0.6 wt% Co). Bladed calcite as well as Mn-bearing calcite were observed in certain samples. Mn-bearing minerals (rhodochrosite, rhodonite) are abundant in later ore at Dukat, with distinct pink band of rhodochrosite and rhodonite, with wispy rhodochrosite crosscutting coarse adularia containing earlier albite which also surrounds piemontite inclusions.

Future trace element analysis planned for this study aims to continue to assess the composition of adularia and its potential as a useful vector for Au-Ag mineralization in epithermal systems.

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Fluid Inclusion Evidence of Structural Modification of Epithermal Bonanza-Grade Gold Veins in the Brucejack Au-Ag Deposit, British Columbia, Canada

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An integrated petrographic and microthermometry study focused on the bonanza grade gold-bearing veins at the Brucejack epithermal gold-silver was carried out to investigate the fluid chemistry, fluid source, and physiochemical conditions of the ore-forming processes of 1. primary bonanza grade electrum; and 2. the consequent structural modification. The SEM-CL textures of the bonanza gold veins re-veal that the Phase 1 quartz crystals comprise (1) CL-homogenous cores and (2) oscillatory-zoned over-growths that predate bonanza grade mineralisation. This quartz was followed by CL-unresponsive Phase 2 quartz, which is the immediate host to electrum. It accompanied deformation and the destruction of Type 1 quartz growth textures. Phase 1 calcite is zoned in optical-CL and occur as infills of interstitial space of quartz crystals, massive bands in multi-incremental veins, massive calcite vein. Fluid inclusion studies reveal that the auriferous Type A veins were deposited from relatively saline (7 to 12 eq. wt. % NaCl; Phase 1.1 quartz) magmatic fluids with homogenisation temperatures (Th) ranged from 170 to 200 °C. In Phase 1.2 quartz, a decrease in salinity (3 to 6 eq. wt. % NaCl) and Th (150 to 170 °C) was record-ed. The calcites in Type A and Type C veins were deposited at low temperature of 120 to 150 °C from low salinity to non-saline fluids (0-1.7 eq. wt. % NaCl). A resurgence in temperatures is present during the (re-)crystallisation of Phase 2 quartz with Th between 165 and 190 °C and a wide range of salinities from 0 to 6 eq. wt. % NaCl. Barren, post-mineral tectonic veins (Vn 4) and quartz strain fringes of pyrite in wall rock were deposited from 7 to 12 eq. wt. % NaCl. A disparity in Th was recorded with most of the FIAs clustered between 170 and 190 °C with some ranging from 270 °C to in excess of 300 °C. The FIA with an electrum inclusion bearing fluid inclusion has a salinity of ~12.5 eq. wt. % NaCl and a Th of ~170 °C. Laser ablation ICP-MS analyses of secondary fluid inclusions hosted in quartz crystals detected Au, Ag, As, Sb, Sr, Cu and Pb, indicating that electrum grains were mechanically (re-)mobilised and captured in SLV inclusions during the associated deformation.

400 REE / Pegmatite Deposits

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Geological characterization and evolution of the Morro Redondo artisanal mine: Insights from a non-economic Li-bearing pegmatite.

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The Morro Redondo artisanal mine (garimpo) explores an LCT pegmatite. The operation focuses on semi-precious tourmaline varieties, including shorl and elbaite (rubellite, melanite, and indicolite), and spodumene and beryl as by-products. Even though the deposit is economic for elbaite, can this pegmatite also be economic for lithium? This studied focused on deposit mapping, petrography and geochemistry to define its prospectivity. The pegmatite body is vertical, discordant, and with a sharp contact with its quartz-biotite schist host of the Chapada Acauã Formation, the final phase of the Macaúbas Group. pegmatite is characterized by strong horizontal and vertical mineral zoning, which are presented here. External zone: fine crystals (1-8 cm) of quartz (graphic texture), Ca-rich albite, K-feldspar, biotite, muscovite (or rarer mica sub-species), tourmaline (vermiform and intergrown with quartz), and almandine. Intermediate zone: coarse crystals (~12cm) of albite, tourmaline, and quartz, the latter in intergrowth and overgrowth textures with the tourmalines, although apatite also shows intergrowth with tourmaline sometimes. Accessory beryl can also occur in this zone. Transition zone: coarse crystals (up to 60 cm) of muscovite, quartz, and albite in smaller quantities. Inner zone: megacrystals (up to a meter) of quartz, albite, spodumene, and lepidolite, the latter often replacing spodumene in a distinctive texture. There is also a distinct zone at the south extension of the body, where spodumene concentrations decrease and crystallization of primary lepidolite increases as the main Li host in the pegmatite. The pegmatite extends for 720 m and its inner zone for 397 m. From its mineralogy, zonation, texture, and type of contact, one may conclude that (1) its characteristic mineral zonation tracks the evolution of the body; (2) despite the occurrence of spodumene and lepidolite, the body is not an economically viable Li deposit; (3) possible magmatic mixing or geochemical disturbance occurred during the crystallization of the pegmatite; and (4) body depth and distance from the source were crucial factors for gemological diversity and mineral zoning.

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Investigating the Formation and REE Distribution in Magnetite-Apatite Ores: Insights from Partitioning Coefficients

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The main point of contention regarding the genesis of magnetite-apatite deposits is what kind of fluids give rise to these rocks. There are multiple competing hypotheses for the formation of IOA deposits, with models that range from purely magmatic to purely hydrothermal. Some IOA rocks host carbonates and apatite, the latter being a home to significant concentrations of REEs. The understanding of how REEs partition between apatite and melt and calcite and melt is essential to

comprehending how they develop. Calcite-apatite partitioning coefficients (DCc/Ap) have proven to be helpful to distinguish igneous from fluid-mediated processes in carbonatites.

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Calcite-apatite (Cc/Ap) partition coefficients (D) has been calculated for 15 IOA samples distributed globally from localities of Kiruna, Humboldt, Buena Vista, Iron Springs and Pea Ridge. The study conducted a detailed petrographic analysis of calcite-apatite minerals, using BSE, CL imaging, EPMA, and LA-ICP-MS to identify growth and alteration zones, P and Ca concentrations, and trace element content within the mineral pair.

The flat, slightly U-shaped pattern for La through Lu and the absolute values for DCc/Ap in some samples supported a magmatic origin of the carbonate minerals, while the other samples did not, suggesting a secondary recrystallized origin of the melt. The results of the IOAs are also compared with a set of carbonatites from Nooitgedacht, Kaapvaal Craton, South Africa which are representative of a magmatic origin and with Jumilla lamproite, which has evidences of secondary recrystallization of the minerals within them.

This research aims to deepen the understanding of the formation of IOA deposits, potentially resolving the longstanding debate over their origin. Additionally, it sheds light on the role of REE portioning in the minerals in IOAs. The demand for REEs increasing due to their critical role in high-tech industries such as electronics, clean energy, and electric vehicles. IOA deposits offer untapped REE sources. Understanding these processes could provide valuable insights into exploration strategies and economic potential.

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Post-orogenic lithium-cesium-tantalum (LCT) pegmatite mineralization in the Benin-Nigerian Shield

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Lithium-cesium-tantalum (LCT) pegmatites are a key source of economic lithium. The timing of LCT pegmatite crystallization within the context of an orogenic system (i.e., pre-, syn- and post-orogenic) appears to vary globally and exerts a primary influence on the distribution of lithium mineralization in orogenic belts. The recent advances in in-situ Rb–Sr mica geochronology have enabled the direct dating of lepidolite, a major phase in LCT pegmatites. When combined with in-situ Rb–Sr, Lu-Hf, and U–Pb geochronology on other related major and accessory phases, the timing of LCT pegmatite crystallization can be accurately determined and placed in the context of a region's magmatic and thermometamorphic history. Here, we present new in-situ Rb–Sr, Lu-Hf, and U–Pb geochronology data and results of petrological modeling from an east to west transect of the Benin-Nigeria shield to constrain the timing of magmatism, metamorphism and LCT pegmatite crystallization related to the Pan-African orogeny. Crystallization ages of Pan-African granites across our transect range from ca. 615–600 Ma. Magmatism is followed by a thermal metamorphic peak at ca. 545–530 Ma, as recorded by Lu-Hf systematics of post-kinematic garnet and monazite U–Pb. The western Benin-

Nigeria shield cooled through biotite Rb–Sr closure temperatures at ca. 510 Ma whereas the more deeply exhumed eastern part of the shield cooled through biotite Rb–Sr closure temperature at ca. 480 Ma. Lepidolite in a LCT pegmatite swarm found in the western part of our transect crystallized at ca. 505 Ma, consistent with post-orogenic pegmatite genesis. In the absence of the wide-scale detachment structures associated with orogenic-collapse, we propose the LCT pegmatites were generated by remelting of highly fractionated Pan-African granite due to post-orogenic thermal maturation of the Benin-Nigeria shield. Garnet-staurolite schists record a static increase in geothermal gradients from ~900 °C/GPa to 1150 °C/GPa. The cause of this late thermal pulse is not yet determined but may be associated with lithosphere delamination, the break-off of the subducting slab or post-magmatic radiogenic heating.

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Lithium-cesium-tantalum (LCT) pegmatites in southern Newfoundland

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Canada's efforts to develop low-carbon technologies has increased the demand for critical minerals, including lithium. Southern Newfoundland is a region displaying favourable geological conditions to host lithium pegmatites, particularly in the aureoles of voluminous, geochemically evolved plutonic rocks. The present research is focused on the Killick pegmatite field, a swarm of lithium-cesium-tantalum (LCT) pegmatites discovered in 2021 in southern Newfoundland. Fieldwork focused on mapping and sampling multiple spodumene-bearing pegmatite dikes. The dykes intruded metasiltstone, bleached meta-quartz arenite, and metavolcanic rocks of the Dolman Cove formation. Due to the homogeneity of the >10 dykes in the Killick swarm, three dykes form the focus of petrographic and mineral chemistry data collection (Kraken, East and Central dykes). The dykes are of variable thickness with irregular widths ranging from <1 to >5m. The textures in the Kraken dyke are mostly equigranular and dykes show no internal zoning, but the East and Central dykes have irregular zoning patterns including layered aplite zones in the contact with the host rock and coarser-grained cores with spodumene up to 15cm in length. Most plagioclase grains are albite, which likely formed due to the alteration of K-feldspar. Muscovite is present as both primary and secondary muscovite. Spodumene is acicular in shape, pale green, up to 15 cm in length, and it formed during the late magmatic stage. In some cases, the spodumene is altered to muscovite and clay minerals. The garnet grains are Mn-rich spessartine and is either magmatic or xenocrystic. The tourmalines are acicular, schorl in composition, and mainly present in the contact zones of the pegmatites with the host rocks. The columbite – tantalite minerals are mostly manganocolumbite to manganotantalite that are rich in HFSE. Apatite, monazite, and beryl are also present in minor proportions. The high Li and Cs content in the dykes and the presence of spodumene, spessartine, and columbite-tantalite group minerals indicate that the pegmatites are highly fractionated. Taken together, these new data provide a better understanding of the magmatic-hydrothermal processes that resulted in the emplacement of LCT pegmatites in southern Newfoundland. The pegmatites may be related to nearby, voluminous, geochemically evolved two-mica granites (Peter Snout and Rose Blanche plutons) or originated by the remelting of the metasedimentary host rocks.

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Zoning, mineral chemistry and classification of black-white microcline pegmatite, Tandilia System, Buenos Aires, Argentina

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Abyssal pegmatites represent the final crystallization stage of melts from the Paleoproterozoic basement of the Tandilia System. These bodies intruded in biotite-garnet gneisses exhibit vein morphology and appear as zoned or unzoned. This study aims to define the mineral composition, classification and genesis of the first zoned pegmatite described in this basement. Field relationships, petrographic analysis and advanced techniques, including XRD, SEM-EDS and $\delta^{18}O$ isotopes, reveal that pegmatite can be divided into three zones: 1) Black feldspar core, 2) White feldspar-tourmaline, and 3) Biotite. Zone 1 is dominated by coarse black feldspar (10-20 cm in size), interstitial quartz and altered plagioclase. The feldspar is perthitic to microperthitic microcline with tartan twinning and sulphide inclusions of galena, pyrite and argentite. Its chemical composition (EDS determination) is 14-16% K2O and 0.56-1.83% Na2O with $\delta^{18}O$ close to +5‰. Zone 2 contains white microcline (15-30 cm in size), biotite, muscovite, quartz, apatite, fluorite, fluorapatite, chalcopyrite, molybdenite, argentite, arsenopyrite and gold. Feldspar composition shows 13-14.2% K2O, 1.95-2.20% Na2O and an average $\delta^{18}O$ around +7‰. This zone also includes tourmaline (chorlo variety) with grain-sizes of 8-10 cm and FeOtot values of 15.40-19.09%. Zone 3 comprises crenulated biotite of ~5 cm, inequigranular texture and fine carbonate and muscovite veinlets containing sphalerite. The pegmatite exhibits distinct zonation, driven by the interaction between different processes. XRD analysis reveals that black feldspar in Zone 1 contains albitic components, while white feldspar in Zone 2 does not. The increased K2O content in the core, along with petrographic texture, suggests that black microcline formed from decomposition of plagioclase by hydrothermal fluids, which is consistent with lower $\delta^{18}O$ values in Zone 1, indicating extensive fluid interaction, and higher values in Zone 2 reflecting minimal source rock interaction and assimilation. Tourmaline chemical analysis suggests a magmatic or partial melting origin, in concordance with previous studies of similar rocks in the region. Additionally, the presence of base and precious metals, along with fluorine, chlorine and carbonate/muscovite veinlets highlights the role of hydrothermal fluids complexes in metal redistribution. These results let us classify this pegmatite as a black and white microcline-quartz-tourmaline zoned vein-type pegmatoid using the CMS (Chemical composition - Mineral assemblage - Structural geology) classification. Detailed studies performed on the pegmatites in the Tandilia System basement, such as those presented here, will provide further insights into the composition, evolution and role of late Paleoproterozoic hydrothermal fluids in the region.

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Mineralogy and Geochemistry of the Yellowknife Lithium Pegmatite Field

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In this study, the lithium pegmatite dikes and their spatially related intrusives are investigated to better understand spatial geochemical gradients that may be useful for exploration targeting on the district- and deposit-scale. We obtained multi-element whole rock geochemical data derived from bore holes, surface composite chip samples and channel samples collected from multiple field campaigns. The geochemical data is screened for spatial trends using x-y element plots, GIS and 3D modelling software. Magmatic and hydrothermal muscovite related to Li pegmatites are currently being analyzed for Rb-Sr muscovite dating using LA-ICP-MS. Spodumene-bearing pegmatites at Yellowknife seem to be spatially related to locally enriched intrusive stocks within the large voluminous body of the parental batholiths. These intrusions are characterized by a high abundance of apatite and are strongly enriched in Li, Cs, Rb, Be and other incompatible elements. However, the background Li concentrations of intrusive in the area is generally high, which disqualifies Li for the use as a pathfinder element. Apparently, fertile intrusions are characterized by exceptionally high 1/(K/Rb), P and Cs/(Cs+Li+Be). Preliminary field and microscopic observations suggest that the Yellowknife pegmatite field shows a concentric zoning around locally anomalously highly fractionated intrusions. A spatial trend from proximal barren pegmatites to more distal spodumene-bearing dikes is recognized. The dikes do not exhibit strong intra-dike zoning but typically are composed of an aplitic border zone and a medium to coarse-grained internal zone. The border zone is composed of primarily quartz, muscovite and accessory phases such as tourmaline, garnet, Columbite-tantalite minerals and cassiterite, whereas the internal zone is primarily composed of quartz, albite, k-spar and spodumene (up to 20 vol.%).

500 Volcanogenic Massive Sulfide (VMS) Deposits

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Glacial dispersal trains in the context of a migrating ice divide and thin till: implications for mineral exploration in northern Quebec and Labrador

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The last glaciation of the Laurentide Ice Sheet (LIS) modified the Canadian landscape and discontinuously deposited glacial sediment of various types over bedrock, including mineral deposits. Glacial sediment produced and dispersed by basal ice and subglacial processes (i.e., till), contain a compositional blend that reflects the bedrock source regions, including sources of potential interest for critical minerals. This study focuses on a core region of the LIS in northern Quebec and Labrador that experienced ice divide migrations, which led to multiple distinct ice flow phases that transported till in different directions. Previous analyses in the region showed evidence of longer dispersal trains in the clast lithology and indicator minerals, while major oxides from the till matrix geochemistry mostly reflect the underlying bedrock, indicating shorter transport distances. This study aims to use trace elements from till matrix geochemical data to determine their impact on dispersal train models by comparing their dispersal signal to those of indicator minerals and major oxides to better understand past ice flow dynamics and sediment source regions. The methods involve a data exploration phase, followed by a log-ratio transformation and standardization to address the constrained nature and log-normal distributions of compositional data. Principal Component Analysis (PCA) is then applied to reduce the dimensionality of the multivariate dataset and to reveal key compositional signatures. K-means clustering of PCA results then groups the elements into compositional assemblages. Results are then analyzed and interpreted in their spatial context to establish relationships with bedrock and glacial landscape features, and to map sediment dispersal patterns. Preliminary findings show similar patterns to that of the major oxides, with the trace elements having slightly greater dispersal magnitudes. These findings, along with previous work, suggest that the fine fraction of the till contains a dominant local provenance signature, whereas distal bedrock sources are more easily identified in the coarser fractions (pebbles, indicator minerals). Ongoing research is now focusing on the potential causes of this discrepancy in dominant bedrock sources and related transport distances and on the implications to mineral exploration in the region. The findings from this study will contribute valuable insights into the glacial dynamics of the region, thus enhancing future ice flow reconstructions and mineral exploration strategies.

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Paragenetic sequence of two ancient volcanogenic massive sulphide deposits from the Snow Lake Camp in Manitoba, Canada

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Volcanogenic massive sulphide (VMS) deposits are important sources of base and precious metals. Ancient VMS deposits have invariably undergone multi-phase metamorphism and deformation that have altered the ore body architecture. The paragenetic work presented here is part of a PhD project seeking to better understand the processes and controls on fluid-enabled metal remobilization during multi-phase metamorphism and deformation. The approach includes mapping structures and geochemical signatures in 3-dimensions. Expanding our understanding of primary and post-depositional geological controls on spatial distribution, grades, and associations of deformed ore bodies could aid in creating vectors for mineral exploration of ancient VMS systems.

The case study used for this work is the VMS deposits of the Snow Lake camp, in west-central Manitoba, Canada, owned and operated by Hudbay Minerals. Snow Lake is host to eight known VMS deposits, interpreted to have formed via a single metalliferous hydrothermal event ~1.9 Ga. Two deposits in Snow Lake are the focus of this study: in-production Lalor mine and in-development phase 1901 deposit. These deposits are ideal case study sites due to the excellent access to underground workings, significant amounts of drill core, and large drill-core databases that have been generously made available by Hudbay Minerals. Comparing data from each deposit provides unique opportunities to understand how differences in spatial distribution of faults and other large structures that may act as fluid conduits affect ore grades, textures, associations, and type of ore-hosted sulphide remobilization.

A total of fifty-four thin sections have been made and employed for this paragenetic study. Some of the samples come from a deep drift in the Lalor mine that runs perpendicular to the strike of several lithologies, shear zones, and five ore bodies that vary in grade and metal content (Cu+Zn+Ag+Au). The other samples come from drill core that intersect the 1901 deposit. The next steps of this PhD are microanalytical studies, including scanning electron microscope (SEM) and laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) to understand the elemental distribution of the ore bodies and hosting lithologies.

The results of this study will be integrated into a 3D geological model that is being developed as part of this PhD project. Combined with new interpretations of deposit-scale folds and faults, as well as multi-variate analyses correlating litho-geochemical signatures to structures and ore bodies, this work will aid in understanding the controls on ore body architecture in ancient metamorphosed and deformed VMS deposits.

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Seafloor massive sulfide occurrences and their tectono-magmatic controls along spreading centers: Insights from a new geologic map of the Juan de Fuca plate

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The active spreading centers that occur between the Juan de Fuca Plate on the western coast of North America and the Pacific Plate host at least tens of seafloor massive sulfide occurrences, including some of the largest known deposits in the ocean (e.g., the 9 Mt Bent Hill deposit at Middle Valley). The sizes and distribution of the deposits, as well as their compositions, are strongly influenced by tectonic and magmatic controls, such as spreading rate and proximity to mantle hot spots. Detailed geological mapping is providing a regional framework for understanding some of these differences.

In this study we present a new 1:1,000,000 scale geologic map of the Juan de Fuca plate. The map covers an area of 890,000 km^2, extending from the shelf to the offshore abyssal region. It includes the entire Juan de Fuca plate, the Explorer microplate, parts of the Pacific Plate and the Cascadia Margin, the Sovanco and Blanco transforms, Axial Seamount, and a segment of the Mendocino fracture zone.

Mapping was carried out in ArcGIS Pro using remote predictive mapping techniques adopted by geological surveys on land and other planets. Ship-based multibeam, side-scan sonar, acoustic backscatter, multiparameter geophysical, and groundtruthing datasets constrained the geologic interpretations. The mapped units were then extrapolated to areas with less data by comparison with regional geophysical datasets. Feature classification was guided by an internally consistent legend including structures, lithostratigraphic units, and volcano formations (subdivided into cones, shields, domes, axial volcanoes, ridges and flow fields).

More than 6,500 lineaments, >1,000 polygons of the different geological formations were mapped, as well as >2,700 volcanic features. Further investigation of the mapped formations and structures provide insights into different metal sources along the Gorda, Juan de Fuca, and Explorer ridges, including N-MORB, E-MORB, and sediment-influenced hydrothermal systems, with implications for understanding the variable compositions of volcanogenic massive sulfide deposits on land.

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Lithogeochemical Discrimination of Source Rocks of Carbonaceous Mudstones in Volcanic Assemblages of the Western Abitibi Greenstone Belt

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The Abitibi Greenstone Belt (AGB) is host to world-class base metal deposits. However, increasing depletion of near-surface deposits requires improved geological models to guide the identification of future exploration targets. Carbonaceous argillites, or black shales, are common ore-hosting units in the AGB and their distinct electromagnetic properties has resulted in many of these rocks being targeted during drilling campaigns. This resulted in a vast yet widely underappreciated archive that holds valuable information to locate deeper mineral deposits.

The black shales are mainly synvolcanic and formed in volcanosedimentary basins spatially correlated with magmatic complexes. This study uses over 500 samples of carbonaceous argillite collected during a regional-scale sampling program in 2011. Whole-rock geochemical analysis was performed on 564 samples from more than 75 different townships. The objectives of the present study are to develop a detailed classification of carbonaceous argillite from the AGB as a tool for mineral exploration including improved understanding of i) metal enrichment, ii) source rock domains, and iii) distinguishing between barren and potentially mineralized horizons. Black shale is visually unclassifiable, however, using geostatistical methods, we have identified groups related to source rock composition (felsic, mafic), mineralization style, and post-depositional processes.

Alteration indices highlight hydrothermally influenced units, including mineralized shales and shales that were derived from volcanic rocks already altered at their source. The europium anomaly (Eu/Eu*) and Zn/Na in particular, identify known mineralized shales in mafic-dominated assemblages including Kidd-Munro and Stoughton-Roquemaure. Two machine learning approaches identify key relationships between the different mudstone units, including spatial variations in the shale geochemistry and their relationship to the host volcanic rocks. Principal Components Analysis (PCA) and Random Forest Clustering identify the element groups that explain most of the variance in the dataset and predict the source rock composition with an accuracy of 92%. (e.g., vanadium, scandium, and chromium are particularly important for distinguishing between felsic and mafic source rocks). Blind tests show the Random Forest model developed using the AGB samples can predict source rock composition and potential links to mineralization (VMS versus orogenic gold targets) in other regions.

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Characterizing critical metal occurrences in metamorphosed and deformed volcanogenic massive sulfide deposits

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Volcanogenic massive sulfide (VMS) deposits are significant sources of base and precious metals and are increasingly recognized for their critical metal potential including Bi, Ni, Co, Sb, and Te. However, their occurrence and behavior during metamorphism and deformation remains poorly understood. This project aims to address this gap by investigating the mineralogical and chemical characteristics of critical metals in VMS deposits metamorphosed from greenschist to upper amphibolite facies.

Preliminary work on the Neoproterozoic Genex deposit, Ontario focused on ore assemblages and textures in both stockwork and (semi-)massive sulfide zones. The Genex deposit is a VMS system hosted in felsic and mafic volcanic and volcaniclastic units. It has experienced greenschist facies metamorphism during the Late Archean Algoman orogeny. The deposit was mined between 1964 and 1966, producing approximately 242 tons of copper concentrate from two primary orebodies, the C and H zones. Historical indicated resources are 214,000 t at 1.68 % Cu.

Reflected light microscopy indicates that massive and semi-massive zones that are enriched in chalcopyrite exhibit the most diverse mineralogical assemblages. Chalcopyrite is the dominant sulfide phase, forming massive aggregates and intergrowths with sphalerite, pyrite, and trace amounts of sulfosalts (assumingly enargite), arsenopyrite, tellurides and electrum. Sphalerite shows chalcopyrite disease, with fine-grained disseminated chalcopyrite. Pyrite textures reveal spongy structures and partial replacement by chalcopyrite. Additionally, pyrite shows deformation-related features such as cataclasis and triple junctions. Of the critical metal-bearing phases besides chalcopyrite and sphalerite, assumed sulfosalts and tellurides show a variation of complex textures including fracture filling in chalcopyrite, sulfosalt rims forming around unknown phases, intergrowth of tellurides and unknown phases.

Whole rock lithogeochemistry on massive sulfide and stringers show enrichment in critical metals such Bi (up to 250 ppm), Co (up to 770 ppm), Te (up to 82 ppm), and Ni (up to 264 pm) besides Cu (>10,000 ppm) and Zn (>10,000 ppm).

Future work will constrain the composition of base metal sulfides, sulfosalts, and critical metal-bearing phases (e.g., tellurides) using electron probe microanalysis and laser ablation inductively coupled plasma mass spectrometry with emphasis on their critical metal content. Refining the textural relationship between the different phases and identifying microstructure using scanning electron microscopy and electron back-scattered diffraction, respectively will complement this work.

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3D Spatial Analysis of Alteration Halos and Short Wavelength Infrared (SWIR) Characteristics of the Lalor and 1901 Volcanogenic Massive Sulfide Deposits in Snow Lake, Manitoba, Canada

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Hydrothermal alteration in volcanogenic massive sulfide (VMS) deposits arises from the interaction of upwelling fluids with host lithofacies, driving geochemical and mineralogical changes that result in zoned alteration halos surrounding mineralization. The Snow Lake camp hosts numerous VMS deposits with economically significant endowments of critical metals. These deposits formed during a single time-stratigraphic ore interval coinciding with contemporaneous volcanism, leading to the stratabound accumulation of sulfide minerals in gently NNE-dipping ore lenses enriched in Zn, Au, and Cu. The Lalor deposit, the largest of these, is currently mined by Hudbay Minerals, with combined resources and reserves totaling 25.3 Mt at average grades of 2.9 g/t Au, 25 g/t Ag, 5 wt% Zn, and 0.79 wt% Cu, including 8.8 Mt at 4.6 g/t Au (Hudbay Minerals). The neighboring 1901 deposit holds combined resources and reserves of 5.3 Mt at average grades of 1.7 g/t Au, 18 g/t Ag, 7 wt% Zn, and 0.34 wt% Cu (Hudbay Minerals). These volcanic successions have undergone extensive syn-VMS hydrothermal alteration, followed by polyphase deformation and amphibolite-grade metamorphism. Metamorphosed hydrothermal alteration styles have been categorized into distinct chemical associations, including K, K-Mg-Fe, Mg-Fe, and Mg-Ca. Extensive mapping and sampling in the Snow Lake camp have yielded valuable data and insights into these deposits. However, there remain opportunities to refine our understanding of alteration assemblages and their relationships to mineralization, building on the strong foundation established by prior work. This study aims to evaluate the effectiveness of short-wave infrared (SWIR) spectroscopy in quantifying alteration halos and to use Leapfrog Geo modeling software with the implicit modeling method to visualize their spatial distribution. SWIR spectroscopy, being an accessible and cost-effective technique, was employed to analyze spatial

trends across the Lalor and 1901 deposits. The resulting spatial model integrates lithological and structural data from publicly available cross-sections and maps and compares these with SWIR-derived alteration data and petrographic analyses, providing a comprehensive framework for understanding hydrothermal alteration patterns.

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Mineral prospectivity modelling of volcanogenic massive sulphide potential in the Kamiskotia area, Ontario, Canada

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The rate of mineral deposit discoveries has declined globally in recent years as most shallow targets have already been discovered. This holds for the Kamiskotia area, a volcanogenic massive sulphide (VMS) district in the Abitibi greenstone belt. Past-producing VMS deposits in this area are hosted by the Neo-Archean Blake River assemblage and share several similarities (e.g., comparable bimodal host lithologies, alteration signatures, deposit morphology, stratigraphic position, and ore assemblages) to suggest further potential. However, no significant deposit has been uncovered since the initial discoveries of the past-producing mines in the 1920s and traditional prospecting is inhibited by relatively low outcrop exposures. This study uses mineral prospectivity mapping (MPM) as a relatively new approach to identify potential exploration targets in the study area. To achieve this aim, random forest (RF) was used as a modelling technique to integrate predictor maps from lithologic, structural, geophysical, and geochemical data prepared in both continuous and binary surface map formats. Forty-four base metal occurrences and 44 non-VMS locations were used to train the RF model, whereas 22 showings were used as test data. Additionally, RF feature ranking was used to constrain the most important predictors of mineralization.

The probability map from continuous predictor maps (continuous MPM) and binary predictor maps (binary MPM) showed high overall classification accuracies (i.e., > 85 %), success rates of classification and prediction, and area under the curve (AUC) on efficiency curves. The success rates and AUCs obtained were higher for the binary MPM than the continuous MPM, suggesting that binary predictor maps outperform continuous maps. The binary MPM was, therefore, selected as the best performer. Ten areas with probabilities greater than 90 % were highlighted as the most prospective areas, out of which six were interpreted as new potential targets away from past-producing mines that may be prime for follow-up. RF ranks predictor maps from subvolcanic-synvolcanic intrusions and faults, mafic and felsic volcanic lithologies, Bouguer gravity and its derivatives, high-Zr rhyolites, evolved mafic rocks, Cu, Zn, and chloritization indices as the most important parameters to consider for follow-up studies in these areas. The results underscore the usefulness of RF MPM in integrating multiple geoscience datasets to map VMS prospectivity and exhibit the potential for new discoveries in the Kamiskotia area.

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The Role of Serpentinization on Hydrothermal Fluid Evolution in the North Atlantic

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"Serpentinization" is a blanket term representing a multitude of redox reactions that occurs in ultramafic rock types when exposed to seawater, collectively resulting in a highly reduced hydrothermal fluid of variable pH, temperature, and critical metal load, that is capable of contributing to overlying seafloor massive sulfide (SMS) deposits, particularly in off-axis oceanic core complex settings of ultraslow-spreading mid-ocean ridge segments. Recent exploration aboard the R/V Falkor (too) in March-April of 2023 discovered three new active hydrothermal vent fields in the North Atlantic, between the ranges of 20 – 25°N, with each deposit representing a varied exposure to ultramafic rock types. These deposits are Puy de Folles, EMARK, and Grappe Deux. The Puy de Folles deposit is hosted exclusively within mafic volcanics at the intersection of the Mid-Atlantic Ridge, and a non-transform offset. The EMARK deposit is hosted within mixed mafic-ultramafic rock types on the inside corner high of the Kane Fracture Zone, wherein multiple minor episodes of detachment faults exposed several serpentinite blocks intercalated with young, glassy, mafic volcanics. Finally, the Grappe Deux deposit is hosted almost exclusively within ultramafic rocks at the toe of an oceanic core complex in a non-transform offset. Trends in the bulk geochemistry of the collected 32 grab samples indicate enrichments of mantle-incompatible critical elements within the mafic-hosted site (Pb, Ag, Hg, As, Sb, Mo); whilst the ultramafic hosted site is enriched in mantle-compatible critical metals (Co, Bi). However, the mixed hosted site demonstrates strong enrichments of critical metals (Ag, Sn, Ga, Ge, Zn, Si), and most notably Au. The mineralogy of the serpentinites provides insight into the hydrothermal and volcanic histories of these SMS deposits, with the mixed-hosted deposit containing "early-stage" serpentinite minerals and geochemical signatures indicative of mafic melt impregnation (elevated Al_2O_3/SiO_2), whereas the ultramafic-hosted deposit contains signatures indicative of a more evolved serpentinite (abundant talc, tremolite, and magnetite), as well as minimal carbonate veinlets. The strong correlations between Au and low temperature phases such as silica and sphalerite at EMARK demonstrates the importance of basalt as a redox buffer for the mobilization of gold. The variable critical metal enrichments at these sites demonstrate the geochemical and temporal variability of ultramafic-hosted SMS deposits as serpentinizing reactions evolve through subsequent buffering interactions with the host rock. These observations provide insight into both the influence of host lithology on critical metal endowment, and the potential effects of prolonged hydrothermal circulation in SMS deposits.

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Gold mineralization in the hydrothermal field at the termination of a detachment fault: A case study of the Tianxiu Vent Field

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Gold mineralization in hydrothermal systems at slow- to ultraslow-spreading ridges commonly occurs either in the hangingwall or the footwall of the detachment fault. However, the Tianxiu Vent Field (TVF) on Carlsberg Ridge is, to our knowledge, the only known example where the mineralization occurs directly at the termination zone of a detachment fault. Located approximately 5 km south of the rift axis near 3°48'N on the slow-spreading Carlsberg Ridge, TVF provides a unique opportunity for studying gold mineralization in this context. Detailed analyses of the mineralogy, mineral chemistry, and bulk geochemistry of massive sulfides from Tianxiu reveal several key findings: (1) both visible gold (native gold and electrum) and invisible gold are predominantly hosted in Cu-rich minerals such as isocubanite and covellite; (2) the content of Au (mean = 5.72 ± 4.38 ppm, n = 43) is positively correlated with Co, Cu, Bi, and Se; and (3) the gold mineralization occurs primarily at high-temperatures under strongly reducing conditions, with additional gold mineralization during late-stage silicification and seafloor weathering. When compared to other detachment-fault-associated deposits along slow- to ultraslow-spreading ridges, the ultramafic source rocks and the strongly reducing conditions at TVF appear to have facilitated Au mineralization. Additionally, the intensity of the fluid/rock interaction is possibly an important factor controlling the distribution of gold. The heterogeneous distribution of gold in Tianxiu is likely due to the spatial variability of fluid pathways within a highly permeable termination zone of the detachment fault. This study underscores a unique mineralization model of gold at the termination of a detachment fault on slow-spreading ridges, which has significant implications for the exploration of massive sulfide resource in off-axis regions.

600 Sedimentary Environments

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From macro to nano: Unraveling the distribution of germanium in the Zn-Pb-Ag Prairie Creek Deposit, NWT, Canada.

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Germanium (Ge) is crucial in advancing technology, especially fiber optics and high-efficiency solar cells. It is commonly recovered as a byproduct of zinc (Zn) production, which poses potential future supply risks, defining it as a critical mineral. Ge is frequently sourced from sediment-hosted Zn-Pb deposits but the deposit-scale distribution and enrichment mechanisms within these deposits remain poorly understood. To help fill this knowledge gap, we use macro- to nano-scale analytical methods to examine the Ge-bearing Zn-Pb-Ag Prairie Creek deposit in Northwest Territories, Canada. We aim to refine the genetic model of this deposit and identify key factors influencing Ge accumulation.

The Prairie Creek deposit exhibits two main mineralization styles: 1) stratiform and 2) quartz-carbonate vein, hosted in Ordovician to Devonian sedimentary rocks. Using whole-rock geochemical analysis, we determined that only the stratiform style is significantly enriched in Ge (up to 300 ppm). The results show a strong correlation between Ge and Zn, indicating that Ge content is associated with Zn-bearing mineral phases. EMPA analysis of the three major ore minerals—galena (PbS), sphalerite (ZnS), and pyrite (FeS_2)—suggests that sphalerite is the primary host for Ge. At least two generations of sphalerite (Sp I and Sp II) occur in the stratiform mineralization. LA-ICP-MS analysis of sphalerite reveals significant Ge enrichment (up to 2600 ppm) exclusively in Sp I, whereas Sp II exhibits much lower Ge concentrations (0.5 to 100 ppm). Trace element mapping shows a spatial correlation between Cu and Ge within sphalerite crystals, with spot analysis identifying a 2:1 Cu ratio. This suggests a possible relationship in their substitution mechanisms. Notwithstanding, atom probe tomography indicates that Ge primarily occurs as nano-inclusions, likely Cu-Ge sulphide minerals, within Sp I, rather than substituting for Zn in the sphalerite crystal lattice.

This work will provide valuable insights into the behavior of Ge in hydrothermal fluids within sedimentary environments, directly guiding strategies to enhance mineral exploration and extraction for Ge-bearing deposits in the Northwest Territories. By refining these strategies, it aims to better meet global demand for Ge and contribute to a sustainable future.

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Investigating Vanadium Enrichment of the Duo Lake Formation at Howard's Pass, Yukon and Northwest Territories

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Black shales are known to contain high concentrations of vanadium (up to 2 wt % V_2O_5), nickel, and molybdenum as stratabound deposits. These deposits are an under-explored critical metal resource that is starting to be exploited in other parts of the world. While the current understanding of these deposits is that they directly precipitate from ocean water, there is a

potential link with hydrothermal systems. To test this, we investigate vanadium rich shales that underly the clastic-dominated Zn-Pb mineralization of the Howards Pass district, Yukon and Northwest Territories.

To investigate the geochemical processes that governed vanadium enrichment in the Duo Lake Formation, research methods such as Fe Speciation, AVS and CRS analyses, as well as isotopic analysis were employed to examine the depositional conditions, redox environments, and fluid interactions that facilitated vanadium precipitation in this region. Additionally, the project will explore the spatial distribution of vanadium relative to other metals, particularly zinc and lead. By comparing the data to previous work on the formation of vanadium mineralization at the Van Property, hosted in the same stratigraphic unit some 60 km to the southeast, this analysis will determine if the deposits share a common source. Through this comparison, the study aims to uncover the mechanisms driving vanadium mineralization in this sedimentary system, contributing to a broader understanding of critical metal deposits.

By comparing vanadium distribution to zinc and lead, this research will clarify the potential for co-mineralization of vanadium with base metals, which could make vanadium extraction more economically viable. This research may also have implications for the development of sustainable mining strategies. As the global demand for vanadium increases, understanding the geochemical controls on vanadium enrichment will be essential for locating new sources of this critical metal. Moreover, identifying the key factors that lead to vanadium and other critical metals' concentration in sedimentary deposits could drive innovations in resource extraction and processing techniques, ultimately improving the efficiency and sustainability of mining operations. This research will provide a more comprehensive understanding of vanadium mineralization in clastic dominated Zn-Pb deposits and inform future exploration strategies for vanadium and other critical metals in the Selwyn Basin and beyond.

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Redox Conditions of the Stratigraphy Hosting Zn-Pb and V Mineralization in the Howards Pass District

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The Howard Pass district spans the Yukon-Northwest Territories border and contains an estimated 400.7Mt of mineralization grading at 4.5% Zn and 1.5% Pb, which accounts for over 30% of global Zn and Pb resources. Mineralization is hosted in the Ordovician to Silurian Duo Lake Formation, which consists of carbonaceous and siliceous mudstone. There are multiple proposed genetic models of a modified exhalative environment including Zn-Pb-rich brines permeating sulfidic muds by downward percolation of the metalliferous brine into unconsolidated sediments, or selective replacement of reactive strata during early diagenesis. Therefore, redox conditions at the time of sediment deposition may play an important role in controlling mineralization. A recent study suggests that global Ordovician through Early Devonian anoxic marine waters were commonly ferruginous (nonsulfidic). Previous workers have used whole rock multi-element geochemical proxies to show that at Howards Pass the redox conditions during host sediment deposition fluctuated from suboxic to sulfidic, but the occurrence of ferruginous conditions has not been fully investigated. This study employs Fe-speciation to test for ferruginous conditions in the strata hosting Zn-Pb mineralization at Howards Pass. Sequential leach analyses will quantify different forms of iron hosted in hosted in the carbonaceous and siliceous mudstones and determine ferrous-ferric oxide phases. Additionally, sulfur from pyrite, sphalerite, and galena will be characterized through extraction of acid-volatile sulfides, chromium-reducible sulfides and bulk analysis of S isotope composition. This study aims to address knowledge gaps in sediment-hosted massive sulfide deposits by interpreting the relationship between redox environments and mineralization processes. The geochemical analyses will elucidate how redox fluctuations impact metal concentration and preservation in sediment, potentially offering broader implications for sediment-hosted ore-deposit exploration. Further, this study will provide empirical data to assess the effects of hydrothermal systems on Fe-speciation analyses.

700 PGE / Magmatic

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Unconventional critical metal enrichment in post-collisional settings, example of the Gull Ridge Ni-Cu-V-Ti mineralization, Baie Verte Peninsula, Newfoundland

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Critical metals are the building blocks for modern technology and the energy transition. Ni, Cu, V, and Ti are essential for building the infrastructure needed for renewable energy generation, energy storage, and electric mobility. Globally, these metals are often sourced in magmatic deposits that occur in ultramafic-mafic systems and formed from mantle-derived melts in rift and/or plume settings. However, in the past few decades new magmatic deposits have been found in convergent margin and post-collisional settings, which is uncommon for most magmatic Ni-Cu-V-Ti deposits. Understanding the processes involved in the formation of these deposits is essential for further exploration and development of new resources. Here, we present a study on the Gull Ridge Ni-Cu-V-Ti mineralization located in the southern portion of the Baie Verte Peninsula of Newfoundland in the Northern Appalachians.

The Gull Ridge pluton is a poorly exposed large highly magnetic polyphase intrusion composed of layered alkaline gabbros, A-type quartz-monzonites and rhyolitic dikes. Mineralization is present within the layered gabbro and it occurs in two styles: (1) disseminated pentlandite, chalcopyrite, pyrrhotite and pyrite in a sulfide-rich medium to coarse grained gabbro and (2) sulphide-poor highly magnetic medium grained gabbro with disseminated vanadiferous ilmenite and magnetite. This study combines detailed core logging, evaluation of the host rock petrogenesis with whole rock geochemistry, sulfide and oxide characterization using transmitted, reflected light petrography and SEM, semi-quantitative to quantitative maps of the ore minerals by SEM and EPMA, in-situ sulfur isotope analyses by SIMS and U-Pb geochronology of baddeleyite and zircon with LA-ICP-MS.

This study aims to reconstruct the evolution of the host rocks and mineralization within the alkaline Gull Ridge pluton but also to evaluate its relationship with other Silurian mafic intrusions in the region and to assess a potential trans-lithospheric continuum with upper crustal porphyry and epithermal systems within the Notre Dame subzone in the Newfoundland Appalachians which may have significant implications for future exploration in the region.

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The role of hydrothermal processes in the genesis of the Alaskan-type Turnagain mafic-ultramafic complex, British Columbia

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The Alaskan-type Turnagain mafic-ultramafic complex in British Columbia, Canada, hosts a large tonnage, low grade magmatic nickel-sulphide resource (measured resource of 423.4 million tonnes at 0.214 % Ni) that provides an excellent opportunity to study the effects of hydrothermal alteration on nickel-sulphide deposits in such complexes. Pentlandite, the primary ore mineral, and pyrrhotite, the dominant sulphide mineral, occur interstitial to magmatic olivine and diopside within dunite and wehrlite, which is consistent with their magmatic origin. However, local serpentinization of magmatic olivine and diopside coupled with the replacement of magmatic sulphides by magnetite, and the subsequent remobilization of pyrrhotite and pentlandite has significantly affected the distribution of nickel and sulphur in the deposit.

A preliminary petrographic and electron microprobe study of olivine in representative samples from the Horsetrail-Northwest Zone was performed to characterize this alteration. Magmatic olivine forms subhedral to euhedral cumulate crystals with Mg numbers (Mg/Mg+Fe*100) ranging from 85 to 97 and concentrations of MnO and Ni ranging from 0.05 to 0.3 wt. % and 0 to 0.7 wt. % Ni respectively. Secondary olivine occurring as rims on relict olivine grains and filling fractures in serpentine, has a higher Mg number (94 to 98), an elevated MnO content (0.15 to 1.3 wt. %), and a lower Ni content (0 to 0.05 wt. %). The negative correlation of Mg number with MnO and the positive correlation with Ni in the magmatic olivine are consistent with convergent margin magmatic processes. In contrast, the elevated Mg number and MnO content of the secondary olivine, and a lower Ni content are indicative of the dehydration of serpentine.

The higher Mg number in secondary olivine is attributed to the sequestration of iron in magnetite during serpentinization, whereas its lower nickel content indicates that nickel was mobilized during alteration. The elevated MnO concentration in secondary olivine reflects the uptake of this component from fluids during serpentine dehydration.

This study identifies two distinct alteration stages in the Turnagain complex: 1) serpentinization of olivine driven by fluids along faults; and 2) the partial dehydration of serpentine due to thrust-induced decompression or heating of the complex by nearby Cretaceous (Cassiar) intrusions. These findings demonstrate that textural relationships, Mg number, MnO and Ni concentrations can effectively distinguish magmatic from secondary olivine in Alaskan-type complexes and reveal a mechanism for nickel remobilization from silicate to sulphide minerals.

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Mineralogical and Geochemical Relationships of Spodumene-Rich Pegmatites with Host Pelitic Schists: Insights from the Trieste Project, James Bay, Quebec

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In Quebec, the James Bay region is well known for the hard-rock Li-bearing deposits hosted called LCT pegmatites, which are crucial for transitioning to greener energy. Within this region lies the Trieste Project, where the swarm of spodumene-bearing pegmatites is hosted in the Neoarchean Salomon River Formation of the La Grande Subprovince, Superior Province. This research is focused on an outcrop called Dyke 1, where assay intervals, such as 28.8 meters at 1.1% Li_2O (including 6.2 meters at 2.3%) from hole DIS23-006, highlight the area's potential as a significant lithium resource. It also provides insights into the spatial distribution of spodumene, its overgrowths, the emplacement of veinlets, alteration patterns, and the distribution of gangue minerals. During fieldwork, spatial mineralogical relationships were carefully documented through photographs and complemented by detailed field sketches. Surface rock samples and drill core samples were collected for petrographic analysis, followed by whole-rock geochemical interpretation of drill hole data. The pegmatite is composed of very coarse-grained spodumene, the primary Li-bearing mineral, along with albite ± K-feldspar ± muscovite, and accessory minerals such as apatite, beryl, and tantalite. Textures such as graphic (plagioclase + quartz intergrowths) and symplectite (spodumene + quartz intergrowths) are observed. The host rock, a pelitic schist from amphibolite facies of the Salomon River Formation, is composed of quartz ± biotite ± muscovite ± cordierite ± staurolite ± plagioclase ± tourmaline. Alteration is characterized by moderate albitization, chloritization, and sericitization in the exocontact zone, while the endocontact zone exhibits weak sericitization. The pegmatite's whole-rock geochemical analysis indicates a high hydrothermal evolution, based on low K/Rb <90 and Nb/Ta <5 ratios, which is geochemically favorable for Li mineralization. In addition, cesium functions as a geochemical vector due to its high mobility into the country rock following the pegmatite emplacement. The integration of systematic photographs, sketches, geochemical data, and petrographic analysis will play a crucial role in understanding pegmatite formation processes, further contributing to lithium exploration efforts in the James Bay region.

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Petrogenesis of a Chromite Autolith in the Platiniferous J-M Reef of the Stillwater Complex, Montana, USA

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The Stillwater Complex is a mafic-ultramafic layered intrusion in south-central Montana (USA) that hosts significant stratiform chromitite deposits and platinum-group element (PGE) mineralization, the latter notably within the J-M Reef. Although PGE mineralization in layered intrusions is typically found in chromitites, the chromitites in the lower part of the Stillwater Complex have relatively low abundances of the PGE. Conversely, the J-M Reef, with the highest PGE grades of any ore deposit of its kind, mainly comprises plagioclase-rich gabbros and troctolites, without any chromitite evident. This study describes a coarse-grained chromitite autolith found within the J-M Reef package, and which contains relatively abundant sulfide and evidence of platinum-group minerals (PGM). This project aims to elucidate the origin and crystallization history of this autolith, in part by comparing its mineral chemistry and textures to the massive chromitite lower in the Stillwater Complex stratigraphy (i.e., in the Peridotite Zone). Thin sections from both samples were analyzed using crystal size distribution and microprobe analysis to assess mineral compositions, grain size distributions and associated sulfide assemblages. The autolith comprises a chromite adcumulate with interstitial serpentine and disseminated sulfides. By contrast, the Peridotite Zone G seam Chromitite shows complex interlayering of chromite and peridotite, with much greater variability in chromite grain size. Early results suggest that the autolith does not share mineral chemical similarities with the G Chromitite (e.g., chromite in the autolith has much higher Al_2O_3 contents), which could mean that the autolith originated from a massive chromitite seam excised during the erosional processes preexisting that formed the J-M reef. More broadly, this project will help understand the mechanisms behind chromitite formation, providing insight into magmatic processes within the Stillwater Complex.

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Chromitite Petrogenesis in the Muskox Layered Intrusion, Nunavut, Canada

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Layered mafic intrusions represent the solidified remnants of basaltic magmatic systems and are important repositories for chromitite, a rock containing >60 modal percent chromite. The processes responsible for the formation of chromitite layers have remained a contentious scientific problem and a variety of models have been proposed, including magma mixing, country roof rock assimilation, in-situ crystallization and variations in gravity settling models from pre-saturated chromite melts. Layered intrusion-hosted chromitite is an important host for platinum group elements (PGE), which play a key role on the development of sustainable technologies and industrial applications, so there is widespread economic interest in improving our understanding of these rocks too. To address this gap in knowledge, we examined a chromitite sample from within the 21st cyclic unit of the classic ~1270 Ma Muskox Layered Intrusion, Nunavut. The sample was collected during a 1988 mapping expedition and contains a portion of one of the two documented chromitite seams in the Muskox intrusion. In this study, we employed a combined petrographic, quantitative textural (e.g., crystal size distribution; CSD) analysis and mineral chemical (electron probe microanalysis; EPMA) approach to investigate the formation of the chromitite and its immediate footwall. The chromitite footwall comprises pegmatoidal plagioclase-bearing pyroxenite, with abundant coarse-grained (cm-sized) base-metal sulfides and disseminated chromite. The utility of the CSD method lies in the information it can provide on the nucleation and growth of the phase(s) of interest. In the case of the Muskox intrusion, where chromitite formation has traditionally been linked to magma mixing with subsequent crystal settling, such processes should be evident in the CSD data. However, our new CSD profiles generally show log linear characteristics which are more consistent with in situ nucleation and growth (crystallisation). Chromite in the chromitite seam appears to simply be the result of increased nucleation of chromite, rather than a change in the style of crystallisation. Most CSDs also show evidence for a stage of postcumulus textural coarsening. Chromite chemical compositions are consistent with previous studies, in particular exhibiting relatively elevated titanium concentrations compared to chromititite-hosted chromite in other well-known layered intrusions (e.g., the Stillwater and Bushveld Complexes). Our ongoing work is directed toward testing the classic magma mixing model for the Muskox chromitites with these approaches and observations.

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Volatile signatures in the Sudbury Igneous Complex magmatic Ni-Cu-PGE deposits: Implications for sulfide melt differentiation and precious metal mineralization

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The offset dykes of the Sudbury Igneous Complex (Ontario, Canada) host significant magmatic Ni-Cu-PGE deposits rich in precious metals (e.g., platinum-group elements, gold), making them superlative sites for understanding metal solubility in fluids and magmatic sulfide differentiation. Despite extensive study, the origin(s) and character of volatile components and their impact on precious metal distribution in the Sudbury sulfide ores remain controversial. Here we aim to evaluate the evidence for volatile activity in differentiated sulfide ores from the distal Podolsky North deposit in the Whistle offset dyke, at the northeast margin of the Sudbury Igneous Complex. We have examined a ~30 cm long channel-cut section, including massive sulfide, chloritic alteration/reaction rim and host gneiss, across the margin of a ~2 m thick sulfide vein. Our integrated analytical approach includes utilizing optical petrography, mineral chemistry (by scanning electron microscopy and microprobe) and stable sulfur isotope measurements.

Petrographic observations revealed a diverse mineralogy of aggregated platinum-group minerals (PGM), and accessory Ag±Bi tellurides within the chalcopyrite-dominated sulfide vein material. Fractured surfaces from the interior of the vein expose decrepitated fluid inclusions, observed as salt evaporate haloes (evaporated 'liquid' phase), together with solid halides and pyrosmalite [$(Fe^{2+},Mn)_8Si_6O_{15}(OH,Cl)_{10}$] daughter phases. It is noteworthy that there is trace Pd present in a few of the halides, and chlorargyrite [AgCl] is commonly observed associated with the fluid inclusions. Epidote occurs in separate parallel bands (i.e., two close to the margin within the sulfide vein and one in the alteration halo), and electron microprobe data reveal this mineral has a relatively uniform composition across the studied section. Chlorite exhibits a minor decrease in Ni concentration away from the vein. Sulfur isotope measurements (on chalcopyrite) indicate variable $\delta^{34}S$ compositions within the vein but relatively homogeneous $\delta^{34}S$ in the chloritic rim and host rock.

Our findings suggest that fluid interactions played a role in the localization and enrichment of precious metals within the highly differentiated sulfides in the Whistle offset dyke, highlighting the complex interplay between volatile activity and metal distribution during solidification of these rocks. By providing new insights into the relationship between volatile components and metal solubility, this study contributes to broader models of magmatic-hydrothermal systems, with potential applications for guiding exploration for precious metal-enriched deposits.

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A study of the nature and distribution of precious-metal minerals in the Norman West Deposit, Sudbury, Ontario: Implications to geoformational processes and precious-metal deportment.

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The Norman West Deposit is an advanced stage Ni-Cu-PGE exploration project on strike with the Whistle offset dyke (which hosted the past-producing Whistle and Podolsky mines). Located at depth (1650-2850 m) with no surface expression, it is divided into contact-style and footwall-style zones based on major sulfide mineralogy and Ni/Cu tenors. The footwall-style zone, which is the focus of this study, shows an atypical texture of alternating bands of chalcopyrite and pyrrhotite not previously reported in other footwall deposits. It occurs in a breccia package, as opposed to typical sharp-walled veins, so does not represent a typical footwall deposit. This study aims to characterise the types, associations and grain sizes of precious-metal mineral assemblages (PMMs, including PGMs and Au+Ag-bearing minerals) to understand the genesis of the deposit and to constrain the conditions related to its formation. Samples from drill core (n=17) were selected for optical and SEM-EDS analyses. Data from SEM-EDS analyses indicates that the dominant Pd-bearing mineral species is michenerite [PdBiTe], up to 150µm in size, which occurs in two populations; population 1 contains up to 0.4 apfu Pt, while population 2 is Pt-free. Michenerite, as well as other Pd-dominant PGM, often occurs in anhedral multi-mineral aggregates along with hessite [Ag_2Te], clausthalite [PbSe], altaite [PbTe] and tsumoite [BiTe], which may include Cl-bearing minerals, including bismoclite [BiOCl] and annite. These aggregates take two forms: those with sharp grain contacts, and those which are droplet-like, found only in chalcopyrite, and show irregular grain contacts with abundant mutual inclusions, suggesting different parageneses. The dominant Pt-bearing species is sperrylite [$PtAs_2$], which

is found as euhedral to subhedral single crystals up to 220 µm, enclosed within sulfides and Cl-bearing annite. Argentopentlandite [$Ag(Fe,Ni)_8S_9$] is the main Ag-bearing mineral. It develops in oriented, cross-hatched intergrowths with pentlandite (exsolution?), a texture not previously reported, and is invariably associated with chalcopyrite. Norman West crystallised from an Fe-Cu-Ni-PGE melt, and quenching above 254°C may explain the dominance of hexagonal pyrrhotite and lack of exsolved phases like cubanite, leading to the pyrrhotite-chalcopyrite banded texture. Segregation of Ni from this melt gave rise to the Ag-bearing pentlandite which subsequently underwent exsolution during cooling. The droplet-like aggregates of PMMs developed as segregations in chalcopyrite and underwent separation during cooling to form the complex aggregates observed, with irregular intra-droplet grain contacts also suggesting quenching. The association of Cl-bearing hydrous silicates and bismoclite with PMM assemblages may also suggest strong oxidising conditions.

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Molten salts as agents of metal enrichment in IOA deposits

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Iron-oxide-apatite (IOA) deposits, also known as Kiruna-type deposits, are not only important sources of iron but can also contain substantial amounts of phosphorus, cobalt, vanadium and rare earth elements, which are critical for both traditional industries and emerging energy technologies (e.g., batteries and electric vehicles). Recently, the significance of molten salts (e.g., carbonate, sulfate, and phosphate) in the genesis of IOA deposits has been highlighted by the ubiquitous presence of iron-rich salt melt inclusions. However, several key questions remain unresolved due to the lack of relevant experimental data, such as the solubility of magnetite as a function of salt melt compositions and trace element partitioning data for magnetite and apatite equilibrated with molten salts.

To address these issues, a series of high pressure and temperature experiments are being conducting using a piston-cylinder press. Based on the composition of salt melt inclusions reported in the literature, the starting materials include calcium carbonate ($CaCO_3$), calcium sulfate ($CaSO_4$), and trace element-doped magnetite, all encapsulated in platinum capsules. Initial experiments are being performed at 1 GPa and 1350 ˚C, focusing on the carbonate-rich side of carbonate-sulfate join, before expanding the composition space to include calcium phosphate and investigating the dependence of magnetite solubility on pressure and temperature. Phosphate bearing experiments are expected to also crystallize apatite, allowing element partitioning between apatite and salt melts to be studied. Run-products to-date consist of a quenched, iron-bearing melt phase and mineral phases, including magnetite and hematite. The textures and chemical compositions of the experimental products are being determined by scanning electron microscopy (SEM), electron probe micro-analysis (EPMA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). Additionally, the trace element signatures of magnetite and apatite in natural samples from IOA deposits will be analyzed and compared with the experimental data.

The outcome of these experiments aims to address the current knowledge gap regarding molten salts and provide new insights into the genetic model of IOA deposits, where molten salts potentially act as important ore-forming fluids.

800 Geophysics

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Development of a Methodology to Measure Electromagnetic Wave Velocity for High-Accuracy Time-Depth Conversion in Mineral Exploration

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Accurate time-depth conversion for electromagnetic (E-M) geophysical methods is crucial for effective subsurface exploration and geotechnical assessments. The accuracy of depth measurements is affected by variations in E-M wave velocity across various media. Conventionally, in common offset ground penetration radar (GPR) surveys, this conversion utilizes underground point reflectors to determine E-M wave velocity, translating two-way travel time (TWTT) into depth measurements. However, the absence of such reflectors in many field conditions limits reliable depth estimation. This study presents the development of a methodology for the direct, in-field measurement of E-M wave velocity in drilled rock core samples that are representative of the media where the E-M survey is conducted, thereby eliminating the need for underground point reflectors and reducing reliance on time-consuming laboratory analyses.

The developed methodology was evaluated by measuring the E-M wave velocity for specimens of uniform lithology with varying lengths. Advanced signal processing techniques were employed, including dynamic corrections, DC-shift, Dewow and background removal filtering to minimize low-frequency noise, median filtering to remove spikes, frequency-wavenumber (FK) migration to enhance signal resolution, and spectral whitening to improve primary reflections visibility. The FDTD simulations complemented the experimental work, aiding in radargram interpretation and optimizing the experimental design. The measured wave velocities were compared with predictive wave velocities from mineralogy analysis of the specimens with good results. Experimental and simulation results indicate that this method offers a repeatable, precise way to measure E-M wave velocity directly in the field, enhancing the speed and reliability of time-depth conversions in E-M geophysical methods.

The developed methodology was applied for high resolution borehole imaging using GPR for delineation of a narrow vein gold deposit. Subsequent mining operations showed good agreement between predicted and measured deposit subsurface geology.

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Gold Prospectivity Mapping in Southwestern New Brunswick Using Airborne Geophysical Data and XGBoost Machine Learning Method

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Airborne geophysical surveys, such as magnetic and radiometric methods, play a pivotal role in mineral exploration by providing systematic spatial coverage and high-resolution insights

into subsurface geological features. These techniques are particularly valuable in regions with vegetation or sedimentary cover. Airborne geophysical datasets are extensively employed in mineral prospectivity mapping (MPM) to delineate areas with high mineralization potential. Recent advancements in machine learning have further enhanced the effectiveness of MPM, offering improved prediction accuracy and interpretability to aid in prioritizing exploration targets.

This study focuses on gold mineralization within a 1,500 km² area in southwestern New Brunswick, a geologically complex yet underexplored region. Southwestern New Brunswick has a long and complex tectonic history that has given rise to a great variety of mineralized systems. Precambrian and Silurian stratiform base-metal sulfide deposits were intensely deformed, and in part remobilized, from Early to late Devonian (Acadian orogeny) and/or Early Carboniferous deformation events. Numerous deposits formed as a result of late- to post-Acadian tectonic activity and include both epigenetic and stratiform deposits.

A suite of complementary geophysical predictor layers was developed and integrated into a predictive model for gold mineralization in the study area. In this study, the Centre for Exploration Targeting (CET) grid analysis is used to delineate the structural complexities by extracting and digitizing magnetic ridges or troughs in the region. The Contact Occurrence Density (COD) and Orientation Entropy (OE) maps are produced using CET analysis. Additional edge detection techniques, such as the First Vertical Derivative (FVD), Tilt Angle Derivative (TDR), and Total Horizontal Derivative (THDR), are valuable for emphasizing the role of structural features in the precipitation of gold mineralization. Furthermore, identifying the source of magma that feeds mineralization is a critical aspect of exploration targeting. Tools like the Analytical Signal (AS) method, Upward Continuation filters, and reduction to pole (RTP) map, are used for this purpose. Also, radiometric layers including radiometric ratio maps of eTh/K, eU/K, and eU/eTh are produced to identify hydrothermally altered zones related to mineralization. In total, 11 geophysical layers were created for delineating the high potential zones for gold mineralization. These geophysical layers were integrated into a predictive framework using the XGBoost machine learning method, a powerful tool for modeling mineral prospectivity. The model was trained and validated using 64 known gold occurrences, ensuring its reliability. Validation metrics demonstrated the robustness of the framework and its ability to accurately predict high-potential gold mineralization zones.

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Integration of geology and geophysics for mineral exploration in the southwest of Bauchi State Nigeria

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This research employs integrating geophysics and geology to identify structural features that can be potential zones for new deposits of solid minerals, including critical metals mineralization in the southwest of Bauchi State, Northeastern Nigeria. A review of the existing literature showed there was alteration associated with mineralization in northern Nigeria. Our study area was map sheet 148.The preliminary exploration workflow involves Airborne geophysics data, which include aeromagnetic and gamma-ray spectrometry (GRS) that have been obtained and processed from the Nigerian Government and interpreted as part of this project. The geophysical data were enhanced using the tilt angle, the analytic-signal amplitudes, the horizontal gradients, and ternary image of the gamma-ray spectrometry data. These were examined to look for faults, lineaments and characteristics fabrics and zones in the aeromagnetic and radiometric data. When comparing out geophysics with geological information, we feel the geophysical data can identify different petrological units within the Basement Complex, such as the 'Migmatite Gneiss', and 'Older Granites', and potentially other unreported petrological units. The GRS data is used to further subdivide the near-surface material and possibly alteration associated with mineralizing fluids that are part of the mineral system. The findings show most of the geophysical lineaments are trending in north-east to south-west direction which is aligned with the surface structural features observed in the study area. Folds are identified, both at regional and localized levels which are trending north-west to south-east. Major Potassium highs are evident, while areas of potassium lows are relatively few. The faults which are evident in most locations trend in the north-west to south-east direction. Granitoid intrusions are interpreted at the lower central part of the area and the upper right side of the area. The coexistence of fault, fold and potassium high alteration, where both fault and fold are discordant with the lineaments and situated close to granitoid intrusion makes these features potential mineral bearing structures. Such coexistence has been identified in other few areas in the location.

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Automated Identification of Exploration Targets with Geophysical Patterns Matching Known Economic Deposits

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This study demonstrates how geophysical data from a single known commercial deposit can be leveraged to efficiently identify similar deposits in unexplored regions. The method automatically pinpoints target exploration polygons whose patterns closely resemble those of the known deposit by analyzing multivariate geophysical signatures from an existing commercial deposit. This approach offers a fast, automated solution that significantly accelerates mineral exploration while remaining highly efficient and scalable.

Using public domain magnetic data (Total Magnetic Intensity, TMI) from the Carajás region in Brazil—a highly prospective area for mineral deposits—we developed a novel workflow that applies Spatial Mixed Principal Component Analysis (PCA) to sliding windows of varying sizes and orientations. This enables the extraction of key spatial patterns, such as the distribution of magnetic anomalies or the orientation of geological structures. The similarity of these patterns is then measured across the region to highlight areas (target polygons) that exhibit geophysical characteristics akin to the known deposit—demonstrated here with the Paulo Afonso Ni-Cu deposit.

This study makes several key contributions. First, it requires minimal training data, relying on only a single known economic deposit to detect additional deposits. Second, it replaces manual, time-intensive interpretation with an automated process, enabling rapid and resource-efficient exploration. Third, the method is highly scalable, allowing application over vast areas and extension to various spatial data types, including lithological and structural data. Lastly, the workflow's predictive power is demonstrated by successfully identifying other known deposits in the Carajás region that were excluded from training.

In contrast to traditional manual approaches, which can take months, and machine learning methods, which typically require large datasets, this technique offers a scalable and efficient alternative. Streamlining the discovery of mineral deposits holds significant promise for advancing exploration strategies and meeting critical resource demands tied to the global energy transition.

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Optimizing UAV-Borne Radiometric Surveys with RadSIMU: A Simulation Tool for Improved Mineral Targeting

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Airborne gamma-ray spectrometry (AGRS) is a widely used method for mapping surface radiogenic isotopes. However, its effectiveness depends heavily on optimizing flight and sensor parameters before conducting field surveys. Suboptimal survey designs can lead to compromised data quality, increased operational costs, and inconsistent outputs. Despite its significance, AGRS lacks robust tools to evaluate survey configurations before data acquisition. Existing methods often rely on iterative manual trial-and-error approaches, introducing inefficiencies and increasing the risk of errors. This study introduces RadSIMU, a Python-based forward modeling and simulation tool developed to aid in survey design before field data acquisition.

RadSIMU consists of four main components. First, the Survey Planner integrates Digital Elevation Models (DEM), radiogenic source distributions, sensor parameters (e.g., detector type, size, volume), and UAV settings (e.g., altitude, speed, flight line spacing, sampling rate). This component analyzes terrain geometry to identify optimal survey directions. Second, the Data Simulator models draped flights over the terrain and calculate radiogenic counts based on the chosen sensor and platform settings. Third, the Terrain Analyzer corrects for errors induced by terrain that occur due to the source and detector geometry. Finally, the Spectra Analyzer processes radiogenic counts and estimates the distribution of key isotopes, including potassium (K), thorium (Th), and uranium (U).

To validate its performance, RadSIMU was tested in a field study conducted at a copper exploration mining site in Arizona, USA. The survey planner and data simulator successfully identified optimal survey directions and UAV parameters, which were then compared with the selections made by experienced operators. The terrain and spectra analyzer corrected the terrain-induced errors to provide spatial distributions of potassium (K), thorium (Th), and uranium (U) isotopic counts. This correction improved consistency, reducing variations in radiation counts by 5% to 15% in areas near valleys and hills. The resulting distribution of isotopic counts showed a strong spatial relationship with local geological features. RadSIMU offers actionable insights for survey design, empowering users to make informed, data-driven decisions. It helps reduce uncertainties and improves data reliability before field data collection begins. Future developments of RadSIMU could expand its use to areas such as environmental monitoring and disaster response planning, further increasing its versatility and usability.

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Inversion Strategy for Large-Scale Semi-Airborne Electromagnetic Surveys: Insights from the Upper Harz Mountains, Germany

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The growing demand for critical raw materials necessitates efficient exploration techniques capable of imaging deep-seated mineral deposits over large areas. Semi-airborne electromagnetics (SAEM) combines the rapid data acquisition capabilities of airborne receivers with the strong signal penetration of grounded bipole transmitters. We applied a multi-patch 3D inversion strategy based on Gauss-Newton minimization and explicit sensitivity calculation to a large-scale SAEM dataset collected in 2022 across 130 km² in the Upper Harz Mountains, a historic mining region known for Zn-Pb-(Cu) mineralization. The survey included 11 overlapping flight patches corresponding to 11 transmitters of 2-4 km length and currents up to 23 A. To handle the inversion of all data, we developed a workflow that begins with creating a high-resolution super-mesh that includes all survey patches. Single-patch inversions were then performed for each subarea to evaluate the data quality and consistency. We clustered groups of neighboring patches afterwards to run inversions of the combined data. However, due to computational limitations, it was not possible to combine more than three or four patches in single inversion runs. Therefore, we interpolated the results from the clustered data set inversions into the super-mesh to obtain a complete resistivity model of the subsurface. Overlapping areas were combined using coverage-weighted means. Finally, we used iterative refinements to optimize the subsurface model by exchanging or expanding the clusters. We were able to resolve complex three-dimensional geological features, such as small-scale faults, folded structures, and mineralized zones, at depths up to 1 km. The final regional resistivity model covering an area of more than 130 km² showed clear correlations with known geological structures and mineral vein networks and revealed important conductive anomalies. Conductive zones, which align with known faults and mineral veins, suggest potential extensions of mineralization at greater depths and offer the potential for identifying new mineral targets.

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Multigrid simulation: an artifact-free stochastic interpolation of geophysical flightline data for decision making

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Decision making based on smooth interpolation (e.g., simple kriging) of geophysical and geochemical data, when used in mineral prospectivity mapping yield high false positive rates, thereby ineffective exploration. Most interpolators result in maps that have less variance than the data itself. We present a novel interpolation technique, called the multigrid simulation,

which is a stochastic interpolation method designed to improve the interpolation of geophysical flightline data. The multigrid method advances the performance of standard methods (e.g., simple kriging) by offering enhanced resolution, computational efficiency, and robust uncertainty quantification. Standard methods yield deterministic maps without properly accounting for the spatial uncertainty, and are often plagued by non-physical artifacts introduced by the interpolation. These maps thus inject substantial bias into the decision making process when it comes to critical mineral exploration (e.g., planning of drill sites). In our work, we address both of these confounding biasing effects by employing the multigrid method. The multigrid method treats non-stationarity associated with large-scale datasets separately as an underlying trend, from which local variation is interpolated iteratively at increasing resolution until acquisition resolution is reached. Implemented in the Julia programming language, which takes advantage of the parallel computing efficiencies therein, we demonstrate the utility of multigrid by using it for interpolation of flightline residual magnetic intensity (RMI) data over the Cape Smith Belt in northern Quebec and demonstrate clear bias reduction with respect to decision making.

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Structural geometry and kinematics of the Quetico Fault, Atikokan area, Ontario: insights from seismic interpretation and field data

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The Atikokan area, which is located 175 km west of Thunder Bay, Ontario, consists of Mesoarchean rocks (greenstone belts, and TTGs) of the Marmion Terrane of the Wabigoon subprovince and Neoarchean metasedimentary rocks of the Quetico subprovince to the south. The east-west-trending Quetico Fault straddles the contact between the two subprovinces. The Quetico Fault is a major Neoarchean dextral strike-slip fault with a strike length of over 400 km. Numerous mineral prospects (e.g., gold, copper, and zinc in Mine Centre) occur along the Quetico Fault, which structurally controlled the formation of these mineralized prospects. Although the Quetico Fault is locally well exposed at the surface, and its surface kinematic history is well known through previous structural field studies, its subsurface geometry is unknown. A new Metal Earth seismic and magnetotelluric transect, along with previous Lithoprobe seismic profiles, suggests that the fault originated as a low-angle thrust fault during duplex formation and south-verging imbrication of the lower crust of the Wabigoon and Quetico subprovinces. The fault formed as a deep-seated low-angle ductile thrust zone in the lower crust which steepens upwards to sub-vertical dip near the surface. Detailed surface structural mapping confirms that the fault then evolved into a dextral transpressional zone during a subsequent deformation event. Our study presents new insights into the structural evolution of Archean fault systems and advanced our understanding of the tectonic processes in the western Superior Province.

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Contribution of Remote Sensing and Geoelectricity to the Characterization of Basement Aquifers in Adamawa, Cameroon

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Adamawa is called Cameroon's water tower because many of the country's rivers originate from there. Despite this supply, accessibility to drinking water is still an important issue. In the Adamawa, this problem pushes the population of the urban and peri-urban localities of the region to extract underground water resources from the cracked and/or fractured basement. However, the complexity of this basement and the lack of preliminary studies by the companies that install water wells mean that the flows generally have a low exploitation potential. In this study, satellite remote sensing and geoelectricity are an important contribution in determining the characteristic signature of productive saturated zones. Remote sensing can be used to identify the structural lineaments that might case fractures in the basement. Geoelectricity surveys have helped to characterize the deep horizons likely to constitute aquifers. Analysis of the satellite images revealed major lineaments in the following directions N49°E, N60°E, N70°E, N78°E, N108°E and N120°E. The analysis of twenty-six (26) electrical sounding that are calibrated with fourteen (14) geological borehole logs revealed that the ranges of resistivities corresponding to the saturated zone are in the flowing three ranges [528 - 7118 Ω m], [190 - 31818 Ω m] and [108 - 78037 Ω m]; and that the sounding curves have a typology that ends with H or are the more likely to have good flow or production rates. Thus, remote sensing and geoelectricity have provided conceptual models of the aquifers of the subsoil that comprise lateritic formations, alterities and fractured and/or fissured formations. This study was able to identify structural and geoelectric signatures of the saturated zone in the basement aquifers of the region, making it possible to better guide future prospecting or investigations.

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HYSIMUv2.0: A Hyperspectral Remote Sensing Toolkit for Mineral Mapping

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Hyperspectral remote sensing (HRS) has been proven to be applicable across a wide range of geoscience applications, including mineral mapping. However, the inherent complexity of geological targets poses significant challenges in designing effective HRS missions. Additionally, the growing diversity of hyperspectral platforms and sensors, both public and commercial, necessitates careful planning to maximize mission success. Simulation studies offer a cost-effective approach to evaluating the capabilities of hyperspectral sensors and platforms, enabling preliminary assessments without extensive data collection.

In this study, we present HYSIMUv2.0 (HYperspectral SIMUlator version 2.0), a versatile forward modelling toolkit designed to help improve the effectiveness and efficiency of HRS missions. HYSIMUv2.0 allows users to generate at-sensor radiance and reflectance images based on simulated or real ground truth maps. Key features of HYSIMUv2.0 include: a ground truth data cube generator for customizable input parameters; integrated hyperspectral sensor functions and filters; inclusion of atmospheric effects from radiative transfer models (6S and libRadtran); and scalability for arbitrary hyperspectral sensors, platforms, and spectral libraries. The toolkit is scale-independent and also supports parallelization on High-Performance Computing (HPC) clusters, suited for the extensive computational demands of high-resolution hyperspectral datasets.

This study demonstrates HYSIMUv2.0's capabilities through case studies that evaluate the resolvability of mineral exploration targets using various platform-sensor configurations. With the continuous advancements in HRS technologies, forward modelling toolkits like HYSIMUv2.0 are essential for optimizing mission designs and assessing the feasibility of survey targets. With its flexibility to accommodate customizable parameters and spectral libraries, HYSIMUv2.0 offers a robust solution for both scientific and industrial applications.

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Impact of Geologically Confirmed Negative Training Labels on Prospectivity Modelling of Canadian Magmatic Ni (±Cu ±Co ±PGE) Sulphide Mineral Systems

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Mineral Prospectivity Mapping (MPM) involves integrating geological, geochemical, and geophysical data to assess the likelihood that an area will contain target mineral deposits. Advancements in Machine Learning (ML) have enhanced MPM's capability to process and extract features from extensive datasets. This study investigates the impact of geologically confirmed negative training labels on the MPM of Canadian magmatic Ni (±Cu ±Co ±PGE) sulphide mineral systems. Two types of labels were compared: randomly selected negative labels and geologically confirmed negative labels derived from other mineral deposit types such as sediment-hosted Zn-

Pb, carbonatite-hosted REE±Nb, and Li-Cs-Ta pegmatites. Gradient Boosting (GB) and Random Forest (RF) algorithms were employed to generate prospectivity models, followed by a risk-return analysis. The models created with geologically confirmed negative labels demonstrated superior Area Under the Receiver Operating Characteristic Curve (AUC-ROC) values, with the GB and RF models achieving 0.930 and 0.923, respectively, compared to 0.909 and 0.891 for models created with random negative labels. Despite this, the random negative labels outperformed the confirmed negative labels in success-rate curves, with Area Under the Success-Rate Curve (AUC-SRC) values of 0.911 and 0.884 for GB and RF models, respectively, compared to 0.854 and 0.836 for the confirmed labels. The random labels identified only 1.8% and 0.98% of the cells as high-return and low-risk for GB and RF models, respectively, compared to higher proportions identified by the confirmed labels. The normalized density index (NDI) further emphasized the advantages of random labels, showing higher values in the low-risk high-return class, particularly for the RF model created with random labels, which achieved an NDI of 20.1. In contrast, the model created with confirmed labels only achieved an NDI of 8.38. The findings suggest that while geologically confirmed negative labels offer higher discrimination power as reflected in AUC-ROC values, random negative labels may provide a more efficient exploration focus, reducing the search space and better concentrating on the most prospective areas with minimal risk.

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From Waste to Energy Storage: A Novel Strategy for Recycling and Regenerating Graphite as an Anode Active Material in Lithium-ion Battery Applications

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Graphite, a critical material for lithium-ion battery (LIB) anodes, is often overlooked in recycling processes and typically downcycled as a reductant in metallurgical slag, where its economic potential is underutilized. However, with proper dismantling to separate the anode from cathode components, spent graphite can be recycled into high-purity material suitable for reuse in battery applications. This study presents a comprehensive three-stage recycling process designed to recover and regenerate high-purity graphite, emphasizing its economic and environmental value.

The first stage involves physical separation, leveraging shaking table stratification and Falcon centrifugal concentration to remove mechanically adherent metallic impurities, primarily copper and aluminum, as well as other contaminants from battery casing materials. These processes efficiently isolate graphite-rich fractions, significantly reducing the metallic impurity load before subsequent treatment.

The second stage employs phosphoric acid (H_3PO_4) leaching to dissolve residual metallic and ionic impurities embedded within the graphite structure. Key impurities targeted include lithium ions intercalated within the graphite lattice (derived from cathode precursors), fluorine ions from the electrolyte and solid electrolyte interface (SEI) layer, and other embedded ions. The mechanism involves protonation and complexation, whereby H_3PO_4 dissociates into $H_3PO_4^-$, HPO_4^{2-}, and PO_4^{3-} ions, which disrupt metal-carbon bonds and stabilize impurities in soluble phosphate complexes. Advanced characterization techniques such as ICP-OES, XRD, SEM-EDS, and XPS confirmed the significant reduction of impurity levels to below 0.1 ppm after leaching.

The final stage, graphitization, restores the crystalline structure of the graphite. Initial analysis revealed a disordered graphitic structure with increased d-spacing, indicative of structural degradation. High-temperature heat treatment reordered the lattice, reducing d-spacing to 0.335 nm, characteristic of high-purity graphite. These structural improvements were verified using XRD and Raman spectroscopy, which demonstrated reduced defect intensity and enhanced graphitic crystallinity.

This multi-step process not only recovers graphite with purity levels exceeding 99.8% but also enhances its structural and electrochemical properties, making it suitable for LIB applications. By integrating physical separation, selective chemical leaching, and thermal graphitization, the study showcases a scalable and environmentally sustainable pathway for recycling graphite. This approach highlights the untapped potential of graphite recovery, reducing dependency on virgin materials and supporting the transition to a circular economy for critical battery components

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Mineral Exploration and Geochemical Data Analysis of Zinc Mineralization using AIMinex: A new Open-Source AI-Driven GUI

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As mineral exploration embraces the era of big data, the application of Artificial Intelligence (AI) techniques to analyze complex mineral systems and optimize exploration strategies becomes increasingly crucial. This work introduces AIMinex, a novel Open-Source AI-driven graphical user interface (GUI), and demonstrates its application to zinc exploration. AIMinex is designed to streamline mineral exploration, geophysical and geochemical data analysis and visualization. Leveraging advanced machine learning techniques, AIMinex enhances the analysis of complex mineralogical, geochemical, geophysical, and geological datasets, enabling more accurate mineral deposit identification and resource estimation.

AIMinex integrates a suite of tools for data visualization (including 2D and 3D plots, unsorted/sorted bar plots, and cluster plots), statistical modelling (such as Principal Component Analysis and clustering methods), and predictive analytics (featuring Random Forest and Support Vector Machine). These features allow users to interactively explore various data, uncover patterns, and make informed decisions. AIMinex is cross-platform, compatible with Windows, Linux, and Mac systems and will be publicly available to geoscientists and exploration professionals, providing a powerful yet user-friendly tool to accelerate and optimize the exploration process.

A case study involving lithogeochemical data of barren and mineralized zinc zones hosted in high-grade marbles illustrates some of the applications of AIMinex. Using Principal Component Analysis (PCA), AIMinex highlights the signature of the mineralized marbles (Zn associated with Hg, Cd, In, Mn, Ag, Cu, S and Se) compared to the non-mineralized marbles (with higher Ca and Si loadings). PCA also helps differentiate the two major styles of mineralization: one associated with dolomitic marble with traces of apatite and the other characterized by more abundant apatite (> 2%), along with a subset of mineralized samples associated with Ba, Sr, and K.

Moreover, PCA reveals that lead is not directly correlated with zinc mineralized zones but occurs in association with Sb and Bi. These findings bring new insights into the understanding of zinc mineralization hosted in high-grade metamorphic terranes, showcasing the power and versatility of AIMinex for optimizing mineral exploration workflows.

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Assessing the Potential of Carbon Capture and Storage in Smelter Slag Tailings from the Zambian Copperbelt

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The global demand for metals such as copper (Cu) and cobalt (Co), driven by industrialisation and the energy transition, has intensified environmental challenges associated with mining. In particular, the Zambian Copperbelt generates significant quantities of smelter slag tailings, a waste by-product from copper extraction, which pose risks such as acid mine drainage (AMD) and land degradation. This study investigates the potential of these tailings for carbon capture and storage (CCS) through mineral carbonation, offering a novel approach to mitigating greenhouse gas (GHG) emissions while enhancing sustainable waste management.

The research focuses on slag samples from two key sites in the Copperbelt: The Black Mountain Slag Heap in Kitwe and the Mopani Tailings Storage Facility. By characterising the mineralogical and geochemical properties of these materials, the study explores their ability to sequester atmospheric CO_2. A heap leaching experiment will be conducted, utilising both acidic and neutral conditions to simulate environmental scenarios and assess carbonation kinetics. Post-leaching analyses will identify changes in mineral phases and assess metal recovery potential, while water chemistry will be evaluated to monitor cation and anion mobilisation. PHREEQC modelling will further examine the risk of AMD and other by-products.

This project addresses a critical gap in the literature, as the CCS potential of Cu-Co smelter slag remains largely unexplored compared to ultramafic and mafic mine tailings. The study's findings will provide valuable insights into the efficiency of slag in CCS relative to other industrial by-products, contributing to a circular economy framework by repositioning slag as a resource rather than waste. Moreover, the research will support sustainable mining practices in the Zambian Copperbelt and similar regions, promoting environmental stewardship while meeting the rising demand for critical metals.

By integrating innovative methodologies with a focus on environmental and economic sustainability, this study lays the groundwork for further exploration of CCS in industrial waste streams. Its outcomes will inform policy and industrial strategies, emphasising the role of mining by-products in addressing global climate challenges.

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Enhancing Robustness in 1D Fourier Transformation: An Inversion-Based Approach Using Gegenbauer Polynomials

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This study presents a novel methodology for 1D Fourier transformation that leverages Gegenbauer polynomials to enhance robust signal analysis. By employing an inversion-based approach, we address the challenges posed by noisy datasets and outliers. The proposed method utilizes the Iteratively Reweighted Least-Squares Fourier Transform (J-IRLS-FT), which integrates Steiner's Most Frequent Value technique to improve the accuracy of Fourier spectrum estimation.

Through the application of Gegenbauer polynomials, our approach effectively constructs an overdetermined inverse problem, allowing for precise approximation of the Fourier spectrum via series expansion. The flexibility of Gegenbauer polynomials, with specific parameter configurations, contributes to the adaptability of the method, enabling seamless transitions into other polynomial families.

Comparative analyses demonstrate that our inversion-based Fourier transformation significantly reduces noise sensitivity compared to conventional Discrete Fourier Transform (DFT). This innovative technique proves particularly effective for accurately characterizing noiseless datasets while maintaining robustness in the presence of noise and outliers.

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3D Modelling of Critical Mineral Resources in Tailings at the Abandoned Lake George Antimony Mine, New Brunswick

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Tailings at the former Lake George Antimony Mine contain high concentrations of antimony (Sb) and arsenic (As) left over from the mining and milling of antimony-gold-tungsten-molybdenum veins from 1972 to 1996. Reprocessing the tailings could help to mitigate environmental risks and generate economic benefits from recovery of critical elements. A thorough characterization of the tailings is essential for accurately assessing the viability of reprocessing. This study used an Olympus Vanta™ portable X-ray fluorescence (pXRF) spectrometer to analyze the composition of the tailings and applied compositional data analysis (CoDA) techniques to interpret elemental relationships. The average concentrations of Sb (3800 ppm) and As (4500 ppm) exceeded the Canadian Soil Quality Guidelines by over 100-fold and 300-fold, respectively, with maximum concentrations reaching 0.7 wt.% for Sb and 1.1 wt.% for As. Antimony showed a strong association with As, S, and Ca, followed by Ti, Pb, and W, indicating potential co-occurrence and shared geochemical behaviour among these elements in the tailings. Three-dimensional models showing the spatial distributions of Sb, As, and S were developed using the 3D kriging method in Geosoft Oasis Montaj, a geostatistical interpolation technique that creates voxel grids by accounting for spatial autocorrelation. Isosurfaces generated from these voxel grids were employed to highlight elevated concentrations of these elements, providing a detailed visualization of their spatial distribution. The results show that Sb is concentrated in the northern part of the tailings storage facility (TSF), particularly in finer-grained tailings, suggesting enhanced retention or potential liberation of Sb in these materials due to their high surface area and reactivity, as well as potential losses of Sb during mineral processing. Arsenic showed high concentrations in both surface and deeper layers and is concentrated in the northwestern part of the TSF. Sulphur levels exceeding 1% were observed in the western portion of the TSF, indicating the presence of sulphide minerals, as confirmed by mineralogical studies, that could pose environmental risks, such as acid rock drainage. These findings highlight the geochemical behaviour and spatial distribution of Sb, As, and S in the tailings and the utility of 3D modelling in identifying areas with elevated concentrations. Further analysis and model refinement are needed to enhance spatial prediction accuracy and inform decisions on tailings reprocessing and targeted remediation strategies.

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Enhancing Mineral Prospectivity Mapping for Gold mineralization in Northern New Brunswick using Machine Learning Approach

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The Canadian Appalachians in New Brunswick contain various types of gold mineralization that developed at different stages of the Appalachian orogenic cycle. The prominent Acadian dextral transcurrent faults in northern New Brunswick—such as the Restigouche, Rocky Brook-Millstream, McCormack-Ramsay Brook, McKenzie Gulch, and Moose Lake faults—played a vital role in shaping the region's geological structures and mineral deposits. Mineral prospectivity mapping (MPM) struggles with ensuring reliable and interpretable outcomes, especially due to weak links between potential maps and metallogenic models. To overcome this, hybrid approaches combining expert knowledge and data-driven techniques improve prediction accuracy and provide deeper insights by utilizing machine learning and statistical methods to analyze large datasets of known mineral occurrences and (or) deposit systems. MPM relies on machine learning models trained on spatially distributed samples of positive and negative locations. The spatial distribution of these training areas can significantly influence the model's ability to generalize and accurately predict mineral potential across the study area. An XGboost-based machine learning algorithm was applied to evaluate 21 distinct mineralization predictor maps, encompassing geophysical, geochemical, and geological features, to generate MPM map for gold mineralization in northern New Brunswick. This study investigates how the selection of ground truth samples—comprising twenty positive (mineralized) and twenty negative (non-mineralized) locations—impacts the performance and generalizability of gradient boosting models. Specifically, we explore the effects of sample localization versus spatial diversity within the study area on the resulting mineral potential maps. Positive samples are constrained to known mineral deposits, while negative samples are selected arbitrarily, based on prior geophysical, geochemical, and lithological data. By evaluating model performance under various sample distribution scenarios, we aim to determine best practices for selecting training samples to optimize the predictive accuracy and spatial reliability of mineral potential mapping. This research provides critical insights for improving geospatial data selection strategies in mineral exploration applications.

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Geochemical Characterization and origin of Iron oxide deposits in Dehbid region, Iran

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Iran is a significant global iron producer, hosting over 200 iron oxide deposits (IODs). In 2023, the country produced approximately 78 Mt of iron ore. Iran boasts reserves of 4.2 Gt of iron oxide, account for approximately 1.7% of global reserves by 2024. Most of this production comes from Iron oxide-apatite (IOA) or Kiruna-type, Skarn, sedimentary and volcano-sedimentary (Fe ± Mn) banded iron ore (BIO), iron oxide copper-gold (IOCG), sideritic Fe-Mn (Cu-Zn-Pb-Ba) Irish-type, laterites, Fe-Mn veins, and placer deposits. The Dehbid district in the southern part of the SSZ is one of the most important iron oxide mining districts, hosting numerous Fe (±Mn) deposits and prospects in Late Triassic – Early Jurassic carbonate rocks and schists. The Dehbid mining district is situated within the Heneshk shear zone, associated with the Zagros Mountains' major oblique-slip thrust fault. Brittle deformation is also prevalent and is characterized by extensive faulting, and geological contacts exhibiting fault displacement. Although some researchers advocate for a vein geometry of iron mineralization in these deposits, detailed geological and structural studies indicate that a significant portion of the iron mineralization is stratiform to stratabound, hosted in Triassic-Jurassic silicified dolomites. However, in some deposits, tectonic activities and later magmatism have also led to the concentration of Fe-Mn ores in carbonate rocks along the later fault zones. The iron oxide mineralization occurs as lenticular orebodies, 100 to 700 meters in length and 2 to 10 meters in thickness, trending northwest-southeast with a dip of 40 to 50 degrees northeast. The mineralized dolomites and schists have been thrust over the metamorphosed volcanic-sedimentary sequences of the Late Triassic-Early Jurassic, by a northwestern-southeastern trending reverse fault, dipping towards the northeast. Detailed geochemical data represents that the Fe2O3 content of ore bodies varies widely from 30 to 91 wt% magnetite-hematite ores. The average content of MnO in the iron ores is high (5 wt%, up to 57%) but P_2O_5 is typically low (0.15 wt%). MgO content in mineralized rocks is high (av. 1.6 wt%, up to 7%), and the values of CaO are significant (av. 8%, up to 46%). The concentration of trace elements in the studied ores are very low, such as Cr (av. 70 ppm), Co (av. 25 ppm), Ni (av. 42 ppm), Ag (av. 2 ppm), Mo (av. 28 ppm and Pb (av. 18 ppm). Zn (34.3 ppm), but Cu (av. 519 ppm, up to 4350 ppm) and Zn (av. 194 ppm, up to 3270 ppm) show higher concentrations. Au also represents very low concentration, up to 50 ppb in the orebodies. Textural relationships between ore and gangue minerals indicate that these ores are sedimentary banded iron deposits. This is supported by LA-ICP MS data of magnetite in stratiform iron ores, showing low concentration of Al, Ti, V, Cr, Co, Ni, Cu, and other trace elements, plus high values of Mn, Fe/V and Fe/Ti ratios.

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From Rust to Risk: The Mobilization of Trace Elements in Kobuk Valley, Alaska

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Kobuk Valley National Park, one of the most remote and pristine wilderness areas in the United States, is experiencing significant environmental changes due to climate-induced permafrost thaw. The Salmon River now shows signs of pollution, including orange-hued waters and a rainbow-like sheen. However, this is not related to any direct anthropogenic causes (i.e. mining or building of infrastructure etc.). These changes can be attributed to the oxidation of pyrite and other sulphide minerals exposed by melting permafrost. This process releases iron and sulphuric acid into the water, leading to increased acidity and the formation of iron-rich precipitates known as "yellow boy". The oxidation of iron and reduced pH also mobilize trace elements such as arsenic, cadmium, lead, and copper, which pose significant environmental and health risks. Weathered rocks, iron-rich precipitates, and sediments were collected from the surrounding affected streams to investigate these processes. These samples will be examined using a range of techniques, including thin section analysis, inductively coupled plasma mass spectrometry (ICP-MS) and X-ray diffraction (XRD), to determine the speciation and distribution of trace elements and to assess their potential for environmental release.

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Experimental Insights into Pyrite-Fluid Trace Element Partitioning in Hydrothermal Systems

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Pyrite (FeS_2), Earth's most abundant sulfide mineral, forms under a diverse range of conditions. Contained within pyrite are trace elements incorporated either as part of the crystal lattice, or as nano-inclusions. Trace elements hosted in pyrite include precious metals, heavy metals, and metalloids. Despite the role of pyrite as a common host mineral in many economically important ore deposits such as orogenic gold, epithermal, and porphyry deposits, there is limited experimental data that measures how trace elements are distributed between pyrite and hydrothermal fluids.

We have employed experimental methods to equilibrate pyrite with simulated ore-forming hydrothermal fluids from which we can measure partition coefficients systematically. Our approach comprises a sealed silica glass ampule containing a trace element standard solution, NaCl, water, and a pyrite-pyrrhotite-magnetite buffer mixture. A coarser grained pyrite seed is also added, and physically separated from the buffer using silica sand. Ampules are sealed under low vacuum, then placed in a box furnace and heated from ~50 °C to the intended run temperature over a period of 1 to 2 hours. Samples are then held at high temperature until equilibrium is achieved. Run temperatures will be consistent with those seen in ore-forming

hydrothermal fluids, approximately 200-400 °C. Once quenched, the experimental run product fluids and pyrite seed will be separated and prepared for SN-ICPMS (fluid), LA-ICPMS, EMPA and SEM (pyrite) analysis. Work to-date has focused on refining the experimental design to maximize the achievable temperature.

Partition coefficients will be calculated for each element from both direct measurements of the pyrite and fluid compositions, as well as using a mass-balance method that relies solely on LA-ICPMS measurement of the pyrite phase. Results will provide a new constraint on pyrite-fluid partitioning that can be used to illuminate the conditions of mineralization.

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The skarn to porphyry transition: Establishing geochronological and geochemical links between skarn and porphyry-type mineralization at Craigmont, British Columbia, Canada

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The Craigmont Cu-Fe skarn deposit is located in the Quesnel terrane of the Canadian Cordillera in southern British Columbia, adjacent to the Late Triassic Guichon Creek batholith, which hosts the calc-alkalic Highland Valley Cu-Mo porphyry district. Skarn-style mineralization is restricted to Upper Triassic Nicola Group volcaniclastic and carbonate-rich sedimentary rocks and occurs as actinolite-epidote-magnetite-chalcopyrite skarn and specular hematite-chalcopyrite±K-feldspar breccias.

Previous research suggested the Guichon Creek batholith only acted as a heat source to the skarn mineralization in Nicola Group host rocks. Recent drilling, however, has revealed porphyry-type alteration that occurs pervasively or as vein halos within the Guichon Creek Border phase (diorite to quartz-diorite) adjacent to the historic Craigmont mine. Field and microXRF petrographic studies on both Border phase and Nicola Group rocks show K-feldspar-biotite, epidote-chlorite, and sericite-quartz±chlorite alteration. Vein types include K-feldspar-chalcopyrite-pyrite-(±molybdenite ±bornite), epidote-chlorite, and quartz. Chalcopyrite, bornite, and molybdenite are typically associated with K-feldspar-biotite alteration.

The LA-ICP-MS U-Pb zircon date of 216±1.1 Ma and molybdenite Re-Os date of 214.1±0.9 Ma obtained in this study are older than previously published dates for the Highland Valley District (211-206 Ma), suggesting there is likely an earlier mineralizing event at Craigmont than previously recognized in the district. Although these two new dates overlap within uncertainty, this does not yet definitively link them as related to the same mineralizing event. Further petrography and U-Pb geochronology on intrusive rocks and U-Pb garnet geochronology of skarn mineralization at Craigmont will be conducted to define the temporal links between skarn, porphyry, and the Guichon Creek batholith.

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Tectonic evolution of the Coriolis Troughs

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Metals are a crucial resource of the modern world used in all aspects of day-to-day life, from construction to technological innovation. Increasing demands on metal resources has led to increased mineral exploration on the seafloor in recent decades. Seafloor massive sulfides (SMS) are a potential source of base and precious metals including copper, zinc, lead, gold, and silver. These deposits have been found in extensional settings such as backarc basins or mid-ocean ridges (MOR) and were formed via the circulation of hydrothermal fluids in the oceanic crust. Volcanogenic massive sulfides (VMS) deposits are a significant host for base and precious metals, as well as trace amounts of other metals. SMS deposits are modern analogues of ancient VMS deposits which play a major role in Canada's mining industry and economy . However, the timing of SMS deposition, whether it forms during nascent rifting or in mature stages of spreading, and relationship with volcanism remains unclear. This knowledge gap will be addressed by producing a remote-predictive structural and geologic map of the southern Vanuatu Coriolis Troughs —a nascent backarc rift that exceeds 100 km in length, 25 to 45 km in width, and exceeds 3 km in depth, mapped at a scale of 1:100,000. As such, the objective of this study is to improve our understanding of structural and magmatic evolution of nascent backarc rifts in the Coriolis Troughs which will help to improve future exploration strategies. This process includes the compilation of ship-track bathymetry data and satellite altimetry data into an ArcGIS Pro workspace. For optimal visualization of structural features, hillshade and slope datasets—derived from bathymetry data, overlies the bathymetric data. Additionally, bathymetric data is reprocessed using "Terrain Texture Shading" (TTS) for three dimensional visualizations of subtle structural and surface features. Classification of geologic units are based on the completed structural map, seafloor morphology, and geophysical datasets, including vertical gravity gradient (VGG), Earth Magnetic Anomaly Grid (EMAG), and side-scan sonar data. In seismically active regions, shallow earthquake focal mechanism data, known as centroid moment tensors (CMTs), will be compared with the mapped lineament orientations to interpret fault kinematics, their stress regimes, and how geodynamic events control the formation and development of new structures. The mapping outcomes of this study will help us to better understand the timing of SMS deposition and how tectonic events and associated magmatism affect their formation.

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Classification of Polymetallic Vein Systems in Late Devonian Multiphase W-Mo-Bi and Sn-Zn-Cu-In Mineralization at Mount Pleasant: Deciphering Temporal-Spatial Metal Zonation and REY Enrichment

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As pathways for mineralizing fluids and recording the evolution of the ore-forming systems, veins are critical features in magmatic-hydrothermal ore deposits. The Mount Pleasant deposit, with its successive intrusive phases and diverse mineralization styles, contains a complex veining system that documents the history of fluid evolution and metal saturation. These deposits are associated with three phases of evolved, Late Devonian A-type granites: fine-grained granite I (hosting W-Mo-Bi), porphyritic granite II (hosting Sn-Zn-Cu-In), and medium-grained granite III, remains unlinked to known mineralization. Vein types and their sequence for each mineralization phase are established by examining mineralogy, crosscutting relationships, and transitions from high- to low-temperature, relatively reduced to more reduced conditions, and low- to high-fS_2. Rare earth elements and yttrium (REY) in these vein–veinlets are identified using µXRF-EDS mapping, SEM-BSE and EDS imaging, and cathodoluminescence. During the first mineralization episode, ore deposition is mostly within breccia pipes, vein-veinlets, and stockwork zones. This stage is associated with greisen I (fluorite+topaz+quartz+sericite) alteration, whereas lower-grade ore intervals correspond to greisen II (topaz+quartz+chlorite+biotite). From early to late, the vein–veinlet sequence includes quartz stockwork, wolframite-arsenopyrite, wolframite-native bismuth-arsenopyrite-löllingite-quartz, wolframite-molybdenite-bismuthenite-löllingite-quartz, wolframite-molybdenite-quartz-fluorite, löllingite-fluorite, molybdenite-quartz-fluorite and quartz-fluorite. Spatially and temporally, tungsten and molybdenum veins display a distinct zonation: earlier stages are dominated by distal tungsten-rich veins, with later molybdenum-dominant veins developing deeper and more proximally, often beneath tungsten-bearing zones. The second mineralization event occurs within breccia pipes, lode-vein-veinlet systems, tin-bearing greisen zones, massive sulfide-arsenide replacement zones, and miarolitic cavities, all of which are partially superimposed on the first mineralization stage. The vein-veinlet sequence comprises quartz stockwork, wolframite-arsenopyrite, cassiterite-arsenopyrite-chlorite, cassiterite-arsenopyrite-sphalerite-chalcopyrite-fluorite, sphalerite-chalcopyrite-cassiterite-stannite, galena-sphalerite-stannite-fluorite, sphalerite-tetrahedrite-quartz-fluorite, quartz-fluorite, fluorite-kaolinite, and rhodochrosite veins. This mineralization episode also has a distinct temporal-spatial zonation: tin-rich veins tend to form earlier and closer to the causative granite (mostly in an endogranitic setting), followed by later zinc-copper-lead vein-veinlets in distal settings. Minerals enriched in REY occur in late-stage molybdenite–quartz–fluorite and quartz–fluorite veins as monazite, xenotime, and REY-rich whitish-green fluorite, primarily associated with the first mineralization stage. Based on µXRF-EDS mapping, fluorite displays oscillatory zoning, with REY content increasing from core to rim. Under cathodoluminescence, REY-rich bands appear yellowish-orange to white, whereas REY-poor zones range from greenish-blue to reddish-brown. In conclusion, the Mount Pleasant deposit exhibits a clear temporal-spatial vein-veinlet zoning—transitioning from early W- and Sn-rich to later Mo-, Cu-, Zn-dominant—with REY minerals primarily concentrated in late-stage molybdenite–quartz–fluorite and quartz–fluorite veins.

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