17th Annual

PDAC - SEG
Student Minerals Colloquium
POSTER EXHIBIT

March 1-4 2026

PROSPECTORS & DEVELOPERS ASSOCIATION OF CANADA

SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

Meet students and discuss their research!

Tuesday, March 3 • 10 a.m. - 12 p.m.
Trade Show North, Hall A

JOIN THE RECEPTION: **Tuesday, March 3** • 3:30 - 5 p.m.
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.

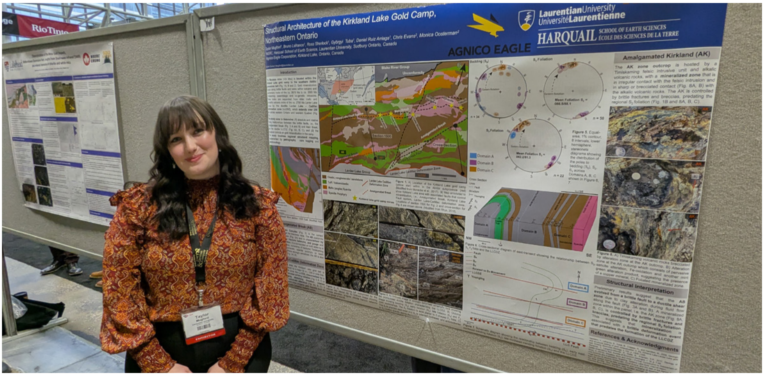
This would not be possible without continued support from our volunteer judges and generous funding from our named sponsors, the Prospectors & Developers Association of Canada (PDAC) and the Society of Economic Geologists (SEG). We also would like to thank past sponsors and volunteers who have contributed 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 67 participants from 29 universities across 11 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-2026/exhibits-2026/pdac-seg-student-minerals-colloquium-2026

Poster judging for the PDAC-SEG Student Minerals Colloquium will take place from **10:00 am - 12:00 pm on Tuesday, March 3,** followed by an **awards ceremony and reception** from **3:30 pm - 5:00 pm** at the **Northern Lights Learning Hub in Trade Show North, Trade Show North, Level 300, Hall A.**

*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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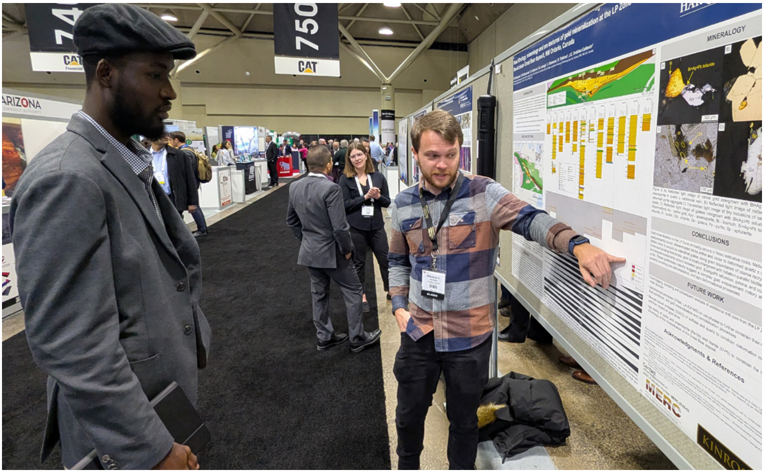

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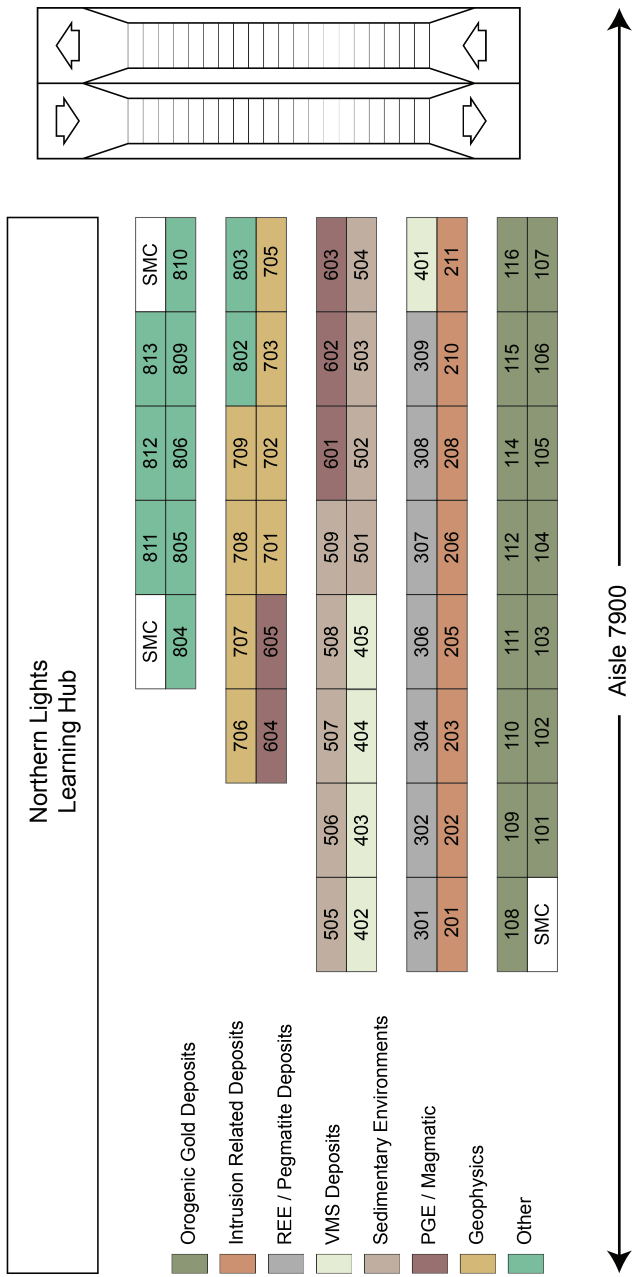

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100 Orogenic Gold Deposits

101 **David Machado – M.Sc.**
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Structural and Lithological Controls on Gold Mineralization at the Pilar Mine, Rio das Velhas Greenstone Belt, Brazil

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The Pilar underground mine (Jaguar Mining Inc.) is located in the eastern portion of the Quadrilátero Ferrífero, within the Neoarchean Rio das Velhas greenstone belt of the São Francisco Craton, Brazil. The area was affected by multiple deformational and hydrothermal events in the Neoarchean, Rhyacian-Ororsirian and Ediacaran. The structural and stratigraphic complexity of the region requires detailed mapping to constrain the primary controls on gold mineralization.

Underground mapping at a 1:100 scale, combined with macroscopic logging of 584 m of drill core, allowed identification of several lithotypes, including: metachert; banded iron formation (BIF) in oxide, carbonate, and silicate facies; quartz veins with sulfides and mafic minerals; quartz–carbonate veins; carbonaceous schist; chlorite-schist; chlorite–quartz-schist; and talc- schist. The dominant hydrothermal alteration styles include carbonation, chloritization, silicification, and sulfidation. Gold mineralization is hosted within BIF and mafic schists, being composed by replacement-style sulfide zones as well as quartz-sulfide veins. Ore minerals include chalcopyrite, pyrrhotite, pyrite, and arsenopyrite. Structural analysis reveals two main deformational phases: (1) an early Archean event responsible for penetrative foliations and isoclinal folds with SW–NE vergence and ENE–WSW axial planes dipping to the SW; and (2) a Paleoproterozoic event associated with localized shear zones, producing open to asymmetric folds with SW–NE vergence and NNE–SSW axial planes dipping to the SE–SW.

In this framework, BIF units acted as preferential fluid conduits due to their rheological contrast, whereas carbonaceous schist behaved as an impermeable barrier, promoting fluid trapping, quartz vein development, and sulfide precipitation near lithological contacts. Two generations of quartz–sulfide veins were distinguished. The first generation is more deformed, sulfide-rich, and absent of carbonate minerals, developing boudinage and folding. The second generation shows intense carbonation, lower sulfide content, better preservation of primary textures, and lower strain, reflecting a later hydrothermal pulse.

These combined geological, structural, and textural observations indicate that gold deposition at Pilar was controlled by the interplay between progressive deformation, lithological contrasts, and multiple episodes of hydrothermal fluid flow.

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102 **Dinah Quaye – M.Sc.**
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Alteration of metasedimentary rocks associated with gold mineralization at the Young-Davidson gold mine

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The Young-Davidson (YD) gold mine is situated within the southwestern part of the Abitibi greenstone belt in Northeastern Ontario. It is part of the Western Cadillac-Larder Lake region, known for its lithological complexities and hydrothermal alteration. Within the YD gold mine, syenite hosts the majority of gold mineralization; however, the potential of gold in the metasedimentary rocks and conglomerates is underexplored, although mineralization has been discovered to extend into them. Previous work on metasedimentary rocks has identified phengite as one of the main alteration minerals; however, the origin and formation of this phengitic alteration assemblage remain understudied. This study aims to expand the understanding of mineralization in metasedimentary rocks at YD by increasing knowledge of the origin of alteration minerals responsible for mineralization.

Hyperspectral imaging and electron probe microanalysis confirm the white-mica as phengitic (i.e., a series between the muscovite and celadonite solid solution with notably higher Si, Fe, and Mg contents and lower Al values), suggesting that the white-mica chemistry is primarily controlled by the Tschermak substitution mechanism, AlIV + AlVI ↔ SiIV + (Fe+Mg)VI, where an increase in Fe and Mg in the octahedral sites is balanced by increased SiIV, simultaneously resulting in a decrease in total aluminium contents.

Non-mineralized metasedimentary samples generally have higher modal abundances of quartz and feldspar, specifically plagioclase, and exhibit weak to negligible sericitic to chloritic alteration. Mineralized samples show more pronounced alteration signatures characterized by an increased proportion of chlorite relative to sericite, with medium-grade mineralized samples having the strongest sericitic overprint. The presence of pyrite and magnetite typically increases with increasing alteration intensity and higher gold grade. A spatial association between chlorite and pyrite with anhedral biotite suggests biotite breakdown contributed to pyrite growth (i.e., $2K(Mg,Fe)_3AlSi_3O_{10}(OH)_2 + 2H_2S \longrightarrow (Mg,Fe)_5Al_2Si_3O_{10}(OH)_8 + FeS_2 + 2K^+ + 3SiO_2$) with an increased intensity of biotite alteration indicative of gold mineralization.

Future work will involve characterizing the main controls of the phengitic series and other alteration minerals using further petrographic and lithogeochemical data. Incorporating hyperspectral imaging with geochemical and petrographic techniques will contribute to the knowledge of alteration minerals in metasedimentary rocks while assessing the relevance of hyperspectral imaging at YD and other orogenic gold terranes.

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103 **Hannah Eaton-Tessier – M.Sc.**
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Geochemistry of pyrite in orogenic gold deposits across Northwestern Ontario

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Northwestern Ontario is host to dozens of highly enriched orogenic gold deposits. Enriched in critical metals alongside gold, these deposits also have potential as economic sources of nickel, cobalt, antimony, and tellurium. Despite the economic importance of these deposits, the ore forming processes and fluid sources that formed these deposits are not fully understood.

This study employs morphological and geochemical analysis of pyrite samples from 17 orogenic gold deposits across Northwestern Ontario to better understand the formation of the deposits. Reflected light microscopy and scanning electron microscopy (SEM) was used for detailed imaging of the pyrite grains, detailing the generations and morphologies present in the pyrite grains to develop a paragenesis for each sample. Following this, the geochemical composition of the pyrite grains was analyzed using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). The geochemistry of pyrite is essential to understanding deposit formation as it reveals information regarding the ore-forming fluid, including the temperature, pH, salinity, and oxidation state. The data collected in this project will allow for comparison of the depositional mechanisms and fluid sources throughout the deposits in the study, creating associations between the trace element assemblages and the stages of gold deposition. The trace element assemblages will also allow for predicting at a larger scale which gold deposits may have economic potential as critical metal sources.

104 **Jacklyn Krueger – M.Sc.**
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Geological and petrological features of the magmatic-hydrothermal component of a hybrid Archean Au deposit setting, Wawa, Ontario

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The Archean (2900-2660 Ma) Michipicoten Greenstone Belt (Superior Province, Canada) hosts several Au deposits attributed to intrusion-related (e.g., Renabie, Magino) and orogenic (e.g., Eagle River, Island Gold) processes. The Wawa Gold Corridor setting is a historical orogenic vein-type Au producer (0.120 Moz Au) centered on the ca. 2745 Ma Jubilee volcanic-plutonic complex; however, recent exploration has defined an early magmatic-hydrothermal gold (MHG) system associated with the intrusion. Here we report results from preliminary studies, based on drill core logging and SWIR analyses, that were initiated to better define the nature of the host intrusion and the posited MHG system and cautiously suggest it may have contributed Au to the later higher-grade orogenic Au vein system. The polyphase dioritic to tonalitic intrusive complex is mainly fine-grained and varies from melano- to leucocratic with minor late-stage leuco-aplitic dikes and coarse mafic pegmatites; hence the system records an evolution to a more felsic and

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hydrous component. Numerous generations of disseminated and stockwork sulfide (Py-Po-Cpy) mineralization (i.e., 14.16 m @ 1.04 g/t Au) of the MHG system occur through the intrusion with associated biotite alteration that predated fabric development (D1-D3). Drill holes with higher modal pyrite related to the MHG event, as established in our working paragenesis supported with SWIR data, suggest that higher than background Au values associated with early pyrite relates to a sericitic alteration of the host rock. Our finding has several important implications: 1) we have established the presence of a significant zone of Au mineralization in the hybrid setting that pre dates the orogenic Au event; 2) the MHG component should plausibly be considered as a potential source of Au in the later orogenic Au event; 3) geological similarities in terms of age, setting, host rocks, and alteration with the world class 20+ Moz 2740 Ma Cote Gold-Gosselin Au deposit; and 4) highlights the importance of better defining the nature of early MHG systems.

105 **Janek Urbanski – M.Sc.**
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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, of northern Quebec. Located approximately 120 km north of Chibougamau, Quebec, the deposit saw production of gold and copper as an open pit operation from 1996 to 2010. New ownership and exploration efforts from Troilus Mining Corporation has led to resource growth of over 12 Moz AuEq. While the deposit is understood to be structurally controlled, the genesis, evolution, nature, and relative timing of fabrics is poorly understood and should be considered in a broader tectonic and regional context.

This work employs a classical structural geology field mapping approach, integrating geometric and kinematic analysis at regional, outcrop, and microscopic scales. This has allowed for the establishment of multiple deformation events and their characteristic fabrics, the timing of mineralization, and for inferences to be made to regional tectonics.

The region has been divided into two structural domains based on geometric similarities between fabrics within each domain. Troilus Main comprises the area southwest of the Parker granitic pluton, while Troilus North comprises the area northeast of the Parker granite. The field area is characterized by fabrics developed during dextral transpression and shearing at upper greenschist to lower amphibolite facies conditions. Observations from the field are consistent with a pure-shear dominant style of transpressional tectonics in the southern domain, while the northern domain corresponds with a change to simple-shear dominant transpression.

The transpressive event is responsible for producing the main observed fabrics associated with deformation event D1, including a moderate to steeply NW dipping S1 foliation and steeply pitching L1 lineation in the Troilus Main domain, and a flatter NW dipping foliation with a more shallowly pitching lineation in the Troilus North domain. A later D2 deformation event is manifested by folded D1 fabrics and narrow shear zones which cut D1 features. Later events are recognized but not associated with mineralization.

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Multiple styles of mineralization with variable timing are recognized to be hosted in the fabrics of the Troilus Main domain. The Troilus deposit is hosted within an anastomosing WSW-ESE trending mylonite zone defining a major regional lineament, within which ductile, brittle-ductile, and brittle structures host variable amounts and types of mineralization. Deposit scale controls include the syn-D1 shear zones and associated S1 foliation which acted as a major fluid pathway. There is also further enrichment corresponding to L1 and L2 lineation geometries.

106 **Joleen Belanger – M.Sc.**
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Tracking metamorphic P-T evolution at the Great Bear deposit, Red Lake, ON

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The Great Bear deposit lies within the Uchi Subprovince, ~25 km SE of Red Lake, Ontario. It is host to Au mineralization in polydeformed Archean volcanic and sedimentary rocks previously suggested to have reached greenschist to lower amphibolite facies conditions. The property is divided into a distinct northern felsic domain and southern mafic domain that are separated by a ~500m wide, NW-SE trending zone of strongly deformed rocks, referred to as the LP Fault Zone (LPFZ). This project focuses on constraining the metamorphic evolution across the property by: (1) determining the P-T conditions of observed mineral assemblage development; (2) determining if there are discernible metamorphic discontinuities across interpreted structures; (3) documenting and modelling metamorphic fluid production or infiltration; and (4) determining if the rocks experienced polymetamorphism.

Core logging and petrographic analysis of metamorphic mineral assemblages and reaction textures across the deposit allowed identification of the variability of metamorphic conditions, fluid production, and deformation fabrics. Metapelites with low variance metamorphic mineral assemblages in the felsic domain are concentrated within the zone of high strain along the LPFZ and are characterized by quartz + plagioclase + white mica + biotite ± garnet ± staurolite ± andalusite. Preliminary pseudosection modelling of mineral assemblage stability and plagioclase chemistry indicate that the rocks reached amphibolite facies peak metamorphism.

Metabasaltic rocks in the mafic domain have assemblages containing calcic and Fe-Mg amphibole + quartz + plagioclase ± chlorite ± biotite ± garnet ± carbonate. Metapelitic rocks south of the LPFZ and limb zone have assemblages of quartz + plagioclase + white mica ± biotite ± garnet ± staurolite ± andalusite. Mineral assemblages suggest that peak metamorphism is amphibolite facies and will be defined with phase equilibria modelling of individual samples, coupled with mineral chemistry of plagioclase and amphibole in the metabasaltic rocks. These results will be compared to the relatively well-constrained P-T conditions from the felsic domain to determine if there is a metamorphic discontinuity across the LPFZ.

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107 Jonathan Koulouras – M.Sc.
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Structural controls, mineralogy, and alteration associated with the Amalgamated Kirkland gold deposit, Kirkland Lake, Ontario

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The Amalgamated Kirkland (AK) gold deposit is located in the world class Kirkland Lake gold camp in the southern Abitibi greenstone belt. The Macassa gold mine is currently producing from the South Mine Complex, and production recently began at the AK deposit. The latter is hosted in conglomerate, greywacke, and alkalic to subalkalic volcanic rocks of the Timiskaming assemblage (ca. 2679–2669 Ma), which is in contact to the south with mafic and ultramafic volcanic rocks of the Larder Lake group (ca. 2710–2704 Ma). A major 50-200 metre-wide, east-west-trending, ductile high strain zone, named the Larder Lake-Cadillac deformation zone (LLCDZ), straddles the Tisdale-Timiskaming contact.

The AK deposit is located immediately south of the steeply north-dipping, reverse brittle Amalgamated Break. The deposit forms a steeply dipping zone, striking east-northeast, which roughly follows an intermediate porphyritic dike. The AK deposit mineralization consists of brecciated and deformed quartz ± ankerite veins containing pyrite, minor chalcopyrite, molybdenite, galena, sphalerite, tellurides, and native gold. Mineralized and unmineralized veins of the AK deposit have sericite-ankerite alteration halos, creating a wide alteration zone extending up to 75 meters into the surrounding host rocks.

The AK deposit is overprinted by two planar fabrics. The older fabric (S3) is a steeply dipping northeast striking cleavage, which is axial planar to a regional open F3 fold plunging steeply to the east. The second fabric (S4) is a steeply dipping north north-east striking crenulation cleavage, which is axial planar to outcrop scale open F4 folds. Preliminary structural observations suggest that the AK deposit formed along a pre-D3 brittle structure, possibly a splay of the Amalgamated Break, prior to peak regional ductile deformation. Future work will focus on determining the relative timing of gold mineralization at the AK deposit relative to that along other major breaks in the Kirkland Lake gold camp, and on characterizing the geochemical and mineralogical alteration footprint of the deposit.

100 Orogenic Gold Deposits

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Mineral Prospectivity Mapping Driven by Geological Knowledge and Data: a Case Study of Orogenic Gold Deposits in Guangxi

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The application of machine learning (ML) in mineral prospectivity mapping (MPM) has made remarkable progress in recent years. However, the current mainstream pure data-driven method often ignores the geological process, resulting in the lack of interpretability and generalization ability of the model. In order to solve this problem, this study proposes a knowledge-data dual driven prediction framework that integrates deposit system knowledge and ML. Taking the orogenic gold deposits in Guangxi as the object, the key factors such as ore-controlling structures, stratigraphic traps and geochemical anomalies were systematically integrated to construct a variety of deposit proxy models, and the algorithms such as random forest (RF), support vector machine (SVM), deep neural network (DNN) and deep forest (DF) were introduced for comparative analysis. The results show that DF model has the highest prediction accuracy and robustness, can effectively describe the non-linear relationship, and generate the prediction results consistent with the geological law. The analysis of feature importance further reveals that structural parameters are the main controlling factor, followed by geochemical and stratigraphic information. The model has identified several potential gold targets in the Youjiang Basin and Qin-Hang Belt in Guangxi, verifying its application ability. This study shows the great potential of geological knowledge embedding in improving the credibility and practicability of ML model, and provides a new technical path for integrating expert knowledge and ML in geoscience modeling in the future.

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Polyphase deformation and dextral transpression along the Quetico–Wabigoon boundary: structural insights from the Atikokan area, NW Ontario

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The Atikokan area, located approximately 175 km west of Thunder Bay, Ontario, lies along the Neoarchean boundary between the Quetico metasedimentary subprovince to the south and Mesoarchean greenstone belts and TTG suites of the Wabigoon subprovince to the north within the western Superior Province. This crustal-scale boundary is defined by the east–west–

trending Quetico Fault system, which hosts numerous structurally controlled gold and base-metal prospects. This study presents new detailed structural mapping and kinematic analysis along an Atikokan transect, focusing on the Quetico subprovince and the Quetico and Rawn fault zones, to better constrain the deformational evolution and tectonic regime responsible for strain localization and mineral prospectivity. Field observations and structural measurements document a polyphase deformation history involving two principal events. An early D2 event was dominated by north–south shortening and resulted in the development of a previously unrecognized, regional-scale, east–west–trending tight to isoclinal syncline with a steep axial plane within the Quetico metasedimentary rocks. This structure is associated with a pervasive, bedding-parallel S2 foliation that transposes primary layering across much of the study area. D2 deformation is further characterized by boudinaged quartz veins, tight folding of veins, and strong flattening of clasts within fine-grained monomictic conglomerates, indicating significant pure shear strain under ductile conditions. This contractional architecture was subsequently overprinted by a D3 dextral transpressional event. D3 deformation is marked by the development of a steep S3 foliation that obliquely overprints S2, localized Z-shaped F3 drag folds, and abundant kinematic indicators, including dextrally sheared quartz veins, tension-gash arrays, and well-developed S-C-C′ fabrics. Within the Quetico and Rawn fault zones, deformation is concentrated into high-strain corridors characterized by steeply dipping foliations, asymmetric strain shadows, and shallow to steeply plunging stretching lineations, reflecting non-coaxial ductile flow. The presence of oblique and locally doubly plunging lineations, together with the oblique relationship between stretching lineations and the vorticity vector, indicates triclinic transpressional flow involving variable extrusion directions rather than simple monoclinic transpression. These relationships are consistent with along strike variations in transpression documented elsewhere along the Quetico-Wabigoon boundary. The results highlight the fundamental role of progressive dextral transpression and the reactivation of earlier contractional fabrics in localizing deformation and fluid pathways along this major Archean transcurrent fault, providing an important structural framework for mineralization in the Atikokan area and analogous settings.

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Pyrite Generations at the Young-Davidson Gold Deposit

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The Young-Davidson (YD) Mine is located within the Cadillac–Larder Lake deformation zone (CLLDZ) near Matachewan, Ontario, and represents a syenite-hosted orogenic gold deposit characterized by extensive hydrothermal alteration. The main host of mineralization is sulphidized syenite associated with strong hematite alteration and quartz veins cutting syenite intrusions. This study aims to identify controls on the formation and evolution of the YD gold deposit. To do this we performed a detailed investigation of pyrite textures (reflected light microscopy), in situ trace element composition and in situ sulfur isotopes analyses.

Here we highlight preliminary findings these analyses of the pyrite grains. 600 spots from 62 samples were analyzed for sulfur isotope analysis by Secondary Ion Mass Spectrometry (SIMS). The first results show that δ^{33}S anomalies changes between -0.2 and 0.3 ‰ while δ^{34}S values are

between -11.5 and 5.9 ‰. Furthermore, to find the trace element content on these different pyrites, LA-ICP-MS was conducted on the same spots. These data are then used to identify the source of the gold and determine which pyrite generations are linked to gold mineralization.

The next steps will involve conducting fluid inclusion to investigate gold carrying fluids conditions and analyzing Fe isotopes by using fs-LA-MC-ICP-MS to obtain additional insights into fluid evolution. These investigations aim to enhance the understanding of gold precipitation from hydrothermal fluids in the region.

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Characterizing the stratigraphy of the Mafic Domain host rocks of the Great Bear gold deposit, Red Lake, northwestern Ontario

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The Great Bear Project is a new world-class gold deposit (total resources of 6.6 Moz) in the Red Lake Greenstone Belt of the Archean Superior Craton. The deposit comprises three ore zones distributed between two domains, known colloquially as the Felsic Domain and Mafic Domain. The LP Zone, which is hosted by metavolcanic rocks of the Felsic Domain, consists of vein-related and disseminated gold and accounts for the largest fraction of gold mineralization at the Great Bear deposit. The Hinge and Limb zones are smaller ore zones located within a property scale fold in the Mafic Domain. These zones are defined by gold-bearing quartz veins that are hosted by mafic metavolcanic rocks and sulfide rich argillite beds. The metavolcanic rocks of the Mafic Domain include high Fe and Mg tholeiitic mafic volcanic rocks, ultramafic flows, rhyolitic tuffs and flows. Thin argillite beds and iron formation commonly define the contact between Fe and Mg tholeiites and are intercalated within the Fe tholeiites. Existing age constraints for metavolcanic rocks of the Felsic Domain indicate emplacement at ca. 2710 Ma, but its stratigraphic relationship with Mafic Domain remains unclear. We hypothesize that the Mafic Domain is either an older basement component that predates the emplacement of the Felsic Domain rocks or a lower stratigraphic component within a continuous Neoarchean volcanic-sedimentary succession that includes the Felsic Domain. This research project aims to: (1) Characterize the mafic metavolcanic and metasedimentary rock of the Mafic Domain; (2) Determine the stratigraphy of the Mafic Domain in relation to the Felsic Domain; (3) Provide absolute and relative age constraints on the deposition of the Mafic Domain rocks.

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112 **Taylor Mugford – M.Sc.**
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Structural Architecture of the Kirkland Lake gold camp, Southern Abitibi greenstone belt (Ontario, Canada)

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The Kirkland Lake gold camp (>24 Moz gold), located within the Abitibi greenstone belt of northeastern Ontario, hosts the Macassa mine, one of the world's highest-grade gold mines (9.18 g/t Au). Gold mineralization is localized along ENE-striking, orogen-parallel, reverse brittle faults, (e.g. Main Break, Amalgamated Break), which cut siliciclastic sedimentary and alkalic volcanic rocks of the Timiskaming assemblage (ca. 2679 – 2669 Ma) and co-genetic intrusions. These rocks are juxtaposed against older volcanic rocks of the Blake River assemblage (ca. 2704-2695 Ma) to the north and Tisdale assemblage (ca. 2710-2704 Ma) to the south. From the Blake River-Timiskaming contact to the north to the Amalgamated Break to the south, Timiskaming volcanic and sedimentary rocks form a south-younging, south-dipping homoclinal sequence overprinted by a steeply-dipping, NE-striking, regional S3 foliation, which is consistently oriented anticlockwise to bedding. Further south, from the Amalgamated Break to the Timiskaming-Larder Lake Group contact, the sequence becomes strongly folded by tens-of-meters-scale F3 folds. The S3 foliation is axial planar to those folds and becomes more pronounced within the Larder Lake-Cadillac Deformation Zone (LLCDZ), a 50 to 800 m wide ductile high-strain zone that straddles the Timiskaming-Larder Lake contact. The LLCDZ is a major structure that extends for over 250 km across Ontario and Quebec and hosts several world-class gold deposits east and west of the Kirkland Lake camp.

Several lines of evidence suggest that gold mineralization at Macassa is pre- or syn- D3 deformation, in contrast to many orogenic deposits along the LLCDZ in Ontario, which are commonly syn-D3. First, south of the Amalgamated Break, a reversal in structural facing towards the LLCDZ suggests that stratigraphy was tilted and rotated along pre-existing faults prior to D3. Second, the Timiskaming rocks young toward the LLCDZ and the older Larder Lake Group volcanics, suggesting that the LLCDZ originated as a north-directed thrust prior to the formation of the S3 foliation because observed S3-bedding relationships are inconsistent with thrusting. Third, gold mineralization within the Amalgamated Kirkland zone, situated in the field study area, is controlled by brittle fractures and breccias that predate the formation of the S3 foliation and LLCDZ. This study provides new insight into the relative timing of mineralization along brittle faults (Amalgamated Break and Main Break) and the ductile LLCDZ, as well as the structural controls on gold mineralization.

100 Orogenic Gold Deposits

114 **Wieland Heinrich Boehme – PhD**
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Constraining ore assemblage, textures, gold composition and timing of deformation and mineralization at the LP deformation zone, Great Bear deposit, Red Lake, ON

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The Great Bear deposit is a new world-class gold deposit, located in the Red Lake greenstone belt of the Archean Superior province, NW Ontario. It has a resource estimate (measured + indicated) of 2.7 Moz Au at 2.81 g/t Au and an additional inferred resource of 3.9 Moz Au at 4.71 g/t Au. Gold is primarily hosted in highly strained felsic rocks of the LP deformation zone, a WNW-ESE trending deformation zone located 25 km S of Red Lake. Stratigraphic and petrographic analysis of representative drill core intervals, microprobe analysis of gold, and LA-ICP-MS U-Pb titanite geochronology were conducted to constrain host lithology, ore assemblage and textures, gold composition, and the timing of deformation and mineralization.

The Great Bear deposit is hosted by felsic volcanic rocks and metasedimentary rocks. The former consists of (1) a quartz-feldspar-porphyritic unit with a dark grey, aphanitic matrix and (2) an altered porphyritic unit with feldspar phenocrysts and an aphanitic matrix. The intercalated metasedimentary units consist of dark grey, fine-grained, massive to thinly bedded sediments. The ore assemblage comprises disseminated pyrite, arsenopyrite, and pyrrhotite, minor chalcopyrite, sphalerite, galena, and magnetite, trace Bi±Ag±Pb tellurides, scheelite, and native gold. A subtle zoning is characterized by gold enrichment and increased sulfide abundance in the central and southeastern LP deformation zone and is expressed by pyrite-arsenopyrite and pyrite-pyrrhotite dominated ore assemblages, respectively. Titanite from the gold-hosting quartz-feldspar porphyry yielded a U-Pb age of 2704 ± 13 Ma. Titanite occurs as equant to elongated grains aligned with the dominant foliation, locally showing biotite-filled pressure shadows and pyrite inclusions.

Native gold occurs disseminated in deformed quartz ± carbonate veins and host rocks. Locally, gold occurs as inclusions in coarse, recrystallized pyrite and foliation-parallel biotite. Gold fineness varies significantly, ranging from 830 to 968. Lower-fineness gold (830 – 891) is associated with abundant galena and Bi±Ag±Pb tellurides and occurs as irregularly shaped intergrowths, partially to fully surrounded by galena and Bi±Ag±Pb tellurides. Gold with a higher fineness (954 – 968) lacks this association. These preliminary results suggest multi-stage gold emplacement, possibly involving low-temperature polymetallic melts, and indicate that mineralization was emplaced prior to 2704 ± 13 Ma.

100 Orogenic Gold Deposits

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Sequestration of Co and Au in the hydrothermal system: Insight from the Tuolugou Co-Au deposit in East Kunlun Orogen, China

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Hydrothermal Co–Au deposits represent an uncommon metal assemblage, and the paragenetic relationships and mechanisms responsible for their co–formation remain poorly understood. The Tuolugou Co–Au deposit in the East Kunlun Orogenic Belt is a representative stratiform system overprinted by multistage tectonic–hydrothermal events, providing an ideal case to unravel Co–Au mineralization processes. To constrain fluid evolution and the physicochemical controls on sequential Co–Au precipitation, we integrated microtextural observations with EPMA and LA–ICP–MS analyses and characterized fluid evolution using Raman spectroscopy and fluid-inclusion microthermometry. Thermodynamic modeling was further applied to reconstruct variations in critical physicochemical parameters.

The early Caledonian exhalative–syngenetic stage is dominated by H_2O-rich fluid inclusions in quartz (187–232 °C; 8.7–14 wt.% $NaCl_{eqv.}$), consistent with SEDEX-type mineralization and forming Co–Au–rich Py I (up to 4.42 wt.% Co; 284 ppm Au). Indosinian overprinting comprises five sub-stages (Da–De). Da–Db are marked by Co-bearing pyrite and siegenite under plastic deformation. The Dc stage represents the primary Co mineralization, characterized by intense Co precipitation as Co-rich pyrite (up to 5.36 wt.% Co) and cobaltite under plastic–brittle transitional conditions, with negligible Au (Au/Ag ≈ 963). Dc fluids contain both H2O-rich and CO2-rich inclusions (268–330 °C; 5.4–9.9 wt.% $NaCl_{eqv.}$). In contrast, the Dd stage marks the primary Au mineralization, featuring native gold (Au/Ag ≈ 859), negligible Co, and the presence of CH_4-bearing inclusions, with coexistence of H_2O-rich and CO_2-rich fluids (226–305 °C; 2.8–9.2 wt.% $NaCl_{eqv.}$). The progressive decrease in Al content of quartz, coexistence of H_2O-rich and CO_2-rich fluids, and elevated Mg–Fe–Ca in quartz and chlorite compositions indicate fluid boiling and enhanced fluid–rock interaction during Dc–Dd, leading to increased pH. Replacement textures in sulfides and reactions with carbonaceous host rocks during Dd further suggest a significant reduction in fluid fO_2. Thermodynamic modeling confirms that increasing pH reduces Co solubility and promotes Co precipitation, whereas large-scale Au deposition requires substantial lowering of fO_2 at moderate hydrothermal temperatures.

These results demonstrate that the sequential Co and Au precipitation in the Tuolugou deposit was controlled by the combined effects of fluid boiling (pH increase) and redox buffering by carbonaceous rocks (fO_2 decrease), providing new insights into the metallogenic processes of global Co–Au systems. These findings emphasize that the integration of Co-rich stratiform precursors, carbonaceous host rocks, and indicators of fluid boiling and redox buffering constitute an effective exploration model for Co–Au deposits. Such criteria may be directly applied to targeting concealed orogenic Co–Au systems in Paleo–Tethyan and comparable metallogenic belts.

100 Orogenic Gold Deposits

116 **Yuka Zhuang – B.Sc.**
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Hydrothermal Fluid Characteristics of Syenite-Hosted Quartz–Carbonate Veins at the Young-Davidson Orogenic Gold Deposit.

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The Young-Davidson (YD) orogenic gold deposit, located at the western terminus of the Cadillac–Larder Lake Deformation Zone (CLLDZ) in the southwestern Abitibi greenstone belt, is hosted by syenite intrusions cut by multiple generations of quartz–carbonate veins associated with extensive potassic-hematite-pyrite alteration. Although previous studies have established the paragenetic framework and major alteration styles at Young-Davidson, fluid inclusion microthermometry has not been systematically integrated into a unified analytical framework. As a result, the distribution and preservation of fluid inclusion assemblages across vein generations and alteration zones remain poorly constrained.

This study uses petrographic analysis and fluid inclusion microthermometry of syenite-hosted quartz–carbonate veins to evaluate how vein generation and alteration style control the distribution and preservation of fluid inclusion assemblages. It further evaluates quick-plate thick sections as an exploration-targeting tool by comparison with traditionally prepared thick sections in terms of analytical efficiency, inclusion preservation, and interpretive reliability. Rapid screening is first applied to a broad suite of veins, and samples showing well-preserved inclusion assemblages are subsequently selected for detailed microthermometric analysis using doubly polished thick sections. Overall, this efficiency-focused workflow provides a framework for evaluating rapid fluid-inclusion screening as an exploration-scale vectoring tool..

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.

200 Intrusion-Related Deposits

201 **Daniel Castano Madrigal – M.Sc.**
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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 in northwestern British Columbia, Canada, is hosted in Triassic–Jurassic volcano-sedimentary rocks intruded by Cretaceous intrusive bodies associated with hydrothermal activity. At the Snip North prospect, multiple vein systems crosscut the hornfelsed volcano-sedimentary host rocks and record at least three mineralization stages. The earliest stage comprises <1 cm magnetite–pyrite–chalcopyrite–carbonate veins, mainly in the deepest part of the deposit and at shallower levels to the east. A second stage is characterized by pyrite–carbonate–quartz–chalcopyrite veins, sometimes with potassic stronger alteration halos. A late, coarse-grained stage consists of thicker quartz – pyrite – chalcopyrite – sphalerite – galena – carbonate veins in a white-mica alteration zone, commonly displaying intense white-mica halos up to 20 cm thick. Along the contact between the volcano-sedimentary rocks and the monzonite intrusions (~850 m), an additional vein type is developed, consisting of fine-grained quartz with molybdenite.

U-XRF and thick-section studies indicate that copper is associated with quartz-carbonate veins and is less disseminated in the host rocks, predominantly chalcopyrite-bearing. SEM analysis reveals electrum-style gold and scarce uranium-rich minerals within the volcano-sedimentary units. High concentrations of massive magnetite, together with localized hematite zones, record variations in oxidation conditions during hydrothermal activity. Overall, the volcano-sedimentary units that host the veins and mineralization are hornfelsed and affected by secondary biotite alteration, locally overprinted by white-mica and late chlorite replacement.

The timing of the hornfels-forming event is still under investigation, and ongoing microthermometric analyses of fluid inclusions will provide further constraints on the evolution of the Snip North system.

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Reading the Fine Print: Coupling pXRF Geochemistry and UV Response to Characterize Cryptic Alteration Halos at Guigui, Santa Eulalia, Mexico

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Carbonate replacement deposits (CRDs) are globally significant sources for Ag-Pb-Zn (Cu) and form from low-temperature hydrothermal fluids interacting with carbonate rocks. The fluid-rock interaction typically leaves a narrow footprint of visible alteration, which poses a challenge during exploration. Ore body geometry is either stratigraphically controlled, as the mineralizing fluids follow more permeable horizons, or fault-controlled, forming near-vertical ore zones. Calcite veins are abundant in CRDs and form as an expression of hydrothermal fluid movement. Elevated amounts of certain elements, like Mn or Fe, can cause fluorescence in calcite under shortwave

ultraviolet light (SWUV). A bright red UV response is associated with high Mn concentrations and commonly increases with proximity to mineralization.

The Guigui exploration project is situated in the southern part of the world-class Santa Eulalia CRD district. Most CRD-style mineralization is primarily hosted within a 1200 m package of prospective Cretaceous limestones. The limestone sequence is overlaid by pre-mineralization Tertiary rhyolites and tuffs, with carbonate veins crosscutting both units.

This study integrates the distribution and intensity of the visually logged UV response with the portable X-ray fluorescence (pXRF) geochemistry data from drill core to assess potential mineralization vectors. PXRF analyses were obtained from carbonate veins crosscutting volcanics and limestone, as well as their adjacent wall rock. A multivariate analysis is applied to effectively discriminate between lithologies and identify hydrothermal footprints, including subtle potassic centres and Mn halos. Furthermore, a key objective is to determine whether the UV fluorescence and geochemical trends of carbonate veins cropping out in the pre-mineral volcanic cap, as well as in the limestones, can be used to characterize cryptic alteration halos. This relationship can be utilized as an on-site tool for exploring CRD systems that extend into upper volcanics.

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High-grade mineralization and nodular alteration above the intrusion-hosted Valeriano Cu-Au porphyry deposit, Chile

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The Valeriano porphyry deposit is located at the northern extent of the El Indio belt in the Frontal Cordillera of Chile. ATEX Resources Inc. began exploration in 2021 and has now completed its sixth drilling campaign, totally over 50,000 m. The deposit is associated with Miocene porphyry and biotite-hornblende granodiorite stocks, hosted by Permian volcaniclastic rocks. A north-trending lithocap of advanced argillic alteration outcrops up to ~4500 m elevation. The intrusion-hosted porphyry mineralization is overlain by extensive polyphase, polymictic magmatic-hydrothermal breccia, with angular fragments of potassic-altered porphyry intrusions as well as A- and B-type quartz veins. The intermineral breccia hosts a high-grade zone, e.g., ATXD25C, 164 m of 1.69 wt% Cu, 0.97 g/t Au, 2.2 g/t Ag and 65 g/t Mo. The intermineral breccia is associated with a white mica-chlorite overprint of potassic alteration, with K-feldspar, biotite and magnetite replaced by illite, chlorite and hematite, associated with chalcopyrite, bornite and digenite and minor high-sulfidation sulphides. A second generation of inter-mineral breccia, inter-mineral breccia 2, was cemented by siderite and sulfides, responsible for the highest Cu and Au grades. Well-crystalline kaolinite + siderite cement and high sulfidation-state enargite/luzonite, chalcocite, digenite, bornite and covellite are intergrown, indicating syn-mineral formation. Earlier chalcopyrite + bornite fragments were replaced by digenite, chalcocite, and covellite, with enargite/luzonite on the rims of earlier sulphides. Enargite/luzonite, covellite and chalcocite also occur disseminated in the kaolinized inter-mineral breccia 2, replacing earlier disseminated sulphides.

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Above the porphyry intrusions and overlying the inter-mineral breccia 2-hosted high-grade zone, a horizon of nodular pyrophyllite + alunite alteration (plus other aluminosilicate minerals, confirmed by shortwave infrared spectroscopy and X-ray diffraction) occurs near the base of the lithocap, as a replacement of white mica and quartz. Logging of 21 drillholes (15 in photographs) indicates that the nodular (previously referred to as patchy) alteration occurs ~600-1000 m above the intrusions, and <500 m above the 0.3% Cu grade shell, providing a shallow vector during porphyry exploration elsewhere.

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Characterization and geochronology of mineralization in the El02 license, Bougainville Island, Papua New Guinea. An approach to its magmatic fertility and its implications for exploration

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This thesis proposal focuses on the exceptional metallogenic potential of Bougainville Island, Papua New Guinea, with emphasis on the characterization and timing of veins and hydrothermal alteration within the EL02 License Exploration Area. Bougainville, renowned for its world-class Panguna porphyry Au-Cu-Ag deposit, remains underexplored mainly due to decades of political conflict and restricted access. The resumption of exploration, enabled by the recent granting and renewal of EL02, the first major license under the Bougainville Mining Act, marks a pivotal moment for both scientific inquiry and local economic development. This research will compile and generate new information, including detailed fieldwork, structural geology, geochemical analyses, and a magmatic fertility assessment, with the purpose of understanding the nature of mineralization and economic potential of the EL02 license and supporting exploration in the island. Initial exploration efforts in the EL02 exploration license by Island Passage Exploration Ltd. have delineated multiple mineralized target zones based on stream sediment and rock geochemical anomalies, despite logistical challenges posed by dense vegetation and complex terrain. Fieldwork and subsequent sample geochemical analyses have identified several key sites, including Marai, Bara, Enara, Isina, and Tangka. This study further proposes zircon geochemistry and geochronologic measurements to evaluate the magmatic fertility and the temporal evolution of intrusive rocks associated with mineralization, thereby enhancing understanding of the tectonic and metallogenic evolution of Bougainville within its unique double-subduction-arc environment and anomalously high Cu-Au mineralization potential. Preliminary results from X-ray fluorescence analysis of samples from the Tangka target show potassic alteration mineralogy commonly observed in porphyry copper deposits. Socioeconomically, this work aims to support Bougainville's economic development, as part of a multidisciplinary effort to bring mining activity back to the region within a sustainable framework, filling the knowledge gaps in Bougainville's geology with new insights into the arc-related porphyry systems of Bougainville and the greater Southwest Pacific region, as well as being a reference and a foundation for future scientific and economic advancements.

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Multi-source fluid mixing controls on bonanza-grade gold-silver epithermal mineralization at the Brucejack deposit, British Columbia, Canada

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An integrated, in situ microanalytical study was conducted on bonanza-grade gold-bearing veins at the Brucejack epithermal gold–silver deposit, British Columbia, Canada, to constrain fluid chemistry, fluid sources, and the physicochemical conditions of ore formation and any potential remobilisation. Analytical methods included SEM, cathodoluminescence imaging, fluid inclusion microthermometry, LA-ICP-MS, SIMS, microdrill-based gas-source mass spectrometry, and MC-ICP-MS.

The primary auriferous veins formed through mixing between a moderately saline magmatic-hydrothermal fluid (7–12 wt.% NaCl equiv.) with homogenization temperatures of 170–200°C and a low-salinity fluid (0–1.7 wt.% NaCl equiv.) at lower temperatures (120–150°C). In-situ SIMS transects across epithermal quartz yielded $\delta^{18}O_{quartz}$ values of 4.75 to 13.96 ‰ (n = 79). The $\delta^{18}O_{quartz}$ values decrease from the cores into the mantles of the crystals and increase towards the rims. The higher values in the cores correspond to a higher contribution of magmatic-hydrothermal fluid, the low values in the mantle reflect an influx of meteoric water and the high values at the rims record either cooling of the hydrothermal system or renewed input of magmatic-hydrothermal fluid.

The radiogenic Sr^{87}/Sr^{86} isotope compositions of the calcite indicate that the earliest bonanza-grade quartz–calcite veins precipitated from fluids with a strongly depleted mantle signature, with ratios of 0.7040–0.7055. Carbon and oxygen isotope data for the calcite are consistent with this interpretation and confirm that meteoric water constituted a significant component of the fluids responsible for most of the bonanza-grade gold at Brucejack. Late-stage calcite veins formed from surficial waters that equilibrated with the Stuhini Limestone during the waning stages of epithermal mineralization.

A thermal resurgence associated with post-mineral deformation is recorded by the recrystallization of Phase 2 quartz, and the trapping of fluid inclusions with Th values of 165–190°C. LA-ICP-MS analyses of secondary fluid inclusions yielded elevated concentrations of As, Sb, Sr, Cu and Pb. Isolated Au and Ag spikes record the presence of nanoparticles in the fluid inclusions, indicating mechanical remobilization of electrum during deformation.

This study demonstrates that mixing between colder, likely steam-heated meteoric water and auriferous magmatic fluids was the dominant process driving gold deposition at Brucejack. This induced rapid cooling and pH increase, destabilizing gold colloids and promoting flocculation. Subsequent formation of weakly mineralized, massive calcite veins reflects the addition of surficial water that equilibrated with the Stuhini limestone. These results highlight the importance of multiple hydrothermal events and deformation in generating/remobilizing bonanza-grade gold mineralization in older, structurally complex terranes.

200 Intrusion-Related Deposits

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Portable X-Ray Fluorescence Spectrometry Screening for Tungsten: Lessons from preliminary analysis of mineralized and unmineralized samples granophile deposits throughout New Brunswick

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Tungsten (W) is essential for hard metal alloys used in cutting and drilling equipment, as well as in heat-resistant coatings for green technologies and defence applications. Its properties cannot be substituted by other metals, and with China producing nearly 80% of global supply and holding ~52% of reserves, W is considered a critical mineral. Although portable X-ray fluorescence spectrometry (pXRF) is widely used for rapid geochemical assessment in various metallogenic systems, its application in granophile mineralization (W–Sn–Mo) remains limited due to the poor analytical performance for W. Nevertheless, several elements detectable by pXRF can serve as reliable pathfinders for W-enrichment. This study evaluates the behaviour of these pathfinders in differentiating W-bearing veins from weakly mineralized or barren host rocks across six deposits and occurrences located in the Central and Southern Plutonic Belt of New Brunswick. These systems are associated with Early to Late Devonian granitic cupolas. Diamond drill cores archived in the New Brunswick government core storage facilities were examined, and a dataset of 220 pXRF measurements was collected using an Olympus Vanta analyzer in soil mode, employing a 6-minute total integration time on flat, dry rock slabs. Calibration was completed with four Certified Reference Materials analyzed repeatedly. Preliminary results reveal three analytical performance groups: (i) elements with small bias and strong goodness of fit (>0.9), including As, Mo, Th, Pb, and Sn; (ii) elements with moderate bias and acceptable goodness of fit (Fe, Cu, Zn, Rb, Bi); and (iii) elements showing extremely poor behaviour, typically due to concentrations near the instrument's detection limit (LOD) or large intercept values (instrument offset). These limitations indicate that pXRF should be used primarily as a qualitative vectoring tool rather than for quantitative W assessment. Multivariate analyses show consistent elemental patterns across deposits. Bi, As, and Mo are effective discriminators of W-mineralized veins, whereas Pb, Zn, and Cu are more closely linked to altered metasedimentary host rocks. These associations reflect mineralogical controls: Bi–As–Mo enrichments correspond to sulphide–wolframite vein assemblages, while Pb–Zn characterizes host-rock sulphides. Despite the masking effect of the metasedimentary rocks, principal component analysis (PCA) successfully differentiates sulphide veins from W-bearing veins based on elemental loadings, demonstrating the value of pXRF as a qualitative support tool during drill-core logging and early-stage exploration.

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Textural and Mineralogical Characterization of Co-, Ni-, PGE-Rich Mineralization in the New Afton Deposit, British Columbia, using Mineral Liberation Analysis and Scanning Electron Microscopy

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Cobalt (Co), nickel (Ni), and platinum-group elements (PGEs) are essential to low-carbon technologies, yet global supply chains for these metals are acutely vulnerable to disruption. Recent studies have identified significant Co–Ni–PGE enrichments in alkalic Cu–Au porphyry deposits of the Canadian Cordillera. Although analysis of ore-stage mineralogy suggests that these elements occur primarily as trace constituents within sulphide minerals, bulk geochemistry and mineral tenors suggest that PGEs and other critical elements may occur as discrete mineral phases.

This study evaluates the possible occurrence of discrete Co-, Ni-, and PGE-bearing mineral phases in the New Afton alkalic Cu–Au porphyry deposit via a detailed mineralogy and textural characterization of Co-, Ni-, and PGE-rich zones. This study unitizes combined Mineral Liberation Analysis (MLA) and targeted scanning electron microscopy (SEM) analysis to develop a high resolution, quantitative mineralogical and textural dataset that can be used to link Co–Ni–PGE enrichment to specific sulphide textures and alteration domains. When applied to a large deposit-wide sample sets, this technique can efficiently link mineralogical variation to observed variations in bulk geochemistry and help better understand the source of Co, Ni, and PGE enrichment observed in production assays.

Here we present data from PGE-, Ni-, and Co-rich zones within the New Afton and nearby Copper King deposits. Preliminary results indicate that PGE-minerals (PGMs; sperrylite, froodite, palladium arsenides) and cobaltite occur in primary sulphide-oxide-carbonate veins and are commonly hosted in or spatially associated with PGE-bearing pyrite and chalcopyrite. These PGMs are typically intergrown with ore-stage mineralogy and are texturally and paragenetically distinct from the sulfides with PGE-bearing growth zones identified in previous studies. Moreover, PGM also appear to be spatially, and possibly paragenetically associated with magnetite–apatite–sulphide veining and possibly later-stage carbonate–quartz veining. These observations suggest that PGE and Co enrichment occurred during multiple mineralizing events and may reflect shifts in redox conditions or the larger magmatic evolution of intrusions associated with the New Afton deposit.

These findings refine genetic models for alkalic porphyry deposits and support evaluation of Co–Ni–PGE by-product potential within existing Cu–Au operations, contributing to Canada's critical mineral strategy.

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Long Lake Zinc Deposit in the Grenville Province, Canada: Evidence of Post-Metamorphic Mineralization and Magmatic Input

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The marble-hosted Long Lake zinc deposit occurs along the contact zone of the marble rocks of the Proterozoic Greenville supergroup with intrusive rocks within the Greenville Central Metasedimentary Belt. Controversial genetic models have been proposed for similar marble-hosted deposits in the Grenville Province; therefore, understanding the processes that controlled the formation and transformation of zinc mineralization is essential for developing exploration strategies for zinc in the Grenville Province and similar terranes. In this study, historical data have been integrated with new field and drill core logging observations, lithogeochemical and petrological data into a 3D geological model to better constrain the geometry of the ore zones and delineate their spatial relationship with various magmatic events and igneous and marble host rocks. Zinc mineralization occurs as lenses up to 5 m thick in two main ore zones with distinct mineralogy and geochemical signatures. Sphalerite is associated with pyrite, subordinate pyrrhotite, chalcopyrite, galena, and molybdenite, calcite, phlogopite, talc, and chlorite, with the abundance of these minerals distinct in the two ore zones. These minerals filled embayments and fractures within calc-silicate minerals such as garnet, pyroxene, and amphibole, indicating that the zinc mineralization formed after peak-metamorphic conditions. Pyrite-bearing zones also occur in halos (up to 3 m) surrounding some of the zinc-rich lenses. Outside the mineralized zones, garnet and pyroxenes are well preserved. Zinc mineralized zones are consistently enriched in Cd, Hg, In, Mn, Se and S, which show high correlation with Zn. Bismuth, Pb, Sb, and Sn have also yielded high values within the zinc mineralized zones, but their enrichment extends to halos (0.1-2 m thick) surrounding these zones. These findings are not consistent with historical interpretations that the Long Lake zinc deposit is a metamorphosed sediment-exhalative deposit and indicate that other processes were involved in its formation after peak metamorphism in the Grenville Province, which may have involved contribution from magmatic sources.

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Process oriented and vector based evaluation of rare earth element (REE) potential in granitoid weathering crusts using archived drill cores from the Souktal Plutonic Complex (Northern Kazakhstan).

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Weathering crusts that have formed on granitoid rock are now being considered more and more a possibility for the extraction of rare earth elements (REE), especially in situations where supergene processes are favorable for the migration and keeping of the secondarily formed REEs. Northern Kazakhstan is home to the Souktal Plutonic Complex, which has thick weathering profiles lying on Proterozoic granite-gneisses, but still, there is not enough of an understanding of the inner mechanisms that control the distribution of REE in these profiles. This study is mainly geared towards evaluating the REE resolution of Souktal weathering crusts through a process oriented, predictive framework as opposed to a deposit confirmation approach. It adopts a process-oriented framework based on archived drill cores, focusing on weathered intervals (30-43 m) from cores C-15 and C-18, where granitic gneisses are transformed into clay-rich assemblages dominated by quartz, kaolinite, feldspars, muscovite, and minor Fe hydroxides.

The study aims at pinpointing the mineralogical, geochemical, and vertical zoning characteristics that rule REE retention and also those that lead to REE being separated and their being increased across different levels of weathering. Ion-exchangeable REE were quantified using a two-step sequential leaching procedure with hydroxylamine hydrochloride (0.2 mol $NH_2OH \cdot HCl$) and sodium hydroxide (1 mol NaOH), followed by ICP-MS analysis of REE, Y, and Sc. Total extracted REE range from 4.1 to 7.8 ppm, indicating a measurable ion-adsorbed REE pool. Light REE dominate over heavy REE, and La/Yb ratios increase between leaching steps. The features are consistent with ion-adsorption-type REE systems and suggest that deeper drilling is warranted to evaluate higher-grade zones and the future REE potential of the Souktal weathering crust.

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Exploration potential of lithium–caesium–tantalum (LCT) pegmatites in the Brasília Orogen, Brazil

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The global expansion of low-carbon technologies has intensified the search for lithium in new frontiers. The Brasília Orogen (Tocantins Province) represents a major Neoproterozoic belt formed during the assembly of Gondwana (640–500 Ma). Its external zone hosts several peraluminous granitic-pegmatitic systems with exploration potential for critical minerals. This study focuses on three suites: Mata Azul (MA), Aurumina (AU), and São Domingos (SD). Methods included mapping 15 outcrops and sampling 6 drill cores, supported by petrographic analysis (n=47), whole-rock geochemistry (ICP-OES/MS), and mineral chemistry via electron probe micro-analysis (EPMA-WDS) on feldspars, micas, tourmalines, garnets, spodumene, Li-Al phosphates, and

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Nb-Ta oxides. Whole-rock geochemistry confirms that all suites are strongly peraluminous (A/CNK 1.07–1.68 and A/NK 1.11–2.25), consistent with evolved magmatism. In the Mata Azul Suite (560–520 Ma), five pegmatitic facies were identified, ranging from quartz-muscovite and graphic textures to specialized lepidolite-albite facies with whole-rock Li up to 12,729 ppm and K/Rb ratios as low as 29. Zonation is well-developed, with core-related pods containing lepidolite and rubellite. Lepidolite in these facies yields high Li_2O (~4.7–6.1 wt.%), F (up to 10.3 wt.%), and Rb (up to 1.1 wt. % Rb_2O). Garnets are spessartine-rich (Sps_{44-68}), and tourmalines evolve from schorl to elbaite (up to ~1.69 wt.% Li_2O). The Aurumina Suite (2.11–2.16 Ga) comprises syeno/monzogranites, albitites, and pegmatites with lepidolite and total Li contents up to 8,555 ppm. Mylonitic granites in this suite host spodumene as porphyroclasts. Nb-Ta oxides evolve from columbite-(Mn) to ferrotitanowodginite, while Li-Al phosphates correspond to the amblygonite-montebrasite series [F/(F+OH) 0.15–0.64]. This suite exhibits the highest degree of fractionation and trace-element enrichment, with Be up to 258 ppm, Cs up to 1,351 ppm, Ta up to 176 ppm, and K/Rb ratios reaching highly evolved values of 20. The São Domingos Suite (2.1–2.0 Ga) consists of albite-rich pegmatites hosting coarse cassiterite and montebrasite. It is geochemically distinct, being P-rich (up to 1.29 wt.% P_2O_5) and exhibiting low K/Rb ratios of 23, with Li contents reaching 993 ppm. The presence of lithium minerals (lepidolite, spodumene, and montebrasite) and highly fractionated geochemical signatures (low K/Rb and high Be-Cs-Ta-Li) demonstrates extreme magmatic differentiation processes required for the development of LCT-type mineralization. These results characterize these suites as fertile environments for critical mineral exploration within the Brasília Orogen.

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Petrogenesis of Neoproterozoic NYF Pegmatites, Perch Falls Quarry, southwestern New Brunswick: Insights from portable field tools with follow up µXRF–EDS and lithogeochemical analyses

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In southwestern New Brunswick, eight NYF-type granitic pegmatite dykes intrude the Neoproterozoic Perch Falls Granodiorite. The steeply dipping dykes are narrow (<1 m) exhibit a consistent NE to E strike and locally contain a central quartz core. They contain quartz and feldspar, as well as magmatic epidote, and in some instances, allanite. Gamma ray spectrometry analyses exhibit variable radioelement concentrations (eTh = 3.6–75 ppm; eU = 0–6.8 ppm). Lithogeochemistry shows silica rich compositions (SiO_2 = 71.1–77.6 wt.%), moderate Al_2O_3 (12.3–15.6 wt.%), and elevated alkali elements (Na_2O = 2.65–4.12 wt.%; K_2O = 3.01–5.62 wt.%), with notable LREE contents (Ce = 8.9–33.6 ppm; La = 5.1–33.9 ppm) and quite variable Zr (23–420 ppm). Portable X-ray Fluorescence spectrometry (pXRF) data confirmed these results, which resemble those of the nearby Prince of Wales Granite, the youngest Neoproterozoic magmatic event in the area. Together, pXRF, gamma-ray spectrometry (GRS), and whole-rock geochemistry provide a petrogenetic framework for interpreting granitic magmatism and late-stage fluid modification in the Perch Falls system, as demonstrated by igneous and hydrothermal assemblages.

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Petrographic and geochemical evidence indicate two stages of hydrothermal overprinting, both with copper. An early Fe–S-rich magmatic–hydrothermal event produced both disseminated to vein-like, Fe-rich domains and chloritization of ferromagnesian minerals, accompanied by epidote–chlorite alteration. A later Ca-rich hydrothermal pulse then occurred, partially retrogressed chlorite to secondary epidote, and promoted the precipitation of titanite along fracture networks. Zircon grains hosted within feldspar-rich domains exhibit very small Th–U–Si–O-rich inclusions, <10 µm in size, only revealed by SEM-BSE imaging. However, typical zircons have visible oscillatory magmatic zoning. As such, the visible textural distribution of these inclusions indicates decoupling of Zr from U–Th, which occurs when radioactive elements are redistributed and reprecipitated during post-crystallization fluid–mineral interactions. These features indicate the localized concentration and remobilization of radioactive elements during late-stage magmatic-hydrothermal processes. The preferential occurrence of altered zircon within feldspar-rich domains further suggests that these zones served as permeable pathways for late-stage fluids, facilitating micro-scale mobility of radioactive elements during hydrothermal overprinting. Ongoing U–Pb zircon geochronology will further constrain the timing of pegmatite emplacement and subsequent fluid-mediated alteration. Zircon-scale SEM-BSE imaging coupled with SEM-EDS analyses reveal zircon textures characterized by U–Th-rich inclusions within weakly zoned grains, indicating that radioactive element enrichment in these pegmatites reflects a combination of primary magmatic fractionation processes and subsequent fluid-mediated modification.

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Exploring the influence of rock geochemistry on biofilm composition in a lithium pegmatite system using metabarcoding

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Microbes inhabit almost every environment on Earth and their community compositions are highly dependent on abiotic environmental gradients. These abiotic environments include different rock types that can have very different chemical compositions. The objective of this research is to investigate the influence of rock geochemistry on distributions in microbial communities, with a focus on lithium, an important chemical element for decarbonization. Biological applications to mineral exploration are growing in popularity and will be a valuable tool as the demand for critical minerals increases. Microbial biodiversity is being investigated using metabarcoding of rock surface biofilms on outcrops in the Hayman Hill area located near St. Stephen, New Brunswick. The study area is located in the St. Croix terrane of Ganderia and the local geology consists of plutonic rocks, including mainly diorite, granodiorite and muscovite-biotite granite, and spodumene pegmatite dykes that intruded metasedimentary rocks. Small (<2 cm diameter and <0.5 cm thick) rock chips were collected from different rock types for 3-domain metabarcoding, a process that generates a total community fingerprint of eukaryotic and prokaryotic rRNA barcodes that can identify organisms down to the species level and determine their relative abundances. Absolute abundances per unit of exposed surface area were determined by normalizing to three internal standards. Preliminary results show a diverse biofilm

community of prokaryotic and eukaryotic microbes and success of a novel DNA extraction method from rock chips. Current work is focused on comparing the rock surface metabarcodes to whole-rock geochemical data from the same samples. Taken together, this study uncovers the relationships between rock type, geochemistry, and microbial community composition on rock surfaces in the study area.

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Melt Evolution: The Transition from Migmatite to Lithium-Mineralized Pegmatite

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The topic of how lithium-rich pegmatites are formed is widely debated. The three main genetic models include pegmatite formation from 1) low-degree anatexis of metasediments, 2) S-type granite melts that have undergone extreme fractionation, and 3) remelting of pre-enriched granites during crustal reheating. A unique outcrop on Mount Begbie near Revelstoke, British Columbia, is being analyzed to settle this debate. Here, we present data from Li2, an enriched pegmatite that contains the lithium minerals lepidolite, elbaite, and petalite. At an outcrop scale, the direct transition from migmatite to mineralized pegmatite is observed. This makes Li2 the ideal candidate for testing the anatexis model of pegmatite formation by documenting how mineral chemistry varies from migmatite, through barren pegmatite, to the mineralized pegmatite zone. Analysis is being done through 1) identification of partial melt reactions based on microstructure and mineral assemblages of representative thin sections, 2) use of micro X-ray fluorescence to document different phases within the rocks, and how their proportions vary between each outcrop sample site, 3) confirming mineral identification and creating element maps of minerals through scanning electron microscopy, and 4) analysis of the trace element composition of major minerals in the migmatite to mineralized pegmatite through laser ablation inductively coupled plasma-mass spectrometry. Narrowing down how lithium rich pegmatites form will allow for better prediction of the distributions of mineralized pegmatites, enabling more efficient exploration for lithium and other critical metals.

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Ferrocarbonatite Complex at Cerro Manomó: Possible Geological Evolution and Potential for Rare Earth Elements

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Cerro Manomó is interpreted as a silicified ferrocarbonatite complex with a highly complex geological history involving multiple geological processes that significantly modified the original

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rocks. Since the first studies conducted in the 1980s, its geological interpretation has been the subject of debate due to the extensive replacement of the original lithologies by metasomatic, hydrothermal, and supergene processes. Despite this complexity, Cerro Manomó is of high scientific and strategic interest because of its anomalies in rare earth elements (REE) and radioactive minerals, positioning it as a relevant target within Bolivia's growing interest in critical minerals.

The objective of this study was to characterize the geology of the northeastern sector of Cerro Manomó and to contribute to the understanding of its genetic evolution by addressing uncertainties related to lithological origins, structural controls, and the processes responsible for the observed geochemical enrichment. The scope of the work focused on integrating field, laboratory, and remote sensing data to propose a coherent and preliminary evolutionary model for the complex.

To achieve this, a multidisciplinary approach was applied, including photogeology, satellite image analysis, detailed geological field mapping, petrographic and mineragraphic studies, X-ray fluorescence (XRF) geochemical analyses, and fluid inclusion investigations. This methodology allowed the identification of key structural features, including the presence of possible annular carbonatite dikes, as well as zones of intense hydrothermal alteration.

The results indicate a polyphase evolution dominated by pervasive silicification and hydrothermal alteration at temperatures close to 400 °C, with secondary mineral assemblages characterized by quartz, hematite, kaolinite, limonite, barite, and bastnaesite. Geochemical data show significant enrichment in REE, Nb, Th, and U, consistent with carbonatitic affinities and comparable to other regional alkaline–carbonatite complexes. Available geochronological data indicate a basement interpreted as a possible Banded Iron Formation (BIF) dated at approximately ~1.2 Ga and a Cretaceous carbonatite intrusion dated at ~139 Ma.

Overall, this study confirms that Cerro Manomó represents a highly evolved ferrocarbonatite complex enriched in REE, whose exploration potential may be structurally controlled by annular features. Further exploration is recommended through geophysical surveys and drilling, as well as detailed evaluation of the rare earth element potential in residual soils, in order to assess the economic viability of the system and its potential future development.

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Tourmaline micro-inclusions in quartz and implications for metallurgy at the Tanco pegmatite, southeastern Manitoba

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High-purity quartz is essential for the production of semiconductors, optical fibers, photovoltaics, electric lights, computer chips, and laboratory equipment. Most high-purity quartz worldwide is extracted from large-volume (>100,000 m3) pegmatites, alaskite granites, metamorphic quartzites, or vein quartz, with zoned pegmatites being a common source due to their largely monomineralic quartz cores. The Tanco pegmatite, southeastern Manitoba, has a volume of 21,850,000 m3 and contains several zones of massive monomineralic quartz. Furthermore, the Tanco mine is a historical Li and Ta producer and current Cs producer, with an on-site ore processing facility. The global need for high-purity quartz therefore presents a potential economic opportunity for the Tanco mine. Samples of quartz from the Tanco pegmatite were analyzed by thin section petrography, and the majority of samples were found to contain abundant micro-scale inclusions of needle-like tourmaline crystals, which have not previously been reported at this locality. Tourmaline needles are commonly aligned parallel to fluid inclusion trails and perpendicular to elongated subgrains defined by undulose extinction in the host quartz. While tourmaline needles are generally evenly disseminated throughout the quartz, in some samples they are clustered into linear trends along the contacts of quartz subgrains. Preferential orientation of tourmaline micro-inclusions relative to fluid inclusion trails and quartz subgrains has implications for both pre- and post-crystallization strain dynamics in the Tanco pegmatite. The presence of these tourmaline inclusions also has implications for potential metallurgical processing of quartz, as they would prove difficult to remove by traditional processing methods due to their small size and ubiquity. Finally, their presence additionally suggests that boron contents in the silicate melt which gave rise to the Tanco pegmatite’s quartz cores may have been higher than previously thought, with implications for crystal fractionation processes in the pegmatite as a whole.

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Pyrite Trace Element Concentration of VMS Deposits in Skellefte District, Northern Sweden

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Volcanogenic Massive Sulphides (VMS) deposits are an important source of precious and base metals. In the western Skellefte District of northern Sweden, the Kristineberg deposit is one of the largest VMS deposits, hosting Cu, Zn, Pb, Au, and Ag. To improve the understanding of the metallogenesis of the deposit and its surroundings, this study will undertake detailed petrographic analysis of 20 representative samples that are a part of satellite deposits associated with Kristineberg. Reflected light microscopy, scanning electron microscopy (SEM), and the examination of etched samples are conducted to describe pyrite textures. This would be followed by laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) to determine the trace element concentrations and map the spatial variations among different generations of pyrite. This will provide initial data to determine the genesis of the deposit and the distribution of trace elements within the sulphides. The study will enhance the understanding of hydrothermal fluids that are responsible for the mineralization near the Kristineberg deposit, and assess the potential pyrite trace element chemistry as a tool for the exploration of other VMS deposits. The results of the study will contribute to a greater understanding of the formation of this deposit and which generation of pyrite may host precious and base metals.

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The effect of ridge-hotspot interactions on regional geology and active seafloor hydrothermal systems: a case study from the Galápagos Spreading Center

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Hydrothermal vents on the global ocean are the modern analogs of ancient volcanogenic massive sulfide deposits now mined on land. Two thirds of the known hydrothermal sites are found along mid-ocean ridges. Of particular interest are vent fields formed under the influence of hotspots: localized sites of excess magmatism associated with mantle plumes. Hotspots are linked to increased crustal thickness (e.g., the Icelandic Plateau), high heat flow, and regional geochemical anomalies, affecting one fifth of the 70,000 km-long mid-ocean ridge system. In some cases, they can promote high-temperature venting (e.g., Axial Seamount). However, the contribution of hotspots to metal endowment over large distances is still unknown.

The Galápagos Spreading Center and its proximal hotspot in the Eastern Pacific offer a natural laboratory to study the regional geology and geochemistry of ridge-hotspot interactions and their effects on the size, composition, distribution and duration of hydrothermal systems. These effects are strongly associated with magmatic and tectonic controls, including magma supply, composition of host rocks, seafloor depth, spreading rate, crustal thickness and permeability. Hotspot activity near the Galápagos Spreading Center is located on the Nazca plate, concentrated on the western Fernandina and Isabela islands.

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To understand how melt is being delivered from the hotspot to the spreading center and its hydrothermal systems, we are comparing 4 vent fields along 700 km of the ridge, at distances ranging from 180 to 650 km away from the hotspot. A new regional geological map at 1:1,000,000 scale and covering an area of 380,000 km² is being studied together with the major and trace element geochemistry of ~300 massive sulfide samples collected from the four sites (Iguanas-Pinguinos, Los Huellos, 89° W and 86° W). Preliminary inspection of samples from each site highlights a strong incompatible-element enrichment (e.g., Ba, Au, Cd and Sr) proximal to the hotspot (Los Huellos), which is reflected by abundant barite. Taking into account the range of temperatures and water depths of the hydrothermal vents, we interpret these enrichments in terms of plume-influenced source rocks from which the elements are leached. One interpretation is that the Galápagos hotspot plumbing system is delivering enriched melts to the proximal mid-ocean ridge, controlling the composition of the hydrothermal fluids.

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Seafloor Hydrothermalism and Ultrafast Subduction: A Recipe for Critical Metal Enrichment

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Seafloor massive sulfide (SMS) systems associated with arc volcanos are recognized as prospective targets for relatively mantle-incompatible elements (e.g., Zn, Pb, Ba, Co, Ge, Ga, W, Sn, In, As, Sb, etc.), and elements with an affinity for magmatic fluids (e.g., Au, Ag, Se, Bi, Hg). However, not all arc-hosted SMS systems are compositionally equivalent, and neither are the magmatic volatiles that contribute to those SMS systems. The VOLPA vent field is a previously uncharacterized SMS system located on the bi-modal felsic (boninite-dacite) Niua Volcanic Complex at the northern end of the Tofua Volcanic Arc, SW Pacific. Here, subduction occurs at full rates of 24 cm yr-1. The rapidness of subduction, and age of the subducting slab result in "cold" serpentinite dehydration reactions that normally occur under the forearc being delayed, and instead occurring in the sub-arc. These dehydration reactions produce highly oxidizing fluids that have the capacity to contribute abundant large ion lithophile elements (Ba, Pb, Sr, Th), volatiles (H_2O, CO_2), and fluid-mobile oxyanions (As, Sb, W) to both the overlying volcanic and hydrothermal systems. These manifest as hydrothermal chimneys that are greatly enriched in barite and minerals indicative of a high sulfidation fluid (gratonite, semseyite, enargite, tennantite-tetrahedrite, anglesite, covellite, and proustite), which is consistent with previously established fingerprints of magmatic volatile flux into SMS systems; however, sulfur isotope signatures of sulfide minerals at VOLPA ($\delta^{34}S$ = -5.1–8.1 ‰) do not conform well to expected values of magmatic volatile flux ($\delta^{34}S$ < 0 ‰). The highly oxidizing conditions facilitated by the cold slab dehydration reactions produced a redox-controlled partitioning of heavier sulfur isotopes into the magmatic fluids, which is consistent with previously collected sulfur isotopes from both forearcs, and the adjacent Niua North vent field. Furthermore, Au is frequently associated with magmatic volatile flux, and despite the strong evidence of magmatic volatile flux to the VOLPA SMS system, the concentrations of Au are lower than the adjacent Niua South deposit, which has no indications of magmatic volatile flux. We demonstrate how Au

abundances in these systems are temperature-dependent, and that magmatic volatiles do not necessarily function as a precondition for Au enrichment. The results of this work demonstrate how magmatic volatile compositions can vary as a function of subduction rate, and provide new insights into how we interpret magmatic volatile contributions to both modern and ancient hydrothermal systems.

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Understanding the Geochemistry and Mineralization of Arsenic-bearing Minerals within the Complex Kidd Creek VMS Deposit

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The Kidd Creek deposit is a high-grade high tonnage Archean Cu-Zn volcanogenic massive sulfide (VMS) deposit hosted in the Kidd-Munro Assemblage within the Western Abitibi Greenstone Belt. This deposit contained several complex zones in the different orebodies of the system with highly variable arsenic contents in different minerals, from 800-1,000 ppm in both sphalerite ore and chalcopyrite ore to nearly 3,000 ppm in bornite-rich ore. The arsenic occurs in seven unique minerals: arsenopyrite, cobaltite, tennantite, enargite, colusite, cattierite, and vinciennite. Microprobe analysis indicates minor amounts of arsenic are also present in solid solution in pyrite throughout the deposit (1400 ppm average; generally increasing from Zn-rich to Cu-rich ore). Arsenic in the bulk samples show the strongest correlation with Co in cobaltite. In addition to arsenopyrite (45 wt.% As), arsenic is present in cobaltite (40 wt.%), tennantite (20 wt.%), enargite (19 wt.%), colusite (9 wt.%), cattierite (6 wt.%), and vinciennite (5 wt.%). Twenty-two thin sections were created from samples containing over 300 ppm As, collected from various depths of the deposit. These samples are being analyzed using reflected light microscopy, scanning electron microscopy (SEM), and laser ablation inductively coupled plasma mass spectroscopy (LA-ICPMS) to constrain the distribution of arsenic-bearing minerals and their origins. For example, high concentrations of arsenic in the bornite zone, and more specifically within the tennantite-rich contact zone, strongly indicate metamorphic remobilization during recrystallization of the Cu-rich minerals (e.g., as a product of exsolution from nonstoichiometric solid solutions). Constraining the behavior of arsenic and the distributions of As-bearing minerals at Kidd Creek allows for a better understanding of the paragenesis and conditions of arsenic mineralization in other VMS deposits.

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Mineralogy and genesis of critical-metal bearing mineralization in the Great Burnt Lake volcanogenic massive sulfide (VMS) deposit, Central Newfoundland

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The early Ordovician Great Burnt Cu deposit is in the Exploits subzone of the Dunnage Zone, in south-central Newfoundland, and is a mafic siliciclastic (Besshi)-type volcanogenic massive sulfide (VMS) deposit. The deposit is hosted by lithologies of the Great Burnt metavolcanic and metasedimentary belt, consisting of interbedded metasedimentary and metavolcanic rocks dominated by psammitic to pelitic turbiditic sedimentary rocks interlayered with mafic volcanic flows and associated volcaniclastic rocks (e.g., tuff, lapilli tuff, breccia), all of which are metamorphosed from upper greenschist to lower amphibolite facies and are multiply deformed. The belt contains several Cu ± Au mineralized zones (e.g., North Stringer Zone, South Pond, Great Burnt Cu).

Core logging, petrography, scanning electron microscopy (SEM), and electron probe microanalysis (EPMA) have been used to document the stratigraphy, alteration, and nature of base and precious metal-bearing mineralization in the Great Burnt Cu deposit. In drill holes, the deposit stratigraphy appears inverted. From top to bottom it comprises mudstones interlayered with laminated to finely bedded silty units, with minor tuff and lapilli-tuff layers. Downhole, this sequence transitions into a mafic-dominated package composed mainly of massive aphyric basalts and plagioclase porphyritic basalt, with subordinate hyaloclastite and mafic volcaniclastic units. This unit comprises the main host of mineralization where it lies in stratigraphic contact with sulfide- and carbon-rich mudstones that locally contain thin mafic tuff layers.

The whole rock geochemical signatures of basalts from the deposits have incompatible-element-depleted MORB to E-MORB, to incompatible-element-enriched OIB signatures, with a rare arc-related signature, consistent with formation within a rifted arc to back-arc basin. Mineralization consists of massive to semi-massive chalcopyrite, pyrrhotite, pyrite with minor sphalerite and ilmenite, and accessory altaite, arsenopyrite, cobaltite, galena–clausthalite, hessite, Co-rich pentlandite, tetrahedrite, and tellurobismuthinite. Alteration associated with the mineralization consists of locally intense chlorite-quartz alteration proximal to mineralization and stringers in mafic rocks, and weak quartz alteration in hanging wall rocks. The mineralization also exhibits features consistent with formation via subseafloor replacement, including relict volcanic clasts in the mineralization, partial replacement of sedimentary beds by sulfide, sulfide stringers in permeable zones in volcaniclastic rocks, and hanging wall alteration.

Further work will include sulfide trace-element concentrations and sulfur isotope compositions of the sulfides will be measured using LA-ICP-MS and SIMS, respectively, to further understand mineral assemblages and metal abundances in the sulfides and the potential and sources of metals and sulfur in the Great Burnt deposit.

500 Sedimentary Environments

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A Groundbreaking Geological Approach to Industrial Mineral Resource Estimation: Integrating Physical, Geochemical, and Petrographic Insights of Calcitc Dolostone in Paciran, East Java

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Limestone is an industrial mineral commodity with significant mining potential in Indonesia and relatively easy extractability. However, its exploitation is often unplanned and carried out with limited attention to economic feasibility and overestimation sometimes occurs in resource calculations with arbitrary assumptions without correct geological characterization.
To overcome this issue, an accurate resource estimation approach is necessary. One of the most critical aspects in limestone resource estimation is the determination of true bulk density, which is influenced by mineral composition and porosity. This study aims to present a systematic geological approach to resource estimation by calculating true bulk density of limestone, which combines several geological parameters such as physical, geochemical, and petrographic observations. Furthermore, this study attempts to compare this approach with conventional arbitrary calculations to answer the frequent problem of resource overestimation. The research was conducted in a dolostone quarry in Paciran, Lamongan, East Java. The investigation began with fieldwork and collecting samples. These observations were validated by physical tests. Representative samples were then selected for laboratory analysis. Petrographic analysis used to determine mineral composition and porosity, while geochemical analysis using XRF used to validate chemical composition. All of these methods were used to calculate true bulk density. The results revealed six layers consisting of both limestone and calcitic dolostone varieties. XRF showed that five layers identified as calcitic dolostone contained 17.45-18.93 wt% MgO, whereas two layers identified as limestone contained only 0.31-0.42 wt% MgO. XRF data indicated that calcitic dolostone consisted of 80.3-86.9% dolomite, with porosity ranging from 16.54-32.76% and bulk density values of 1.91-2.37 g/cm³. In contrast, limestone with 1.5%-1.9% dolomite displayed porosity of 16.06- 28.62% and bulk density values of 1.94-2.28 g/cm³. Using a block model , the resource potential was calculated for an area of 4,000 m². For the calcitic dolostone layer, with total thickness of 28.5 m, the total resource was estimated at 395,608 tons. In comparison, calculations that are often carried out in Indonesia with the assumption of a dolostone density of 2.5 g/cm3 (realistic) or 2.7 g/cm3 (optimistic) without considering porosity are 436,000 tons and 470,880 tons, representing a difference of 10.2% and 19%. These findings demonstrate that calculating true bulk density is affecting limestone resource estimation. Calculations should therefore employ bulk density values derived from porosity and composition rather than density assumption to achieve accurate and realistic results. By integrating geology, petrographic, and geochemical data, resource estimation can be performed more realistically.

500 Volcanogenic Massive Sulfide (VMS) Deposits

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Understanding the origin of hematite in red beds occurring in Paleoproterozoic fluvial-alluvial rocks of northern Saskatchewan and Nunavut

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The Earth has undergone fundamental changes in oxygenation throughout its history, with the first significant accumulation of atmospheric oxygen occurring in the Great Oxidation Event (GOE) at ca. 2.4 Ga. A major source of evidence for the GOE is the appearance of red beds deposited in fluvial-alluvial environments which contain oxidized minerals such as hematite. An important component of evidence that is often overlooked is whether the mineral constituents of red beds represent primary oxygenation from the atmosphere or were inherited from a source rock. To draw conclusions on the atmospheric state, hematite or its precursors must precipitate at the time of deposition in the form of detrital ferric hydroxides, or shortly after during shallow burial and infiltration of sediment by groundwater containing ferromagnesian minerals.

The Belcher Group of Nunavut, Canada, was deposited ca 2.0 to 1.8 Ga and contains alluvial-fluvial red beds that have not been studied in detail. The main hypothesis is that these rocks will show evidence of oxidative weathering, but a competing alternative hypothesis is that these rocks will not contain evidence of oxidative weathering because of a Deoxidation Event that began around 2 billion years ago. Red bed samples from the Belcher Group are compared with samples from the similarly aged red beds of the Missi Group and Martin Group, both in northern Saskatchewan, to determine the atmospheric conditions of the Archean cratons of Canada ca. 2.0 - 1.8 Ga. Samples were examined under transmitted and reflected light using a standard optical microscope. Identification of bulk iron oxide composition was performed using powder X-ray diffraction. Iron oxide phases showing promising habits were further distinguished using Raman microscopy. Backscatter imaging and microprobe analysis were carried out to highlight representative textures for each sample and obtain additional geochemical data.

Evidence of oxidizing conditions on the Archean cratons of Canada during the deposition and formation of the red beds of the Belcher, Missi, and Martin groups is present in the form of authigenic hematite as black rims on quartz, as alteration of phylosilicates such as biotite and muscovite, and as martitization of detrital magnetite grains. However, red beds provide only qualitative information on atmospheric oxygenation; more quantitative evidence is required to determine the magnitude of a deoxidation event.

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Characterization of Uranium Mineralization and Alteration in the Pike Zone of CanAlaska Uranium's West McArthur Project, Saskatchewan

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Unconformity-related uranium (U) deposits are among the most economically significant uranium resources globally due to their exceptionally high grades, substantial tonnages, and critical importance for the nuclear energy sector. These deposits form through complex interactions between oxidized basinal fluids, reduced basement lithologies, structural conduits, and complex hydrothermal systems. Improving our understanding of the geological, mineralogical, and geochemical processes responsible for uranium mobility and deposition is essential for refining exploration models. The Athabasca Basin hosts some of the world's highest-grade examples of this deposit type. As global demand for uranium increases, so will the need for targeted research that can help refine genetic models for this deposit type and aid the industry in identifying and characterizing new deposits in the Athabasca Basin. Of key importance is the identification of alteration styles and mineralogical vectors that can be used as pathfinders to high-grade uranium mineralization on the deposit scale. This project focuses on the Pike Zone of CanAlaska Uranium's West McArthur project and aims to characterize the composition and paragenesis of U-bearing mineralization via detailed analysis of thin sections and hand samples. The methods used for this project build on previous field-based data collection and integrate conventional petrography with quantitative Mineral Liberation Analysis (MLA), Electron Probe Microanalyzer (EPMA), and X-ray Fluorescence (XRF). This multi-method approach is designed to produce high-resolution mineralogical and geochemical data sets, together with well-constrained paragenetic sequences, that will support targeted exploration in the West McArthur project. These data sets will also provide new insights into the formation and evolution of unconformity-related uranium deposits in the Athabasca Basin and elsewhere. This will help refine our general understanding of how uranium is transported and concentrated in natural systems and how mineral assemblages formed during these processes can be used as pathfinders for exploration.

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Investigating Shale-Hosted Vanadium in the Selwyn Basin, Yukon & Northwest Territories

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Howard's Pass is located along the Yukon-Northwest Territories border in the Selwyn Basin and hosts 15 sediment hosted massive sulfide deposits (SHMS), a resource yielding >400Mt grading

4.84% Zn. These 15 SHMS deposits are strata bound in the Active Member subunit (ACTM) within siliceous, calcareous, and carbonaceous mudstones of the Ordovician-Silurian Duo Lake Formation (DLF). Throughout the DLF, enrichments of vanadium, up to 2890 ppm, held in clay minerals and organic matter, occur in intervals, and in the footwall of the ACTM. Approximately 80km southeast of Howard's Pass is the Van Property, at a similar stratigraphic position in the Duo Lake Formation, vanadium, up to 6000 ppm, is found in rutile, clay minerals, and organic matter. Recent studies indicate that vanadium at Howard's Pass is not hosted in rutile, suggesting that the enrichment may represent either a less evolved form of the mineralization observed at the Van Property or a distal extension of that mineralization system. Although three competing genetic models have been proposed to explain the base metal accumulation in sediments, the sources of metals and their transport pathways remain underexplored in the Howard's Pass District. This research will focus on the Zn- and V-rich mineralization in the DLF, where we employ geochemical proxies (Fe-speciation, acid volatile sulfides/chromium reducible sulfides, whole rock bulk geochemistry, stable isotopes, and reflected light microscopy, scanning electron microscopy) to infer the paleo-depositional conditions of the metal enrichment. Lithogeochemical analysis on three drill cores across the DLF at HP, indicate intervals enriched with V, U, Mo, and Ni correlating with elevated concentrations of organic matter. These intervals show elevated levels of metal enrichment relative to average shale compositions worldwide. Local episodic euxinia occurs throughout the formation, suggested by the degree of pyritization, reactive iron, and sulfur systematics. Stable isotopes can aid in cross validating and refining these interpretations of redox conditions by determining the extent of euxinia, sulfate reduction, and basin restriction. The results will provide insights into how redox fluctuations during sediment deposition may have impacted metal concentration and preservation in sediment and potentially have broader implications for the understanding of sediment-hosted ore deposits.

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A Drill Core Stratigraphic Classification of Angikuni Basin Sedimentary Rocks

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The Baker Lake Group within Atha Energy's Angilak Property (Nunavut) preserves a diverse Paleoproterozoic supracrustal succession that hosts significant uranium mineralization but remains only partially characterized at the drill-core scale. This project establishes a preliminary lithostratigraphic framework for ten representative samples collected from the Atha Energy KU drill site, spanning the Christopher Island and lower Kazan formations of the Dubawnt Supergroup. Hand sample and petrographic descriptions, supported by ongoing geochemical analyses, reveals a sequence of fine-grained siltstones, quartz- and feldspar-rich sandstones, volcaniclastic units, felsic tuffs, and a polymictic conglomerate. These observations indicate stratigraphic continuity across the sampled interval and highlight textural and mineralogical features—including hematite staining, volcanic clast populations, calcareous alteration, and localized quartz veining—that may record depositional processes and post-depositional modification within the Angikuni Basin. Integration of whole-rock geochemistry will refine unit classification, constrain tectonic setting, and evaluate whether secondary minerals preserve signatures related to basement-hosted uranium mineralization in the region.

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Trace element and sulphur isotope geochemistry of sphalerite in the Ge-bearing Zn-Pb-Ag Prairie Creek deposit, NWT, Canada

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The Ge-bearing Zn-Pb-Ag Prairie Creek deposit is located in the Mackenzie Mountains, NWT, adjacent to the Selwyn Basin. This region is recognized as a highly prospective area for Zn and Pb, and more recently for Ge. Ge is globally sourced from sediment-hosted Zn-Pb deposits and is mostly hosted in sphalerite (ZnS). However, the deposit-scale distribution of Ge and the local conditions that allow its enrichment remain poorly understood. Here, we investigate the trace element and sulphur isotope geochemistry of sphalerite from the Prairie Creek Deposit to refine the genetic model and elucidate the key factors influencing Ge accumulation.

The Prairie Creek deposit exhibits two main styles of mineralization: 1) stratabound massive sulfides (SMS) and 2) quartz-carbonate veins (MQV), hosted in Ordovician to Devonian sedimentary rocks (Fraser, 1996; Paradis, 2007). SMS mineralization contains mostly pyrite, sphalerite, and galena, with minor calcite and quartz, whereas MQV mineralization consists primarily of calcite and quartz with variable pyrite, sphalerite, galena, and tetrahedrite. At least two generations of sphalerite (Sp I and Sp II) are present in both styles, distinguished by texture, color, and size. LA-ICP-MS analysis of sphalerite reveals significant Ge enrichment (up to 2600 ppm) exclusively in Sp I from SMS, while Sp II from SMS and both Sp generations from MQV exhibit much lower Ge concentrations (0.1 to 100 ppm). Trace element mapping in SMS Sp I shows a spatial correlation between Ge and other elements, including Cu, Ag, and Tl. However, only Cu shows a consistent positive relationship in spot analyses, suggesting a potential substitution mechanism between Cu, Ge, and Zn. In contrast, TEM analysis indicates that Ge primarily occurs as nano-inclusions, likely Cu-Zn-Fe-Ge sulphides.

Furthermore, we are collecting in situ sulphur isotope data in sphalerite from SMS and MQV, using Secondary-Ion Mass Spectrometry (SIMS). This will allow us to distinguish the source of sulphur and reconstruct the physicochemical conditions influencing Ge incorporation in the Prairie Creek deposit.

This work will provide valuable insights into the behavior of Ge in hydrothermal fluids within sedimentary environments through combined trace element and sulphur isotope geochemistry. Ultimately, guiding strategies to enhance mineral exploration and extraction of Ge-bearing deposits in the Northwest Territories.

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Inversion effects on Pb-Zn Mineralization in the Irish Ore-Field

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Inversion-related deformations are associated with N-S compression during the Variscan and Alpine. Orogenies on the pre-existing mineral endowed NE-SW Rathdowney fault Trend. The Rathdowney fault Trend in south-central Ireland, hosts world-class Zn-Pb-Ag deposits at Lisheen and Galmoy mines and Rapla prospect. Our study combines the seismic, aeromagnetics, borehole and outcrop data, supplemented by petrographic, cathodoluminescence, micro XRF-EDS mapping and U-Pb LA-ICP-MS geochronology of associated fault rocks and vein infills to determine the geometry, nature, timing and effects of inversion structures on the Irish Ore Field.

Mineralization occurs as massive semi-massive and disseminated galena, sphalerite and pyrite or marcasite, and to a lesser extent chalcopyrite, niccolite and tennantite directly linked to the syn-sedimentary Mississippian N-S extension phase. The stratabound mineralization is hosted in dissolution-precipitation breccias of clean dolomitized limestones predominantly in the hanging wall of Mississippian ENE-WSW laterally discontinuous segmented normal fault arrays. The fault zones show with 5 – 250 m displacement and associated extensional calcite veins were dated to 342.0 ± 9.6/14.5 Ma.

The mineralization was later folded, duplicated, offset and truncated by large NE-SW oriented oblique-slip dextral Variscan related and later Alpine related NNW-SSE dextral strike-slip faults. Variscan inversion takes the form of folds, reverse faults, hangingwall buttressing and reverse reactivation of mineralized normal faults. This deformation was accompanied by a complex set of NE - SW trending, dextral reverse faults that laterally offset the mineralised normal faults by > 100m, resulting in displacements between 150 – 400 m on individual reverse faults. Where reverse faults localise on pre-existing normal fault segments, the faults and relay ramp zones are offset by dextral oblique-slip. Associated grey-white hybrid extensional-shear calcite veins were dated to 302.4 ± 6.3/11.5 Ma. Additionally, N-S inversion during the Alpine Orogeny is indicated by fold tightening, NNW-SSE dextral and NE-SW sinistral strike-slip faults, and horizontal to near-vertical dated to 67 ± 9.6/9.8 – 28.9 ± 7 Ma. The NNW-SSE strike slip faults also offsets the mineralized ore bodies. In conclusion, the deposits were deformed and affected by the later inversion related orogenies and these effects should be considered during exploration.

500 Volcanogenic Massive Sulfide (VMS) Deposits

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Carbonate-Hosted Geothermal Lithium in the Leduc Formation, West-Central Alberta

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Lithium is a critical metal for battery and energy-transition technologies, yet Canada's current lithium production is dominated by hard-rock pegmatite deposits. Sedimentary geothermal brines provide a potential low-carbon source of lithium, but exploration has largely focused on volcanic and clastic basins. In contrast, western Canada hosts extensive Devonian carbonate reef reservoirs containing hot, saline formation waters that may represent a distinct geothermal-lithium system. This study evaluates whether the Leduc Formation beneath the Hinton–Edson corridor of west-central Alberta exhibits the thermal and geochemical conditions required for lithium recovery.

The Leduc Formation consists of laterally extensive, reef-rimmed carbonate platforms at depth. These reservoirs contain hot, highly saline formation waters, making them favourable for both geothermal energy production and direct lithium extraction (DLE). In carbonate systems, dolomitization and Mg–Ca exchange can control how lithium partitions between minerals and brines, which affects both lithium concentration and recoverability.

This project integrates formation-water geochemistry, well-log records, and temperature–depth models to assess lithium potential and geothermal co-production in the Leduc Formation. Publicly available brine analyses were screened for Li, Na, Ca, Mg, and Cl to evaluate lithium concentration, Mg/Li ratios, and compatibility with adsorption- and ion-exchange-based DLE technologies. Reservoir depth and temperature data were used to identify zones where favourable thermal and geochemical conditions coincide.

Screened formation-water data show that Leduc brines in the Hinton–Edson area commonly contain tens of milligrams per litre of lithium, with higher values concentrated in structurally confined reef complexes. Public formation-water records compiled by the Government of Alberta indicate that Devonian carbonate units, including the Leduc Formation, contain lithium concentrations of up to approximately 140 mg/L in some wells, with many values above 50 mg/L in central and west-central Alberta. These concentrations are comparable to those reported from early-stage geothermal lithium projects in Europe and the western United States. High salinity, elevated temperature, and carbonate buffering favour lithium extraction, while the region's extensive oil and gas well network provides a low-cost pathway for resource testing and development.

These results suggest that Alberta's Devonian reef systems represent a previously under-recognized carbonate-hosted geothermal lithium target. The Leduc Formation has the potential to support co-production of geothermal energy and lithium, providing a low-carbon, infrastructure-ready pathway for critical-mineral development in western Canada.

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The Fluid Provenance and Ore Mineralisation History of the Ecton Copper Mine, Central England

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Mississippi-Valley type (MVT) ore deposits are significant global sources of lead and zinc. These deposits are the result of relatively low temperature hydrothermal fluids precipitating ore minerals in cavities and veins, typically occurring in regionally-significant ore districts that contain multiple deposits (e.g. Pine Point, Canada; Irish Midlands, Ireland; and Viburnum Trend, USA). The MVT deposits of the South Pennine orefield, central England, are historically important, producing large amounts of lead, zinc, and fluoride, predominantly during the 19th and 20th centuries. Located in this orefield is Ecton Mine, with an extensive history of mining dating back to the Bronze Age. Between 1760 and 1820; the Deep Ecton mine produced 100,000 tonnes of copper ore before its eventual closure and flooding. The copper ore, mainly chalcopyrite, formed in vertical cylindrical pipes, cross-cutting bedding in the host carbonates. Within the South Pennine orefield, the high abundance of copper makes Ecton anomalous. Many aspects of Ecton mineralization (such as fluid composition, emplacement temperature, and structural controls) remain unclear, particularly within the context of other deposits in the South Pennine orefield. Research on Ecton ore genesis is made difficult by a lack of useful study material; resources were totally exhausted and the site is formally recognized, and protected, as a historical landmark.

Here we utilize samples from the Deep Ecton mine, obtained through various museum collections, to characterize fluid provenance and mineralization processes leading to the formation of the Deep Ecton orebody. We integrate petrographic observations, cathodoluminescence, SEM/EPMA and LA-ICP-MS mineral chemistry, as well as sulfur isotope analyses, on our samples to achieve these aims. Analysis of marcasite and pyrite textures using element mapping and trace element data show multiple generations of crystallisation, the latter recognised by chemical zoning of Cu, Ni and Co in single crystals. These observations suggest either changes in fluid chemistry during precipitation, or multiple pulses of fluid. The samples also contain Ni-rich minerals like gersdorffite, and relatively Ni-rich pyrite (up to 17.5 wt.%), showing that the hydrothermal fluid was enriched in elements not present within the other MVT deposits of the South Pennine orefield. Relatively light $\delta 34S$ values (avg. -15.9‰) are consistent with the biogenic sulfate reduction that commonly occurs in MVT deposits. If the Ecton deposit is genetically related to the regional MVT, then the mineralizing fluids would have had to reach higher than typical temperatures to mobilize the copper and transport it across the South Pennine orefield.

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Characterizing the mineralogy of the Tuscan target, Sudbury Igneous Complex, Sudbury, Ontario

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The Tuscan ore body is located in the East range of the Sudbury Basin near the Capre 3000 Ni-Cu deposit and on the western side of the Amy Lake fault. The ore body was found in 2008 and composes of sharp, narrow footwall veins of 20-40cm thickness. Initial sampling and assay results of the target revealed enrichment of platinum group elements (PGE) ~180g/t Pt+Pd+Au+Ag within the copper sulphide vein with low sulphide platinum group element (LSPGE) mineralization ~17.7g/t Pt+Pd+Au+Ag hosted in Sudbury breccia about 100m beneath mineralized sulphide vein. No further research has been conducted on Tuscan since its initial exploration in 2008 and therefore lacks a detailed characterization of its ore assemblage, occurrence of PGE minerals with their relation to sulfide mineralization, and the occurrence of alteration. The goal of this study is to identify the mineralization styles in which sulfides and PGE minerals occur, to characterize if hydrothermal alteration is present and to constrain the potential relation between alteration and mineralization. The study will focus on five drill holes intersecting the Tuscan ore body and combining petrography and geochemistry. Characterization is obtained from macroscopic observations (historic and recent core logs) and detailed thin section petrography using both standard reflected and transmitted light microscopy and scanned electron microscopy. The geochemical composition of the studied drill holes will focus on metal composition including PGE on samples collected over the summer. The results of this study will provide mineralogical context for ore sulfide and PGE mineralization and will compare the data with other PGE-hosting deposits within the SIC to draw conclusions regarding their formation at Tuscan.

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From textures to tenors: Investigating mineral assemblages, textures, and Ni distribution within the Geminid Nickel Deposit

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Exploration of the Geminid Nickel Deposit has been ongoing since its discovery in 2023. This study is the first investigation of the deposit at the microscale. The deposit is situated in Northeastern Ontario, 40 km east of Kirkland Lake, along the Larder Lake – Cadillac Break within the Abitibi Greenstone Belt, a region renowned for its mineral endowment. The deposit was discovered during exploration drilling for Gold Candle Ltd. on and around the historic Kerr-Addison mine site, an underground gold mine that operated from 1938 to 1996 and produced over 11 Moz of gold. Drilling 2 km east of the Kerr-Addison Mine intersected a 23m wide section (not true thickness) of millerite mineralization with an average grade of 1.9% nickel. Follow up drilling defined an approximately 300 by 700 meter mineralized zone with vertical planar geometry of millerite-dominated mineralization hosted mainly in the ultramafic facies of the

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Larder Lake group below the contact with Timiskaming sediments. To date, no comprehensive study has examined the mineral assemblages, or nickel distribution within the Geminid Deposit, limiting models describing its formation, potential economic value and Ni recovery. This study focuses on characterizing magmatic and secondary sulphide mineral phases and textures and evaluating their relationship to nickel distribution. So far, two dominant sulphide mineral assemblages that have been identified are millerite + pentlandite ± chalcopyrite and pyrrhotite + pentlandite. Analytical methods include: (1) Detailed petrographic analysis of magmatic and secondary mineral assemblages; (2) XRD analysis to determine mineral phases present; (3) SEM and µXRF for phase mapping and phase distributions at different scales within selected samples, (4) LA-ICP-MS analysis to investigate minor and trace element contents including PGE's. The results will be used to determine: (1) the distribution of Ni and related metals; (2) factors governing nickel mobilization; (3) if Ni tenor is controlled by primary magmatic or secondary minerals within this deposit. This study will provide a foundation for future genetic interpretations and economic evaluations. Beyond advancing the understanding of the Geminid Deposit, this research addresses a broader gap in knowledge of secondary (altered) sulfide systems and millerite dominated mineralization.

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Geology of the Magmatic Sulphide Ni-Cu Tyko Project

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The Tyko Project is a Tier-1 Ni-Cu magmatic sulphide occurrence located near Manitouwadge, Ontario and owned by GT Resources. The best drill hole intersections include 12.9% Ni, 2.7% Cu, 0.67 g/t Pd, and 0.34 g/t Pt, over 0.9 m, and 10.4% Ni, 3.4% Cu, 0.53 g/t Pd, and 0.34 g/t Pt across 2.3 m.

Drilling has identified multiple mafic intrusions with varying degrees of mineralization. The goal of this project is to understand the geological relationships of these intrusions to constrain which events are related to known mineralization.

Samples were studied in thin section and submitted for high-precision Fusion ICP-MS trace and rare earth element analyses. The slope of the rare earth element spidergrams and lambda values of the rocks were analyzed to define units. Based on this data, 4 geochemically distinct intrusions have been identified.

Rare earth element patterns clearly delineate 3 mafic intrusions, with steep, shallow, and flat slopes. The shallow slope represents melagabbro, hosting Ni- and Cu- rich mineralization. This rock has coarse-grained interlocking anhedral clinopyroxene, with euhedral magnetite crystals and disseminated to net-textured sulfides. The steepest slope represents a mafic magnetite-rich gabbro hosting disseminated sulfides. The rock has a cumulate texture with subhedral hornblende, euhedral magnetite, and interstitial plagioclase. The flat slope represents an unmineralized leucogabbro. The leucogabbro is primarily subhedral amphibole and clinopyroxene with interstitial plagioclase. All lithologies are intruded by tonalites from the 2730 Ma Black Pic Batholith. U-Pb zircon age dates and EPMA analysis are still pending.

The classification of these intrusions will help to narrow down future drilling efforts at the Tyko deposit allowing for more focused targeting of economically significant lithologies.

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From Bedrock to Till: Mineral-Chemistry Vectoring to Cu–PGE Mineralization — Insights from the Marathon Deposit, Northwestern Ontario.

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The Cu-PGE Marathon Deposit (Northwestern Ontario) is situated within the Coldwell Complex which is part of the Midcontinent Rift in North America. The deposit is hosted by the Two Duck Lake Gabbro, which is subdivided into three main mineralized zones: 1) the Footwall Zone, characterized by net-textured disseminated pyrrhotite with minor chalcopyrite and trace platinum-group minerals (PGM); 2) the Main Zone, the thickest and most continuous zone, has disseminated chalcopyrite with less pyrrhotite and PGM, mainly kotulskite [$Pd(Te,Bi)_2$] and sperrylite [PtAs2]; and 3) the W-Horizon, which exhibits lower overall sulfide abundance, (bornite and chalcopyrite) and a diverse assemblage of PGM including common keithconnite [$Pd_{20}Te_7$], zvyagintsevite [Pd_3Pb], and isoferroplatinum [Pt_3Fe].

This study systematically compares the mineral chemistry of the mineralized bedrock and that of the till overlying the deposit. Petrographic characterization of the deposit is integrated with analytical methods, such as scanning electron microscope (SEM), electron microprobe (EPMA), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), to assess mineral-chemistry variation across the various mineralized zones. Chalcopyrite trace-element mineral chemistry data were obtained exclusively from analyses of bedrock thin sections, whereas magnetite and clinopyroxene were evaluated in both bedrock and till.

Multivariate statistics, principal component analysis (PCA), and element-ratio biplots show that clinopyroxene and magnetite exhibit systematic trace-element variations across the Footwall Zone, Main Zone, and W-Horizon. Proximal till grains consistently overlap with mineralized bedrock compositional fields, whereas background till defines a separate geochemical population (e.g. background clinopyroxenes have elevated Mg concentrations >75,000 ppm, and generally lower Fe, Zn, and Co than samples from mineralized zones). Our results demonstrate that silicate- and oxide-mineral chemistry may complement traditional PGM and sulfide indicator-mineral approaches.These results offer new approaches to discriminate mineralized zones from the background and vector toward Cu–PGE anomalies in glaciated terrain, with direct implications for brownfield and greenfield exploration and surficial geochemical targeting of similar deposits.

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Petrogenesis of chromitite associated with the platiniferous J-M Reef, Stillwater Igneous Complex, USA

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The ~2.7 Ga Stillwater Igneous Complex (StIC, USA), particularly the J-M Reef, is the most enriched platinum-group element (PGE) deposit in the world. Precious metal enrichment in layered intrusions like the StIC is commonly hosted in chromitite seams. Even though numerous chromitite seams occur in the lower parts of this intrusion, chromitite has not traditionally been associated with the J-M Reef. The primary objective of this research is to study the petrogenesis of newly discovered and undocumented chromitite seams from the J-M Reef (at the Stillwater Mine) and compare their chromite chemistry to that of chromitite seams of the lowermost Peridotite Zone (PZ). A ~50 cm drill core containing one major (~15 cm) and three minor (~1 cm) chromitite seams hosted in coarse-grained anorthosite and gabbronorite was studied here. In addition to petrography, quantitative textural data were obtained from crystal size distribution (CSD) and apparent dihedral angle (ADA) measurements, as well as chromite chemistry by electron microprobe.

Three out of nine thin sections across the studied section were used for CSD and ADA analyses (comprising three subsampled areas per thin section from the main chromite seam totalling ~3000 CSD and ~2000 ADA measurements). Chromite seams only form embedded in coarse-grained intercumulus minerals (plagioclase, clinopyroxene, and orthopyroxene) with distinct grain boundaries, but chromite seams do not form together with cumulus plagioclase. Chromite grains form two distinct shapes: large and polygonal versus small and rounded. Thin (<1 mm) silicate rims are common around chromite grains. CSD mean grain sizes for the three samples are 0.138, 0.188, and 0.287 cm, whereas CSD volume phase abundances are 34.50, 37.44, and 41.32 vol.%. The CSD plot shapes exhibit kinks at distinct size fractions (i.e., different populations) in all samples. CSD slope values for the three samples are -6.780, -11.77 and -14.38 mm-1. Median average ADAs for chromite-chromite-clinopyroxene are 64.33, 79.54, and 84.61. For chromite-chromite-plagioclase, median average ADAs are 66.33, 71.97, and 81.11. The latter ADAs are farther from textural equilibrium, i.e., a single true dihedral angle value, for each sample.

Overall, we find that the fine-grained chromite occurs in higher volume abundances, exhibits steeper CSD slopes and reveals lower median ADAs (a lower degree of textural equilibrium). Coarser-grained chromites exhibit the converse characteristics. Rims around chromite show that a reactive interstitial melt existed coevally with chromite; the extent to which this postcumulus reaction drove the textural coarsening observed in the rocks is being investigated.

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Linear Gravity Inversion for 3D Subsurface Density Modeling Using Series-Expansion Discretization

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Geophysical inversion is widely used to estimate subsurface properties and better understand geological structures. In this study, a three-dimensional gravity inversion was carried out to determine subsurface density variations using a series expansion–based inversion approach. The method is built on a linearized inversion framework in which the density model is represented as a weighted combination of orthogonal basis functions. This allows the subsurface to be described using a limited number of expansion coefficients rather than a large set of individual density values. Reducing the number of unknown parameters makes this approach particularly suitable when gravity data are sparse, as it improves the stability and solvability of the inverse problem. For comparison, both the conventional Gaussian least-squares method and the proposed series expansion–based inversion were applied independently. Their performance was evaluated using synthetic gravity data, including cases with significantly different initial models to test the ability of each method to recover the true subsurface structure. Additional tests were conducted using noisy synthetic data to examine the robustness of the inversion under realistic measurement conditions. The results show that both inversion approaches perform well and reliably minimize the misfit between observed and calculated gravity data when the inverse problem is overdetermined. However, in underdetermined situations—which are common in practical gravity surveys—the Gaussian least-squares solution becomes unstable unless extra constraints are introduced. In contrast, the series expansion–based method naturally reformulates the problem into a reduced parameter space, producing an overdetermined system and improving stability without the need for external constraints. The proposed method was also applied to field gravity data from the Shendi–Atbara Basin in Sudan. Although the application involves simplifying assumptions, such as representing the subsurface as a single vertical layer rather than a fully discretized 3D model, this choice was made to focus on assessing the feasibility and stability of the approach. Overall, the results demonstrate that the series expansion–based inversion method is a robust and effective alternative to the Gaussian least-squares approach, especially when gravity measurements are limited and sparsely distributed.

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Stratigraphic Correlation of the Timiskaming Assemblage using Gamma Ray Spectroscopy in Lebel Township, ON

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Stratigraphic correlation in the Kirkland Lake Region has proven difficult due to extensive folding, faulting, and alteration present in the region. Lebel Township hosts the Timiskaming

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Assemblage, a series of interbedded alkalic and non-alkalic volcanic and sedimentary units composed primarily of conglomerates, tuffs, trachytic flows, lithic sandstones, and greywackes. The stratigraphic units of the Timiskaming, specifically the fine-grained tuffs and greywackes are difficult to distinguish due to pervasive chlorite and sericite alteration. The units of the Timiskaming Assemblage in the study area generally strike East-West and are relatively well preserved compared to the other units in the Kirkland Lake area. This study explores if gamma ray spectroscopy is a reliable tool for correlating stratigraphic units using data collected from outcrops, rather than from drill holes. Gamma ray logs are a widely used technique in geoscience, used by petroleum geologists, geophysicists, and hydrogeologists to interpret lithology, aquifers, and aquitards for decades. They provide a measure of the radioactivity of the rock, using potassium (K), uranium (U), and thorium (Th). Measurements of the amount of K (%), Th (ppm), and U (ppm) present in different outcrops will be taken using the gamma ray spectrometer. These values will then be compared to values obtained by laboratory lithogeochemichal analysis, and thin sections will be analysed to further characterize the alkalic nature of the units. Due to the non-invasive, user-friendly nature of the tool, if it proves to be reliable for correlating stratigraphic units through outcrop mapping, it could be helpful for correlation over large study areas with limited access to drill logs, as well as correlation across fault lines and determining trends in mineralization.

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Mineral Prospectivity Mapping of Intrusion-Related Gold Deposits in Southwestern New Brunswick Using a Deep Learning-Based Framework

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Exploration at the regional scale is inherently challenging, as it requires assessing extensive areas while committing substantial time and financial resources to progressively narrow the search to the most prospective targets. Mineral prospectivity mapping (MPM) offers an effective means of addressing this challenge by constraining the search space and systematically delineating zones with elevated mineralization potential. Conventional machine-learning (ML) approaches, owing to their relatively shallow model architectures, can be limited in their capacity to capture higher-order interactions and complex nonlinear relationships that typify geological datasets. In contrast, deep-learning (DL) models enhance representational capability through hierarchical, multi-layered architectures, enabling the extraction of higher-order features from multivariate inputs. Among deep learning models, deep autoencoder (DAE) network plays a central role in unsupervised anomaly detection, particularly for extracting high-level features from geoscientific data with strong non-linear characteristics.

This study investigates intrusion-related gold (IRG) mineralization within a ~1,500 km² area in southwestern New Brunswick, a region with a prolonged and complex geological evolution and a well-established prospectivity for IRG systems. Numerous documented gold occurrences within and surrounding the study area exhibit diagnostic IRG characteristics. Two principal styles of gold mineralization are recognized in southwestern New Brunswick. IRG systems are predominantly developed within the St. Croix and Mascarene terranes and are exemplified by the Clarence Stream deposit northwest of the study area. Mineralization in these systems commonly occurs in shear zone–controlled quartz veins, hydrothermal breccias, and stockwork vein networks,

with additional disseminated mineralization in adjacent host rocks. In contrast, orogenic gold mineralization is chiefly associated with the New River and Annidale terranes, as represented by the Cape Spencer deposit southeast of the study area.

An integrated suite of geological, geochemical, and geophysical predictor layers was constructed and incorporated into a predictive framework for gold mineralization. Key predictors identified through Shapley Additive Explanations (SHAP) were subsequently input into a DAE to derive compact, nonlinear latent representations that capture higher-order relationships among the datasets. These latent embeddings were then combined with the original predictors and used to estimate gold prospectivity via a Random Forest (RF) classifier coupled with the DAE framework. The resulting prospectivity maps demonstrate strong spatial correspondence between high-prospectivity zones and known mineral occurrences. Model performance metrics, including a receiver operating characteristic area under the curve (ROC-AUC) of 0.986 and an area under the success-rate curves (SR-AUC) of 0.746, indicate the robustness and effectiveness of the proposed methodology.

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Effects of acquisition height and noise level on DL-based super resolution of aeromagnetic data

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The application of deep learning (DL) for super-resolution of aeromagnetic maps has gained traction within the past decade. However, many of these applications are focused on improving the resolution of signatures on a sparsely gridded map. This research instead focuses on improving the resolution of signatures on aeromagnetic maps acquired from different heights, using a DL model as an alternative to downward continuation (DC). Using transformer-based DL architectures, we trained a network to recognize both signal and noise patterns in aeromagnetic maps generated from varying upward-continued heights with different noise intensities. The training datasets included both ground magnetic data acquired at five locations in Sweden and synthetic data generated by a model representative of high-susceptibility bodies within a lower-susceptibility host. Preliminary findings indicate that the DL model generally performed better at resolving signatures from lower-altitude data under high noise than from higher-altitude data with equivalent noise levels. Compared with downward-continued maps, the DL model produced superior resolution and a higher peak signal-to-noise ratio (PSNR) at certain height and noise thresholds. However, these effective thresholds depend on the PSNR of the input data. Beyond these height and noise thresholds, the DL model offered no clear advantage over DC. We conclude that the resolving power of the DL-based approach and its potential superiority over the DC filter is strongly dependent on acquisition height and noise levels in aeromagnetic datasets.

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Artificial Intelligence-Driven Integration of Aeromagnetic and Radiometric Data for Mineral Prospectivity Assessment in the Abakaliki Region, Southeastern Nigeria

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The Abakaliki area of Ebonyi State, situated within the Lower Benue Trough of southeastern Nigeria, is renowned for its intricate structural framework and substantial mineral potential, particularly for base metals and associated mineralization. This study offers an innovative integrated analysis of aeromagnetic and radiometric data to identify structurally controlled and alteration-related mineral zones in the Abakaliki region.

Aeromagnetic data were processed to obtain reduced-to-pole and residual magnetic anomaly maps, from which analytic signal amplitude (ASA), tilt derivative, and total horizontal derivative (THDR) were derived to enhance fault structures and lithologic boundaries. Spectral radiometric data (K, U, Th) were processed to generate ternary composites and alteration-sensitive ratio maps (K/Th, U/Th) for identifying hydrothermal alteration signatures.

To enhance the detection of subtle anomalies, the Analytical Hierarchy Process (AHP), a decision-making framework that considers multiple criteria to structure complex problems, and a Deep Learning algorithm (Convolutional Neural Network (CNN)) were developed to classify and predict high-prospectively zones using combined aeromagnetic-radiometric attributes. Euler deconvolution and spectral depth analyses were employed to validate the depth and geometry of the anomalous sources.

The study reveals strong spatial correlations among magnetic lineaments, radiometric enrichments, and predicted mineralization zones, confirming the effectiveness of the AI-driven data-processing workflow. This approach offers a reproducible, data-driven framework for mineral exploration in the Abakaliki region of Nigeria and similar underexplored terrains worldwide.

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Integrating remote sensing data and field samples with deep learning for geological mapping in northeastern Québec

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In the initial phase of mineral exploration, one key source of information are geological maps, which help locate potential prospection targets. They are usually produced through ground truth observations and, when that is not available, by extrapolating the geological data through conceptual or numerical methods (e.g. defining lithological boundaries by interpreting aeromagnetic maps or through indicator kriging). They usually rely on one or few data sources or assume linearity between variables, which may limit their capability to faithfully model the complexity of real geological data. Artificial intelligence offers a promising tool to address this issue. In particular, deep learning algorithms can process multivariate geospatial sources

of information and infer non-linear relationships hidden in complex datasets. The SCB-Net, a recently developed deep learning algorithm using convolutional neural networks, has demonstrated success in generating predictive lithological maps by integrating field samples with remote sensing and geophysical data. It leverages publicly accessible multidisciplinary datasets from Google Earth Engine and from Québec Spatial Reference Geomining Information System, SIGÉOM. However, the accuracy of its predictions in regions with limited geoscientific data, which is often the case of mineral exploration frontiers, still requires investigation. In order to test the algorithm's predictive capability in data-sparse regions, this study aims in training the SCB-Net in a location with high-density data and apply that model in an understudied area. The training dataset will be the well-documented area of the Grenvillian Central Metasedimentary Belt. The model will then be tested in the metasedimentary Wakeham Group, in the allochthonous northeastern section of the Grenville Province. Despite limited available data, many field campaigns documented its enrichment in REE and potential to host IOCG-type and skarn-type mineral deposits with Co, Cu, Pb and Zn, strategic elements of surging demand due to the ongoing global energetic and digital transition.

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Pre-Collisional Extension and Potential Kimberlite Formation on the Ontong Java Plateau

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The Ontong Java Plateau (OJP), Earth's largest oceanic plateau, formed through plume ridge interaction between 120-90 Ma and later migrated toward the Australian Plate during Pacific slab rollback. Despite its approach toward subduction, the OJP exhibits extensive post-emplacement extension, including horst-graben systems and Alnöitic intrusions dated to 34-45 Ma. Seismic data further suggest vertical pipe-like bodies resembling kimberlites, while the plateau's unusually thick lithosphere (up to ~280 km) and MARID-like xenoliths, typically associated with continental cratons, raise the possibility of kimberlite-like magmatism within oceanic lithosphere. This study asks whether pre-collisional extension beneath the OJP could generate the pressure-temperature conditions necessary for diamond stability and kimberlite genesis.

We investigate this through a series of thermomechanical numerical experiments using SOPALE, an Arbitrary Lagrangian-Eulerian viscoplastic modeling framework. Models incorporate a 700-km-wide plateau underlain by 120-280 km of lithosphere, realistic crustal thicknesses, and plate-motion boundary conditions derived from reconstructions of Pacific slab rollback. The simulations track the evolution of strain, strain rate, surface deformation, and thermal structure over 11 Myr-coinciding with the timing of Alnöitic magmatism. Extracted geothermal profiles are compared with diamond stability fields and thresholds for kimberlite melt generation. Model outputs are further evaluated against seismic constraints on lithospheric thickness, MARID xenolith geochemistry, and mapped extensional fault systems.

Preliminary results suggest that slab-pull forces acting on the trailing edge of the plateau may induce focused extension and localized asthenospheric upwelling, producing elevated temperature-pressure regimes potentially suitable for kimberlite formation within oceanic lithosphere.

This work addresses two key gaps in global geodynamics: (1) the mechanism driving extension adjacent to an advancing subduction system, and (2) the plausibility of kimberlite generation in oceanic lithosphere. By integrating modeling with geological and geophysical constraints, this project proposes the first mechanistic framework linking OJP extension to deep mantle melting processes, with implications for both tectonic evolution and economically significant magmatism in oceanic domains.

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Spatially Aware Machine Learning for Automated Lithological Mapping Using UAV-borne Radiometric and Magnetic data

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Automating lithological mapping via supervised machine learning (ML) requires rigorous accounting for spatial autocorrelation. Without this, reported model accuracies often reflect spatial proximity between samples rather than true geological generalization. ML can effectively integrate multi-sensor data to map lithology in areas with limited outcrop. However, conventional random cross-validation (CV) frequently yields overly optimistic performance metrics by ignoring spatial dependence. This study evaluates these challenges using UAV-borne radiometric and magnetic datasets from a copper exploration site in Madison, Montana. This study followed a three-step analytical framework. First, spatial dependence was quantified using Moran's I correlograms. Second, spatial block CV was implemented to enforce geographic separation between training and testing subsets. A sensitivity analysis was then conducted to determine how block size, shape, and validation strategy influence data leakage and model robustness. Results indicate that random CV substantially overestimates the model performance, yielding a Balanced Accuracy (BA) of 0.981. In contrast, spatial CV provided a more realistic assessment, with BA decreasing to 0.529 when using 700 m blocks. The sensitivity analysis revealed that block size has a more significant impact on performance than block shape. Small blocks failed to eliminate spatial correlation. Conversely, blocks exceeding the scale of spatial dependence yielded lower, yet more honest model performance metrics. These findings demonstrate that integrating spatial autocorrelation into validation steps is essential. This approach generates reliable predictive models and mitigates the risk of misleading results in mineral exploration.

800 Other

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Mapping Geological Information Flow in the Mining Value Chain: Strengthening downstream Decision-Making with robust Orebody Knowledge

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A comprehensive understanding of geological information and its uses across the Mining Value Chain (MVC) (in the form of orebody knowledge, OBK) is essential for improving the reliability, efficiency, and sustainability of mining operations. While geological information represents the data generated through exploration, drilling, and testing, OBK is the integrated interpretation of that information, supporting cross-disciplinary decision-making across the MVC. Although OBK underpins risk reduction and value realization, geological data often remain fragmented or disconnected from operational and strategic decisions.

This study introduces the Geological Information in the Mining Value Chain Map (GiM Map), a systems-based framework that visualizes how geological information flows, transforms, and integrates into OBK to support decision-making across the mining value chain—from exploration and mineral processing to environmental management and closure. The GiM Map integrates 505 information nodes and 2,786 directed connections, classifying data by type, certainty, and function across the MVC. A proxy-weighting analysis ranks models by their cumulative input score. The number of data linkages increases downstream through the MVC, quantifying the transformation of raw data into decision-oriented outputs. The GiM Map establishes a reproducible foundation for applying Value of Information (VoI) and Return on Information (RoI) approaches, linking data quality and connectivity directly to economic and environmental outcomes. The findings position OBK as a strategic enabler of corporate performance and sustainability, demonstrating that the flow, quality, and integration of geological data across the MVC are fundamental determinants of value creation, operational transparency, and long-term resilience in the mining industry

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Groundwork for the Preparation of a New Stockpile of 205Pb for ID-TIMS Geochronology

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Analytical tools are crucial for advancing our understanding of the geological processes that govern the transport and enrichment of metals in the Earth's crust. One such tool fundamental for the formation of genetic models for mineral deposits is geochronology. Many deposit medals fall within age ranges best suited for U-Pb and Pb-Pb systems, which require precise measurement of small quantities of lead isotopes present in the rocks using isotope dilution thermal ionization mass spectrometry (ID-TIMS). For the correction of internal fractionation within the TIMS instrument, a reference solution known as a double spike is added. The ^{202}Pb-

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^{205}Pb double spike solution comprised of synthetic isotopes of lead. This system has been shown to produce the most accurate and reproducible age data. As well, in the U-Pb system, other mixed spikes containing ^{205}Pb, such as those produced by the EARTHTIME initiative, have been shown to produce data at a similarly high standard. The caveat to using synthetic ^{202}Pb or ^{205}Pb is that they are not naturally occurring and cannot be mined or extracted; they must be produced via particle accelerators or from nuclear reactor waste. Current stockpiles that were produced in the late 80s are being depleted and are at the end of their lifetimes. If the geologic community wishes to continue producing high-level geochronologic data with the U-Pb and Pb-Pb systems, a new stockpile will need to be produced. The large cyclotron at the TRI-University Meson Facility (TRIUMF) was used for the production of the initial ^{205}Pb stockpile and will be utilized again for this production run. The process begins with numerical modelling of the production process. Utilizing both the FLUKA and GEANT4 software to model beam particle interactions that produce ^{205}Pb will serve as a method to further optimize production. By varying target thickness and geometry, as well as beam parameters such as energy and duration, the goal of this project is to produce experimental parameters that would lead to efficient production that could produce a new stockpile larger than what was previously created.

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Secondary enrichment of silver in the five-element veins, Cobalt Embayment, Ontario, Canada

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The Cobalt Embayment in northwestern Ontario, Canada, is a historic mining district, famous for its five-element veins that were previously mined for the precious metal Ag and critical metals Co and Bi. Numerous studies examined the genesis and fluid composition of these veins. This led to multiple models and hypotheses that remain strongly debated to this day. However, there has been no nanoscale investigation to characterize the underlying mechanisms of silver (Ag) enrichment toward massive Ag. This study explores these mechanisms using a combination of scanning electron microscopy and transmission electron microscopy to characterize mineralized samples from the now-abandoned Cobalt and Hudson Bay mines in the Cobalt Embayment, ON. These investigations show that silver occurs as Ag nanoparticles within dolomite and as secondary As-Sb minerals, including stibioclaudetite (antimonate), Fe-rich clay, and organic matter. The Ag nanoparticles recorded within stibioclaudetite preserved traces of growth mechanisms, including polycrystalline aggregates formed by non-oriented attachment and monocrystalline aggregates formed by oriented attachment. Based on these results, we developed a "dendritic texture model of formation". Furthermore, the association of Ag with As-Sb phases and carbonates provides evidence supporting mineral replacement reactions and fluid transport as enrichment mechanisms for silver. The mineral replacement reaction model describes processes in which Ag-bearing parent phases such as breithauptite, dissolves and reprecipitates, forming Ag nanoparticles. The hydrothermal fluid transport model is supported by the occurrence of Ag nanoparticles finely distributed in carbonates. The current results of this study provide an additional mechanism for enriching Ag-bearing phases in five-element veins and contribute to our understanding of how high-grade silver vein deposits form.

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Alloys, Inclusions, and Isotopes of Gold Particles from Placer Deposits at Flat, Alaska, and Implications on Lode-Source Relationships

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Placer deposits have historically been an important source of gold, yet the lode sources of these deposits often remain enigmatic. Thus, work to develop and implement methodologies to better define placer mineralization sources has academic and economic implications. Combining gold particle inclusion data with gold alloys, isotopes, and morphological characteristics creates the most comprehensive picture of placer gold source signatures. Gold grains from three locations in Flat, Alaska are analyzed to elucidate the sources of the placer gold. Flat is a historic gold mining town in the Kuskokwim Mountains consisting of placer deposits on creeks that drain multiple sources of mineralization, including district mineral occurrences that are the target of modern exploration-and potential undefined regional sources. The placers and local lode sources exhibit signatures of a multitude of mineralization types including orogenic gold, epithermal, polymetallic veins, reduced intrusion, porphyry Cu-Mo-Au, granite Sn-W, and magmatic REE mineral systems. This study aims to fingerprint the signatures of placer gold at Flat through the integration of Electron Microprobe Analysis (EPMA), LA-ICP-MS, and SEM techniques. EPMA has commonly been utilized to determine the major alloy content in gold particles, but this method alone has limitations, which led to a new direction, centering around inclusions within the gold particles. Usage of LA-ICP-MS offers a lower detection limit than EPMA, advantageous for analyzing a broader suite of trace elements in the alloy than available by EMPA. LA-ICP-MS/MS analysis allows for analysis of Pb isotopes with the utilization of ammonia in a collision cell to reduce the interference of Hg. The inclusions are first visually identified, counted, and compositionally analyzed under SEM. Mineral intergrowths, morphology, and other qualities such as rims are also noted in the host grains. Once this information is gathered, the inclusion signatures are plotted into two broad categories: metals and nonmetals. Preliminary EPMA results show variations in Au-Ag alloy content across the drainages with an increase in Ag content from Happy Creek to the Schoolhouse site, and finally Flat Creek. The average median across sites is 13.19 wt% Ag and total range is 0.22-50.09 wt% Ag. This study aims to further refine the mineralization style of the local sources, discover enigmatic distal sources, and contribute to the development of utilizing gold grains in deposit type characterization, specifically its application to placer-source relations.

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Spinel chemistry in the lowermost part of the Barberton Greenstone Belt, South Africa: Insights into the petrogenesis of the Bon Accord Ni-deposit

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The Bon Accord nickel deposit was hosted in ~3.5 Ga ultramafic-mafic rocks of the lowermost Onverwacht Group of the Barberton Greenstone Belt, South Africa. Although mined out a century ago, its extremely unusual Ni-rich mineral assemblage and abnormally high NiO content (~15 wt.%) have led to multiple petrogenetic interpretations, including an extraterrestrial origin or an oxidized fragment of Earth's outer core. A more recent study proposed the formation of the Bon Accord as an altered (komatiite-hosted) nickel-sulfide deposit, based on the presence of such mineralization in close proximity that can be stratigraphically and structurally correlated with the Bon Accord. Here, we undertake a petrographic and chemical analysis of spinel minerals in a sample of the Bon Accord body, as well as spinels associated with the nearby sulfide mineralization, to evaluate whether a petrogenic relationship exists between both and if the sulfide mineralization is a plausible precursor to the unique Bon Accord paragenesis.

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Geochemical Performance of Bauxsol™ for Acid Mine Drainage Treatment

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Acid mine drainage (AMD) from open-pit mines contaminates surface and groundwater, causing significant damage. Therefore, alternative solutions are needed to address this significant environmental issue. Bauxsol™ is an amendment derived from pre-neutralised Australian bauxite residue produced during the alumina refining process. It has been studied in several countries, where its effectiveness in stabilising water and soil has been demonstrated. This study evaluates the effectiveness of Bauxsol™ produced at the Vaudreuil alumina refinery in Quebec using Virotec technology for neutralising acidic mine drainage and immobilising dissolved metals.

Granulometric and mineralogical analyses reveal its fine texture (d_{50} = 2.6 μm) and high specific surface area (22 $m^2.g^{-1}$), which promote chemical reactivity. The material is dominated by ferric and aluminous phases (gibbsite 28.4%, hematite 25.3%, goethite 13.2%), providing a strong buffering capacity and adsorption sites.

Batch tests carried out on waste rocks generating AMD show a gradual increase in leachate pH, rising from 2.9 (control) to 6.75 after 24 hours with 15% Bauxsol™ amendment, indicating controlled neutralisation. At the same time, the redox potential (Eh) decreases from 823 mV to 431 mV, limiting sulfide oxidation and metal release. Unlike lime, which induces extreme alkalinity (pH > 12) and very low Eh even at the initial ratios, Bauxsol™ provides gradual chemical stabilization, reducing ecotoxicological risks associated with overly basic conditions.

The effectiveness of Bauxsol™ in immobilizing metals is notable. Aluminium (Al) and iron (Fe) are removed from aqueous phase by more than 99% with just 8% amendment, mainly through hydroxide precipitation and adsorption on ferric oxides. Trace metals such arsenic (As), chromium (Cr), lead (Pb), Zinc (Zn), Cobalt (Co) and nickel (Ni) are captured. However, the chemical composition of Bauxsol™ leads to a significant release of sodium (Na) (up to 2895 $mg.L^{-1}$ for Na) increasing the electrical conductivity (12.5 $mS.cm^{-1}$) and posing a risk of salinisation. This phenomenon, although secondary to neutralisation, requires careful dose management to avoid impacts on water quality.

In conclusion, Bauxsol™ could serve as an effective alternative for stabilising AMD, thanks to its buffering capacity and its combined mechanisms of sorption and coprecipitation.

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Mineralogy and Geochemistry of Tailings at the Abandoned Lake George Antimony Mine, New Brunswick, Canada

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Mine wastes in Canada are both an environmental liability and a potential source of critical minerals, but gaps in geochemical and mineralogical understanding limit their reprocessing. The Lake George Antimony Mine operated intermittently between 1876 and 1996 and was once the largest primary antimony (Sb) producer in North America. Mineralization occurs as a vein-type, intrusion-related system hosted by greenschist-grade metasedimentary rocks, with antimony as the dominant commodity and associated W, Mo, and Au. Tailings generated from on-site milling of Sb–Au–W–Mo ores (1972–1996) are stored in an unlined tailings storage facility. These tailings contain elevated Sb and As concentrations, raising concerns about metal(loid) mobility and potential impacts on surface and groundwater, while also representing a potential secondary resource for critical minerals due to historically low processing efficiency. Approximately 100 tailings samples were analyzed using ICP-ES/MS following four-acid digestion for near-total element recovery, and INAA for total metal(loid) concentrations. Compositional data analysis (CoDA) was applied to interpret elemental relationships. The tailings contain median concentrations of 2750 ppm Sb (400–7140 ppm), 4330 ppm arsenic (As; 240–13,200 ppm), and 370 ppb gold (Au; 1–1500 ppb). Particle size analysis indicates that most tailings are sandy silt (Folk classification). Major minerals include quartz, mica-group minerals, and mixed-layer clays (illite–smectite), with minor carbonates such as calcite and ankerite–dolomite, and sulphides including pyrite, arsenopyrite, and stibnite in deeper, unoxidized samples. Oxidized surface samples contain secondary antimony oxides and Sb–Fe oxides, with fewer sulphide and carbonate minerals. Antimony shows strong geochemical associations with silver (Ag), Au, As, and bismuth (Bi), followed by thallium (Tl) and sulfur (S), suggesting potential co-occurrence and shared geochemical behavior within the tailings. To evaluate potential environmental risks, acid-base accounting (ABA) was conducted on ten bulk samples collected from oxidized and reduced zones, representing different grain sizes and depositional environments. The results indicate

the presence of potentially acid-generating (PAG) material, although on-site drainage from the tailings is currently circumneutral. Integration of mineralogical, particle size, and geochemical data offers a robust approach for assessing environmental risks, guiding monitoring strategies, and evaluating the potential for tailings reprocessing to recover critical minerals.

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Characterising battery-grade graphite in the Grenville Province

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Graphite is a critical mineral due to its high supply risk and its importance in green-energy technologies, notably being used as the anode in rechargeable lithium-ion batteries. The southwestern Grenville Province contains many natural flake graphite occurrences and showings in both metacarbonate and metasilicate host rocks. However, it is unclear which host rock contains graphite with properties more amenable for downstream battery manufacturing. Properties of natural flake graphite that make it optimal for battery manufacturing include: (i) high crystallinity, (ii) large flake size, and (iii) an absence of microscopic and atomic substitutions. High crystallinity and lack of inclusions are important for conductivity whereas large flake size is better for effective beneficiation. Here, we evaluate if metacarbonate host rocks contain higher-quality graphite compared with graphite hosted by metasilicate rocks. Both rock types are current prospects for graphite exploration and mining, but it is unclear which one, is preferable for battery applications We use a combination of optical microscopy and scanning electron microscopy to quantify graphite flake size and inclusion impurities and transmission electron microscopy to characterize atomic (i.e. substitution) impurities. Raman spectroscopy is used to study the crystallinity of the graphite. In general, graphite hosted by metacarbonate rocks is more consistently of a higher crystallinity with fewer microscale inclusions. Although both carbonate-hosted and metasilicate-hosted graphite have potential for downstream battery manufacturing, flake graphite hosted by metacarbonate rocks appears to be superior. We suggest that host rocks should be an important consideration when prospecting for flake graphite to be used in rechargeable battery manufacturing.

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From Rust to Risk: Analysis of Trace Element Mobilization and Iron Isotopes 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. As Arctic temperatures rise, previously frozen ground is melting, exposing once-buried minerals to the atmosphere. This thaw has led to observable shifts in water chemistry, most notably in the Salmon River, with the water gaining an orange-hue and rainbow-like

sheen. Unlike anthropogenic contamination which may result from mining or infrastructure development, these changes stem from the oxidation of pyrite and other sulphide minerals that were once locked in frozen ground. However, the study area lies in close proximity to the Red Dog Mine, suggesting that natural acid rock drainage processes associated with permafrost thaw may parallel, interact with, or potentially amplify contamination and drainage patterns observed at the mine site, particularly given similarities in regional geology and the widespread presence of sulphide-rich lithologies.The oxidation of these minerals releases iron and sulphuric acid into the water, leading to acidification and the formation of iron-rich precipitates. This process not only alters the river's appearance but also mobilizes trace elements such as arsenic, cadmium, lead, and copper. These metals pose significant ecological and human health risks. Elevated concentrations of these contaminants can be toxic to aquatic organisms, disrupt food webs, and compromise water quality for downstream communities. Similar processes have been observed in other Arctic and sub-Arctic regions, underscoring the broader implications of permafrost thaw in driving natural acid rock drainage.

To better understand these transformations, weathered rocks, iron-rich precipitates, and sediments were collected from affected streams for analysis. These samples were examined using a range of techniques, including thin section analysis, inductively coupled plasma mass spectrometry (ICP-MS), and secondary electron microscopy (SEM), and Fe-isotope analysis to determine the speciation and distribution of trace elements and assess their potential for environmental release. Given the rapid pace of climate change, continued investigation into these geochemical shifts is essential for predicting and managing their environmental impact.

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Biotite Geochemistry as an Exploratory Vectoring Tool in the Zafranal Cu Porphyry Deposit, Southern Peru

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Vectoring toward mineralized centers in porphyry Cu systems remains a key challenge during exploration, particularly in deposits characterized by complex intrusive architectures and multiple magmatic–hydrothermal pulses. In such settings, conventional lithological and structural criteria may be insufficient to discriminate fertile intrusions. Mineral geochemistry provides an effective alternative by recording the physicochemical conditions of magma–fluid interaction. Among alteration minerals, biotite is especially suitable due to its stability during carolinaearly magmatic and hydrothermal stages and its capacity to incorporate elements sensitive to these processes.

This study evaluates the geochemistry of hydrothermal biotite as an exploration vectoring tool in the Zafranal Cu porphyry deposit, located in the Western Cordillera of southern Peru. The deposit is hosted by metamorphic and volcano-sedimentary rocks intruded by multiple dioritic to quartz dioritic bodies, resulting in a complex intrusive framework and a well-developed hydrothermal zonation dominated by potassic alteration at the core. Biotite samples were collected from different intrusive units with variable mineralization affinity and degrees of hydrothermal alteration.

Major and trace element compositions of biotite were determined by electron microprobe analysis. The dataset was evaluated using the XMg parameter [Mg/(Mg+Fe)] as a primary discriminator, in combination with bivariate diagrams involving elements sensitive to magmatic–hydrothermal processes (e.g., F, Ti, Mn, Cl) and integrative geochemical indices. This approach aimed to identify systematic compositional trends and to define coherent biotite populations related to distinct geological environments.

The results reveal non-random, systematic compositional variations in biotite. XMg effectively organizes the dataset and allows the recognition of at least two main biotite populations. One population is characterized by lower XMg values and relatively higher Ti and Mn contents, reflecting a more magmatic signature. A second population displays higher XMg values, enrichment in F, and depletion in Ti and Mn, consistent with increased hydrothermal influence. These populations correlate with different intrusive phases and alteration styles, particularly potassic alteration associated with hypogene Cu mineralization.

The observed geochemical patterns demonstrate that biotite consistently records magmatic–hydrothermal processes controlling porphyry system evolution. At Zafranal, biotite geochemistry proves to be an effective tool for discriminating intrusive units with different mineralization potential and for supporting exploration vectoring at the deposit scale. The methodology and results highlight the broader applicability of biotite geochemistry as a vectoring tool in comparable porphyry Cu systems.

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