SMC 2022

# 13th Annual PDAC - SEG Student Minerals Colloquium

JUNE 13-15, 2022
Metro Toronto Convention Centre (MTCC)


JUNE 28-29, 2022
Online

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The Student Minerals Colloquium (SMC) brings together geoscience students and industry professionals at the world's largest minerals and mining industry conference.

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

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

This year, we invite you to celebrate the **13th Anniversary of the SMC**.

Since its inception in 2009, the SMC has adapted to include in-person and online poster presentations available to a worldwide audience. This would not have been possible without continued support from our volunteer judges and generous support from our partners and sponsors at uOttawa, Laurentian University's Mineral Exploration Research Centre, Metal Earth, PDAC and SEG.

This year, judges will select six winners for the best online and in-person poster presentations at the BSc, MSc, and PhD Levels. We expect 44 participants in 2022; 32 in-person and 12 online.

In-person poster judging will take place from 10 - 11 a.m. on Tuesday, June 14, followed by an awards ceremony with coffee and tea at 11:30 a.m. in room 717. Online poster winners will be announced on June 28.

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

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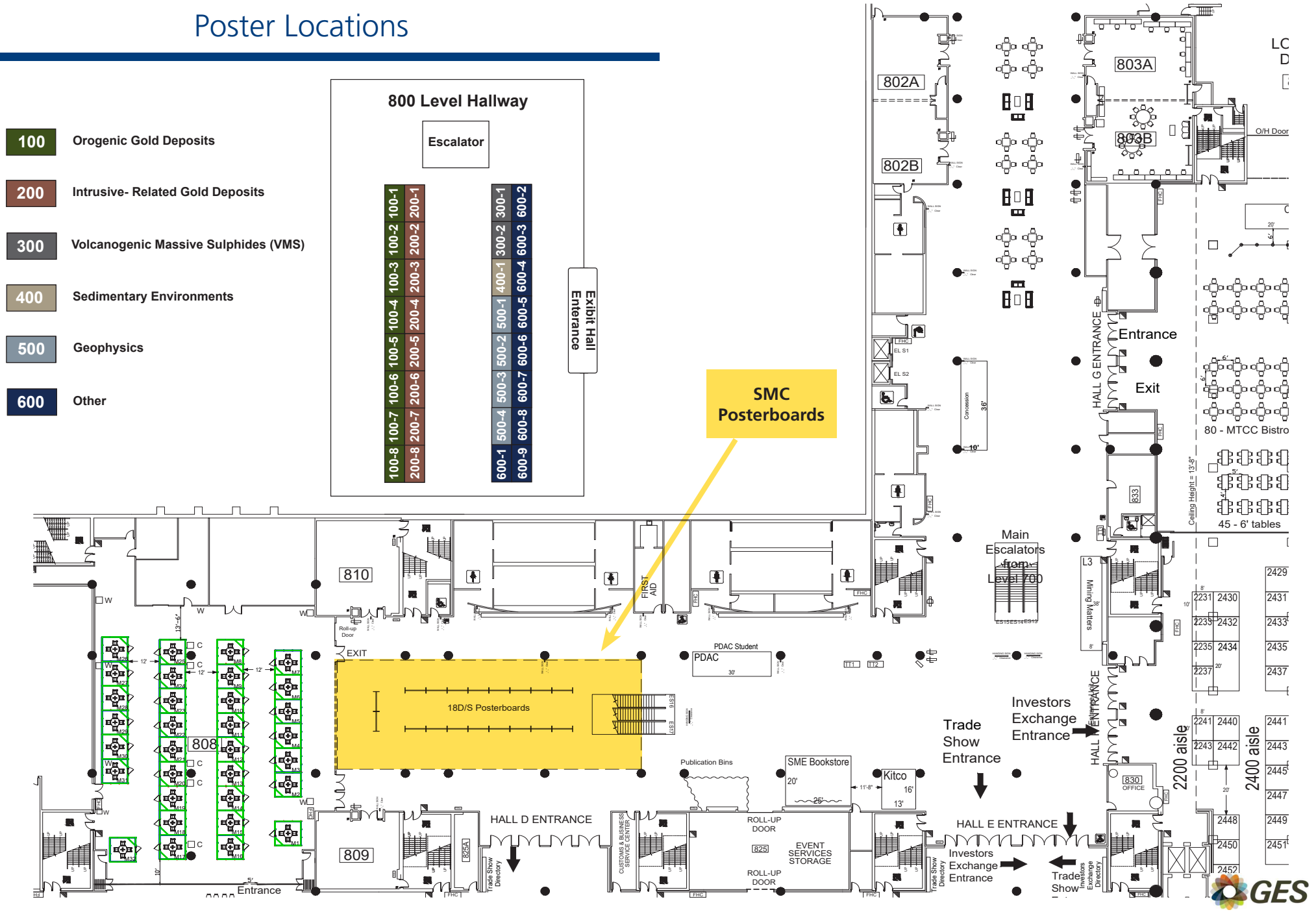

## 100 Orogenic Gold Deposits

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Table of Contents - Abstracts

## 200 Intrusion-Related Deposits

IN-PERSON



ONLINE



## 300 Volcanogenic massive sulphides (VMS)

IN-PERSON



ONLINE

## 400 Sedimentary Environments

IN-PERSON



ONLINE



## 500 Geophysics

IN-PERSON



ONLINE



## 600 Other

IN-PERSON



Table of Contents - Abstracts



ONLINE

# Abstracts


## 100 Orogenic Gold Deposits

**Shalaila Bhalla** - MSc
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**IN-PERSON**

**Geology of the Ormaque deposit, Val-d'Or, Quebec** (100-1)

The Ormaque deposit is a new gold discovery by Eldorado Gold Corporation within the renowned Val-d'Or mining camp in the Archean Abitibi greenstone belt, Quebec. Ormaque is located 2 km north of the Larder Lake-Cadillac Fault, 1.5 km south of the past-producing Sigma mine, and 1 km east of the Lamaque mine, where the fault-valve model for orogenic gold deposits was first proposed. Ormaque is hosted by a porphyritic diorite (C-Porphyry) intrusion emplaced within volcaniclastic supracrustal rocks of the ca. 2706 Ma – ca. 2700 Ma Val d'Or Formation. The C-Porphyry consists of amphibole, epidote, chlorite, and plagioclase phenocrysts in a quartz-feldspathic matrix. Three sets of veins are present at Ormaque based on cross-cutting relationships, vein morphology, textures, and orientations: (1) early quartz-carbonate-chlorite (QCC) veins and veinlets, (2) mineralized quartz-tourmaline-carbonate veins (QTC), and (3) late barren quartz-ankerite (QA) veins. The early QCC veins predate mineralization and ductile deformation. The mineralized QTC veins occur as deformed veins within steeply south-dipping shear zones cutting through the C-Porphyry and as extensional flat-lying veins oriented roughly perpendicular to the shear zones. The late QA veins are flat-lying perpendicular to the shear zones and postdate mineralization and ductile deformation. The shear zones are north-side-up ductile faults with the same orientation as regional foliation. They overprint and offset QCC and QTC veins. Primary alteration associated with both deformed and extensional QTC veins is characterized by tourmaline, carbonate, pyrite, chalcopyrite, and gold, and the late alteration is characterized by chlorite and muscovite which postdates foliation development. This study provides new information on the geometry and attitude of the QTC veins and shear zones at the Ormaque deposit.

**Ian Campos** - MSc
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**Structural controls on gold mineralization, Magino gold mine, Wawa Subprovince, Northern Ontario** (100-2)

The Magino gold mine is located approximately 40km northeast of the town of Wawa, within the Michipicoten greenstone belt of the Archean Wawa subprovince. It is a past-producing underground mine being redeveloped as a large tonnage open pit gold deposit with proven and probable reserves of 2.4 Moz of gold at a grade of 1.15 g/t Au. Gold mineralization at Magino is primarily hosted in the Webb Lake stock, a steeply-dipping ca. 2724 Ma tabular trondhjemitic body which intrudes steeply-dipping ca. 2738 Ma felsic metavolcanic rocks of the Wawa assemblage. The Webb Lake stock and Magino deposit underwent three episodes of ductile deformation and two pre- to syn-tectonic auriferous alteration events (Au1 and Au2; respectively). Gold mineralization occurs in two settings: 1) massive sheeted to stockwork style, steeply dipping pre tectonic quartz veins with primary auriferous quartz-white mica-pyrite selvages (Au1, pre-D1); and 2) steep to flat-lying fibrous quartz-carbonate/tourmaline veins with secondary auriferous iron carbonate-albite-pyrite selvages (Au2, syn-D1). The pre-tectonic quartz veins are transposed and boudinaged along the steeply-dipping WSW-ENE striking regional cleavage (S1). The fibrous quartz-tourmaline veins were emplaced syn- to late-D1 and are deformed within D2 shear zones. Flanking structures and asymmetric Z-shaped drag folds are indicative of dextral shear along the shear zones. A later flat-lying differentiated crenulation cleavage (S3) and associated shallow crenulation lineation (L3) overprints earlier structures

and is overgrown by metamorphic chloritoid porphyroblasts within the older surrounding felsic metavolcanic rocks, suggesting that alteration of these rocks occurred prior to peak metamorphism. Mineralization is offset by Matachewan(?) diabase dykes with an apparent sinistral, E-side up sense of motion. Further work is being undertaken to provide absolute timing constraints on mineralization through Re-Os and U-Pb geochronology of post-Au1 molybdenite and syn- to post-Au2 xenotime, respectively.

**Joy Carter** - MSc

**Sulfide Chemistry of the Fenelon Gold Deposit, Québec** (100-3)

The Abitibi Greenstone Belt hosts several world class gold deposits. Most of these deposits are located in the southern Abitibi, where exploration endeavors have been focused for the last several decades. In recent years, increasingly more effort has been expended to explore the highly prospective northern Abitibi, most notably by the Wallbridge Mining Company Ltd. Wallbridge acquired the Fenelon Gold deposit in 2018, which is situated in the northern Abitibi along the Sunday Lake Deformation Zone. This poster presents the sulfide textures and chemistry related to gold mineralization at the Fenelon Property. A combination of reflected light microscopy, scanning electron microscopy (SEM), and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), were used to establish the relationship between sulfide and gold precipitation in the Fenelon deposit.

The two main areas of known gold mineralization at the Fenelon Gold Property are known as the Area 51 and Tabasco zones. Area 51 mineralization is hosted in quartz veins that crosscut the main intrusive body in the Property, the Jeremie Diorite. Tabasco mineralization is associated with a shear zone along the contact between the Jeremie Diorite and the host sediments. The textures and chemistry of sulfides from both zones reveal the relationships of the sulfides to the gold mineralization and significantly enhance the understanding of mineralization at the Fenelon deposit. This study contains the first observations of sulfide textures and chemistry at the Fenelon Property and is among the few studies that have been conducted along the Sunday Lake Deformation Zone. Its success will encourage future exploration in the northern Abitibi and generate growth for the Canadian mineral resource sector.

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**Alteration and Mineralization of the Southwest Zone at the Troilus Gold-Copper Deposit, Quebec: Implications for a Revised Genetic Model** (100-4)

The Troilus Gold Project is a low-grade, high-tonnage deposit situated on the Eastern limb of the Frôtet-Evans greenstone belt in the Archaean Opatica Subprovince of Quebec in Canada's Superior Province. Past production included over 2 million ounces of gold and 70,000 tonnes of copper during operation from 1996 and 2010. First drilled in 2019, the Southwest Zone (SWZ) represents a promising extension to the mineralization of the Troilus deposit, with 510,000 ounces of gold being inferred in a 2020 preliminary economic assessment and mineralization of the zone having since been extended in all directions. However, the Troilus deposit occurs in an underexploited region of tremendous gold potential. In addition, the Troilus deposit's genetic model remains enigmatic, with conflicting literature describing it as an Archaean porphyry, mesothermal lode-gold deposit, and/or multi-stage orogenic deposit. Recent studies have increased support for a multi-stage, orogenic style model through petrographic and geochemical analysis and characterization

100 Orogenic Gold Deposits

of fluid inclusions that support evidence for a metamorphic ore fluid. This study seeks to build on current knowledge by characterizing the alteration and mineralization encountered in the main lithologies of the SWZ. Analysis was performed using petrography, lithogeochemistry, high resolution micro X-ray fluorescence (μXRF), and synchrotron radiation X-ray fluorescence (SR-μXRF).

Volcanic affinities ranging from basaltic to rhyolitic were characterized for rocks surrounding a central body of diorite. REE profiles indicate a change from an extensional tectonic regime in the southeast to compressional, orogenic suite to the northwest. Stratigraphic tops lie to the northwest within a bimodal sequence of tholeiitic to calc-alkaline volcanic rocks intruded by early diorite and late deformational felsic dikes. Two superimposed episodes of mineralization separated by peak metamorphism support a syn-deformational orogenic gold genetic model, which was modified from previous research by this study. In detail, mineralization likely started with disseminated Au-Cu mineralization during prograde greenschist to amphibolite facies metamorphic conditions that was controlled by host rock sulphidation. This was likely followed by shear hosted Au quartz-chlorite vein swarms under retrograde greenschist conditions. Thermal zonation of ore and brittle-ductile to ductile deformational regimes indicate the SWZ likely represents a lower structural level than previous mine workings, indicating promising gold potential at depth within the SWZ and in the region of past production to the northeast.

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**The Archean Hammond Reef deposit: the formation of an orogenic gold deposit in a contractional step-over-zone along a major strike-slip fault system** (100-5)

Hammond Reef is an epigenetic gold deposit with a resource estimate of 0.8Moz. It is located in the Marmion Shear System (MSS) within the south central region of the Western Wabigoon Subprovince in northwest Ontario. The MSS is a system of north- to northeast-trending anastomosing shear zones that straddles the contact between the Neoarchean Diversion stock to the west and the Mesoarchean Marmion Batholith to the east. Multiple shear sense indicators, including the refraction of a mylonitic foliation in the shear zone, drag folds, and shear bands, suggests that the MSS is a major sinistral transcurrent fault system. The Hammond Reef deposit occupies a ENE-trending bend along the MSS, where it is characterized by intense sericite, chlorite and carbonate alteration. It is associated with syn-tectonic hydrothermal quartz breccias and shallowly dipping quartz-carbonate veins with down-dip striations, which formed during bulk NNW-directed shortening across the bend. This suggests that the Hammond Reef deposit formed along a contractional step-over zone between two regional sinistral transcurrent faults. Compression across the bend resulted in more fracturing that localize the migration of hydrothermal fluids and the precipitation and concentration of gold. Its structural setting is analogous to that of the St. Ives gold field in western Australia, where several deposits occupy second-order faults in a contractional step-over zone between the Playa fault and the Boulder-Lefroy fault.

**Alix Hauteville** - PhD
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**Structural evolution and mineralization characteristics of the Boulanger orogenic gold deposit (French Guiana)** (100-6)

The Amazon Craton (South America) is composed of both the Guiana Shield in the north and the Central Brazilian Shield in the south, separated by the Amazon-Solimões basin. Many similarities

have been described between the Guiana Shield, the Superior Province and the West African Craton, particularly in terms of lithostratigraphic succession. The Guiana Shield remains an under-explored territory, the comparison of structural characteristics between orogenic gold deposits from this metallogenic province, might therefore contribute to an improvement in exploration targeting.

In French Guiana (Guiana Shield), several orogenic gold deposits are distributed along a set of ESE-WNW trending sinistral crustal-scale shear zones best-known as the North Guiana Trough (NGT). These deposits are often hosted within Paleoproterozoic greenstone belts or within late pull-apart detrital basins. The Boulanger gold deposit, located along the NGT, is hosted within mafic meta-volcanic rocks and meta-volcanosediments. Petro-structural study of the Boulanger gold deposit suggests a complex polyphase deformation history involving at least two mineralizing events. These events seem related to multiple local deformation stages (D1a, D1b and D2), suggesting potential gold remobilization and/or late gold input. The first auriferous event is associated with the formation of N120-trending, sub-vertical dipping shear veins related to reverse shear zones and associated with sub-horizontal extension veins, both filled by a quartz-carbonate-tourmaline-pyrite-gold assemblage in which gold occurs as micro-inclusions within pyrite. The associate deformation stage (D1a) developed N110-120-trending isoclinal folds within the S0/1a crenulation schistosity. The D1b deformation stage is marked by the emplacement of dextral "en echelon" veins and might be related to the emplacement of the North Guiana Trough from ~2130 Ma to ~2080 Ma during the Rhyacian collisional stage. We consider that the D1a to D1b deformation stages form a single, progressive, ductile to ductile-brittle deformation episode in a compressional regime.

The second mineralizing event is associated with the development of local N040-trending deformation corridors overprinting both the S0/1a foliation and the D1-related shear and extension veins. The D2-related veins are only visible within the coarse-grained meta-volcanosediments and are filled by a quartz-pyrrhotite-tourmaline-gold assemblage, where gold is visible at the macro-scale. D2-related veins formed by folding/delamination of S0/1a foliation during the D2 deformation stage are particularly visible where pyrrhotite crystallized within the fold hinges. The aim of this poster is to present new macro- and micro-structural observations in order to propose the first structural model of the structural evolution of the Boulanger gold deposit.

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**Gold fineness of Ontario's Gold Deposits** (100-7)

A study of gold fineness in Ontario gold deposits is part of Metal Earth's Gold Fingerprinting Project, which aims to better understand the microchemical signature of native gold using modern in-situ techniques with the potential to define unique elemental attributes in gold ore systems from the gold itself. The study examines 158 gold grains from 64 significant deposits across Ontario, which were analyzed using Scanning Electron Microscope-Energy Dispersive Spectroscopy and electron probe microanalyzer. Typically, these are coarse to very-coarse gold grains primarily associated with quartz, carbonate, pyrite, and chalcopyrite. Gold fineness includes not only the silver content, but also other minor elements present in gold in wt.% (i.e., (Au/all elements) *1000). Au, Ag, Cu, Hg, and Te were measured, and were found to be homogeneously distributed within the grains. In general, the data display variations in gold fineness that range from a high of 993, to a low of 686. The highest values are from the Red Lake camp whereas the Mikado, Bjorkman and Vermillion gold grains have the lowest. The Kerry, Richardson, and Upper Beaver mines have the highest Cu values, with an average of 2400, 2170 and 1482 ppm, respectively. Gold from the Upper Beaver mine has the highest values of Hg at 3.9 wt.%, In the Abitibi greenstone belt, gold grains from deposits along the Larder Lake-Cadillac fault zone have higher fineness, Hg and Cu values compared to deposits along the Porcupine-Destor fault zone. Results to-date indicate the potential to develop gold-based exploration techniques that will be validated through the acquisition and interpretation of other trace element data in gold using Laser Ablation Inductively Coupled Plasma Mass Spectrometry.

100 Orogenic Gold Deposits

**Michael Tamosauskas** - MSc
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**Depositional History and Gold Potential of the Ament Bay Assemblage in the Sturgeon Lake Greenstone Belt, Northwestern Ontario** (100-8)

Evaluating the sedimentology, provenance and stratigraphy of the Ament Bay assemblage can provide insights into the geologic history of the Sturgeon Lake greenstone belt and the metallogeny of Archean extensional basins. The Sturgeon Lake greenstone belt makes up the easternmost portion of the western Wabigoon terrane of the Superior craton, and is comprised of mostly Neoarchean volcanic assemblages, minor siliciclastic successions, and calc-alkalic- to alkalic intrusions. The Ament Bay assemblage is the youngest supracrustal assemblage of the Sturgeon Lake greenstone belt and dominantly consists of polymictic conglomerates, subarkosic to arkosic arenites and greywacke-mudstone sequences. These lithofacies are intruded by alkalic porphyritic rocks, which are also incorporated as clasts in Ament Bay assemblage conglomerates, indicating a coeval relationship between sedimentation and magmatic activity. Features such as abundant planar bedding, spatially associated faults and locally derived debris suggest that Ament Bay assemblage sedimentation occurred in a subaqueous setting within a transtensional pull-apart basin. The lithofacies of the Ament Bay assemblage resemble the auriferous 2670-2680 Ma Timiskaming assemblage, a prominent regional exploration target for gold in the Abitibi greenstone belt. In the Timiskaming basin, alkalic magmatism and coeval deep-reaching extensional faults are critical factors for gold metallogeny. Because these mechanisms are postulated to have occurred during the formation of the Ament Bay assemblage, this study provides insights into its gold potential and considers possible factors which may have impeded metal endowment.

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ONLINE

**Structural evaluation and mapping of hydrothermal alteration in the Fatira-Abu Zawal area of the Eastern Desert, Egypt** (100-9)

The Eastern Desert of Egypt experienced a lengthy period of deformation induced by a newly culminated crust known as the Arabian Nubian Shield in the Proterozoic Eon. The Eastern Desert was demonstrated to be a prospective area for gold occurrences linked with the accompanying tectonic events. The Fatira Shear Zone (FSZ) is located at the boundary between the Northern and Central Eastern Deserts of Egypt. The region exposes metavolcanic rocks twisted by the dextral displacement of the FSZ in relation to the Barud magmatic dome. Numerous distorted intrusive granites and felsic dikes were investigated as part of recent exploration, which was accompanied by several potential mineralization sites, including orogenic gold deposits. In the studied region, the integration of diverse geological and remote sensing data, combined by the analysis of aeromagnetic enhanced maps, allowed for the identification of unique lithologies, structural characteristics, and hydrothermal modifications. Aside from that, the integrated data collected from

the various interpretation methodologies is used to identify and confirm mineralized localities in the Fatira and Abu Zawal regions, as well as define their relationship to the geological key structures associated with FSZ that have been investigated over most of the study area. The final outcomes for the ASTER, Sentinel 2 hydrothermal alteration, and orientation entropy heat maps prove the robust linkage between these mineralized locations and the major structures associated with the FSZ late stage of deformation, as opposed to other structures studied throughout the area of interest.

**Shelby Brandt** - MSc
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**Structural Context of Gold Mineralization in the Santoy Gap Hanging Wall Deposit, Seabee Property Area, Central Glennie Domain, Reindeer Zone, Saskatchewan, Canada** (100-10)

Currently, the only producing gold mine in Saskatchewan is SSR Mining's Santoy Mine situated within the Pine Lake Greenstone Belt in the central Glennie Domain. This is a structurally controlled, Paleoproterozoic, orogenic gold deposit situated along the Santoy splay of the Tabbernor fault. While the Tabbernor fault appears to have acted as a conduit for auriferous fluids to flow, it is remains unclear how polyphase folding in units surrounding this fault influenced mineralization. This thesis aims to better define the structural controls on mineralization of the Gap Hanging Wall deposit at Santoy mine and evaluate how the deposit formed in relation to the complex structural evolution of the Glennie Domain. The thesis comprises two main components: a broad-scale analysis of the structural geology of the central Glennie Domain, coupled with detailed mapping and 3D modelling of the Gap Hanging Wall deposit. The latter (detailed analysis) will be presented in this poster.

The Gap Hanging Wall deposit is hosted in an apophysis off the northern edge of the tonalitic Lizard Lake pluton. Said apophysis is folded by F3 on a 25-50 m scale with folds oriented about 37-353 hingeline. An initial cubic model measuring ~800m on each side was created in Leapfrog GeoTM using lithologs to identify hangingwall and footwall contacts of the Lizard Lake pluton. A supplementary, more detailed model was also created which focused on the deposit's exposure at depth (440 and 460m below surface). By adding Au assay results, a numeric model was created which shows gold distribution within the pluton.

Additional data including level plans, hand samples, thin sections, assay results, and upwards of 300 structural measurements were all considered in the context of the models to draw conclusions about the timing, mechanics, and structural controls of gold mineralization in this deposit. This poster examines the possible mechanics of veining as well as the orientation and abundance of veining in relation to the folded apophysis. This poster also describes the distribution of gold mineralization, associated alteration package, and the structural setting of the deposit within the larger Santoy shear zone.

**Ali Shebl** - MSc
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**Integrated airborne geophysical and remote sensing datasets for mineral potentiality mapping: A case study from Egypt** (100-11)

Increasing the amount of integrated data has demonstrated its role in narrowing the area to be explored and significantly increases the likelihood of favorable mineralized zones. Moreover, the incipient step for mineral exploration should be concisely performed as it constitutes the

100 Orogenic Gold Deposits

base for the further costly detailed exploration programs. As the current research integrates aeromagnetic, spectrometric gamma-ray, ASTER, Sentinel 2, and PRISM datasets, it can be considered the primary exploration program of mineralized zones at the central part of the Egyptian Eastern Desert. Aeromagnetic data was mainly utilized to decipher the structural patterns of the study area, while spectrometric gamma-ray reasonably identifies hydrothermal alteration zones that have been confirmed through several techniques (including constrained energy minimization band ratio, relative absorption band depth, directed principal component analysis) utilizing ASTER and Sentinel 2 multispectral data. Spatial overlay analysis on the findings revealed three mineralized-promising zones. Our results were confirmed by extensive fieldwork, which at the same time emphasized the observed structural and hydrothermal outputs.

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**Insights into the occurrence, texture and chemistry of gold in the Kibali Gold District, Moto Greenstone Belt, DRC.** (100-12)

The Neoarchean Moto Greenstone Belt in the Congo Craton hosts a well-endowed gold province with historical production spanning over 100 years. Critical exploration work and scientific studies have been conducted in the giant Karagba-Chauffeur-Durba (KCD) gold deposit and, to a lesser degree, its associated peripheral gold deposits (Gorumbwa, Kombokolo and Agbarabo) to constrain the behaviour of gold and its setting. The strong destructive alteration in the KCD deposit obstructs the primary signatures of the gold and makes it difficult to interpret its origin. It should also be noted that these deposits do not contain quartz-vein mineralisation. Thus, our work aims to present a study of the gold origin of the broader KCD area deposits based on gold textures and mineral chemistry, widely demonstrated as a powerful tool. An extensive data set with several boreholes logged, microscopic studies on 4809 gold grains, and mineral chemistry using Scanning Electron Microscope (SEM-EDS) on 397 gold grains were used in this study. Detailed petrography highlights wide ranges of gold grain area from 0.2 to 58875 µm2, with 407 µm2 as an average. The individual Au grain morphology falls predominantly into the angular category (56%), followed by rounded-lensoid form (24.7%) and irregular (10.3%), with minor bi-lobate and elongate. Geochemical data reveals mainly Au-Ag alloys dominated by native gold with averages of 86.86 wt.% of Au and 11.26 wt.% of Ag. The concentration of Hg ranges from <0.01 wt.% to 25.73 wt.%. In addition, the aurostibite occurs mainly in the Gorumbwa samples with minor amounts in KCD, with Sb values varying between 28.36 and 38.15 wt.%. Therefore, the heterogeneity of gold composition with respect to Ag suggests a degree of variability in the pressure and temperature conditions at the time of Au precipitation. The lower temperatures facilitate the incorporation of Ag in the Au-Ag alloys, and Au content in the alloy is expected to increase with increasing temperature. Other processes which may account for differences in gold grain Ag content relate to gold cycling in placer settings, where the development of high purity Au-rich rims occurs on the placer grains. Afterwards, the variable Hg and Sb content suggests some gold formed under the physicochemical conditions of a fluid system cooling below 220°C. Thus, the gold texture, occurrence, and chemical composition suggest a possible variety of processes giving rise to gold mineralisation on the deposit scale, then overprinted by regional hydrothermal events.

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IN-PERSON

**Regional-scale prospectivity analysis of western Rajasthan, NW India for carbonatite-alkaline complex related REE mineralisation** (200-1)

Rare earth elements (REEs) are a group of 17 metals considered critical for future industrial development. This study investigates the potential for carbonatite-alkaline complex related REE in western Rajasthan, NW India, using Fuzzy Inference Systems (FIS), a supervised, knowledge-based symbolic artificial intelligence technique; and Self Organising Maps (SOM), a neural network-based unsupervised machine learning clustering algorithm.

The supervised approach uses a multi-stage FIS based on a generalised conceptual REE mineral systems model, which is also used to identify the targeting criteria for REE deposits. These targeting criteria were represented by mapping their spatial proxies in GIS layers, derived using spatial analysis and geoprocessing tools. The first stage of the multi-stage FIS consists of three individual FIS representing (1) mantle plume metasomatised sub-continental lithospheric mantle (SCLM) in extensional settings, forming fertile source regions in favourable geodynamic settings; (2) trans-lithospheric structures providing favourable lithospheric architecture for transportation of REE-bearing fluids and (3) near-surface higher-order structures that constitute shallow crustal architecture facilitating carbonatite-alkaline complex emplacement. Uncertainties associated with the approach were quantified using Monte-Carlo simulations and subjectively defined confidence values. Consequently, REE prospectivity was mapped at three probability levels, draped over a confidence layer.

The unsupervised approach applies SOM to gridded geophysical and topographical datasets, aiming to replicate the results of the FIS modelling while automating the process, eliminating human bias and time-consuming, labour-intensive data pre-processing. This approach did not use any interpreted, processed, or manually generated data, such as surface or bed-rock geological maps, faults, etc., relied on the algorithm to identify crucial features to delineate prospective areas.

The results of both approaches were comparable; hence, the unsupervised approach is a reliable, time-saving tool for automated prospectivity modelling, particularly in unexplored regions with insufficient geological data for supervised studies requiring a significant number of multi-parametric datasets. Several REE targets are identified from both approaches (FIS and SOM). Project-scale detailed ground exploration is recommended for the Kamthai-Sarnu-Dandeli and Mundwara regions and their immediate surroundings, where areas of high prospectivity are mapped at high probability levels. Exploration of the Siwana ring-complex region is recommended. High-resolution data collection is recommended for the regions to the north and northeast of Sarnu-Dandeli, south of Barmer and Mundwara, to resolve and delineate targets for ground exploration. The supervised approach presented here can be applied to geodynamically similar regions (mantle-plume-related intracontinental extensional settings) whereas, the unsupervised approach can be applied to unmapped virgin areas for REE exploration globally.

200 Intrusion-Related Deposits

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**Domaining of downhole geochemical data – an automated approach applied to the northern limb of the bushveld complex** (200-2)

The Northern Limb of the Bushveld Complex is host to some of the largest platinum-group element (PGE) deposits in the world; however, there is limited understanding of the precise controls on the style and spatial distribution of mineralisation. Geochemical domains can be used as an initial step in understanding magmatic processes and for generating 3D orebody models, however the interpretation of domains and where boundaries should be placed can be subjective and time consuming when interpreting many drillholes. Boundary detection methods using continuous wavelet transforms (CWT) were first used in the geosciences to identify boundaries in downhole geophysical data. The method was further developed to allow for multivariate inputs, and to improve visualisation of the CWT scalogram, enabling easy interpretation of boundaries across multiple spatial scales of observation. This work shows how the multiscale, multivariate CWT method can be effectively used to domain downhole bulk geochemical data from a series of exploration drillholes from the Northern Limb to facilitate repeatable domaining that takes downhole spatial continuation into consideration. The attributes describing these domains can then be clustered to allow for spatial correlation across drillholes. The results of this workflow are shown to be a good comparison to results of manual geochemical domaining on Northern Limb drillhole data as performed by a geologist, with the additional benefit of minimising human bias, enabling (re)interpretation of drillhole data with increased speed, and the ability to use different inputs to identify domains for specific purposes or at different scales of observation. Given the method relies on identifying inflection points in the data (rather than absolute values) to determine boundaries, this study also investigates the application of this method on portable XRF data which is typically biased and noisy.

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**Mineralization of the Escape PGE–Ni–Cu sulfide deposit, Thunder Bay North Igneous Complex, Northwestern Ontario** (200-3)

The 1.1 Ga Midcontinent Rift System (MRS) preserves abundant extrusive and intrusive magmatism formed during the failed attempt to break apart the North American craton. MRS rocks are located around the Lake Superior region, with several mafic–ultramafic intrusions that host orthomagmatic Ni–Cu–platinum group element (PGE) mineralization. The Thunder Bay North Igneous Complex (TBNIC) comprises a series of MRS-related mafic–ultramafic intrusions that were emplaced into the Archean Quetico Basin of the Superior Province. The Escape deposit of the TBNIC comprises variably altered wehrlites that host PGE-rich orthomagmatic sulfide mineralization. Mineralization chiefly occurs as disseminated to net-textured sulfides, with lesser amounts occurring as blebs and veinlets. The sulfide assemblage typically comprises pyrrhotite, chalcopyrite, and pentlandite, with lesser to trace cubanite, pyrite, and millerite.

This study is investigating the critical ore-forming processes of the Escape system, particularly the contamination history and sulfide liquid–silicate melt interaction (i.e., R factor). Extended primitive mantle-normalized trace-element patterns for the ultramafic rocks at Escape are similar to ocean island basalts and other MRS-related ultramafic intrusions (e.g., Seagull, Disraeli, Kitto), consistent with a mantle plume source. The lack of both Th enrichment and negative Nb anomalies suggests that the Escape magma(s) did not assimilate significant amounts of

Archean Quetico metasedimentary rock, which is characterized by high Th/Nb ratios. This does not necessarily rule out the possibility that S was added to the system from a crustal source via selective contamination. This possibility is being evaluated further using multiple S isotopes.

Variations in R factor can be evaluated in bulk-rock Cu/Pd–Pd space, where high-R factor, PGE-rich systems plot at lower-than-mantle Cu/Pd values and high Pd values. Data from the Escape deposit falls within the range of mantle values and is relatively flat (i.e., limited variation in Cu/Pd and large variation in Pd), indicating less system complexity relative to other world-class magmatic Ni–Cu–PGE deposits (e.g., Norilsk–Talnakh, Marathon). The ultimate goal of the project is to integrate these data to develop a holistic genetic model of the Escape deposit that will lead to improved exploration criteria.

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**A new look at PGE-Ni-Cu-Co mineralisation of the Northern Limb of the Bushveld Complex** (200-4)

The Northern Limb of the Bushveld Complex, South Africa, is host to one of the world's largest resources of platinum-group elements (PGE), along with significant Ni, Cu and Co, and contains the giant Platreef deposit within Critical Zone stratigraphy. The Platreef is a world-class complex marginal style PGE-Cu-Ni-Co deposit, comprised of a series of pyroxenite sills which rest upon variable Archean-Palaeoproterozoic country rocks. More recently it has been recognised the Platreef flattens out and thickens down-dip, transposing into a more stratiform reef-style mineralisation. In addition to the Critical Zone, the Lower and Main Zone of the Northern Limb also host less well known, but still notable in their own right, PGE and sulfide mineralisation. Whilst substantial research has been undertaken on the near surface Platreef resources, the deeper Critical Zone and Lower Zone have received less attention. Exploration and mining in the Northern Limb is expanding, and as such, it is now possible to study the deeper Critical Zone and Lower Zone. Multiple sulfide enriched units, chrome units and PGE units are seen outside of the PGE-rich Platreef that has been mined at surface, within the deeper Critical Zone and Lower Zone.

It is well accepted that a combination of magmatic, contamination and hydrothermal processes have all played a part in developing the highly variable metal budget of the Platreef, however the role of these processes in the deeper Critical Zone and Lower Zone are less well constrained. Therefore, this ongoing study integrates bulk rock geochemistry, mineralogical studies, PGM and sulfide studies and S isotopes, to assess the role of these processes in generating the variability of mineralisation seen throughout the Critical and Lower Zone. In turn, this will help establish how geometallurgy varies throughout the Northern Limb, giving implications for processing, as mining activity and exploration in the area continues to expand.

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**The Vermelhos Cu Deposits, Curaçá Valley District, Brazil: Mineralogical Constrains on the Ni-PGE-Au Rich Zones** (200-5)

A significant number of Cu deposits are hosted in the Curaçá Valley, located in the Paleoproterozoic Itabuna-Salvador-Curaçá belt in the northern part of the São Francisco craton, Brazil. The ore zones are characterized mainly by chalcopyrite-bornite-rich lenses that occur as

200 Intrusion-Related Deposits

massive sulfides, breccias and veins hosted in mafic-ultramafic rocks. Different genetic models have been proposed to explain the various styles of mineralization in the Valley, including magmatic sulfide and Iron Oxide Copper Gold (IOCG) models. The Vermelhos deposit, located in the northern region of the Curaçá Valley, comprise mineralized zones that locally exhibit higher Ni:Cu ratios than other deposits in the district. Ni-rich mineralization is hosted mostly in gabbro-norites and anorthosites containing magmatic orthopyroxene, clinopyroxene, plagioclase, phlogopite, +/- hornblende, Cr-rich hercynite, Cr-rich magnetite, apatite and monazite. The magmatic sulfides, which include pentlandite and Ni-bearing pyrrhotite (0.1-1.4% Ni), and in lesser amount tellurides (mostly melonite - NiTe2) are seen in sharp contact and/or filling embayments in the magmatic silicates and spinels. Chalcopyrite, various Ag-, Ni-, Bi-, Pb-, Sn-, Pd-, Pt-bearing tellurides and electrum occur mantling, and in sharp contact with, actinolite. These sulfides also occur filling corroded zones and fractures in Cr-rich hercynite, Cr-rich magnetite, Al-rich chromite, and ilmenite, as well as filling fractures in pyrrhotite that contain inclusions of phlogopite. Chlorite, K-mica, epidote, carbonate, serpentine, talc, magnetite as veins, pyrite and violarite replaced the early phases. Based on the mineralogical and textural relationships and the association of sulfides with chromite-bearing mafic-ultramafic intrusive rocks, we propose that at least part of the sulfides (pentlandite and pyrrhotite) formed during magma crystallization and fractionation, possibly involving mixing of alkaline and mafic-ultramafic magmas to explain the coexistence of magmatic monazite, apatite, phlogopite and chromite. Mantle-derived magmas or crustal contamination may have provided the S for the magmatic sulfides. Chalcopyrite and the various precious metal tellurides may have been a product of late crystallization of sulfide melts and/or of hydrothermal/metamorphic processes at pressure and temperature conditions where re-crystalized spinel, actinolite and phlogopite are stable.

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**New insights into the magmatic and footwall controls on the emplacement of the Platreef PGE-Ni-Cu-Co deposit, northern Bushveld Complex** (200-6)

The northern limb of the Bushveld Complex, South Africa is widely regarded as one of the world's largest resources of platinum-group elements (PGEs). These PGEs, as well as significant amounts of base metals (Ni, Cu, Co), are vital for the growth of sustainable and environmentally friendly technologies. They are particularly important to the electric vehicle revolution, a market that is expected to grow significantly in the coming decades. Therefore, it is becoming increasingly important to better understand these deposits, in particular focussing on the source of their metal budgets and emplacement, processes which are vital for developing genetic and exploration models.

The Platreef forms the major PGE-Ni-Cu-Co deposit in the northern limb and forms the Critical Zone (CZ) equivalent to the wider Bushveld. It is enigmatic for several reasons. The mineralised portion of the Platreef has a grade comparable with the Merensky Reef of the western and eastern limbs, typically 3-4 g/t (Pt + Pd + Rh + Au), but can increase up over 10 g/t, over a much greater thickness (tens of metres, rather than typically < 1m in the Merensky Reef), and has significant higher base metal credits and a higher Pd/Pt ratio. The Platreef also differs from the CZ as it lies north of the Thabazimbi-Murchison lineament (TML), and rests directly on the metasedimentary units of the Transvaal Supergroup, and accompanying footwall structures. These features are likely to have had a significant impact on the emplacement and magmatic pathways of the northern limb magmas.

The Platreef is proposed to have formed from several discrete magmatic units, each with their own metal budgets, thicknesses and geochemical character. Several localised studies have been carried out, but at present there remains no overarching geological model to explain the differences in these units across the whole northern limb. In addition, little research has focussed on the basement architecture of the Transvaal Supergroup, and how these pre-existing structures influenced magmatic emplacement, thickness and grade.

This research aims to examine the geochemistry and mineralogy of the magmatic units which constitute the Platreef along a continuous strike section with variable footwall rocks and structures. Additionally, potential magmatic sources for each unit will be examined using trace elements and radiogenic isotopes. Examining the Platreef at localities throughout the northern limb gives the best opportunity to understand the Platreef stratigraphy, and its magmatic and structural controls, on a broader scale to produce an overall emplacement model.

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**Alteration Characterization using Machine Learning applied to SWIR, XRF, and photographic textural data** (200-7)

Consistent and high-throughput classification of alteration facies in the mineral exploration and extraction industry is difficult to achieve without intelligent application of empirical data inputs. We examine data-driven methods to improve on alteration classification using integration of short-wave infrared (SWIR), X-ray fluorescence (XRF), and photographic textural metric datasets of coincident readings taken from a historic epithermal gold mine and porphyry copper deposit prospect in central Chile. Methods of parsing these seemingly disparate datasets are examined, and their relevance to establish supervised classification workflows based on known alteration facies.

Alteration facies in drill core are typically classified visually or logged by a geologist. This approach is beneficial from the perspective of understanding how observed alteration assemblages fit into known zonation patterns for a given deposit style, based on well-established models, like the classic porphyry copper alteration zonation model (Dilles et al., 2012; Gustafson and Hunt, 1975; Halley et al., 2015; Jerome, 1966; Jones, 1992; Shujun et al., 1984; Sillitoe, 1973). A downside of this approach is its dependence on subjective interpretation of the alteration minerals and textures observed, and as a result it may vary widely between interpreters and lead to complications when integrating large drillhole databases into the 3D environment. Increasingly popular approaches utilize hydrothermal mineral assemblages identified by SWIR instruments and may integrate geochemical information (Halley, 2020) to aid in constraining compositional parameters indicative of a given alteration type (Dilles et al., 2012; Halley et al., 2015).

We propose that alteration can be well constrained in a semi-automated fashion using a combination of mineralogical (SWIR), compositional (XRF), and textural (photographic) data, thereby decreasing the subjectivity of classification and increasing the consistency and throughput of alteration characterization.

200 Intrusion-Related Deposits

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**An overview of the Devonian intrusive rocks in New Brunswick and their relationship to the porphyry-style gold, copper, and molybdenum mineralization** (200-8)

Porphyry systems provide two thirds of the world's Cu and significant proportions of Mo, Zn, Pb, and precious metals (Au, Ag) to our world economy. One of the useful research tools utilized in developing a genetic model for porphyry systems is geochronology. In this study, we review the Devonian porphyritic intrusive rocks in New Brunswick that are spatially and temporally related to porphyry mineralization. In general, porphyry Cu-Au deposits are formed at convergent margins, either coeval with subduction or in post-subduction settings. These porphyry Cu±Mo±Au systems are commonly associated with shallowly emplaced intermediate intrusions, and derivative low- to high- temperature (300-700oC) hydrothermal systems. Most of these mineralized porphyry-related systems originate by injection of fertile oxidized intermediate I-type volatile saturated magma rich in S and metals. Cu, Mo, and Au porphyry deposits in the northern Appalachians occur over a wide time span from the Cambrian, through to the Mississippian. In these mineralization systems, the fertile magma is sourced from subduction (or collisional)-related oxidized magmas, which are rooted to the larger batholith-sized intrusions at depth. Based on geochemical data, some of these intrusions show evidence of slab failure and adakitic features. The occurrence of porphyry Cu-Mo-Au systems in New Brunswick are a function of multiphase, high level of intrusions, oxidized intermediate compositions, and the nature of host sequences. The Devonian oxidized I-type porphyry intrusions of central and southern New Brunswick include: Eagle Lake (356.7±4.4 Ma, U-Pb zircon) (Cu-Mo-Au), Sorrel Ridge (378.1 Ma, U-Pb zircon) (Cu-Mo, Sn and W), Evandale (390.4 Ma, U-Pb zircon) (Cu-Mo), Pokiok (Nashwaak (420.7±1.8/-2.0 Ma, U-Pb zircon), Allandale (402±1 Ma, U-Pb monazite), Hawkshaw (411±1 Ma, U-Pb on titanite), Skiff Lake (409±2 Ma, U-Pb zircon), Hartfield (415±2 Ma, U-Pb titanite) (Cu-Au-Mo), Falls Creek (Mo), and Magaguadavic (403±2 Ma, U-Pb zircon) (Cu-Mo). Porphyry systems in northern New Brunswick include the Benjamin River porphyries (400.7±0.4 Ma, U-Pb zircon) (Cu, Au, Mo, Ag), Popelogan (Cu-Mo), which is related to Red Brook Granodiorite (383±1/-3 Ma), Sugarloaf, Squaw Cap (415±0.5 Ma, U-Pb zircon), Nicholas Denys (381±4 Ma, U-Pb zircon) (Mo-Cu-Fe), Mulligan Gulch (419±1, U-Pb zircon) (Au), Patapedia (364.4 ± 0.4 Ma, U-Pb zircon) (Cu-Zn-Pb), Rivière Verte (368 ± 2 Ma , U-Pb zircon) (Cu-Mo), Quisibis porphyries (Cu-Mo), and McKenzie Gulch dykes (386.2±3.1 and 386.4±3.3 Ma, U-Pb zircon) (Cu-Ag). Intrusion-related gold systems are related to similar Middle Devonian hypabyssal intrusions and dykes, like Clarence Stream, Poplar Mountain, Lake George, Williams Brook, and Elmtree.

# 200 Intrusion-Related Deposits

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**Drift Prospecting & Deep Learning** (200-9)

Copper-porphyry (Cu-porphyry) deposits are large tonnage low-grade mineral deposits. Cu-porphyry systems supply three-quarters of the global copper resources and are essential to meeting the world's copper demand. As the world economy transitions to renewable energy, infrastructure upgrades will increase the global demand for copper by an estimated 275% to 350% by 2050. This demand would exceed the projected copper mineral resources. Exploration methods that are faster and lower in cost than current approaches must be developed to meet the projected demand. Indicator minerals (IM) are minerals that contain textural or chemical information indicating specific mineralization in bedrock from which the minerals were originally sourced. Detrital IMs have led to numerous discoveries of deposits and apply to Canadian Cu-porphyries. The research objective of this project is to help improve Canadian critical metal security by advancing our ability to identify critical copper-related minerals. The goal of the research is to develop a quantitative approach to IM identification that overcomes the limitations of qualitative manual IM methods. The research aims to achieve greater than 90% classification accuracy of Cu-porphyry IMs by using unsupervised and supervised machine learning. Machine learning methods will be applied to optical microscope, cathode luminescence, micro–X-Ray Fluorescence, and scanning-electron-microscope data to identify IMs. The aim is to produce accurate IM data with a tenfold reduction in cost and a tenfold increase in speed compared to conventional methods. The machine learning models' effectiveness will be evaluated on the accuracy in predicting mineral classification identified by scanning-electron-microscope (>90% Cu-porphyry IMs classified correct) and against commercial IM data.

# 300 Volcanogenic massive sulphides (VMS)

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**IN-PERSON**

**Geodynamic Influences on VMS Endowment in Archean Greenstone Belts from Trace Metal Constraints** (300-1)

Trace elements can reflect the characteristics of VMS deposits with their geochemical fingerprints recording the behaviour of the hydrothermal fluid and makeup of the leached volcanic footwall. The Neoarchean Abitibi Greenstone belt hosts world-class Au and base metal (Cu-Zn-Pb) VMS deposits that share a crustal heritage reflected in the geochemical signatures of their ores. This study examines the potential relationship between the geodynamic context of the deposits and their trace element geochemistry based on a new comprehensive database of ore samples collected from over 300 Canadian VMS deposits. We used unsupervised and supervised machine-learning methods to characterize pyrite geochemistry in hundreds of VMS deposits and occurrences in different settings. Statistical analyses of the trace elements in pyrite reveal systematic relationships between deposits with different host rock compositions. Pyrite from VMS deposits dominated by primitive mafic and ultramafic host rocks are enriched in Cu, Co, Se, Ni, and Mo (i.e. Mattagami, Timmins, and Val d'Or camps), whereas deposits with tholeiitic to calc-alkaline felsic footwalls are enriched in Zn, Pb, As, Ag, Te and Au (i.e. Blake River Group). In addition, large tonnage deposits typically contain pyrite with higher concentrations of Cu, As, Sn, Se, Te, and In suggesting the link to felsic magmatic contributions, which are in turn key metal sources of bigger VMS forming systems. Principal Component Analyses (PCA) of pyrite chemistry combined with clustering methods confirm trace element indicators of mineralizing processes, including Au-enrichment that is correlated to enrichment in elements such as Bi-In-Se-Te in some deposits and is also thought to be related to magmatic input. Hierarchal and k-means clustering indicates higher Au-grades are associated with elevated In and Te content in pyrite; and large, Au-rich deposits host pyrite with significant Cu-Bi-In-Te-Sn enrichment interpreted to reflect a felsic-magmatic input of metals. PCA results show that the inferred temperature of the hydrothermal system is also a likely control on the trace element geochemistry of pyrite. Au-rich and large VMS deposits are enriched in Ag, As, Bi, In, Hg, Sb, Se, Sn, and Te, which reflect a combination of magmatic inputs (e.g., Bi, In, Se, Te) together with long-lived lower-temperature hydrothermal systems (e.g., in Ag, As, Hg, Sb, and Sn) that contribute to the sizes of the deposits. Thus, the distribution of trace metals in pyrite can fingerprint Au-rich (i.e. Horne, LaRonde Penna) and giant VMS deposits (i.e. Kidd Creek) while revealing geodynamic-scale enrichment processes. MERC-ME-2022-17

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**Lithotectonic classification of seafloor massive sulphides (SMS) using critical metal endowments** (300-2)

Seafloor massive sulphide (SMS) deposits are characterized by an abundance of critical metal-bearing sulphide minerals, which are precipitated from hydrothermal fluids that circulate through oceanic crust. These hydrothermal convection cells are driven by an anomalous heat source, making them a relatively common occurrence at plate margins and intraplate hot spots. There is currently a lack of consensus upon the classification scheme of SMS deposits, largely due to the geochemical and lithotectonic variability between deposits. SMS deposits adjacent to Mid-Ocean Ridges (MOR) are relatively well-classified, and this has enabled researchers to compile geochemistry databases, and to subclassify the deposits (mainly according to host lithology). Back-arc basin, arc volcanic, and intraplate SMS deposits are not yet subclassified, despite the potential for widespread contrasting host lithology, depth, and hydrothermal fluid properties between SMS sites. This is problematic, because arc volcanic and back-arc basin deposits exhibit a known preservation bias, whereas MOR deposits are typically subducted and recycled. Therefore, it is important to subclassify arc volcanic and back-arc basin-related SMS sites, in order to understand the controls on SMS critical metal endowment relative to lithotectonic setting, mineralogy, mineral texture, paragenesis, and hydrothermal fluid properties (temperature, pH, REDOX, salinity, magmatic volatile contribution, boiling, depth). My on-going research utilizes EPMA, and LA-ICP-MS data, as well as previously established literature values, in order to consider the distribution and controls on critical metals. Newly acquired geochemical data from the Niua Volcanic Complex's volcanic arc-related SMS deposit, VOLPA, displays a host of controls on critical metal abundances, including effects of boiling and structural controls on sulphide formation, in addition to the suspected presence of magmatic volatiles. Preliminary results indicate that SMS chimneys are most prone to critical and precious metal enrichments when fluids can freely exploit extensional fractures as a highway to the surface, and when an impermeable cap rock restricts fluid mixing with oceanic sea water. These factors not only complicate the subclassification scheme of SMS deposits based solely on host lithotectonics (as is the current status of MOR deposit classification), but also provide important context to our current classification scheme of ancient volcanogenic massive sulphide deposits (VMS). Further research will characterize and compare the remaining lithotectonic settings, which will more adeptly allow for comparison of critical metal endowments between SMS and VMS sites, both spatially and temporally.

**300** Volcanogenic massive sulphides (VMS)

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**Insights into ancient back-arc magmatism from the intraoceanic Lau Basin, a multivariate statistical approach** (300-3)

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

Here, we present a global study of active submarine spreading regimes in the oceans and their potential ancient analogs. We have compiled high-quality geochemical analysis of more than 5000 unique samples of submarine volcanic rocks from a wide range of settings, including mid-ocean ridges, ridge-hotspot intersections, intraoceanic arc and back-arc spreading centers, and ocean islands to explore: i) lithogeochemical variations and their geodynamic triggers; ii) similarities with the AGB; and iii) classification tools for different lithotectonic settings.

Principal components analysis (PCA) and t-distributed stochastic neighbor embedding (t-SNE) identify small- and large-scale mantle flow regimes and petrogenetic controls on whole-rock chemistry that reflect: i) degree of partial melting; ii) upwelling asthenosphere; iii) subduction related input; iv) mantle mixing; v) and assimilation of crustal material. The study reveals the important influence of spreading rates, dislocating spreading centers, mantle mixing, distance to subduction zones, and implications for microplate architecture and initiation of rifting events. We used agglomerative hierarchical clustering and a density based spatial clustering technique (DBSCAN) to identify systematic similarities and differences in volcanic rock geochemistry between different extensional regimes, with examples from the Lau Basin, Manus Basin, Bransfield Strait and the Abitibi Greenstone Belt. The clusters clearly distinguish different lithotectonic environments and form the basis of machine-learning Random Forest classification models that can be applied to new samples to identify their lithotectonic affiliation.

The results provide insights into initiation of oceanic rifting, microplate interactions, processes related to regional metal endowment, and the preservation potential of well-endowed crust that may have important parallels in Archean greenstone belts. MERC-ME-2022-18

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IN-PERSON

**Seeing below the sand: Integrated Sed-Cu targeting in Ngamiland, Botswana** (400-1)

Ngamiland District in northwestern Botswana is an attractive exploration jurisdiction due to its stable political and economic framework, history of mining, well-regulated mining sector, and dataset availability. However, the Kalahari Desert poses a significant challenge to mineral exploration due to the absence of exposure of mineral-bearing strata. Sand thickness is on the order of 50 to 100 meters (m), with some locations reaching up to 150 m, leaving few outcrops of bedrock above the sand. Leveled partial-leach soil geochemistry data for the Ngamiland region closely follows surface-level sand dune patterns, calling into question their spatial accuracy. This causes challenges in mineral targeting as traditional outcrop sampling and other near-surface geochemical exploration methods are often not successful in this region. Therefore, novel ways of exploring through cover need to be developed to increase the success rate of target generation in this region and those with similar conditions. The Ghanzi-Chobe belt shows great promise as a host to strata-bound copper sulfide mineralization, due to known discoveries (e.g., Boseto and Motheo mines) along with the redox interface between the Ngwako Pan and D'Kar Formations within the belt. In this study, we synthesize knowledge about the regional geology of the Ghanzi-Chobe belt, previous discoveries, and geophysical magnetic maps and use a random forest machine-learning algorithm to extend the known favorable stratigraphic horizon. Considering environmental, social, and political sensitivities, the Okavango Delta is identified as a no-go zone for exploration activities and is treated as such throughout the targeting process. The resultant prediction raster is combined with a 2D joint inversion of magnetic and gravity datasets to identify 425 kilometers of favourable Sed-Cu stratigraphy along Ngwako Pan-D'Kar contacts. Four wildcat targets in areas of poorly defined stratigraphy that warrant further characterization are also identified. Favourable areas can then be followed up through the application of drilling, geophysical, and geochemical tools that penetrate below the cover. The results show that the target search-space can be reasonably reduced by employing machine learning for dataset integration, despite the challenges produced by the Kalahari Desert.

400 Sedimentary Environments

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**Mapping the hydrothermal dolomitization footprint and supergene alteration associated with Zn-Pb deposits using PRISMA and Sentinel-2 satellite imagery: An Example from the Jabali Zn-Pb(-Ag) ore, Western Yemen** (400-2)

In this study, we have developed a multi-scale workflow based on hyperspectral remote and proximal sensing, focusing on mapping the distribution of the hydrothermal and supergene alteration associated with the Zn-Pb(-Ag) Jabali deposit (Western Yemen).

The Jabali ore is mainly exposed on the eastern flank of a local structural high, known as the Jabali-Majnah paleohorst, situated on the northwestern edge of the Sab'atayn basin, one of the hydrocarbons producing basins of Yemen. The Zn-Pb(-Ag) ore concentrations are hosted by massive, locally oolitic, and bioclastic, partly dolomitized platform carbonates belonging to the Jurassic Shuqra Formation (Amran Group). The economic mineralization, consisting of 12.6 Mt at 8.9% Zn, 1.2% Pb, and 68 mg/kg Ag, is characterized by Zn-bearing nonsulfides, derived from preexisting Mississippi Valley-type (MVT) primary sulfides, still present in minor amounts. The surficial part of the deposit occurs generally in form of outcropping rocks dominated by Fe-oxy-hydroxides of supergene origin (the so-called "gossans"), whereas the Zn minerals lie mainly in the subsurface.

The deposit was analyzed using the spaceborne PRISMA hyperspectral sensor (from the Italian Space Agency). The analysis of satellite data was validated by VNIR-SWIR ASD analyses of rock samples. Mineral assemblages identified from their spectral signatures were verified with XRD-QPA and ICP-ES/MS analysis. Image processing for mineral map production included mainly Relative Band Depth (RBD) and band ratios methods, using specific scalars applied on both the hyperspectral samples data e satellite image products. Ratio images obtained from the processing of PRISMA L2C images were created, resulting in dolomites distribution mapping by enhancing the spectral differences between limestones and dolomites (major features centered at 2,340 nm and 2,320 nm, respectively). The distribution of gossans and alteration products was successfully obtained, instead, using the spectral features of iron-bearing minerals (around 900 nm) and band ratios method.

This study demonstrates that the combined use of satellite-ground-based sources of spectral data may be a powerful exploration strategy for the Jabali ore in Yemen and possibly worldwide, where fieldwork may result logistically challenging and unsafe. Since the PRISMA sensor covers the mineral-diagnostic wavelength regions at hyperspectral resolution and signal-to-noise ratio (SNR) from ≥ 200:1 (VNIR) to >100:1 (SWIR 2), it is able to accurately recognize the earth's surface materials, helping fine discrimination between different geological targets based on their distinct spectral response in each of the narrow bands in the VNIR-SWIR region.

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IN-PERSON

**Predictive lithology mapping using semisupervised machine learning** (500-1)

An ongoing challenge facing the mineral exploration industry is delineating potential targets beyond known mines, boreholes, or outcrops into adjacent underexplored regions where the geology is far less constrained. However, remote-sensing data (e.g., airborne geophysics, satellite imagery) can provide insights across large regions with adequate resolution. The standard approach is for geoscientists to interpret these datasets to improve our geological knowledge in these underexplored areas. While still an essential component of the industry, these manual domain-expert interpretations can introduce a bias and become incredibly time-consuming as datasets grow. Machine learning is an attractive alternative, which can efficiently provide unbiased insights. One popular use for machine learning is predictive mapping; here, remote sensing data are combined with our limited observations on the ground to make lithology predictions for an entire region of interest. These machine learning predictions can produce a starting geologic map or enhance existing geologic maps, thereby improving our ability to identify targets in either case.

Over the past decade, supervised learning (SL) methods have become the common approach for predictive lithology mapping. In essence, SL methods learn a relationship between the co-located remote sensing observations and training targets (e.g., determined lithologies from outcrops) in order to make predictions for where the lithology is unknown. Arguably, the biggest challenge with these problems is that the amount of training data is inherently limited (e.g., minimal outcrop exposure), which can lead to a phenomenon called overfitting; this translates to the SL model generalizing poorly to the data where the lithology is unknown (i.e., the unlabeled data). Semisupervised learning (SSL) is a different machine learning approach that is better designed for these minimal training data situations. The advantage of SSL techniques is that they incorporate all the information (i.e., the training data and all the unlabeled data) during the learning process, which can provide improved predictions compared to SL methods.

We explore the effectiveness of SSL methods using a dataset from New South Wales, Australia, where the geologic map and geophysical data are provided. We simulate multiple exploration scenarios where we vary the a priori knowledge of lithology with each experiment, and the task is predicting the lithology for the rest of the map in each case. Our results show that SSL can be up to 10% more accurate than SL depending on the situation, which means SSL predictions can further reduce our risk when identifying exploration targets.

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**Three-dimensional Multifocusing Imaging of Crooked-line Seismic Profile – A Novel Approach For Exploration Industry** (500-2)

Seismic surveys conducted along severely crooked traverses can provide volumetric images of the subsurface, which can resolve complex three-dimensional (3D) structures and reduce geological modeling uncertainty. However, irregular acquisition geometry with low-fold coverage and uneven spatial distribution of data points adversely affect the resolution of resulting images. We introduce a generalized multifocusing algorithm to generate 3D high-resolution image volumes for crooked-line/3D seismic data with arbitrary survey geometry acquired over complex subsurface geological structures with irregular topography and complicated near-surface condition. The extended method simultaneously corrects for elevation statics, normal moveout, and azimuth-dependent dip moveout effects. This method can be directly applied to seismic data collected over rugged terrain without requiring prior standard elevation statics corrections. We evaluated the performance of the new method on different generic complex synthetic models and a real data set with crooked-line surveys. The numerical tests have shown that the new approximation is significantly accurate for gently to highly curved interfaces beneath low to relatively high heterogeneous overburden with rugged topography, even at large offsets and midpoint separation. Application of the proposed method on the Larder Lake crooked-line transect acquired over complex subsurface geology with rough topography and noisy data environments yielded a high-resolution stack with a high signal-to-noise ratio. Applying the proposed stacking algorithm followed by a 3D post stack time migration approach improved the quality of the image and enhanced interpretation significantly compared to the swath 3D migration method. Also, the proposed workflow imaged steeply dipping layers coherently and identified new reflectors, which are not visible in the swath 3D image cube. The new approach resolved the ambiguity involved in the complex geological architecture of folded structures in the Larder Lake structural basin, which is connected to regional-scale deformation zones. Also, the multifocusing technique provided structural attributes, which can be a great asset in structural interpretation. The experiments show that the proposed method has the potential of exploring high-risk hidden deposits with high confidence.

500 Geophysics

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**Tectonic fabric along the Haida Gwaii margin from receiver function analysis** (500-3)

The western coast of Canada is a geologically complex area, home to a poorly defined triple junction between the Pacific Plate (PA), the North American Plate (NA) and the Explorer Microplate (Ex) lying north of the subducting Juan De Fuca Plate (JdF). To the east, the mainland is composed of a series of juxtaposed exotic terranes that were accreted during Jurassic and mid-Cretaceous translations. The Pacific Coast is also Canada's most seismically active region. In 2012, the Haida Gwaii margin hosted a Mw = 7.8 earthquake with a thrust component, adding to a growing body of evidence that the PA is subducting beneath NA. The goal of this study is to estimate seismic anisotropy (seismic wave-speed variations along different directions of propagation) in the crust to identify dipping structures and/or material anisotropy in the area surrounding the Haida Gwaii margin. Using a combination of permanent and temporary stations we calculate receiver functions (RF) and migrate these to depth using a 1D velocity model followed by a harmonic decomposition over back azimuths. We optimize the first-order harmonic over a series of crustal depth ranges to identify dominant orientations for each depth interval below individual stations. We find signs of dipping structures and/or material anisotropy beneath all stations in the study. At shallow crustal depth, we see a coherent pattern of roughly margin-parallel orientations that persists ~420 km from the margin. We also identify dipping structures beneath the archipelago of Haida Gwaii, under part of northern Vancouver Island, and along the eastern edge of the Alexander terrane in addition to signs of material anisotropy both above and below these depths. These results represent a combination of modern tectonics and fossil fabrics and add to the body of knowledge about the history and current tectonic regime of this geologically complex area.

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**Assessing the geophysical attributes of hydrothermally altered gold deposits using petrophysical logs and geochemical analysis** (500-4)

As mineral exploration activities seek deeper targets, geophysical methods will play a greater role and it will become crucial to comprehend the geophysical responses related to the mineral systems. Understanding how different alterations have changed the physical properties of the rocks cannot be achieved unless a good understanding of the geological, geophysical, and geochemical information is established. Borehole geophysical methods measure the characteristics of minerals that form the rocks. However, minerals consist of several crystals and alterations can change the characteristics of these crystals by adding or removing elements. Mass balance equations can be used to understand the element changes related to metasomatism and relate these changes to petrophysical signatures.

The Rouyn Property is an orogenic gold deposit in the Superior Province of Abitibi Greenstone Belt, and it spans 12 km along the Cadillac-Larder Lake-Deformation Zone (CLLDZ). Gold is mostly found in the rocks from the Piché Group that also are the physical expression of the CLLDZ. These rocks are mostly carbonated schists formed by hydrothermal alteration of mafic rocks (mostly komatiite).

The results of the mass balance analysis allowed us to identify mass gains and mass losses for given elements at each borehole and for specific portions of the Piché. Such variation can correlate with the variation of the geophysical parameters. For example, areas of the Piché group where K+ was gained also display an increase in the spectral gamma ray. In addition, we observed that in sections of Piché that has gained Ca2+, the rock density was decreased. This could be well related to the carbonate alteration of komatiites and its intensity. Carbonate minerals usually have a lower density than minerals forming Komatiites and other minerals formed during alteration (e.g., chlorite and fuchsite). We have also identified areas that probably correspond to the destruction of magnetite from the komatiite by hydrothermal fluids to form pyrite and arsenopyrite and to precipitate gold. We see that this hydrothermal alteration corresponds to variations in the magnetic, resistivity, density, velocity, and IP responses that were measured downhole.

As our work continues, we expect that a good relationship among geophysical, geochemical, and geological data in hydrothermally altered gold deposits will be established and will provide guidance in upscaling these relationships to surface geophysics and mineral exploration.

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500 Geophysics

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ONLINE

**Constraining the folding geometry and structural control of the Saint Lawrence Deposit using resistivity, EM and LiDAR** (500-5)

The Saint Lawrence Deposit is a Wollastonite skarn located in the Central Metasedimentary Belt of Ontario (25km NE from Kingston). This deposit is divided into two blocks. The western block comprises vertical similar folds made of different skarn layers, mainly Wollastonite and Diopside skarns, accompanied by quartzite and massive sulphides.

The skarn units are metasomatized, exhibiting high t° hydrous minerals such as vesuvianite, and are intruded by granitic and gabbroic bodies. Wollastonite has been transported from the limbs to the hinges by flexural slip. This requires a sound understanding of the geometry of the fold to predict Wollastonite rich zones, but has been challenging to accomplish by surface mapping alone due to the amount of cover. In addition, the geology of the eastern block is poorly understood, and hence it is not clear if the folds located in the west continue in the eastern block. To provide additional structural constraints, resistivity, frequency domain EM, LiDAR and drillhole data were employed to improve the knowledge of fold geometry, structural relationship between the blocks and the presence of massive sulfide bodies. Resistivity and EM profiles were deployed perpendicular to the axial plane of the folds, and showed high contrast between the resistive wollastonite layers and diopside layers as they repeated themselves as the profile cuts the fold. LiDAR data shows a clear picture of the extent and shape of the fold on the western block, and a radically different folding style on the eastern side. LiDAR data further reveals a significant displacement between the western and eastern blocks. To explain the discontinuity of the folding, offsets between blocks and fluid pathways of hydrothermal fluids, a dextral strike-slip fault is proposed. As the geophysical data did not reveal any low resistivity zones, the presence of massive sulphide bodies was discarded. This study revealed the relevance of combining geophysical, geological and mineralogical observations to constrain the geometry of a major Wollastonite deposit.

Other

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**IN-PERSON**

**A study of 2020-2021 Mount Etna Paroxysms: A morphological and geochemcial analysis** (600-1)

Mount Etna is one of the most active modern volcanos, located in Sicily, Italy. It has been active over the past 15k years and most notably is responsible for nearby town desecration of Mascali in 1928 and Catania in 1669. More recent and violent eruptions have been observed as of late with eruption episodes lasting days or months and a maximum of 37 days separating each episode. Most recent paroxysms are K-trachybasalt, with few exceptions.

The objective of this project is to study the latest paroxysms from Mount Etna, from the 2020-2021 paroxysmal cycle to determine if the composition has changed from older previously studied samples.

To do this, a total of 12 paroxysmal samples (including ash, lapilli, and lava flow) were collected, with eight being studied in detail. Composite images of these samples have been created using microscopy images obtained with a stage attachment stitched together with FIJI and ImageJ attachments. These eight samples were then carbon coated to be studied by back scattered light with SEM. 3D microtomography was provided for these samples in March, leading to preliminary analysis of bubbles. This data was collected at SYRMEP beamline Elettra Sincrotrone in Trieste, Italy. Major elements were analysed through ICP-OES while Rare Earth Elements (REE) and other trace elements were analysed using ICP-MS.

Using previous data collected from Mt. Etna paroxysms and the SEM geochemistry available, tentative trends are viewed for a depletion in incompatibles, depletion in SiO2 content and a cyclicity to Anorthite content for plagioclase phenocrysts. This data suggests that Mt Etna may be recharging with newer more primitive magma over the past decade. To continue this study, the bulk rock geochemistry will be studied, and the tomographic data will be analysed. Implications of this lead to the preliminary conclusion that this influx of new magma is due to a change in the extensional regime in the Sicilian region.

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**Mixed Methods Approach for Secondary Data Using Survey Reports from an Exploration Industry Database** (600-2)

The rich information acquired from incident and near miss reporting has been studied with high-risk industries and such industries have used statistics acquired from past incident reports to reveal trends to improve occupational health and safety. Therefore, the proposed project aims to understand the specific nature of injury severity reports within Canada's mineral exploration field, to enhance existing occupational health and safety. The proposed research is unique as the data arises from the entire mineral exploration industry, gathered by Prospectors and Developers Association of Canada (PDAC), to represent a group of companies, working across Canada. Data of this magnitude, and on such a long timespan, in this workforce, has never been conducted before. The lack of limited research can be attributed to the fact the mineral exploration field is complex. Mineral exploration has unique health and safety needs that arise due to the nature of the working environment; remote locations subject to extreme weather and terrain, difficulty recruiting skilled workers, lack of available resources, and most efforts conducted by companies with low market capitalization, all contribute to the unique health and safety issues. Mineral exploration is no exception when it comes to the ideology that every workplace needs tailored and individualized approaches to health and safety systems. Although closely linked to mining, it likely requires a different approach from the efforts produced to increase safety in production mining. Determining factors that influence health and safety within mineral exploration are crucial to better understanding safety culture, safety consciousness and the specific needs of this field. The health and safety environment of mineral exploration is unique and multidimensional, and it is pertinent that research be conducted directly within this field to bridge gaps in prevention and practice. The expected outcome for this project is twofold; highlight the health and safety trends in the industry and determine common trends, areas of importance, critical issues, and actionable training suggestions to mitigate risk in the field for workers. This will be done by taking survey data and showcasing points for industry and occupational health and safety advocates through knowledge transfer components, to provide a deeper understanding of the roles and root causes that lead to injuries and fatalities.

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**Sustainable Supply Chains: Transdisciplinary Approach to Supplanting Mercury in Artisanal and Small-Scale Gold Mining (ASGM)** (600-3)

Artisanal and small-scale gold mining (ASGM) is an unmaximized opportunity for socio-economic development. The term ASGM, describes a heterogeneous mining sub-sector with a population of about 20 million people in over 80 countries generally characterized by informality and low levels of mechanization.

The general consensus is that, on balance, ASGM is a net negative despite a half century of targeted efforts by academics, private companies, NGO's, and others. Debate remains regarding the continued causes for the many health, safety, and environmental concerns perpetuated by ASGM. Of particular significance is the continued utilization of mercury which has negative impacts on global health/well-being. Mercury is a potent neurotoxin which can be used to separate gold from waste.

This project is testing the hypothesis that ASGM actors are rational agents who are more interested in earning an income than adhering to the status quo of using mercury to concentrate gold. Additionally, the project is seeking to understand how increased demand for transparent and sustainable gold supply chains can fuel mining engineering research. This is being completed by leveraging burgeoning consumer demands for sustainability to fund geometallurgical research on mercury alternatives for ASGM. As a pilot, the methodologies are being deployed with two ASGM cooperatives in Anenea District Peru. Although more remains to be discovered, the results indicate these miners act as rational agents which some may classify as entrepreneurial, Ananean ASGM have relatively few resources to evaluate the efficacy of mercury alternatives, and there is opportunity to scale this type of sustainable supply chain model.

To date, this project has helped to create the infrastructure necessary to scale a feasible program for artisanal and small-scale gold miners to better identify and implement more effective mercury alternatives. This is the first step towards maximizing the opportunity for ASGM to act as a driver of positive socioeconomic development and brings greater clarity to the best methods for catalyzing that transition.

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**The determination of oxidation rates of pyrite and marcasite for acid mine drainage and mineral waste solutions** (600-4)

Minerals with high sulfide content such as pyrite (FeS2) and marcasite (FeS2 polymorph), along with the interaction of H2O and bacteria, are the main driving force in mining sites for acid mine drainage (AMD) and other environmental damage. The following closed system oxidation experiments done on pyrite and marcasite to confirm oxidation leach rates and to find the rate laws of oxidation lead to a better understanding of how these mineral solutions may interact in tailings ponds. The experiments were done on pure pyrite and marcasite and then compared to experiments done on natural site samples of these minerals. The indication of a galvanic cell forming from the interaction of these minerals suggests faster oxidation than when they are separated, meaning there should be changes in best practice of how minerals are treated in tailings facilities to prevent / limit AMD.

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**Assessment of arsenic distribution and speciation in lake sediment samples at the Yellowknife City Gold Project, Northwest Territories, Canada** (600-5)

The Yellowknife City Gold Project (YCGP) encompasses a 791.6 km2 property near the city of Yellowknife, Northwest Territories, Canada. It is located in the southern part of the Yellowknife Greenstone Belt (YGB). The YGB is a metavolcanic sequence that is intruded by felsic bodies and unconformably overlain by a conglomeratic package. At the YCGP, gold is associated with pyrite and arsenopyrite and mining activities may increase the mobility of arsenic in mine-influenced environments such as lake sediments. Arsenic is an element of concern at the YCGP, due to the historical release of thousands of kilograms of arsenic trioxide particulates to the atmosphere by nearly a century of gold mining activities. The presence of arsenic in the form of arsenite (As3+) is challenging, due to its bioavailability and mobility. This study aims to monitor the spatial distribution and speciation of As at the YCGP to identify the source of As anomalies (geogenic or anthropogenic) and design methodologies for long-term environmental compliance. To achieve this objective, a lake sediment sampling program was conducted across the property. To assess the distribution pattern of arsenic, statistical analysis, including the robust inverse distance weighted (IDW) interpolation method, was applied to a dataset of 433 lake sediment samples. The IDW interpolation results indicate that arsenic is highly enriched over the major shear zones (up to 1000 ppm) that are a dominant host of pyrite and arsenopyrite. Also, higher As values were identified in samples collected over metavolcanic and metasedimentary rocks more so than felsic intrusions. Therefore, a geogenic source (weathering of bedrock) is the main factor contributing to arsenic enrichment in these areas. To identify As speciation, 18 lake sediment samples were analyzed using the X-ray absorption near edge structure (XANES) spectroscopy at the 20-ID beamline, Advanced Photon Source, US. This experiment was conducted by examining the behaviour of the near-edge spectrum of arsenic and comparing it with the spectra of 5 well-characterized standards. XANES data indicated that arsenate (As5+) is the predominant arsenic species in sediment. Also, mixed oxidation states including As2+-As5+ and As3+-As5+ were identified that can be modelled as a combination of arsenite- and arsenate-containing compounds in lake sediment samples. The coexistence of reduced and oxidized As species may have important implications when it comes to bioavailability and long-term stability. However, additional petrological and geochemical studies are required to reveal the mineralogical association and the possible anthropogenic sources of As3+. The result of this study assists in monitoring the concentrations of As and identifying the geochemical processes that occur during As transportation and sedimentation in lakes.

Other

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**Taxing Taxonomies of Taxes: regulations, standards, initiatives etc.** (600-6)

In natural resource extraction, mineral mining corporations are frequently made out to be the negligent party. These corporations are often accused of not paying government taxes, mistreating local communities, and destroying the environment. This is not fair. In Canada, more challenging is the fact that such corporations have historically been granted special favours; for example, mining corporations often owe a lower percentage of taxes than many others. That they pay less, is not a corporation's fault. It does not make them 'wrong' or 'cheating their taxes.' Further, adding little expenses miscellaneously, taxes, does not amount to increasing their corporate social responsibility (CSR). Such actions minimize the overall expectation of such responsibility and reduce it to a money-grab, ignoring the actual benefits to which actual CSR can contribute. This is a political challenge.

My dissertation will address concerns of Canadian governance, fiscal and regulatory responsibility within the mineral and metal mining sector of the extractive industry. Specifically, this study will focus on Canadian mineral mining corporations and their activities in specific regions of Canada, noting the comparative difference with respect to federalism. Fiscal regulation and tax revenue collection from multinational corporations operating in the mineral mining sector, has become notably precarious. Since the beginning of the second millennium, the payment and collection of taxation, among other fiscal regulations, have become the focus of transparent international corporate responsibility.

Financial interdependence highlights the necessity of scholarship into the political and economic proclivity of countries and corporations to pursue anti-transparency measures with respect to extractive resource revenue. The Extractive Industry Transparency Initiative (EITI) functions among states to encourage extractive fiscal transparency. While corporations and individual states are encouraged to join and become compliant with the global initiative, EITI- inclusiveness omits sub-state governments. In Canada, many natural resources are regulated by sub-state (provincial) governments. Ideally, such initiatives, legislations, agreements, and standards, exist to make opaque operations of extractivism transparent. These additional regulations, while intended to reduce illegal activity, direct money to less-developed-country governments and their populations, also increase the expenses of extractive corporations.

Although Canada federally legislated the Extractive Sector Transparency Measures Act (ESTMA) to address EITI challenges, the now-more-expensive products and activities are not contributing to saving any government, corporation, or population more money. A single standard is needed. The efficacy of such initiatives as the ESTMA, or global EITI, need to be assessed to determine their regulatory value. Better, fair, regulation is required.

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**A tool for the exploration of undercover ore deposits: Laser ablation ICP-MS method for the in-situ measurement of element contents and Pb isotope ratios on fracture coatings in drill cores** (600-7)

Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) for in-situ measurement of element concentrations and isotope ratios in geological samples is a powerful tool that has allowed for increased analytical sensitivity and spatial resolution. Several recent studies have demonstrated the use of fracture coatings in mineral exploration but require laborious removal and acid digestion of fracture coatings. With this in mind, element contents and Pb isotope ratios in fracture coatings were measured for samples from the McArthur River unconformity-hosted uranium deposit, Athabasca Basin, Canada using image mapping LA-ICP-MS to establish an in-situ method for analyzing the chemistry of fracture coatings. Classifying the chemical composition of fracture coatings above ore deposits is a useful proxy for mineral exploration, as fractures provide permeable fluid pathways for element dispersion from ore deposits into the surrounding rocks and overburden. The development of an in-situ method of analyzing the chemical composition of fracture coating, allows for the study of fracture coatings to be applied to a wide range of geological environments and deposit types, especially where fracture coatings are insufficient for acid digestion methods.

High resolution compositional maps of mounted fracture coatings from backscattered electron (BSE) imaging show varying topography and mineralogy on fracture coatings including Mn and Fe oxide, clay, silicate, and carbonate minerals. Areas of interest (~500 by 500 µm) were targeted in a cell spaced grid pattern using a 50 µm spot, with 200 µm spacing between spots and 100 µm between lines using an ESI-NWR Eximer 193 nm ArF Laser Ablation System interfaced to a quadrupole ICP-MS. Rasterized maps generated in Iolite™ effectively demonstrate the chemical distribution of element contents and Pb isotope ratios on the fracture coatings allowing for the chemical mapping of minerals. Sample spacing, depth of laser penetration and reproducibility were varied in this study to develop optimum parameters for in-situ fracture coating analysis to overcome sample surface topography and more rapid sample acquisition time without loss of spatial resolution and analytical sensitivity. Bulk geochemical values can be calculated using an integration of 2D image data and is compared to different fracture coating acid digestion methods (i.e., aqua regia, weak acid leach) and the implications to exploration programs is discussed. This is the first application of using LA-ICP-MS for measuring element concentrations and Pb isotope ratios in-situ on fracture coatings and demonstrates the importance as a new geochemical tool to the mining industry for future mineral exploration.

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**Analysis of magmatic productivity at the Rochambeau Rifts, northern Lau back-arc Basin** (600-8)

The Rochambeau Rifts are a series of 'en echelon' back-arc spreading segments located in the northwestern Lau Basin. They exhibit fast spreading rates (~110 mm/yr) and effusive volcanism. Recent marine expeditions to the area have mapped a prominent axial volcanic high in the southern rift segment ('Lobster Caldera'), while dense arrays of off-axis volcanoes occur among the northern rift segments indicating significant intraplate volcanism. To better characterize the volcanism and to quantify the crustal accretion in this region, we prepared a geological map

Other

at 1:200,000 using remote predictive mapping (RPM) approaches based on high-resolution marine geophysical and acoustic data compiled from the recent surveys in the area. Roughly 2500 volcanoes and 1600 lineaments were mapped, in addition to several formation types that are assigned based on crustal type, structure, composition and age. Nearly 70% of the mapped volcanoes belong to widespread volcanic flow fields that display high acoustic backscatter intensities, suggesting that a majority of the volcanoes are unsedimented and therefore young. Overlapping fabrics and high fault densities associated with the active rift valleys imply high crustal permeability, which may have provided melt pathways. Large-scale stresses produced in response to spreading center adjustments and microplate rotation may be responsible for generating the complex mantle flow patterns beneath the area contributing to enhanced magmatic productivity. Diverse geochemical signatures obtained from dredge samples along the active rift valley in the northern region (recovered during the SS07/2008 voyage of the R/V Southern Surveyor) indicate complex mantle input beneath the area, including mixing of a MORB-like and an enriched OIB-like melt, associated with the hot and nearby Samoan mantle plume. These influences may be similar to well-endowed ancient greenstone belts in which there is a close relationship between magmatic productivity, crustal permeability, and mineral endowment. We further suggest that certain areas within the Rochambeau Rifts may contain many of the crucial components necessary for, as of yet undiscovered, Seafloor Massive Sulfide (SMS) deposits. This is Metal Earth Contribution MERC-ME-2022-04.

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**A geological map of the Monzier Rift and Eissen Spreading Centre, North Fiji Basin: controls on arc rifting and related volcanism** (600-9)

Intra-oceanic arc rifts are important settings for VMS deposits, due to the presence of a long-lived heat source, and deeply penetrating structures that transport metal-rich fluids through the crust. However, the mechanisms by which arc rifts initiate and evolve, particularly in oceanic settings, are poorly understood. The Matthew-Hunter region in the southern North Fiji Basin (NFB), SW Pacific, is a present-day setting where the processes that control subduction initiation, arc rifting, and related-volcanism can be directly observed. Here, the southward-propagating Eissen spreading centre has intersected remnant Vitiaz arc crust, inducing a deflection and reorientation of the propagating tip, that is now actively extending as the oblique, east-west Monzier rift. To better understand how arc rifts develop, a new 1:1,300,000 lithostratigraphic assemblage map of the Monzier Rift and Eissen Spreading Centre is presented. It was constructed using remote predictive mapping (RPM) techniques incorporating high-resolution ship-based multibeam, gravity, and magnetic data. Seafloor images and groundtruthing samples were also used to verify the map and develop the legend. Formation-level geological units were identified in training sets at scales of 1:75,000, and then used to interpret areas where geological data are sparse. Structures including major faults and spreading centers were also mapped. Analysis of the map suggests that the Monzier Rift is rifting relict Vitiaz arc crust and has connected with the newly formed Matthew and Hunter subduction zone in the south. The map can be subdivided into three assemblage types: back-arc crust, relict arc crust and intraplate volcanoes. The most extensive assemblage is the back-arc crust of Eissen Spreading Center, followed by the relict arc crust of the Monzier Rift. Volcanic ridges and seamounts of the Monzier Rift range from cone-shaped volcanoes up to 3 km in diameter and fissure volcanoes from 1 to 18 km in length, most of which are elongated in a NNE-SSW direction. Samples analysed from recent dredges on the RV Southern Surveyor (2004, 2006, 2009) and the RV Akademik Nesmeyanov (1990), presented in Patriat et al.

(2019), confirm a diverse geochemistry, including boninites, adakites, and back-arc basin basalts (BABB). The relict back-arc crust in the Monzier Rift may be eventually incorporated as a 'proto' fore-arc of the nascent Matthew and Hunter subduction zone as suggested by other studies. The rifting and melting of pre-existing, hydrated (volatile-rich and fertilized) arc crust, in proximity to a newly developing subduction zone, may create favorable conditions for significant SMS formation and could be used as an analogue for ancient VMS deposits on land.

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**ONLINE**

**HFSE enrichment in Bükk Mts., NE-Hungary – Geochemistry and mineral composition** (600-10)

In the Bükk Mts, NE-Hungary, formerly unknown rare earth element (REE) – Nb – Zr – Th - Ta enrichment was found recently. Two main enriched areas exist – at the SE and NE part of the mountain – both along fault zones. The enriched rock bodies are Triassic metavolcanics and siliciclastic metasedimentary rocks, and they are embedded in non-enriched carbonate rocks. The elements enriched belong to the group of high field strength elements (HFSE), which are usually stable during the processes of metamorphism and weathering, and their enrichment is connected to carbonatites and alkaline magmatism. In the Bükk Mts. there is no known magmatic source, but based on our results the enrichment has a metasomatic origin. It is proved by the micrometric grain size and textural position (disseminations and nests, pseudomorphs) of the alteration minerals.

Chemical composition of the samples was analysed by ICP and XRF. The enrichment factors of the HFSEs are significant (REE: 5-10, Zr: 2-19, Nb: 12-16, Th: 3-10-(30), compared to the upper crust.). All the enriched samples are characterised with a negative Eu-anomaly, and with increasing HREE/MREE ratios with increasing total REE content. P and Ti are depleted during the alteration process. The enriched rock bodies are always K-rich compared to the unenriched rock bodies.

Mineral composition was analysed by optical microscopy, XRD and electron-microprobe (SEM+EDX). The rock forming minerals are feldspars (albite and different potassic feldspars), dioctahedral phengitic micas, quartz and calcite. Other important minor and accessory minerals are the various Fe- and Ti-oxides, biotite and apatite, while the rare element bearing minerals are zircon, REE-phosphates (most probably monazite-(Ce)), Nb-bearing Ti-oxides and occasionally Ca-REE-Ti-Nb-oxides and REE-carbonates. These minerals were only detectable by electron-microprobe, due to their small grain size and low abundance.

Our results show that samples with higher mica and feldspar content have higher HFSE content, while calcite-rich samples are less enriched. Some minerals disappear during the alteration process (albite, chlorite and partly Ti-oxides and apatite), while others are generated (new micas and potassic feldspars, rare element bearing minerals). The results suggest that the mineralization was caused by alkaline fluids penetrating across the fault zones.

Other

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**Potentially the largest unexploited 'invisible' gold resource hosted in detrital pyrites of the Witwatersrand tailings dumps** (600-11)

The Witwatersrand Basin is the world's largest gold province hosting over 53 000 tons of native Au predominantly in quartz pebble conglomerates. The Witwatersrand gold tailings dumps are subjected to secondary mining operations which involve traditional extraction techniques (further comminution and cyanide leaching) that lead to 30-50 % recovery of gold missed by the historical beneficiation. This leaves a projected 1325-1855 tons of refractory gold together with an estimated 30 million tons of sulphide material which reports to the discard stream after secondary mining. The mineralogical deportment of this remaining or refractory gold is not well constrained. The study is a dedicated gold deportment and ore characterization of 47 kg composite Witwatersrand tailings material from the Klerksdorp and Carletonville Goldfields. The tailings material is subjected to a modified pre-concentration to define density fractions. The analysis involves optical microscopy, X-ray powder diffraction, quantitative evaluation of materials by scanning electron microscope, fire assay, aqua regia digestion, inductively coupled plasma mass spectrometry and laser ablation inductively coupled plasma mass spectrometry. Results from the analyses indicate that about 80,16 % (2,42 g/ton) of gold is distributed in the heavy mineral concentrates which are predominantly made up of silicates (44,15 %), sulphides (35,12 %) and oxides (20,12 %). Detailed in situ analyses suggest the gold in the concentrate fraction is 'invisible-' or 'solid-solution' gold hosted predominantly in pyrite and arsenian pyrites, Au grades range from 0,11- 48,69 g/ton. Given that the Witwatersrand Goldfield is historically a native gold deposit, identification of invisible gold in detrital pyrites (stable under Archean surface conditions) represents a potentially under-exploited resource which explains the refractory nature of the 50-70 % Au remaining after secondary mining. The implications of these findings for the economics or tailings remaining and for the genesis of the Witwatersrand goldfields will be discussed.

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**Comparison of critical mineral and element content of black schists from NE-Hungary** (600-12)

Critical raw materials play an ever-growing role nowadays. For instance, 30 critical raw materials are included on the EU's list of Critical Raw Materials published by the European Commission in 2020. In our study, we focus on these critical elements: natural graphite and geochemically related elements of graphitization (titanium, niobium, vanadium, strontium and rare earth elements). Our aim was to examine in detail two Hungarian occurrences and to compare them.

The first occurrence is Dédestapolcsány (Rágyincs Valley, Uppony Mts.), exposing the Tapolcsány Formation (Silurian, deep sea facies). The collected samples are black colored, intensely deformed and fine-grained schistose siliceous black schists. The second occurrence is Szendrőlád (Szendrő Mts.), exposing the Szendrőlád Limestone Formation (middle-late Devonian, basin facies). The examined samples are intensely deformed black schists from the Szendrőlád-6 drill hole (from 278-295 m depth) and from surface outcrops along the valley of Helle creek.

The samples were investigated with polarizing petrographic and ore microscopy (OM), scanning electron microscopy (SEM-EDX), X-ray powder diffraction (XRD), X-ray fluorescence spectrometry (XRF), inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectroscopy (ICP-AES). In addition, a structural geology survey was also carried out in the Rágyincs Valley.

According to our results, all the samples have metamorphic texture. As the main Ti mineral, anatase and rutile are often found in the deformed zones with low Nb and V content. Vanadium also occurs in mica plates (muscovite, muscovite with Na and phengite). Maximum V content is 957 ppm for Dédestapolcsány and 843 ppm for Szendrőlád. As REE-containing minerals, xenotime and monazite-(Ce) grains can be found. Goyazite-gorceixite mixed crystals with low Ce and Nd content occur in the samples from Dédestapolcsány, while REE-carbonates (bastnäsite-parisite mixed phases) can be observed in the samples from Szendrőlád. As a Zr-bearing mineral, zircon is also frequent in the samples from both occurrences.

Graphite can be found as µm sized flakes scattered in the matrix and as 100-300 µm sized grains (with low S content) arranged in the direction of deformation in the case of Dédestapolcsány. Regarding the samples from Szendrőlád, graphite (also with low S content), appears as 20-50 µm sized flakes arranged in >300 µm aggregates. By XRD, graphite cannot be detected directly on the curves due to its low quantity and heavy peak overlapping with quartz peaks. However, its direct quantification is possible by Rietveld refinement: 2.1-3.9 weight% for Dédestapolcsány and 1.5-3.0 weight% for Szendrőlád.

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**Classification of pyrite LA-ICP-MS maps using machine learning tools** (600-13)

Pyrite LA-ICP-MS mapping has become a common technique for the study of pyrite in ore deposits, since pyrite textures and trace element compositions provide unique insights into the evolution of its host ore system. In this regard, a relatively unexplored aspect is the statistical classification of new pyrite compositional maps based on the direct use of previously established compositional "libraries" for specific pyrite types. Correct classification of pyrite is especially important in the context of mineral exploration, to detect specific pyrite generations associated with economic mineralization, or to compare new pyrite data with well-known indicative pyrite groups in a mining district or described in the academic literature.

In this study we explore a method for the classification of pyrite compositional maps using the Random Forests machine learning technique. For this purpose, we considered pyrite LA-ICP-MS maps from the Colosseum Au deposit, southern California. Gold mineralization here is closely associated with pyrite. We used pyrite LA-ICP-MS maps representative of the two main pyrite generations in the Colosseum mine, which are (1) early pyrite, characterized by coarse, euhedral crystals (>500 µm); and (2) late pyrite, characterized by aggregates of finer-grained euhedral crystals (<150 µm). These have been defined through detailed petrographic observations.

Before classification, we improved on the definition of the pyrite generations already described in the Colosseum Au deposit through the unsupervised clustering of the individual pyrite compositional maps. This ensures that these pyrite generations are defined in a statistically robust way. Two main pyrite generations were identified using this statistical approach, which broadly correlate with the early pyrite-late pyrite textural definition. Also, a third transitional group was defined for clusters that cannot be confidently assigned to a group. These are the classes used for Random Forests model training.

Our preliminary classification results using the Random Forests approach suggest that the main pyrite generations in the Colosseum deposit can be correctly classified in most cases, and the obtained classified maps are petrographically meaningful. Conversely, the transitional pyrite generation is the most difficult to correctly classify, as expected considering how it was defined. These results will be corroborated by considering more compositional maps in the future.

These preliminary results suggest that the supervised classification of pyrite LA-ICP-MS maps can provide reliability on the interpretation of new maps, where pyrite generations are well constrained. This highlights pyrite LA-ICP-MS maps as a potential routine tool for exploration in new and already consolidated mining districts.


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