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# Atlantic Geoscience Society Abstracts: 49th Annual Colloquium and General Meeting, February 3 and 4, 2023
# Résumés de l'Atlantic Geoscience Society : 49e colloque annuel et assemblée générale, 3 et 4 février 2023

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# Atlantic Geoscience Society

# ABSTRACTS

*49th Colloquium & Annual General Meeting 2023*

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Truro, Nova Scotia

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The organizers and all AGS members were saddened to learn of the sudden passing of Alan Stuart Ruffman. He was a marine geologist, civic activist, disaster historian, and long-time member of AGS. Alan died peacefully at his home in Halifax on December 28, 2022, at the age of 82. He will be greatly missed as a passionate member of the society, especially his input on better ways to run the society. As a result, Alan, posthumously received the AGS Distinguished Service Award (Laing Ferguson Award) in recognition of his exceptional and altruistic contributions to the Atlantic Geoscience Society and to fostering the public appreciation of Atlantic geoscience over a long period of time.

The 2023 Colloquium & Annual General Meeting was held at the Inn on Prince, Truro, Nova Scotia, on February 3rd and 4th. On behalf of the society, we thank Colloquium organizers Denise Brushett, Lynn Dafoe, Rob Raeside, Deanne van Rooyen, and Chris White, as well the numerous student volunteers and judges, for facilitating an excellent meeting with over 90 submitted abstracts and close to 200 registrants. AGS acknowledges support from the corporate sponsors and partners of the meeting: Nova Scotia Department of Natural Resources and Renewables (Geological Surveys Branch), New Brunswick Department of Natural Resources and Energy Development (Geological Surveys Branch), Geoscientist Nova Scotia, Engineers and Geoscientists of New Brunswick, Acadia University (Department of Earth and Environmental Science), Saint Mary's University (Department of Geology), Prospectors and Developers Association of Canada, and Atlantic Geoscience.

In the following pages, we are pleased to publish the abstracts of oral and poster presentations from the meeting on a variety of topics. Best undergraduate and graduate student oral and poster presentations are recognized and indicated by an asterisk in the title. The meeting included eleven sessions: (1) Same coin, two sides: unifying conservationist values with mineral

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production needs in navigating the crises of the Anthropocene; (2) Marine and coastal geoscience for sustainable development; (3) Environmental geoscience; (4) New developments in the study of igneous systems and associated critical mineral deposits in the northern Appalachians; (5) Palaeontological and sedimentological advances in Maritimes geology; (6) Showcase of developments, programs, and research that promotes education in the Earth sciences; (7) Gold in the northern Appalachians; (8) Tectonic interactions of Appalachian-Caledonide terranes and their host continents; (9) Geoscience communication; (10) Terrestrial and seafloor surface processes and climate change; and (11) Mineral deposits. Also included with the conference was a full-day certification course on the use of the portable XRF by Dave Lentz (UNB) and Claude Bureau (Imdex Limited).

After two years of pandemic restrictions, the traditional Saturday evening banquet was held in person, at which the society announced the winners of the student poster and paper awards, and the recipients of the Nelly Koziel Award, the Laing Ferguson Distinguished Service Award, and the Gesner Medal. The student award winners are noted at the end of the appropriate abstract. The guest speakers at the banquet were Ian Spooner and Terry Matheson who jointly gave an entertaining talk entitled "The Truth about Stories" about exploits in northern British Columbia and their experiences on the set of "The Curse of Oak Island".

Although the abstracts have been edited as necessary for clarity and to conform to Atlantic Geoscience format and standards, the journal editors do not take responsibility for their content or quality.

THE EDITORS

## Using bench-top micro-XRF to characterize alteration systematics and critical mineral potential of Metasomatic Iron Alkali Calcic (MIAC) systems along the Cobequid–Chedabucto Fault Zone, Nova Scotia, Canada

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Metasomatic Iron and Alkali Calcic (MIAC) systems host various critical mineral deposits globally and form via metasomatic hydrothermal processes that pervasively replace host rocks through a predictive sequence of alteration facies. These alteration facies range from barren high temperature (HT) Na facies to HT Ca–Fe facies (amphibole and magnetite) that have potential to host Iron Oxide Apatite (IOA) deposits, to HT K–Fe facies (biotite and/or K-feldspar with magnetite) and low temperature (LT) K–Fe facies (K-feldspar and/or muscovite with hematite) that have potential to host magnetite to hematite-type Iron Oxide Copper Gold (IOCG) deposits. The metasomatic Fe-oxide deposits commonly have enrichments in various critical minerals such as Co, Cu, Mo, REE, and U. Although Fe-oxide deposits are typical of MIAC systems, other variants such as Fe-carbonate (e.g., siderite, ankerite), Fe-silicate (chlorite), and Fe-sulphide (pyrrhotite, pyrite) deposits are also now recognized.

Regional mapping paired with whole-rock geochemical analyses are powerful tools in discriminating MIAC alteration facies and their regional distribution for mineral deposit exploration. However, overprinting alteration facies can complicate the interpretation of geochemical data. Here, we apply micro-X-ray fluorescence elemental mapping and quantitative analyses to samples of metasomatic iron deposits (Bass River, Mount Thom, Copper Lake, and College Grant) from the Cobequid-Chedabucto Fault Zone (CCFZ) in Nova Scotia to (i) demonstrate the use of micro-XRF in spatially resolving geochemical data of multiple overprinting alteration facies and (ii) investigate/characterize the alteration systematics of critical mineral occurrences along the CCFZ. Additionally, these results will be compared to similar MIAC systems in Canada and globally.

## Environmental baseline survey of lipid membranes in deep marine sediments of the Scotian Slope, Canada

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Continuous deposition of organic matter from multiple sources coupled to high sedimentation rate makes continental margins ideal areas for organic matter burial and preservation. Sediments in marine environments harbor microorganisms from three domains of life: Archaea, Bacteria, and Eukarya and their taxonomic composition and abundances are controlled by physical and chemical properties of the environment. The complex cellular membranes of these organisms are composed of intact polar (IPLs) and core lipid (CL) that can be used for taxonomic reconstruction. We hypothesize that microbial lipid assemblage of shallow surface Scotian Slope sediments reflect geochemical environmental condition of the ocean floor including hydrocarbon seepage. In this study, a comprehensive identification and quantification of membrane lipids of the Scotian Slope has been produced by focusing on archaeal and bacterial IPLs and CLs. A detailed profiling of the abundancy and diversity of microbial lipids is produced to resolve the natural microbial community composition and environmental factors controlling their distribution. We are analyzing 74 sediment samples from 32 piston and gravity cores collected from upper 8 m of oceanic surface sediments across an ~500 km-long area reaching over 3 km water depth from four cruises between 2015–2018, using high-resolution ultra-high performance liquid chromatography–quadrupole time of flight mass spectrometry. A rich diversity of lipids including 50 archaeal and 65 bacterial and eukaryal lipid classes has been detected. Their distribution pattern and diversity change by sediment and bathymetric depth and hydrocarbon seep sites have unique lipidome compared to ambient sediments. The majority of lipids extracted from Scotian Slope sediments sourced from organisms living within the sediments and are independent of detrital organic matter loading. Primary results reveal hydrocarbon seeps impact bacterial and eukaryal lipid assemblage of the sediments more than archaea. These lipid classes may therefore mark indirect indicators of hydrocarbon seepage.

## The origin, timing, and style of copper mineralisation at College Grant, Nova Scotia, Canada

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As Canada moves away from carbon-based energy sources, the need for critical minerals and elements such as copper will significantly increase. Copper mineralisation is known to occur along the Minas Fault Zone (MFZ) in Nova Scotia. The mineralisation is part of a structurally controlled hydrothermal system along the MFZ. College Grant in Avalonian Nova Scotia was historically mined for copper and was initially interpreted to be a porphyry deposit. More recently, new evidence suggested that it has more of an iron oxide–copper–gold (IOCG) affinity; a relatively new deposit style that can be explained through the metasomatic iron and alkali-calcic (MIAC) model. Mineralisation is hosted in Silurian siliciclastic rocks and the College Grant pluton, a gabbroic intrusion dated at ca. 340 Ma by U–Pb apatite and titanite methods. Intense albitization is typical of many IOCG deposits; however, micro-XRF mapping shows only minor albitization and little Ca movement out of the mafic minerals. SEM–MLA mineral mapping shows replacement textures between hematite and titanite, and previously unrecognized minerals such as magnetite, ilmenite, and sphalerite. The copper mineralisation is associated to quartz–carbonate veining, hematite, and is surrounded by greenschist facies metamorphism. The alteration mineral assemblage associated with the Cu mineralisation is albite, chlorite and actinolite. Mineral chemistry, such as Ni/(Cr+Mn) vs Ti+V from hematite suggests concentrations more typical of skarn deposits. Stable isotope (O, C, and S) data from quartz, calcite, hematite, and chalcopyrite suggest both the ore and alteration fluids may have sedimentary and/or meteoric origin, supporting the idea that the hydrothermal alteration was shallow and structurally controlled. Therefore, copper mineralisation at College Grant may not be an IOCG deposit, but instead a skarn deposit that likely formed coevally with emplacement of the gabbroic pluton during prolonged movement along the MFZ.

## Regional mapping and qualitative petroleum resource assessment of the Magdalen Basin, Gulf of St. Lawrence, Canada

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The Geological Survey of Canada conducted a broad regional study of the Magdalen Basin in the Gulf of St. Lawrence, as part of the Marine Conservation Targets initiative. MCT is a national initiative to protect more of Canada's offshore areas, and resource assessment and related regional mapping are part of the review process. This study assembled a large seismic and geologic database that allowed new regional mapping of several key horizons in this basin. Digital seismic data was donated by industry, and reprocessing undertaken both in-house

and with contractors. Wells were correlated and tops from literature were used to identify regional reflection packages. Regionally consistent two-way time interpretations add to confidence. Depth conversion used regional time–depth functions from literature, which were developed from refraction data, with a residual correction for the water column. Nine regional depth maps and eight isopach maps were produced, including pre-Horton Basement, Horton Group Isopach, Base Windsor Group, Top Salt, Top Bradelle Formation, Bradelle/Cumberland Isopach, and Top Cable Head Formation. These maps illustrate that the pre-Horton basement is about 15 km deep in the centre of the basin. Two main trends are visible in the Horton Grabens, which may relate to basin formation, and no significant reactivation of deeper Appalachian structure is observed. In the basin centre, the more robust Base Windsor Unconformity horizon reaches about 12 km deep, and a key reservoir and source sequence in the Bradelle Formation reaches 7 km. These maps are useful for considering regional stratigraphy. The new mapping also constrained basin models and became the input for our Qualitative Petroleum Potential map. Basin modelling reveals scenarios where oil may be preserved. The petroleum potential of the region is highest north of Îles de la Madeleine and southeast of Îles de la Madeleine and northwest of Cape Breton Island, Nova Scotia.

## REY mineralization in the Late Devonian Mount Pleasant Fire Tower Zone W–Mo–Bi deposit, SW New Brunswick, Canada

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The Fire Tower Zone (FTZ) at the Mount Pleasant deposit is associated with subvolcanic granitic intrusions in the Late Devonian Mount Pleasant Caldera Complex. High-tonnage, low-grade, W–Mo–Bi ore bodies and limited-tonnage, high-grade Sn–Zn–Cu–In ore zones are related to early (Gr-I, a fine-grained granite) and later (Gr-II, a granite porphyry) stages of the Mount Pleasant Granitic Suite, respectively. The distribution of rare earth elements (REE) and yttrium (collectively referred to as REY) were characterized for the different styles of FTZ mineralization utilizing whole-rock geochemistry, micro-X-ray fluorescence (μXRF), and shortwave ultraviolet (UV) light. Ore zones are characterized by high concentrations of fluorine and yttrium (up to 7% and 5444 ppm, respectively) with average $La/Yb_N$ = 5.11, Eu/Eu* = 0.12, Ce/Ce* = 1.10, Y/Y* = 1.16, Th/U = 2.33, and Zr/Hf = 23.06. Chondrite-normalized REE patterns in the causative intrusion and the ore zones are generally similar (e.g., pronounced negative Eu anomalies and flat bird wing-shaped REE pattern). The REY-rich phases (e.g., fluorite, monazite, xenotime, zircon, rutile, and titanite) are strongly associated with moderately altered wolframite + molybdenite + loellingite + bismuth mineralization and are most prevalent in the breccia matrix. Fine- to medium-grained (100 μm to 2 mm diameter) oval-shaped monazite and anhedral to euhedral medium- to coarse-grained fluorite (up to 3 cm across) are widespread throughout the ore zones. Based on μXRF analysis, these minerals contain elevated LREE + Y, some HREE (including Gd, Dy, and Er), and anomalously high W, Bi, and As. The enriched yttrium contents of fluorite and prismatic zircon were identified by utilizing shortwave UV and μXRF. Ferberitic wolframite exhibits higher contents of Eu and HREE (e.g., Tb, Er, Yb, and Lu). The second mineralizing stage lacks noticeable REY enrichment. REY-bearing minerals were remobilized and depleted because of the comparatively higher alteration ratios and were subsequently reprecipitated along the later veinlets. Therefore, the first stage of mineralization associated with Gr-I has the highest potential for REY at the FTZ.

## Who done it? The mystery of the giant Goldenville groove casts

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The Meguma terrane is home to the Cambrian metasandstone-rich Goldenville Group. These turbidite packages show many sedimentary structures including flute casts, sand volcanoes, and large enigmatic groove casts. One such occurrence of these large groove casts is located near Fall River, Nova Scotia. The origin of these large groove casts is currently unknown but given the consistency in size and shape of the grooves, we speculate that they may have originated from a biogenic source. One example is a large organism being dragged across the sediment surface during

a gravity flow. Analysis of the structures is complex because the rocks of the Goldenville Group are deformed, and the sedimentary structures are strained. Reversing strain is an important step in interpreting the origin of the large groove casts. One method to identify strain ellipse orientations and ratios is to examine sedimentary structures, such as equant sand volcanoes and circular and meandering trace fossils, and then apply an inverse strain value to the groove casts. A 3D model of the groove casts created using photogrammetry software will then be compared to various large objects or organisms that were present in the Cambrian to find a potential match for the groove casts. The results of this investigation have implications including the size and abundance of animals from the Cambrian in Nova Scotia.

## Life cycle of the North American geoblog

Callan Bentley

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Here, we examine the birth, embryology, larval stage, and maturation (and perhaps senescence?) of a representative North American geology blog ('geoblog'), *Mountain Beltway*. How are blogs born? How do they develop through time? What good are they? Familiarity with the milestones and hallmarks of this particular effort can provide long-term context of the motivations, logistics, reactions, accolades, and endurance that relate to providing engaging geoscience content in an informal, personalized setting online. Author Callan Bentley began geoblogging in late 2007 and continues to this day—15+ years of experience writing first *NOVA Geoblog* and then *Mountain Beltway*. There are two principal benefits to geoblogging; (1) it provides a way to connect with people who are interested in geology, and (2) it manifests as a durable online archive of useful information that anyone can access with a web search. To this can also be added a benefit to the author, (3) it's fun and fulfilling. This talk will provide a brief episode of *Mountain Beltway*-specific navel-gazing that will unfold numerous lessons of broader applicability. Participants should come away with a tidy toolkit of ideas that can help them assess whether geoblogging is worthy of their time and attention.

## How to leverage TikTok as a platform for science communication

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With TikTok emerging as one of the most popular social media platforms, there is significant potential for science communicators to capitalize on this success and to share their science with a broad, engaged audience. To increase the visibility of the geosciences on TikTok and to determine best strategies for communication on the app, our team created a TikTok account called "Terra Explore" (@TerraExplore). We produced 48 educational geoscience videos over a 4-month period between October 2021 and February 2022, reaching more than 2 million people. In this talk, I review our findings and discuss best practices for creating and sharing short form video content on TikTok and beyond.

## Where's the carbon? Spatially mapping carbon on the seafloor, eastern Nova Scotia, Canada

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Coastal sediments contain some of the largest stocks of organic carbon on earth and play a vital role in influencing the carbon cycle. Protecting organic carbon hotspots is essential to mitigating climate change since coastal development and bottom trawling can disturb the seafloor, driving the remineralization of organic carbon into carbon dioxide. Terrestrial carbon stocks are well studied and mapped, but our knowledge of standing stocks of marine sedimentary carbon and the role that it can play in minimizing the effects of climate change are poorly understood. One of the challenges in mapping the seafloor environment is the issue of characterizing spatial heterogeneity of different substrata, which is critical in estimating organic carbon standing stocks in the marine environment.

In this study, we use high-resolution multibeam echosounder (MBES) data from the eastern shore islands off Nova Scotia to predict the distribution of percent organic carbon in surface sediments. We applied benthic habitat mapping approaches, utilizing high-resolution continuous

coverage environmental variables (bathymetry, backscatter, current velocity, bottom salinity, bottom temperature, ruggedness, slope, and Euclidean distance) combined with subsea video and sediment grab sample ground truthing to generate thematic maps of sediment types for the area. We then compared that to the measurements of organic carbon from the sediment samples, which were spatially modelled using different methodologies to estimate organic carbon standing stocks in the area by substrate type. These high-resolution sedimentary organic carbon maps can help determine the best methodological approach for using MBES surveys to spatially map carbon and identify carbon hotspots, which are essential for seabed management and climate mitigation strategies.

## Using till geochemistry and LiDAR-based surficial mapping to understand glacial dispersal patterns associated with the Brazil Lake LCT Pegmatites, southwest Nova Scotia, Canada

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Till sampling for matrix geochemistry and indicator mineralogy, in conjunction with LiDAR-based surficial mapping, is ongoing (since 2019) in the Brazil Lake Li–Cs–Ta–(LCT) pegmatite district of southwestern Nova Scotia, a region that has seen increased staking and exploration activity for critical minerals (e.g., Li, Cs, In, Sn, and Ta). Recently, the Nova Scotia Geological Survey, in collaboration with the Geological Survey of Canada, have undertaken research to increase exploration success in regions covered by glacial sediments by documenting how critical minerals and elements are dispersed in till from the pegmatites at Brazil Lake. Newly available LiDAR data assisted to decipher past glacial trajectories, which in turn, influenced targeted sampling locations. A total of 105 till samples were collected from varying distances up-ice, overlying, and down-ice of the Brazil Lake pegmatites to define the extent of dispersal from the known pegmatites, and from the surrounding areas to provide regional background context and assess the potential for additional pegmatites buried by extensive till cover in the region. Samples collected for till matrix geochemical analysis were submitted to test the applicability of different acid digests (sodium peroxide fusion, 4-acid, lithium metaborate fusion, and aqua regia). Three size fractions of till were analyzed and assessed for their efficacy in detecting dispersal: coarse sand (1.0–2.0 mm), silt and clay (<0.063 mm), and clay (<0.002 mm). This presentation includes the geochemical results and surficial geological interpretations to date as they pertain to the geometry of glacial dispersal trains, net glacial dispersal in the region, the effects of multiple glaciations on till provenance, depositional history, and the potential for additional critical and base-metal mineralization.

## Machine learning approaches for broad-scale characterization of seafloor geology on the Northwest Atlantic Shelf, Canada

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Mapping seafloor surficial geology provides information necessary for effective marine spatial planning, assessing natural and anthropogenic disturbances to the environment, and science-based fisheries and natural resource management. Traditional methods for seafloor geological mapping depend on expert by eye interpretation and delineation into seafloor classes (e.g., substrate type or geomorphic classes). However, these methods are generally subjective, non-repeatable, and lacking in statistical validation. Recent advances in computing technology and modelling techniques, such as machine learning (ML), have allowed scientists to use spatial predictive modelling to efficiently produce statistically accurate and spatially continuous map products that characterize various aspects of seafloor geology. This research applied common machine learning algorithms to generate a variety of thematic seafloor maps across the Northwest Atlantic Shelf using coarse resolution (>400 m) open-source datasets. Seafloor substrate maps (hard substrate occurrence, modified Folk class, mean grain size, and % mud/sand/gravel) were modelled using random forest, trained with observations from Natural Resources Canada (NRCan) Seabed grainsize analysis and seafloor photograph databases for offshore Canada. A semi-automated approach was developed to classify seafloor morphology from the GEBCO 2020 bathymetric grid, using a k-means clustering algorithm and manual assignment of feature names based on standardized feature definitions. The standardized workflow from this study enables the integration of datasets from a variety

of sources and provides output maps that are comparable over large regions and across a variety of ocean governance boundaries.

## Geochronology of northern New Brunswick, Canada: improving our understanding of gold metallogeny

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Understating of the evolution of tectonic settings in space and time is critical for understanding metallogeny and evaluating mineral potential. This compilation includes 152 ages from across northern New Brunswick (north of 46.75°) to compare and evaluate tectonic, stratigraphic, chronologic, and spatial context of gold occurrences. The compilation includes only ages between 480 and 360 Ma with errors of less than ± 10 Ma, and includes both U–Pb (zircon, titanite) and $^{40}Ar/^{39}Ar$ (muscovite, phengite, phlogopite, feldspar, and amphibole) analyses. Ages represent crystallization, detrital, deformation/metamorphism, and mineralization/alteration, and are integrated with compiled stratigraphic columns for the region. Five episodes of gold mineralization are recognized: (1) Ordovician (ca. 465 Ma) volcanogenic massive sulphide mineralization hosted by the Bathurst Supergroup; (2) ca. 435 Ma which corresponds to mineralization associated with deformation of the Bathurst Supergroup and Salinic orogenesis; (3) ca. 420 Ma to 408 Ma mineralization, which corresponds with the Lower Devonian deposition of bimodal volcanic and sedimentary rocks; (4) ca. 390 Ma, which corresponds with break-off of the Acadian slab and Middle Devonian plutonism and formation of the Elmtree Deposit; and (5) ca. 370 Ma hydrothermal activity at Williams Brook Au and Menneval. This compilation has highlighted areas in need of additional geochronological constraints: (1) controls on the timing of deformation and faulting throughout the region, as faults are major conduits for mineralizing fluids and many known gold occurrences are structurally controlled; (2) ages of gold (and associated metals) mineralization for the numerous poorly constrained occurrences, (3) refinement of timing of amphibolite grade metamorphism in the Trousers Lake Metamorphic Complex; and (4) the timing of dyke emplacement, including timing of lamprophyres, across northern New Brunswick to better understand crustal architecture, potential sources, and deep-rooted structures.

## Gold remobilization resulting from continued shear zone displacement at the Elmtree Deposit, northeastern New Brunswick, Canada

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The Elmtree Deposit, host to gold and polymetallic mineralization, straddles the Melanson Brook Fault that follows the boundary of the Elmtree Inlier and the Nigadoo River Syncline. Throughout the deposit gold is primarily refractory and hosted in arsenopyrite and pyrite, although local free gold and electrum is observed in portions of the deposit. Characterizing the mechanisms responsible for the occurrence of free versus refractory gold is necessary for developing a full understanding of the deposit. Dating of sericite (muscovite) in situ using the $^{40}Ar/^{39}Ar$ method has identified two events associated with gold mineralization: (1) emplacement of vein sericite between ca. 398 and 386 Ma (n = 5) coincides with the primary stage of gold mineralization and associated with sulphidation of iron in the wall rocks and the precipitation of refractory gold with pyrite and arsenopyrite; and (2) development of sericite wall rock fabrics and local deformation of vein-hosted sericite between ca. 391 and 377 Ma (n = 7) that coincides with subsequent movement of the Melanson Brook Fault. Raman thermometry of carbonaceous material of samples from the deposit and surrounding unmineralized rocks (n = 20) indicates peak temperatures between 296° and 324°C (± 30°C), and deformation of pyrite at these temperatures occurs via variable degrees of pressure solution and (or) cataclastic flow. The occurrence of pyrrhotite pseudomorphs of pyrite suggests that pyrite was desulphidized to form pyrrhotite due to coupled dissolution–reprecipitation reactions driven by stress associated with displacement of the Melanson Brook Fault and facilitated by low $fS_2$ fluids. Desulphidation of auriferous pyrite releases both gold and forms bisulphide complexes that act as ligands for gold transport, which is then electrochemically precipitated onto sulphides (e.g., arsenopyrite, pyrrhotite) at sites of high charge density. This

is consistent with free gold/electrum occurring along grain boundaries and fractures within sulphides.

## The Carboniferous–Permian fossil record of Prince Edward Island, Canada, grows in significance

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For many years, the fossil record of the latest Carboniferous to early Permian redbeds of Prince Edward Island (PEI) was considered to be sparse and inconsequential. Its most famous famous fossil *Bathygnathus borealis*, the first *Dimetrodon* discovery in 1845, was considered an anomaly. This perception changed with the publication describing the exceptional parareptile *Erpytonyx arsenaultorum* discovered in 1995. The footprint record of tetrapods was unknown prior to the 1980s, when trackways were reported from Point Prim and Malpeque. Since that time discoveries of tetrapod footprints have grown at an increasing rate and at increasing number of localities. The discovery in September 2022 of a yet undescribed articulated tetrapod skeleton near the *Erpetonyx* site caused an unexpected media stir that brought the fossil record of the Island into many people's homes. Subsequently in September 2022 the wrath of Hurricane Fiona was felt most profoundly on the north shore of PEI; large tetrapod trackway-bearing sandstone blocks in the National Park were completely removed in that event, while resulting erosion brought to light many new sites, across the north shore in particular. The footprint record represents a diverse record of vertebrates, favouring reptilian taxa from the diminutive *Hyloidichnus* sp. to *Dimetropus* sp., one of the largest early Permian reptilian taxa. The fossil record of tetrapods and their trackways now places PEI firmly in the league of the southwestern USA and Germany as important biodiverse paleoequatorial vertebrate sites of the early Permian.

## In situ $^{40}Ar/^{39}Ar$ dating of illite: implications for the timing of mineralization at the Cape Spencer gold deposit, New Brunswick, Canada

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The Cape Spencer gold deposit, located approximately 15 km southeast of Saint John, has an inferred mineral resource estimate of 151 000 oz. The Cape Spencer area presents polyphase fold and thrust style deformation of the rock units related to the docking and adjustment of the Meguma terrane, as documented through different movements along the Minas Fault Zone between the Late Devonian and Late Carboniferous. The deposit presents characteristics of orogenic-style gold systems in which Au is hosted in quartz ± carbonate ± plagioclase ± pyrite ± specularite veins that vary from several millimetres to several decimetres in width and within sericitized (illite–carbonate ± quartz ± pyrite ± specularite), pyrite-rich rocks along the thrust faults and folds. The timing of gold deposition is bracketed by the age of the youngest unit affected by the alteration and displaying the ductile to brittle fabrics associated with gold mineralization, the Lancaster Formation (Bashkirian), and the emplacement of aplitic dikes (273.7 ± 1.3 Ma) that crosscut the fabrics of the host rocks. White micas (illite) collected from both the Cape Spencer Formation and the Millican Lake Granite were dated via in situ $^{40}Ar/^{39}Ar$ to establish a minimum age of the alteration event associated with the gold deposition. The illites define a foliation $S_a$ related to a first episode of deformation within the polyphase fold and thrust belt. The in situ $^{40}Ar/^{39}Ar$ ages vary from 260.2 ± 4.9 to 300.6 ± 6.4 Ma and reflect continuous mica crystallization, recrystallization, and/or fluid migration along a strongly sheared and brittle faulted area leading to isotopic resetting below the closure temperature. These data also attest to the near-contemporaneous nature of deformational events that produced overprinting relationships of folds and cleavages. This resulted in sub-microscopic and lattice defects associated with deformational microstructures that could have substantially contributed to Ar diffusion release.

## Methane clumped isotopic study of two deep-sea, Scotian Slope cold seeps, Canada

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Methane ($CH_4$) is produced in sedimentary basins by thermogenic cracking of deeply buried organic-rich source rocks and through the reduction of $CO_2$, $HCO_3^-$, or acetate by microbial methanogenesis. In 2021, an ROV expedition, organized by the Nova Scotia Department of Natural Resources and Renewables collected seep gas from two active sites, 2A-1 (the Hole) and 2B-1 (Clamshell). Three different types of gas samples were collected from these two sites: (i) seep gas, (ii) void gas, and (iii) sediment gas. We used a customized non-isobaric gas sampler with the ROV, which enabled collection of gas bubbles from the seep sites. The seep gas from both sites is dominantly methane (90–99% $CH_4$), but each site has different ebullition rates (Hole>>Clamshell). Methane carbon isotope ($\delta^{13}C$) compositions of the two seep gases are similar ($\delta^{13}C_{Hole}$ −70.6‰ to −70.8‰; $\delta^{13}C_{Clamshell}$ −70.7‰ to −71.0‰) and indicate the gas was sourced from microbial carbonate reduction. The $^{13}C$ value for the three types of gas samples (seep gas, void gas, and sediment gas) suggests the gas fractionation ($\varepsilon_{Hole}$ = 0.1; $\varepsilon_{Clamshell}$ = −6.1) is different in these two sites. The methane clumped isotopic data further indicates a biogenic origin and a microbial formation temperature range (45°C to 70°C). Isotopic fractionation of the seep gas derived from three sample types from the same location clearly suggests the buffering of the gas discharge rate is affecting the kinetic isotopic fractionation component. The formation temperature derived from the $\Delta^{13}CH_3D$ superimposed with the local geotherm suggest the methane formation depth to be between 1000 m and 1500 m below the sea floor.

## Early Cretaceous palynology of the Upper Member of the Missisauga Formation in Panuke B-90, Scotian Margin, Canada

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Biostratigraphic studies of Mesozoic–Cenozoic strata along the Scotian Margin began in the early 1970s, focussing on zonation schemes for separate disciplines. Subsequent works, however, have evolved into an event stratigraphic approach, combining palynologic with micropaleontologic and nannofossil events, as well as seismic horizons. Extensive taxonomic treatment of Late Cretaceous and Cenozoic palynomorphs from the Scotian Margin were also undertaken but did not encompass the Triassic to Early Cretaceous interval. Thus, we aim to develop a detailed taxonomic review and a comprehensive event-stratigraphic scheme for this earlier interval based on palynology, integrated with paleoenvironmental and sequence stratigraphic interpretations. Our initial focus is on conventional cores in Panuke B-90 and Cohasset A-52 to develop a composite Lower Cretaceous succession, supported by analyses of cuttings from deeper wells that penetrate pre-Cretaceous strata (e.g., Argo F-38) to provide a broader context. The sedimentary facies, trace fossils and initial palynologic data of the Panuke B-90 cores indicate, at the base, a transition from a shoaling marine to a mainly estuarine setting, followed by a transgressive cycle through the Upper Member of the Missisauga Formation that culminates in normal marine environments again near the base of the overlying Naskapi Member of the Logan Canyon Formation. It is apparent that this transgression is not continuous but intercalated with smaller cycles, well documented by the fluctuations of terrestrial (pollen and spores) versus marine (mainly dinoflagellate cysts) palynomorph dominance across this interval. The assemblages from the Upper Member of the Mississauga Formation are typical of the Early Cretaceous, probably Barremian. An Aptian age is expected for the overlying Naskapi Member based on previous studies that reported the presence of the age-diagnostic ammonite *Deshayesites* sp. Ongoing work on the Panuke B-90 conventional cores and coeval successions will contribute to a comprehensive event-stratigraphic framework for the Scotian Margin.

## Paleoenvironmental trends in the Lower Cretaceous Upper Member of the Missisauga Formation, Scotian margin, Canada: a sedimentological and ichnological integration

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Basins along the Scotian Margin formed as part of North Atlantic opening, with Middle Triassic rifting leading to eventual Early–Middle Jurassic breakup. In the overlying passive margin succession, the Lower Cretaceous section is dominated by siliciclastic deposits reported from a variety of marine, shallow marine, and fluvial settings. In concert with ongoing palynological analyses, the present study contributes to the development of an event stratigraphic scheme by focussing on paleoenvironmental interpretations. Ichnological and sedimentological analyses were used to build a preliminary facies model, with an initial focus on the Upper Member of the Missisauga Formation conventional cores from Panuke B-90 and Cohasset A-52. Depositional conditions began as wave-influenced normal marine, with a distal *Skolithos* Ichnofacies. Restricted bay and possible deltaic deposits followed, with wave-influence decreasing up section and the ichnofossil assemblage gradually replaced by an impoverished archetypal expression of the *Cruziana* Ichnofacies. Overlying sandstone bodies are interpreted as tidally influenced estuarine channels based on the presence of herringbone cross-stratification, cyclical bedding, wood with *Teredolites* borings, and rare elements of a highly impoverished *Skolithos* Ichnofacies; however, barrier shoreface and tidal flats are present, suggesting a mixed wave- and tide-influenced estuary. Outer estuary conditions followed, with barrier shoreface, tidal flat and central bay deposits. Impoverished *Cruziana* Ichnofacies dominate, with elements of the *Skolithos* Ichnofacies locally present. The top of the Missisauga Formation shows indication of more normal marine conditions, with intermittent marine macrofauna and limited ichnological suites implying some degree of dysoxia. Storm influence is evident near the transition into the overlying Naskapi Member of the Logan Canyon Formation based on the presence of possible hummocky cross-stratification, a weakly stressed *Cruziana* Ichnofacies and more diverse marine macrofauna. Future work will entail detailed facies analysis and comparison with palynofacies to build a comprehensive paleoenvironmental model and a refined sequence stratigraphic framework.

## Interpreting difficult geological topics for a general audience

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Providing geoscience outreach activities for the public helps many people to become more literate in Earth science. Sometimes the unexpected happens and we must contend with difficult questions of interpretation. A difficult question would be an interpretation or explanation that is not simple and has many parts that are considered 'technical.' Another issue may be the accessibility of language using technical terms. The audience must rely on you to explain these topics or questions carefully, so everyone understands. The starting point is having an audience 'with you' as soon as you say hello and start the outreach event. Being open and clear, having stated objectives, and encouraging questions and comments all leads to a connection between you and the audience. From my experience, I have found that using simple methods of detailing complex processes or a series of events helps in comprehension. By the midpoint in the event, I would begin to use terms that are complex and by the end of the event, my descriptions are laced with geological terms. The 'confidence' of the audience is important for them to believe you, to feel comfortable asking questions, and to further their enthusiasm and knowledge. Your enthusiasm must be constrained so that you don't appear to be sensationalizing your topic. As I move from one location to another, I often use the time to talk to people about their interest in this outreach event. I follow four easy guidelines: (1) start simply and add complexity; (2) use accessible language and illustrations; (3) encourage discussions and questions; and (4) invite young people to participate in some way.

## Exploring Nova Scotia's minerals and gems

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Minerals have always fascinated people of all ages with their beautiful colours and elegant crystals. Nova Scotia hosts beautiful specimens of minerals and semi-precious gems, such as various minerals of the zeolite group, agate, amethyst, pyrite, and many others. The Atlantic Geoscience Society's (AGS) Education Committee supported the idea of a brochure about minerals and gems following the very successful brochures entitled *Nova Scotia Rocks* 2nd edition and *Nova Scotia Pebbles*. Graham Williams, Martha and Robert Grantham, and Howard Donohoe formed the committee that produced the brochure *Nova Scotia Minerals and Gems*, with the assistance of committee consultants Jennifer Bates, Doug Wilson, and Helen and Rod Tyson. Our idea was to show how to identify minerals, picture the minerals, and locate where they may generally be found. Four panels describe how to identify minerals through their physical properties, and two panels focus on safety, provincial guidelines for collecting, and acknowledgements. The remainder of the brochure features pictures and brief descriptions of 46 minerals. Also included is a simplified geological map that shows where the minerals and gems may be found. This brochure joins many others in promoting the collection of minerals and rocks, and examining the geological wonders of Nova Scotia. Companions to this brochure are *The Geological Journey Map of Nova Scotia, Nova Scotia Rocks*, and *Nova Scotia Pebbles*. The AGS has also produced seven videos ranging in length from 12 minutes to 2 hours related to the geological and resource heritage of the Atlantic Provinces. All these brochures, maps, and videos demonstrate the AGS's intention to promote Earth science literacy through accessible outreach programs for the public and educators.

## Geological and geophysical basin characterization of the Cenozoic across the Tangier 3D Seismic Survey, central Scotian Slope, Canada with focus on the subsurface architecture of associated prospective hydrocarbon seep sites*

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Nova Scotia has potential undiscovered hydrocarbon reservoirs in the deep-water region of the Scotian Margin. Deep-water environments can involve major challenges with high exploration risk because the presence, quality, size, and distribution of source and reservoir rocks are still relatively unknown in many areas. New data are therefore needed to de-risk offshore exploration for the next generation of discoveries. This research project investigates the shallow (0 to 3 km) Cenozoic section of BP's Tangier 3D Seismic Survey, located on the central Scotian Slope. The Tangier 3D Area is one of the most geologically complex regions of the Scotian Slope encompassing two salt structural regions: the western diapiric and eastern canopy complex subprovinces. Seismic interpretation and attribute analysis of the Cenozoic suggests that the region hosts a complex subsurface geology comprising of modern-day and paleo-channels and canyons, sediment drifts, slope failure complexes, and slope drapes. Salt-related structural features, which some occur deeper than 3 km, include welds, wings, feeders, pedestals, rollers, withdrawal minibasins, rafted overburden, and growth and crestal faults. Also observed within the Tangier 3D Area are three amplitude anomalies, which two are situated above diapirs and one above a salt canopy, interpreted to be direct hydrocarbon indicators (DHIs). The shallow-level DHIs strongly indicate the presence of migrating fluids. The architectural investigation of these DHIs provides evidence of a working petroleum system governed by salt mobility, which provides migration pathways for deeply sourced fluids. However, further study is needed to determine if the fluids filling these DHIs are thermogenic hydrocarbons escaped from deeper Jurassic or Cretaceous sources and breached reservoirs.

**Winner: AGS Graham Williams Award for best graduate student poster*

## Post-Acadian brittle structures adjacent to the Cape Breton Highlands, Nova Scotia, Canada

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Late Devonian to Permian rocks, deposited in the Maritimes Basin, form a cover sequence to terranes assembled in the Canadian segment of the Appalachian mountain belt. An assessment of structures observed on fair to poor quality, vintage, offshore seismic data in the Gulf of St. Lawrence aims to provide insight to post-Acadian brittle deformation north and west of the Cape Breton Highlands. Seismic reflection data in the Cabot Strait show a fault zone (the Cabot Fault Zone) that resembles a positive flower structure in cross-section. The southernmost fault in this fault zone extends onshore to the location of the Aspy Fault. Rocks outcropping adjacent to, and northwest

of, the Aspy Fault may form the onshore expression of the offshore Cabot Fault Zone. To the northwest, between Lowland Cove and Cape St. Lawrence, Horton Group rocks outcrop along the coast with northwesterly strike and dips between 20° to 35° northeast. Offshore seismic data image a northeast dipping monocline (approximately 30° dip) comprising Windsor Group and younger strata. The top of the monocline subcrops at the seafloor, where it is truncated by a down-to-the-west fault with a throw of up to 5000 m. This structure appears to follow the northwest edge of the Blair River Inlier southward to Pleasant Bay. South of Pleasant Bay, northwest-dipping Carboniferous strata overlie a poorly imaged triangle-shaped feature, which may indicate a tectonic wedge of Aspy terrane rocks inserted at the stratigraphic level of the Windsor Group. Potential field data and the orientation of offshore faults suggest that the wedge extends onshore near Cheticamp (Grand Falaise).

## The science questions underpinning the potential for offshore wind turbines on Atlantic Canada's continental shelves

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Offshore wind farms typically host tens to hundreds of turbines that are individually sited on foundations or anchored if floating. These turbines are connected by inter-farm cables which feed into one or more marine-based substations, further feeding one or more shore-connected high-voltage cables—all infrastructure that requires knowledge of water depth, metocean conditions, and seabed/subsurface geology. With this industry set to establish itself on the continental shelf of Atlantic Canada, knowledge of the geological conditions from the seabed to tens of metres below will be essential for farm layout and foundation design. Thus, geoscience questions addressing regional geomorphology, Pleistocene glacial retreat and sea-level change, the characteristics of key individual stratigraphic layers, and the magnitude and patterns of sediment mobility are important. In Atlantic Canada, ongoing efforts to address these questions are using legacy data, but new data is required to further our understanding of the shallower portions of the shelf. Examples include: what is the distribution of buried tunnel valleys under offshore banks, and might their complex facies infill affect foundation conditions? How and where would the organic sediments, left by a coastal suite of landforms drowned during transgression, affect foundation or landfalling cable stability? How active is salt diapirism, and could it be considered a geohazard? Are demonstrated sediment mass failures also a risk? What is the current understanding of sediment mobility in shallow waters, and how does that affect infrastructure armouring/depth of burial? What is the variability of the geotechnical properties of our offshore sediments? What is the foundation suitability of offshore Tertiary semi-consolidated bedrock? To conclude, the initial scope of a developing regional foundation suitability model will be presented for the Eastern Scotian Shelf.

## Integrating STEM in the geology classroom with a focus on earthquakes

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All students, regardless of their future career, should have the knowledge and skills to deal with the changes and challenges that come from an information-based and technologically oriented society. Earth Science acts as an important component of a student's STEM education. Some of the basics of Earth Science might be obvious such as weather, oceans, and earthquakes. The greater impact comes from understanding humans' influence on the Earth. Topics such as climate change, environmental sustainability, protecting the environment, and resource management are gaining a greater importance. These issues will play a major role in the lives of students in the next generation.

In our session, I will be speaking about two STEM tools with a focus on earthquakes: a tabletop earthquake simulator and a Raspberry Pi seismograph. The simulator is a hands-on way to engage learners in developing creative ways to design earthquake proof structures. This activity also encompasses problem solving skills related to urban design, engineering, and architecture. The other tool, an affordable and high-quality seismograph, allows students to watch and learn more about our planet with real-time insights into everything that makes the Earth move. Students can interpret and analyze real-world data while contributing to a global seismic network.

## Organic geochemical analysis of potential intra-salt Early Jurassic oil shows of the Scotian Basin, Canada

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Well-completion reports have detailed putative oil shows within Early Jurassic Argo Formation salt-bearing units and carbonates from the Scotian Margin. While the presence of oil shows is commonly made by odour, fluorescence, and visual staining observations on-site during drilling operations, accurate verification requires geochemical testing of core plugs, side-wall core, and cuttings. These core materials are often heavily contaminated with hydrocarbon-based drilling fluids. In this study, we are evaluating whether oil-stained lithologies and salt fluid inclusions within the contaminated cuttings can be extracted and fingerprinted to identify native in situ or migrated hydrocarbon. A total of 11 Early Jurassic-sourced carbonates, siliciclastic, and halite-dominated cuttings samples from the Argo F-38 well are being analyzed. These cuttings contain extensive drill mud. Experimental series of sample washes was therefore performed prior to powdering and extraction of the sample. The series of washes show exponential decreases in their hydrocarbon recoveries with each successive wash. Moving forward, we will measure these fractions using comprehensive two-dimensional gas chromatography–mass spectrometry (GC×GC–MS), and flame ionization detection (GC×GC–FID) and apply subtracted chromatograms and multivariate chemometric techniques to create hydrocarbon fingerprints of the drill mud contaminants to resolve the hydrocarbon fingerprints associated with native in situ bitumen or migrated hydrocarbon. It is hoped that at the end of this study, information about the type and maturity of the source rock will be established, and new geochemical data will be developed, that will help infer if the Early Jurassic and/or older source have generated hydrocarbons within the Scotian Margin.

## Characterizing metamorphism and its relationship to deformation in the northeastern Meguma terrane, Nova Scotia, Canada

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The Meguma terrane of mainland Nova Scotia underwent regional greenschist to amphibolite facies metamorphism between ca. 410 and 380 Ma. The relationships between deformation and metamorphism in the northeastern Meguma terrane are not well understood, a problem further complicated by the presence of voluminous granitic intrusions (some of which are deformed). The plutons produced contact metamorphic aureoles that overprinted regional metamorphic mineral assemblages in some areas. This study is focused on the area between Trafalgar and Country Harbour with the objective of documenting and interpreting the mineralogy, deformation history, and pressure–temperature conditions recorded in the rocks to help contribute to the understanding of the relative timing and conditions of deformation and metamorphism in the northeastern Meguma terrane. The highest grade regional metamorphic rocks in the study area are garnet–staurolite–biotite–muscovite schist, in which fabrics indicate that the metamorphism was pre- and syn-deformational in most areas but may be post-deformational in others. Additionally, andalusite schist, andalusite-cordierite schist, and gneiss occur in contact aureoles around plutons. Forward and inverse thermodynamic modeling suggest temperatures from ~500°C to ~550°C and pressures ranging between ~3.5 kbar and ~4.5 kbar in the main metasedimentary assemblages of the study area. Temperatures are up to ~600°C in contact aureoles at similar pressure conditions. However, the fabrics and overprinting relationships in the contact aureole rocks show that contact metamorphism predated the deformation, and therefore potentially predated regional metamorphism. This result is surprising because the sequence of events has previously been interpreted to be the opposite, suggesting that the events are diachronous across the area. The implication is that the Chedabucto fault system may have had a major influence on the sequence of metamorphism and deformation in this part of the Meguma terrane, related to juxtaposition with Avalonia.

## Kimberlite emplacement conditions as told by experimentally produced reaction coronae on ilmenite macrocrysts

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Kimberlites are mantle-derived magmas typically emplaced in Archean cratons as pipe-shaped structures consisting of various facies including coherent kimberlite (CK) and diamond-host Kimberley-type pyroclastic kimberlite (KPK). The composition, crystallisation conditions and emplacement processes of these kimberlites are poorly understood. Kimberlites contain various mantle-derived materials including diamonds and oxide minerals such as ilmenite. Ilmenite macrocrysts are not in equilibrium with the kimberlite melt and react to form reaction coronae (rims of one or more secondary phase/s). We observed in kimberlites from the Orapa cluster that the reaction coronae assemblage varies based on the conditions of emplacement for different kimberlite facies. Reaction phases in Orapa kimberlites are magnetite, perovskite, anatase, and titanite. We are now performing piston-cylinder experiments using proposed synthetic kimberlite melt mixtures and natural ilmenite macrocrysts at various pressure–temperature conditions (600–1200°C, 0.5–1.0 GPa). The aim of these experiments is to crystallise reaction coronae that are found in natural kimberlite samples in order to determine kimberlite emplacement conditions including temperature, pressure, and oxygen fugacity and to find constraints on initial kimberlite melt composition. Initial experiments show crystallisation of magnetite and perovskite at 1100–1200°C, 0.5–1.8 GPa and –2.1 to 0.1 DNNO for few synthetic starting mixtures with varying Si/Ca. We now aim to determine the conditions and composition required to crystallise titanite. We have successfully crystallised titanite using granodiorite starting mixture and are now testing the temperature limit of titanite crystallisation and effect of composition. Understanding the crystallisation condition of titanite is important since titanite coronae formed in KPK of the studied Orapa kimberlites. Therefore, its crystallisation is key to understanding the emplacement of these often diamond-bearing kimberlite facies.

## Remarks on the principles of *Urban Geology*

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The term "urban geology" can be traced back to the 1950–1960s with a growing awareness of the interactions between engineering issues of large construction projects and local geology in urban environments. In the 1990s, urban geology studies were increasingly undertaken by the Canadian Geological Survey. Many useful studies were published by the Geological Association of Canada, including one focused on the "Urban Geology of Halifax Harbour". Over the past several years, through necessity during pandemic years – my attention to the local geology around home and work took on a greater priority. Through development of projects such as self-guided tours, online videos, public guided walks, and teacher workshops, I am pursuing a broad approach to "urban geology" that is centred around five key principles. The components of the current projects include topics of: (1) geology of sidewalks; (2) biographies of diversity; (3) historic and modern maps; (4) geology of place; and (5) development for a Google era classroom.

Foundational geology knowledge about concrete sidewalks includes concrete trace "fossils", subjects that will capture the imagination and remain of interest throughout life. By relaying diverse and untold stories of local people who have contributed to geology knowledge, urban geology brings local cultures together with geoscience. Also, by using historic and modern maps, urban geology provides citizens with foundational knowledge to understand the specific geology of their home, school, or park. While striving to meet established high school geology learning outcomes, urban geology resources can be made available widely with modern digital tools. A summary of recent work at several sites around Halifax Harbour is used as an ongoing case study. *Urban Geology* seeks to highlight linkages between history, culture, and observable geology of specific places, to build interest and maintain critical geologic knowledge of citizens and communities.

## A geological biographic: Samuel Gaskin and the maps of Nova Scotia, Canada

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Employed in the mapping unit of the Department of Nova Scotia Mines and Minerals from 1950 to 1977, Samuel Gaskin is recognized as the first African Nova Scotian to work in the provincial geoscience department. Samuel Gaskin's father and mother both emigrated from Barbados to Halifax in 1902, a period of increased immigration for employment with the Dominion Iron and Steel Company in Cape Breton. Samuel's father Abraham worked initially as a carpenter and then owned a store on Brunswick Street with his second wife Lillian in the early 1920s. Samuel and

his brother Kenneth were born and educated in Halifax at this time.

In 1950, Samuel Gaskin was one of the first recruits into the Canadian Intelligence Corps' 3 Intelligence Company, and eventually attained the final rank of Master Warrant Officer. Gaskin was highly respected for his expertise in aerial photo interpretation, map making, and training of fellow unit members and cadets. He participated in annual summer exercises at the Canadian Army's Camp Borden in Ontario, and in 1964 and 1967 he and his unit distinguished themselves in winning many national awards.

Also in 1950, Gaskin was hired as the Mapping Photographer in the Nova Scotia Department of Mines. A booklet published by the Department explained the new process of generating an updated and more accurate map of Nova Scotia. Gaskin is shown in photographs along with the other team members, including Eva Duncan and Don Bernasconi. The first map that credits Samuel Gaskin's contributions was the 1956 edition of "Minerals of Nova Scotia". Samuel's brother Kenneth was also active in the public service, as the Recording Secretary, Army of the Nova Scotia Civil Service Association.

This biographic poster was developed to highlight Samuel Gaskins family history and recognize Gaskin's important contributions to geology and mapping in Nova Scotia.

## Geoheritage: the Challenger expedition (1873) and glacial striations at Point Pleasant Park, Nova Scotia, Canada

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In May of 1873, the HMS Challenger sailed into port at Halifax Harbour. As the second stop of a multi-year oceanography expedition, the Challenger visit to Halifax had a lasting impact on the geoscience of Nova Scotia. The site of glacial striations at the Prince of Wales Tower at Point Pleasant Park had been a known geological destination. Charles Lyell had visited the site in 1842 and Louis Agassiz in 1844, when both were debating the glacial (iceburg) drift versus glacial theories. During the visit of the Challenger in Halifax, the Museum Curator, Rev. David Honeyman took the crew on a geology excursion to visit the glacial striations in the park. As an artefact of the expeditions notes and observations, a photograph was taken by a member of the crew. This photo is the oldest known of the glacial striations that remain visible at the site.

In the decade that followed, David Honeyman continued to make detailed observations about the surficial geology around Halifax Harbour. He noted other striations, measured their directions and plotted these on an Admiralty Chart from 1854. Honeyman also noted that amygdaloidal basalt cobbles observed at Cow Bay had been moved, by glacial action, from their original site at Blomidon, a direction that corresponded with the glacial striations. Honeyman shared his observations at the Geologists' Association meeting in 1883 and the British Association of Science meeting in Montreal in 1884.

This poster brings attention to the significant site of urban geology at Point Pleasant Park. Consideration is given to options and issues for developing a small interpretive panel at the site of the glacial striations. The interpretive panel has opportunity to highlight the significance of this geoheritage site, show historic maps, and provide a modern interpretive depiction of glacial cover and ice flow directions.

## Recognizing the contributions and ongoing legacy of Dr. Erwin Zodrow (1934–2022)

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Dr. Erwin Zodrow was awarded the Gesner Medal by the Atlantic Geoscience Society in 2021, recognizing his contributions to palaeobotany and knowledge about the Cape Breton fossil fern forests. Born in Germany in 1934, Erwin moved to Canada at the age of twenty. He graduated with a BSc from St. Francis Xavier University in 1962, and then completed a Masters of Mineral Economics at Pennsylvania State University in 1968. Erwin was made Assistant Professor of what is now Cape Breton University (CBU) in 1970 and completed a PhD (Geology) in Applied Statistics from the University of Western Ontario in 1973. Erwin was also an active Research Associate of the Nova Scotia Museum from 1977 until 1997 and taught at Cape Breton University for nearly 30 years. After retiring in 1999, Dr. Zodrow continued an active research program as an appointed Emeritus Professor, authoring another fifty papers in 'retirement'. Dr. Zodrow passed away on December 1, 2022.

Beyond publications and students, Dr. Zodrow also left a physical legacy: the largest collection of Carboniferous fossil plants in Atlantic Canada. Many of these specimens, including type material, were recovered from horizons that are no longer easily accessible. A portion of this material

was moved to Sydney Mines in 2004, where it forms the core display collections of the Cape Breton Fossil Centre (CBFC), a public-facing institution that has welcomed tens of thousands of visitors. In 2021, a second lot of his collection was transferred to the CBFC, seven cabinets and over eighty drawers of material, including his figured specimens. Additional material, beyond the capacity of the CBFC to house remains at CBU. In addition to celebrating Dr. Zodrow's life and contributions, this session is intended to initiate a discussion about opportunities arising from his collections, to further paleontology and science education in Nova Scotia.

## The second edition of "The Last Billion Years: A Geological History of the Maritime Provinces of Canada" —reflecting two decades of progress

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In 2001 the Atlantic Geoscience Society (AGS), with Nimbus Publishing, produced the first edition of "The Last Billion Years: A Geological History of the Maritime Provinces of Canada" (LBY1). It was an immediate hit: the first print run sold out within weeks, and reviews were enthusiastic. The success of LBY1 continued over the ensuing years, eventually with over 10 000 copies in print. Significant advances in the understanding of Maritimes geology since 2001 warranted an updated edition (LBY2), published in May 2022. LBY2 is essentially a new book, although similar in structure to the first edition. The new edition comprises chapters and boxes, the latter being "mini-chapters" devoted to specific topics. General aspects of geology, with a Maritimes slant, are introduced in Chapters 1–3. The next five chapters describe the geological history of the Maritimes, from the late Proterozoic ("a billion years ago") to the Ice Age. LBY1 included a single chapter on resources and environmental concerns, whereas in LBY2 these topics are covered by three chapters, one each on resources, natural hazards, and human-induced problems (such as climate change). There are new boxes on rivers, building stones, remote sensing, and evaporites and limestones. New and revised graphics include updated paleogeographic maps from 850 to 3 Ma and revised geological maps of the Maritimes. As in LBY1, LBY2 features many attractive photographs and artworks, including some new watercolours. About 50 experts compiled the text, which in turn was reviewed by a geologist, three non-geologists, and a technical editor. As was its predecessor, LBY2 is aimed at an interested, non-specialist audience. Funding for LBY2 was provided by AGS, the Canadian Geological Foundation, the Association of Professional Engineers and Geologists of New Brunswick, and the Association of Professional Geologists of Nova Scotia, with in-kind support from the Geological Survey of Canada.

## Predictive mapping for base and critical metal exploration using multivariate statistical analyses in the New Québec Orogen, Québec, Canada

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Remote predictive mapping is increasingly used to identify and investigate potential exploration targets. This project applies principal component (PC) analyses and K-means clustering algorithms to geochemical data from the New Quebec Orogen to investigate spatial distribution of possible exploration vectors, and to link those exploration vectors to large-scale crustal structures. The dataset of 11 260 lake sediment samples containing the chemical results using inductively coupled plasma mass spectrometry was obtained from the Système d'information géominière of Québec and ioGAS-64™ was used to apply the multivariate techniques. The metals Ag, As, Au, Bi, Co, Cr, Cu, Fe, Mo, Pb, Se, Th, U, V, W, and Zn were selected because were analyzed in all the samples and are economically significant. The results show that four principal components (PC1–PC4) yielded eigenvalues ≥1.0 and account for 58.0% of the variability. PC1 and PC2 account for 38.7% of the variability between Se, U, Mo, and W (PC1) and Cu, Ag, Au, Se, Zn, and Cr (PC2). PC3 accounts for 11.6% with an enhanced separation between As, Zn, Bi, Pb, Fe, Ag, and Mo. PC4 accounts for 7.8% with positive eigenvectors for Pb and Bi. A K-means clustering equals to 6 was obtained using these PCs. The association yielded by PC1 was interpreted as metals transported by sedimentary processes and might highlight hazard areas. The high scores of PC2 and the K-means results correlated with Ni–Cu–PGE occurrences reported within the Retty and Hurst zones. The results of these analyses show that the methods can pinpoint the location of known

metal occurrences with excellent spatial accuracy, and in several tested areas accurately outline known geological units. These types of statistical techniques can therefore be used to predict similar occurrences in underexplored areas that can then be selected for exploration.

## Composition and origin of xenocrysts in the Eastern Shore spessartite dykes, Nova Scotia, Canada

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The Eastern Shore dykes are a swarm of mantle-derived spessartite (lamprophyre) dykes in the Sheet Harbour area of eastern Nova Scotia. Only two of the dykes, Pleasant Harbour–Borgles Island and Popes Harbour, contain abundant xenoliths and xenocrysts. Some of the xenoliths are granulite-facies metamorphic rocks that in previous studies were shown to contain high-pressure mineral assemblages and hence were interpreted to represent deeper crust of the Meguma terrane. However, other xenoliths include dioritic rocks and coticule-bearing pelitic rocks that resemble rocks exposed at surface in the Meguma terrane. This study was undertaken to investigate the xenocryst minerals in the dykes to determine their composition and provenance. Xenocrysts were studied in two samples from the Borgles Island – Pleasant Harbour dyke that were selected because they contained abundant and varied xenocrysts. About twenty thin section-sized chips were cut from those samples, and 14 chips with abundant xenocrysts were studied in polished sections and analyzed for major and trace elements by electron microprobe and LA–ICP–MS. Based on the petrologic evidence, the xenocrysts are divided into two groups: (1) xenocrysts that are possibly derived from deeper crustal levels, including kyanite, garnet, clinopyroxene (augite) and pargasitic amphibole; and (2) xenocrysts that are more likely derived from shallow levels such as sulphide minerals and quartz. The sulphide xenocrysts consist of pyrite with small inclusions of chalcopyrite; they could not have survived in the spessartite magma under high P–T conditions. The silicate xenocrysts may have been derived from disaggregated xenoliths in which similar minerals have been reported, some of which have textual similarities to the xenocrysts. However, the origins of the pyrite and large quartz xenocrysts remain uncertain.

## Thanks for letting us into your head: why we need geoscience podcasting in the Anthropocene

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Geoscientists have an important role to play in helping society navigate the challenges of global change, not only due to our training in Earth System Science, but also because of our ability to leverage the ways in which Earth's history records natural experiments in climate change, extinction, hazards, and other contemporary threats. We know that the "deficit model" of science communication is deeply flawed and doesn't produce the intended outcomes; simply providing the public with more information is not enough to deepen understanding or inspire people to change their behaviors (e.g., to take action on climate change or disaster preparedness). Instead, we know from decades of communication research that empathy and storytelling are some of our most powerful tools in the science communication toolkit. In this presentation, I'll argue that podcasts–digital audio narratives that are typically presented as a series–are particularly effective at building empathy and are an underutilized approach to fostering public engagement with Earth science. Throughout this presentation, I'll illustrate these points with examples from existing podcasts, and outline some of the challenges and opportunities for those interested in exploring this new spin on an ancient, time-honored tradition.

## Absolute ages and stratigraphic timing for late-postglacial mass failures in St. Anns Basin, offshore Nova Scotia, Canada

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St. Anns basin is a small (1200 km$^2$) intrashelf basin on the eastern Scotian Shelf south of Cape Breton Island. It is the site of multiple mass transport scarps, deposits and related phenomena hosted in glacial and post-glacial mud.

The eastern Scotian Shelf is one of the last places with ice cover on the Scotian Shelf during the retreat of the Laurentide Ice Sheet. Unravelling the deglacial history in this region remains challenging due to the complex seabed geomorphology alongside the marine transgression that followed deglaciation, and until now, lack of absolute dating. Here we present the first chronology for the glaciomarine strata in the basin from an archival sediment core using radiocarbon ages from mixed benthic foraminifera and shell fragments. This core contains several brick red mud units interpreted as ice calving events analogous to those in Laurentian Channel. The ages indicate that the core site was free of ice cover as early as 14.1 ka and experienced much higher sedimentation rates compared to those found in nearby Laurentian Channel. This is interpreted as indicating a local sediment source. Relative ages established using seismic correlation of glaciomarine and marine mud packages combined with seabed morphology from OLEX bathymetry imaging, show multiple mass failures at one stratigraphic horizon. This and a pre-existing post-glacial core date (~8 ka) correlated to these failure sites suggest a seismically induced event triggering the slope failures. This updated chronology of sediments in St. Anns Basin has the potential to further constrain the timing and process of glacial cover on the eastern Scotian Shelf.

## Microplastic in beach sediment from Marys Point, Shepody National Wildlife Area, southeast New Brunswick, Canada

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The Shepody National Wildlife Area (NWA) hosts 50–95% of the world's Semipalmated Sandpiper population during their >3000 km migration south. The sandpipers rest and feed on a variety of biota, including mud shrimp, other crustacea, molluscs, worms, biofilms, etc.), that live on and in the NWA's inter-tidal mudflats backed by sand and gravel beaches. Plastic waste is now widely documented as polluting these environments, where it often breaks down into particles of <1 mm size (microplastic), becoming difficult to collect and remove, while becoming more available for ingestion by biota in the sediment and eventually accumulating progressively up the food chain, potentially in humans or sandpipers. Previous studies investigating the microplastic fraction have focused on the readily visible, surficial sediment (<5 cm depth), disregarding the processes active in sediment that may mix the vertical sediment column, distributing the plastic to a greater depth. This initial study aims to investigate microplastic distribution across and vertically within a sandy beach section at Marys Point, using a sediment corer. Samples are analyzed in 4 cm depth increments, with microplastics separated and compositionally classified for each increment via a novel procedure using low-cost, non-toxic chemicals: four density separations, involving solutions with increasing densities (fresh water, saline water, and low and high concentration $NaH_2PO_4$ solutions), followed by an oleophilic separation. Separated microplastics were then further analyzed by microscopy to determine size, shape, and colour. The total microplastic count from all samples is 1565 particles, equating to 1.24 particles per gram of sediment collected, with a range of 0.38–5.19. The densest plastics (>1.5 g/cm$^3$) are most common, with fibrous blue/green and white/clear material dominant in most density fractions. Preliminary statistical analyses indicate no significant trend relative to beach location or depth in the core.

## Detrimental unintended consequences of the Uranium Exploration and Mining Act of Nova Scotia

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Exploration for and mining of uranium (U) have been prohibited in Nova Scotia since the early 1980s. The 2009 legislation cementing a long-running moratorium states its intention: to protect "the health and safety of Nova Scotians and the quality of their environment." It directly prohibits exploration for U and, for mining, stipulates that if "the uranium content of the total amount of material then removed…" exceeds "…0.01 per cent by weight", it is illegal to mine. This work highlights unintended consequences of this design without comment on the merits of U prohibition. U behaves geochemically like other elements (e.g., rare earth elements [REEs], Nb, Ta). The concentration cutoff approach to prohibition is thus problematic for exploration and mining of other commodities. The spectre of U co-enrichment discourages investment in mineral exploration in Nova Scotia, as discovery of prospects co-enriched in U would jeopardise those investments. In Greenland, a politicized prospective REE-U-Zn-fluorspar mine (Kvanefjeld) illustrates that U co-enrichment is a real-world problem; opponents prevented the mine's approval by legislating a U prohibition, likewise using a 100 ppm cut-off. (The status of a revised proposal treating U as waste is pending.) In Nova Scotia, another consequence of the

prohibition's design is emergence of a subversive path to mining U-coenriched ores; if an ore body is coenriched with U, excavation of surrounding waste rock could dilute the bulk U content below 100 ppm. *To restate:* Legislation to protect the environment requires mines, in the case of U co-enrichment, to be deliberately destructive to comply with that same law. Numerical models demonstrate how contrasting U content between ore and host determines the dilution required to achieve compliance. Legislative approaches prohibiting sale of U products and inclusion of their value in deposit appraisals and mine plans may prevent harms to the broader mineral resources sector.

## Paragenesis of pyrite at the Lone Star deposit, Yukon, Canada

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The Klondike region of the Yukon Territory, Canada, is famous for extensive placer deposits, recovering over 20 million oz since discovery, but lacks any major defined bedrock resources. As a result of a surge in exploration activity, recent drilling efforts have delineated several new bedrock targets, including the Lone Star deposit near Dawson City, Yukon. The Lone Star deposit is hosted by a suite of Late Permian plutonic, volcanic, and sedimentary units known as the Klondike Assemblage. This assemblage formed as a result of subduction-related arc magmatism, followed by Late Permian–Early Triassic regional greenschist–amphibolite facies metamorphism during accretion onto Laurentia as part of the Yukon-Tanana terrane. Gold deposition is thought to be middle–late Jurassic, mainly occurring within discordant quartz veins with common pyrite mineralization but overall low sulphidation (galena, sphalerite, chalcopyrite, etc. only trace). This study adds to the overall understanding of the Lone Star deposit by establishing relations between pyrite paragenesis and gold mineralization. This is done through detailed examination of a suite of samples, selected based on differences in pyrite occurrence. Initial observations by reflected light and SEM have delineated at least 2 major pyrite types from a textural perspective: syn-tectonic and post-tectonic. Samples have been analyzed by LA–ICP–MS using individual spot analyses on pyrite core and rim, and trace element mapping is planned for a subset of samples. Of the trace element suite measured, we found consistently detectable levels of Co, Ni, Cu, As, Sb, Pb, Te, and Bi. Spot analyses have revealed both discrete core–rim trace element concentrations and grains that are relatively homogeneous, providing evidence for discrete pyrite growth events involving different trace element sources. Ongoing work will establish relations between texture type and element distributions to determine if there were discrete pyrite-forming events, and whether these can be related to the influx of gold-bearing fluids.

## Everything you wanted to know about budget photogrammetry and digital surface modelling but were too afraid to ask

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Natural scientists require accurate surface modelling for research but hiring a professional may strain budgets, introduce logistical challenges, and fail to be flexible as the project progresses. An overwhelming array of drone, RTK, GNSS, photogrammetry, and LiDAR products and software packages are available to individuals producing surface models. Each product or software claims to be user friendly. However, the plethora of options often complicates more than simplifies the process. Adding insult to injury, the proprietary nature and prohibitive cost of these products and services are often barriers to new or under-funded researchers. Although photogrammetry is a general technique, software packages in this field are advertised to sectors with large buying power, including natural resources, governments, public companies, and developers. After use, it is often difficult to disseminate results as these products have proprietary designs that do not provide the transparency required of repeatable scientific research. In this presentation, we will discuss how a persistent and tech-savvy researcher can utilize many new or old techniques and instruments to produce accurate, repeatable, results. Because these techniques are often conceptually easy to understand, they can be accessed by researchers, students, citizen scientists, and other lay people. This presentation provides a user-friendly guide for digital surface modelling where a budget GNSS, optical level, consumer-grade drone, and low/no cost or open-source software can be used within a user-friendly framework. Accuracy requirements, ease of implementation, and technical prowess are considered when this workflow is followed. An associated baseline model made at Kingsport Beach, Nova Scotia and associated results will be presented.

## A note on the discovery of Miaolingian acritarchs in the Flagg Cove Formation, Grand Manan Island, New Brunswick, Canada: implications for the stratigraphy of the Castalia Group

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Pre-Mesozoic rocks on Grand Manan Island are divided into two groups; an older Grand Manan Group of early Ediacaran or older age, and a younger Castalia Group, considered to be latest Ediacaran to earliest Cambrian. The Castalia Group as it is currently defined comprises a basal sequence of clastic marine sedimentary rocks assigned to the Great Duck Island and Flagg Cove formations and an upper sequence of mainly mafic volcanic and volcaniclastic rocks assigned to the Ross Island, North Head, Priest Cove and Long Pond Bay formations. A maximum age for the Castalia Group is ca. 600 Ma, based on the presence of volcanic clasts in conglomerate of the Great Duck Island Formation that are derived from the underlying Ingalls Head Formation (ca. 618 Ma). Additional age constraints include a U–Pb age of 539 ± 3 Ma for felsic tuff from the Priest Cove Formation and a minimum age of earliest Cambrian based on an assumed intrusive relationship between the ca. 535 Ma Stanley Brook Granite and the Flagg Cove Formation. However, stratigraphic relationships are generally poorly known due to intense deformation and thrusting, and most contacts are faulted.

The Flagg Cove Formation consists of quartzose sandstone and green to dark grey silty shale, previously reported to contain rare trace fossils (*Planolites*) in strata along Flagg Cove. A sequence of sandstone and silty shale containing abundant morphologically simple trace fossils, including *Planolites*, at the south end of Stanley Beach in Flagg Cove recently yielded organic walled microfossils (*Micrhystridium* sp.) of a type also found in the King Square Formation in the Saint John area. This suggests a much younger (Miaolingian) age for the Flagg Cove Formation, indicating that its relationship with the Stanley Brook Granite and inclusion in the Castalia Group need to be re-evaluated.

## Critical minerals in Canada: a glimpse inside a complex can of worms

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The *Critical Minerals* concept originated when western nations feared supply disruptions during the Cold War. Canada's *Critical Minerals List* differs from most others because we include some commodities that lack obvious supply risk, which we ourselves produce. This redefinition reflects the importance of natural resources to our economy. Many Critical Minerals are linked to renewable energy and decarbonization initiatives, labelled the *Energy Transition*. Examples include Co, Li, V, and graphite (for EV batteries and energy storage), REE (for EV motors and wind turbines) and elements involved in solar energy (e.g., Ga, Ge, In, and Te). Many are byproducts of Cu, Ni, or Zn extraction, or mutual coproducts. Increased demand for many Critical Minerals is widely predicted as a consequence of Energy Transition. This simple narrative is complex in detail.

21st Century technology evolves on a yearly timescale, unlike exploration and development, which takes decades. This lends uncertainty to exact predictions. For many commodities global production will remain small in absolute terms, even if it quadruples on a proportional basis. This may limit opportunities for new producers. For some commodities (e.g., REE) mineralogical complexity complicates development efforts for apparently large resources. Byproducts are commonly extracted in smelting, so domestic production is lost if processed elsewhere. The emissions of production must also become part of project assessments if these are linked to climate objectives. On a wider scale, aspects of recent *Critical Minerals strategies* seem to conflict with other policies for environmental protection and Indigenous land rights. We should expect a wider and perhaps polarized debate to develop. Geoscientific research to understand the true potential for Critical Minerals across Canada and assist in their sustainable development is an important future requirement for the future. In this respect, Canada presently seems to lag behind other jurisdictions such as the USA, EU, and Australia.

## Seabed and shallow sub-surface deposit characterization on the innermost shelf, eastern Nova Scotia, Canada: Facilitating offshore renewable energy by filling in the "white zone"

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Seabed engineering infrastructure requires knowledge of deposit geometry, its 3D spatial variability and physical properties. Quaternary deposit mapping has long been especially challenging in the "white zone", a vernacular for nearshore areas lacking suitable data control for maps at an appropriate scale for engineering structures. Post-glacial marine transgression has modified, redistributed, and partly denuded the deglacial sequence, commonly leaving patchy deposit remnants across a rugose bedrock surface. Recent access to various sources of multi-scale bathymetric renderings, combined with legacy high resolution seismic profiles, facilitates much improved surficial mapping. Sparse and scattered seismic profiles provide 3D control for deposit recognition and mapping through the rugosity and patterns of the shaded relief renderings. Variable scale mapping is underway, defining seabed contacts among bedrock outcrop, glacigenic deposits, transgression systems tract (sand and gravel) remnants and post-glacial mud. Map display of deposit sequences and burial depth helps facilitate regional scale 3D visualization.

A patchy deposit pattern prevails. Local moraines help reconstruct deglacial patterns. Glacial sculpting was partly steered by bedrock structural weaknesses. This created occasional shore-normal bedrock valleys providing late- and post-glacial accommodation space. Locally thicker sediments might support foundation piles and more benign cable routing and landfall. However, specific geotechnical characterization is lacking and glacigenic deposits might present engineering challenges.

Mud is common in topographic lows, derived from coastal erosion. Remnant transgression-derived sand and gravel is the least understood map unit, usually consisting of a lag only. Yet rare, scattered paleo-littoral facies are recognized. Landward-thickening aprons beyond the headlands have a simple sheet geometry but little recognizable stratigraphic evolution. However, in Chedabucto Bay, a more storm-protected setting has preserved varied facies including constructional ridges with re-activation history, bars, and prograding bodies at several elevations. The time transgressive nature, unclear sediment pathways and fates, and lack of direct sampling and chronology present challenges.

## First occurrence of Triassic vertebrate fossils in New Brunswick, Canada

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The Fundy Basin of Nova Scotia and New Brunswick, Canada, is the most northern extent of the Triassic–Jurassic Newark Supergroup on land. Mesozoic sedimentary rocks in New Brunswick are rare by comparison to the neighbouring province of Nova Scotia. The Upper Triassic is known for the oldest dinosaurs in Canada, together with other vertebrates, invertebrates, plants, and ichnofossils from the Upper Triassic of the Wolfville and Blomidon formations. The present study has found the first evidence of vertebrate life from the Triassic of New Brunswick in the Alma area the Bay of Fundy. A single horizon from strata at Waterside Beach has yielded isolated vertebrate bones (vertebral element, limb bone, isolated tooth and bone fragments), while at a second outcrop along Dennis Beach, a single horizon of mudstone preserved vertebrate ichnofossils. UAV-based photographs have been collected to digitally preserve 3D models of the outcrops. This documents the current context, as these coastal sites experience tidal erosion, exposing new outcrop. The ichnoassemblage includes footprints of dinosauromorphs (e.g., lagosuchians; ichnotaxon: *Rotodactylus*), lepidosauromorphs/archosauromorphs (ichnotaxon: *Rhynchosauroides*), Archosauriformes and "Rauisuchia" (ichnotaxon: *Synaptichnium*), and an un-identified dinosaur-like track.

Rotodactylus is thought to represent dinosauromorphs that are close to the beginning of the dinosaurian clade and is an index ichnogenus with a limited stratigraphic range of Early Triassic (latest Olenekian) through the Middle Triassic (Anisian to the earliest Ladinian). The elements of the fossil assemblage described here are commonly found together and comparable to other sites of similar Early–Middle Triassic age in Morocco, South America, and Poland. This restricts the age of the Triassic strata at Dennis Beach and the vertebrate footprints preserved at that locality to between the latest Lower Triassic and the Middle Triassic, making it the oldest evidence of vertebrates from the Mesozoic in Canada inferred from footprints and isolated bones.

## Addressing the 3Ws relevant to understanding the nature of Meguma gold deposits, Nova Scotia, Canada

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The Meguma terrane of southern Nova Scotia is well-known for its slate belt-type auriferous gold mineralization, which is generally attributed to the deformation and metamorphism related to the Neoacadian orogeny. Although variably mined and studied for over 150 years, little has been done to characterize the nature of the gold, either physically or chemically. Hence, such relevant questions as why, where, and when gold forms, in addition to where it originates, remain poorly constrained. These 3Ws are of paramount importance not only for the successful economic exploitation of any ore deposit but also for the genetic models which drive exploration for both additional deposits and reserves. To address this knowledge gap and heighten its importance, and thus provide direction for future research, here we review what is known about gold at various scales – regional to stopes to hand samples or core to microscopic lastly its invisibleness – and then integrate this with the possible mechanisms (e.g., sulphidation, fluid unmixing, oxidation, mobilization) which may have resulted in its original precipitation and, perhaps, subsequent upgrading by comparing and contrasting Meguma gold with other gold deposit settings. The end use of this approach can be used to address, but not limited to, such outstanding questions as: (1) what is the difference between vein-type gold and the so-called but ill-defined "disseminated type"; (2) why are some saddle reefs more gold mineralized than others; (3) why do ore shoots exist and when did they form; (4) why did gold plate onto ribbons of wall rock; (5) why and how did localized pockets of bonanza-grade gold form; and (6) how many gold events are represented. As the application of relevant analytical methods (e.g., in situ LA–ICP–MS analysis; fluid inclusion studies) provide the means to address some of the 3Ws, such data are incorporated into the presentation.

## Survey of porewater geochemistry within deep marine hydrocarbon seep sediments of the Scotian Slope, Canada

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The ocean floor surface sediments of the Scotian Slope, Nova Scotia, are host to a complex network of microbially mediated reactions that knit together the carbon, sulphur, and nitrogen biogeochemical cycles. The energetics of biogeochemically controlled redox gradients are further governed by microbial heterotrophy. These microbial biogeochemical zones change if surface sediments are impregnated by hydrocarbon seepage that migrates up from deeper within the basin. Porewater profiles of $F^-$, $NO_2^-$, $NO_3^-$, $CO_3^{2-}$, and $SO_4^{2-}$ were used to reconstruct biogeochemical stratification depth profiles that can provide comparative evidence for anion behaviour in active cold seep sites. These profiles define microbial metabolic processes within the sediment subsurface. To test this hypothesis, 50 samples stratigraphically collected across 9 sediment cores were separated, centrifugated and analyzed using ion chromatography. A comparative study between two methods of data analysis was applied to the samples. Fluoride concentration seems uncorrelated to sediment depth and unique sample heterogeneity might be the leading factor to its variation. However, $NO_2^-$, $NO_3^-$, and $SO_4^{2-}$ display decreasing concentrations with increasing depths. Sulphate concentration decreases dramatically in both ambient and hydrocarbon impacted marine benthic sediments although, in hydrocarbon impacted sites, it appears to occur at a much shallower depth suggesting that the redox gradient is much more pronounced and as much sulphate reduction has not yet transpired with the ambient sediments at the same depth. Nitrate and $NO_2^-$ trends also show similar pronounced reduction patterns occurring at shallower depths for hydrocarbon impacted sediments suggesting widespread increased microbial and bacterial activity in these regions.

## Zircon petrochronology of the West Barneys River Plutonic Suite: insights into the origin of a potential critical element (REE and Zn) deposit in Nova Scotia, Canada*

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The transition to a green energy future requires a significant increase in the supply of critical elements; therefore, it is essential that we advance our knowledge of the processes that concentrate them. Of the 31 elements that Canada has deemed to be critical, many of them are concentrated by igneous rock-forming processes. For example, the rare earth elements (REE) are known to be concentrated by magmatic processes associated with the emplacement of alkaline to peralkaline igneous rocks. This research focuses on the West Barneys River Plutonic Suite (WBRPS) in Nova Scotia, which has elevated concentrations of REE and Zn. The WBRPS is a complex, heterogeneous mix of coeval lithologies ranging in composition from mafic to felsic plutonic rocks. Published U–Pb data indicates a range of crystallization ages between ca. 495 and 460 Ma, however, there remain many knowledge gaps related to the origin of these rocks and the associated REE and Zn mineralization. Ten representative samples were collected from the WBRPS that range in composition from gabbro to quartz syenite. Of those, seven samples yielded dateable zircon with identifiable autocryst, antecryst, and xenocryst domains. Preliminary interpretations of LA–ICP–MS U–Pb data yield an emplacement age range between ca. 465 and 430Ma and indicate multiple magmatic generations of varying compositions. These new petrochronological data indicate that the WBPRS had a prolonged and complex emplacement history spanning over 30 Ma, and further interpretations of zircon trace element data will elucidate the magmatic processes that concentrated REE and Zn.

**Winner: AGS Rupert MacNeill Award for best undergraduate student oral presentation*

## Analysis of pre-, syn-, and post-mineralization porphyry to pegmatitic dykes associated with various types of mineralization: dissecting source, fractionation, emplacement, and timing of complex magmatic hydrothermal systems

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Dyke systems in a wide range of settings have long been examined to help understand many aspects of complex magmatic hydrothermal systems from various porphyry to pegmatitic settings. Regional to detailed mapping of these superimposed magmatic systems in any specific region unravels that relative history, and with their geometry enhance our understanding of the controls on emplacement (far-field stresses to caldera collapse), and their relation to mineralization; that relative chronology is then tested with geochronology (dating), which now is often detailed petrochronology. Robust lithogeochemistry is used extensively with petrology to characterize each set of dyke systems against other intrusive and even extrusive magmatic systems within any particular region, i.e., analogous to chemostratigraphy. Petrology (groundmass, phenocrysts, phenoclasts, lithics) with mineral chemical analysis to determine physiochemical parameters have also been used increasingly; the lithogeochemistry and petrology helps place Temperature (Tzr, Tap, Tmz) and Pressure (Pqz, Phb, Pbt) constraints to help our understanding of the overall plumbing system, especially the hypabyssal environment of emplacement, but also the associations and evolution of the causative magmatic system. From the deeper level to subvolcanic realm is where volatile exsolution, then hypersolidus to subsolidus, endo-granitic to exogranitic alteration takes place as well as hydrothermal mineralization processes. The challenges of discerning magmatic fertility, and even magmatic enrichment versus hydrothermal enrichment processes in forming mineralization from lithogeochemistry and mineral chemical systematics has evolved considerably; however, the nature or character of dykes (pheno-crysts and groundmass), emplacement, and quenching allows further interpretation of these two fundamental processes. Pressure versus thermal quenching and undercooling related textures, in injecting melts to pyroclastic tuffisitic systems helps preserve features of interest in many dykes and dyke swarms, even zoning within dykes, that are often overlooked. Constraints from HEAT3D analysis of cooling rate of dykes and even their associated overall magmatic systems relative to known liquidi–solidi are under-utilized.

## Origin to emplacement of Pabineau Falls aplitic granite dykes, northeastern New Brunswick, Canada: evidence of extreme fractionation

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The post-tectonic Middle Devonian Pabineau Falls Granite (PFG) is a porphyritic coarse-grained biotite granite located in northeastern New Brunswick (Canada) that has been previously dated by U–Pb zircon (397.2 ± 1.9 Ma). The western part of the PFG has been intruded by an unrelated coarse-grained to pegmatitic Be-bearing molybdenite-mineralized (endogranitic) leucogranite that is named the Pabineau Lake Granite (PLG). The PLG has been dated at 390 ± 1 Ma (U–Pb zircon), and therefore cannot be related to the cooling of the PFG. Narrow felsic dykes (<1 m width) are also known in the PFG that have textures ranging from quenched aplitic to microcrystalline, so four were sampled at Pabineau Falls to examine their composition and ascertain their ages. The microcrystalline dyke is the youngest and cross-cuts the other dykes orthogonally. All four of these leucocratic dykes are more fractionated than the PFG (Zr/Ti, Zr/Hf, Nb/Ta, Rb/Sr), but similar to the PLG, although none are mineralized; these dykes and the PLG are high silica (>75 wt.%), calc-alkalic, mostly ferroan with ASI of 1.05 to 1.08 like the PLG, and hence typical of post-orogenic suites. Chemical characteristics such as low CaO (<0.5 wt.%), $P_2O_5$ (<0.04 wt.%), and Al/Ga (3659) are consistent with within-plate (A-type) granites, although these characteristics are exaggerated by very low T fractionation. The youngest microcrystalline dyke has low Zr (38 ppm) consistent with extreme fractionation. The ratios Zr/Hf, Nb/Ta, and Y/Ho covary and decrease to 13.6, 2.2, and 30.4, respectively, whereas Rb/Sr increases to 9.1. The Th and Y decrease as Nb, Ta, and U increase with fractionation. These dykes have bird-wing chondrite-normalized REE profiles, with pronounced Eu/Eu* (0.206 to 0.132) consistent with considerable feldspar fractionation. Pqz for the most pressure-quenched dyke is 220 MPa, similar to the result from the PLG.

## Constraints on Ediacaran foreland exhumation and sedimentation in the Avalon Zone: provenance and maximum depositional age of the Flatrock Cove Formation in Newfoundland, Canada

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In the Avalon Zone of Newfoundland, evidence of Ediacaran orogenesis begins with a switch from arc-adjacent submarine fan sedimentation (Conception Group) to south-directed foreland basin deltaic progradation of the St. John's and Signal Hill groups at ca. 565–560 Ma. The Flatrock Cove Formation, with a maximum depositional age of 551.7 ± 9.7 Ma, is the youngest known part of this foreland succession and provides evidence of southeast-directed Ediacaran fold and thrust propagation coeval with proximal foreland growth sedimentation. Basal growth sequences of the Knobby Hill (KH) Member record axial braided fluvial sedimentation and limb rotation along a growing anticline. Pebble provenance data from KH show that arc volcanic clasts were replaced upward by arc plutonic clasts, consistent with the exhumation of nearby arc basement. Conformably above this unit are alluvial fan strata of the Piccos Brook (PB) Member that record radial southwest-directed sedimentation from the newly emergent Flatrock thrust. Proximal fan facies here unconformably onlap deformed hangingwall Conception Group strata, forming the Lilly Unconformity that suggests displacement of at least 2.5 km of stratigraphy across the Flatrock thrust at this time. Angular sedimentary clasts in the PB Member were sourced by erosion of Ediacaran sedimentary strata along the hangingwall of the Flatrock thrust. Detrital zircon populations in the KH and PB members are dominated by grains from ca. 640–565 Ma Ediacaran continental arc sources, with lesser ca. 790–730 Ma grains with a wide range of sub-chondritic εHf values related to Tonian arc sources, and 1800–1400 Ma grains with highly negative εHf values derived directly or indirectly from Paleoproterozoic cratonic sources. Notably, the PB detrital zircons are characterized by progressively older Ediacaran and Tonian peaks and a greater proportion of >1 Ga grains, further corroborating that progressive exhumation of older parts of Avalonian basement coincided with Ediacaran foreland deformation and sedimentation.

## YouTube: don't let these myths stop you from making an impact!

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YouTube is the world's second most used social media platform, with >2.5 billion monthly users in 2022 (Statista.com) and widespread uptake across demographic groups. This creates enormous opportunities for earth science communicators. However, potential content creators may be deterred by perceived barriers to entry, including hardware and skills deficits, market saturation, time commitment, and lack of audience interest in 'niche' topics. Using local and international examples of earth science outreach successes on YouTube, this talk argues that these concerns

are largely based on misconceptions about the requirements of effective video-based communication, and that there are opportunities within the YouTube landscape for content creators of all abilities.

## Machine learning focal mechanism inversion for hydraulic fracturing-induced earthquakes

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Hydraulic fracking has contributed to an increase in induced seismicity in recent years in Fox Creek, Alberta. Earthquake focal mechanisms, relying on polarities of earthquake first motions, provide insight into the state of stresses in a region. Traditional methods for manually determining the polarities of first motions are not suitable for microearthquakes due to the large volume of data and owing to their low signal–noise ratio. Machine learning provides a reliable and efficient way for polarity classification. Using data obtained from the Tony Creek Dual Microseismic Experiment, this study aims to show that machine learning can reliably solve for polarities of earthquake first motions and characterize the focal mechanisms of hydraulic fracking-induced earthquakes. The project will provide greater insights into the state of stresses and geologic structures (such as faults) in the study area and will improve our understanding of earthquake-triggering mechanisms during hydraulic fracking. In this presentation, we introduce the seismic data, proposed methods, and preliminary results.

## Greenfield discovery of the Khundii mineral district, southwest Mongolia

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Systematic exploration by Erdene Resource Development Corp. since 2005 in an underexplored region of southwestern Mongolia resulted in identification of three resources, including two epithermal gold deposits and one porphyry Mo–Cu deposit, plus several prospects and advanced projects that form the newly defined Khundii ('Valley') mineral district. The district is hosted by a Carboniferous island-arc terrane, part of the Central Asian Orogenic Belt. A regional exploration program was initiated by Erdene in 2009 over 110 000 km$^2$, based on the success at the Zuun Mod Mo–Cu porphyry deposit. Exploration included compilation of existing geological, geochemical and geophysical data and interpretation of satellite imagery, followed by ground exploration that included stream, soil and rock chip sampling, and geological and alteration mapping. Following the discovery of the Nomin Tal Cu–Au prospect in 2011 a 400 x 400 m soil survey over most of the exploration license identified Pb-, Zn- and Au-in-soil anomalies over a ~1.5 × ~5.5 km area. The first drill hole in the soil anomaly discovered the Altan Nar Au–polymetallic intermediate sulphidation deposit; veins of coarse crystalline quartz–adularia and carbonate gangue host the metal sulphides. The Bayan Khundii low-sulphidation gold deposit was discovered in 2015, ~16 km southeast of Altan Nar, including 7 m at 27.5 g/t Au from 14 m depth in an early drill hole. Discovery of the Khar Mori Au prospect was announced in early 2021, ~3.5 km north of Bayan Khundii, with one drill hole reporting 45 m of 5.97 g/t Au from 10 m depth. Later in 2021, drilling discovered wide zones of disseminated gold at Ulaan Southeast (up to 258 m at 0.98 g/t Au from 92 m depth), ~800 m west of Bayan Khundii. Epithermal quartz–adularia–Au veins with colloform bands and illite alteration at the Bayan Khundii deposit overprint earlier porphyry-related lithocap alteration.

## Geochemical variations in biotite composition from the Devonian South Mountain Batholith, Nova Scotia, Canada: constraints on magma redox state and petrogenesis

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We report on the composition of biotite from the peraluminous Devonian South Mountain Batholith (SMB) of southwestern Nova Scotia, Canada. Biotite analyses were obtained from 55 unmineralized samples representing 11 plutons. Sample petrography indicates biotite saturation broadly coeval to other rock-forming minerals in the paragenesis, inferring that biotite chemistry reflects both within-pluton and batholith-scale variations in crystallization conditions. Biotite compositions are siderophyllitic with Fe/(Fe+Mg) ranging from 0.6 to 0.98, and Al-rich, with $^{IV}$Al ranging from 2.2 to 2.9 atoms per formula unit (apfu; 22 oxygen basis), the latter reflecting the coexistence of other Al-rich phases. Biotite anion sites are dominated by OH (>3 apfu), followed by F (0.1–1.7 apfu) and Cl (<0.1 apfu), with a general trend of decreasing OH, increasing F and decreasing Cl, with increasing differentiation. Pressure-temperature estimates for biotite crystallization (250–400 MPa and 705–625°C) suggest minimum water contents of 6–7 wt.% for SMB magmas when compared to water-saturated granite phase relations. The redox state of the SMB was estimated by comparing measured biotite Fe#–Ti relations with those calculated using the MELTS thermodynamic model. Results indicate that the observed biotite Fe#–Ti variation is consistent with crystallization at FMQ to FMQ-1, with more oxidizing conditions suggested for some samples, particularly the most strongly differentiated. The relatively reduced redox state of the SMB, similar to other peraluminous granitoid occurrences worldwide, aligns with other measures of $fO_2$ for the SMB, including Ce-in-zircon oxygen barometry and the occurrence of primary ilmenite. The observed correspondence between the estimated $fO_2$ and that imposed by graphite–gas equilibrium suggests a role for reduced carbon in the generation and evolution of the SMB. This result is consistent with evidence for SMB interaction with graphite-bearing felsic granulite of the underthrust Avalon terrane, and assimilation of carbonaceous and sulphidic metasedimentary rocks during pluton ascent and emplacement.

## Portable-XRF geochemistry and EDS mineralogy of the Maple–Hovey manganese deposit, northern Maine, USA

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The Silurian Aroostook County manganese district in northern Maine consists of northern, central, and southern sub-districts. Collectively, they represent the largest manganese reserve in the United States. This study focuses on the central sub-district where the largest known deposit, the Maple-Hovey deposit, is located. Detailed field mapping, cross-section characterization and sampling across two continuous exposures of the primary ore zone, portable-XRF analyses, petrography, and preliminary energy dispersive spectroscopy (EDS) mineral identification via electron microprobe have been conducted to characterize the lithogeochemistry, chemostratigraphy, and mineralogy in the deposit to better constrain its metallogenesis. Field observations show that the manganese deposit is presented as a continuous but swell-and-pinch layer, and the primary ore zone consists of thinly laminated, very fine-grained manganese ironstone. The ore and surrounding host rock are dominated by a layered sequence with varying mineralogy. Petrographic observations and EDS spectra reveal a chlorite-rich host rock, Fe-rich layers largely consisting of hematite with lesser magnetite and pyrite, Mn-rich layers of varying compositions of Mn-silicates, oxides, and carbonates, and P-rich layers occurring in the primary Mn ore zone. Cross-cutting veinlets containing a Mn-silicate (possibly rhodonite, $MnSiO_3$), albite, and other minerals indicate minor hydrothermal activity. Spessartine garnet occurs as a major Mn-silicate, indicating high Mn and Al concentrations allowed its formation at low temperatures and greenschist-facies peak metamorphism. Initial results from portable-XRF data show that Fe and Mn are generally found in discrete layers. Barium, Ni, and Ti are of varying but relatively high concentrations both within and surrounding the ore zone. These observations support the interpretation that the Maple-Hovey Fe–Mn Deposit represents a sedimentary accumulation with similarities to the well-characterized Silurian Woodstock Fe–Mn deposits in New Brunswick, Canada, and other Fe–Mn deposits worldwide.

## Rare earth element mineralization associated with the peralkaline Fox Harbour Volcanic Belt, southeastern Labrador, Canada

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The Fox Harbour Volcanic Belt (FHVB) is host to the most advanced rare earth element (REE) project in Atlantic Canada. It is located in the Grenville Province in southeastern Labrador and is one of several REE-mineralized Mesoproterozoic peralkaline complexes across Labrador, including the Strange Lake and Flowers River complexes and the Red Wine Intrusive Suite. The FHVB is 64 km long, ranging in thickness from 50 m in the east to 3 km in the west, and contains three parallel mineralized belts composed of mainly peralkaline and non-peralkaline rhyolite, trachyte, and basalt. The felsic rocks are A-type (mostly A2-type), peralkaline to peraluminous and plot in the within-plate granite field. Rare-earth-element mineralization is hosted in the most evolved rocks composed of pantellerite, comendite, and pantelleritic and comenditic trachyte, which are characterized by the highest REE, Zr, Nb, U, Th and FeO contents. The Zr content is ≤26 361 ppm, and the light REE and heavy REE enrichments are ≤20 000 times and ≤1000 times the chondrite concentrations, respectively. The main REE minerals are allanite, fergusonite, locally REE-titanite, rare britholite, chevkinite, bastnaesite, synchysite and monazite. The rarity of REE-fluoro-carbonates replacing allanite argues against significant hydrothermal remobilization of REE. Uranium–Pb geochronology in zircon yielded igneous crystallization ages ca. 1.3 Ga and suggest a long-lived magmatic activity. Host rocks are overprinted by Grenvillian metamorphism ca. 1.05 Ga. Non-peralkaline rhyolite yielded a younger age than the more evolved comendite, and pantellerite returned only a metamorphic age. This study highlights the complex evolution (magmatic, hydrothermal, and metamorphic) of the rocks and challenges several aspects of the current models for this type of deposit, such as the lack of significant REE mineralization in peralkaline extrusive rocks, increase in degree of fractionation over time, and the presence of significant hydrothermal REE overprint.

## On the discovery of a new *Pygocephalus cubichnia* from the UNESCO World Heritage Site at Joggins Fossil Cliffs, Nova Scotia, Canada

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The Carboniferous Joggins Fossil Cliffs UNESCO World Heritage Site, located in Nova Scotia, has long been known for its extensive paleobiodiversity. The ichnofossil record at Joggins is less known compared to body fossils. The late citizen scientist Donald Reid (known as "The Keeper of the Cliffs") contributed significantly to our understanding of the fossil record at Joggins. In his extensive ichnological collections is a morphologically unique "shrimp shaped" cubichnia (resting trace). The trace fossil is associated with faint invertebrate trackways that lead up to the resting trace and verifies the identification of this specimen as an invertebrate resting trace. The trace fossil was recovered from the upper Joggins Formation (876 m above the base) and was found in fine-grained rippled sandstones that are interpreted to be from an Open-Water to Poorly-Drained Lithofacies Assemblage transition. Horseshoe crab walking traces (*Kouphichnium*) are well known from this trace fossil horizon. The trace fossil specimen also has examples of invertebrate resting traces *Selenichnites* and *Rusophycus* preserved in convex hyporelief, that are commonly ascribed to horseshoe crabs and crustaceans, respectively, when found in freshwater paleoenvironments. This stratigraphic interval has previously yielded body fossils of *Pygocephalus* shrimp preserved in organic rich limestones and sideritic ironstone nodules. The Joggins Cliffs have yielded an abundance of trace fossils ascribed to horseshoe crabs, yet only two of their body fossils. *Pygocephalus* shrimp body fossils are common at Joggins, yet no trace fossils have yet been assigned to this invertebrate and perhaps have gone unrecognized. We interpret the trace fossil to have been produced by a *Pygocephalus* shrimp based on its morphological similarities to known body fossils from the Joggins Formation that are found in proximity to the trace fossil horizon. This new trace fossil morphology likely warrants a new ichnotaxon.

## Age and petrogenesis of lithium–cesium–tantalum (LCT) pegmatites in the northeastern Meguma terrane, Nova Scotia, Canada

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As Canada moves towards a renewable energy-based future, critical elements that are essential for green technologies will only increase in demand. Of the 31 elements that Canada has deemed to be critical, many of them can be concentrated by igneous rock-forming processes, including the processes that result in the formation and emplacement of granitic pegmatites. Pegmatite-forming processes can concentrate elements such as lithium, cesium, and beryllium. The pegmatites in this study were discovered in 2020 in the northeastern Meguma terrane of Nova Scotia and are associated with voluminous Devonian, peraluminous granitoid plutons. These pegmatites were studied to determine their age, extent, tectonic setting, and petrogenesis. The pegmatites mainly intruded coeval peraluminous granite and metasedimentary host rocks as dykes and irregular blobs. The granite plutons have abundant septa, rafts, and xenoliths of the metasedimentary rocks that were metamorphosed to amphibolite facies during the Devonian. The mineralogy indicates that these pegmatites are LCT pegmatites and that they can be divided into three groups. Group 1 pegmatites are "barren" and have a simple mineralogy of quartz, albite, microcline, and muscovite. Group 2 pegmatites have the same mineralogy as the Group 1 pegmatites with the addition of tourmaline and garnet. Group 3 pegmatites contain large (up to 6 cm in diameter) euhedral beryl, especially near the northern margin of the Meguma terrane adjacent to a major, dextral transpressive fault zone (Cobequid–Chedabucto Fault Zone). In addition to beryl, Group 3 pegmatites contain tourmaline, garnet, albite, microcline, muscovite, and apatite. A Devonian $^{40}Ar/^{39}Ar$ date is interpreted to represent the cooling age of pegmatite emplacement. Five Carboniferous $^{40}Ar/^{39}Ar$ dates are interpreted to represent the timing of a crystallization or recrystallization event caused by hydrothermal fluid movement along the Cobequid–Chedabucto Fault Zone. The pegmatites are inferred to have formed by fractionation from muscovite–biotite granite magmas.

## Recognizing gold mineralization pathfinders with portable XRF and micro-X-ray fluorescence spectrometry in the Williams Brook epithermal system, New Brunswick, Canada: analysis of indicator elements and minerals

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Numerous gold occurrences/deposits occur in and around the Tobique–Chaleur Zone in northern New Brunswick (NB) and the adjacent Gaspé Peninsula. Gold occurrences in northwestern NB are typically associated with large-scale crustal structures or their subsidiary splays (e.g., the Rocky Brook–Millstream Fault system). The Williams Brook (WB) property, situated in the northwest part of the Chaleur Bay Synclinorium, is hosted by Early Devonian volcanic-sedimentary rocks of the Wapske Formation (Tobique Group) and exhibits characteristics of a low-sulphidation epithermal Au system. Finding and exploring for this type of system can be challenging and requires a variety of techniques and approaches to be successful. In this study, portable X-ray fluorescence (pXRF) spectrometry, multi-element four acid digestion ICP–AES/–MS (ME–MS61), and micro-X-Ray Fluorescence (μ-XRF) Energy Dispersive spectrometry were used to analyze samples from the WB property. Composition-based multivariate techniques (compositional biplots and correlation analysis) were applied to the pXRF and ICP-based multi-element datasets. Compositional biplots derived from the data showed that Au, Ag, As, and Sb are closely associated. A mineralogical study conducted on polished thin sections from core samples identified gold-bearing minerals using μ-XRF. These results show that gold occurs primarily in association with pyrite, galena, and sphalerite, with sericitic, chloritic, and dolomite alteration associated with gold-bearing quartz veins. Comparison of pXRF and ME-MS61 datasets in terms of identifying pathfinder elements found that ME-MS61 provided more reliable results; however, the benefits of pXRF acquired data (i.e., non-destructive, faster, and convenient to use in the field) cannot be overlooked. These findings not only give us a better understanding of the minerals and geochemical signatures present in the gold deposits at WB, but also provide a useful guide for identifying similar deposits in the future through the use of indicator minerals and elements.

## Rock avalanches in northeastern Baffin Island, Canada: understanding low occurrence in a region of high hazard potential*

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Large landslides in fjord environments have the potential to cause catastrophic damage and trigger secondary submarine landslides and tsunamis. Of the 14 largest tsunamis on record, 10 were triggered by subaerial landslides, often rock avalanches, into fjords or lakes in high relief glaciated terrane. These complex hazards are well documented in the fjords of Greenland, Norway, and Alaska, with several resulting in fatalities and permanent damage to coastal settlements. However, despite the recognized hazard potential, few rock avalanches have been reported on Baffin Island where the extensive coastline is deeply incised by fjord systems. Are rock avalanches going unnoticed in this isolated region? Or are these events comparatively less common on Baffin Island despite high relief, rapid deglaciation, thawing permafrost, and regions of active seismicity? Here we develop the first systematic inventory of onshore rock avalanche deposits in this area, mapped using high-resolution optical imagery and digital elevation models, to answer these questions and evaluate the prevalence and distribution of rock avalanches in NE Baffin Island. In a study area that encompasses ~60 000 km$^2$ of fjord terrane between the hamlets of Clyde River and Pond Inlet, on the NE coast of Baffin Island, we find only 6 preserved onshore rock avalanche deposits within the study area. Of these, only 2 deposits are dated, using historical imagery, to the last century while 4 deposits can only be inferred as post-glacial, without a more precise age limit. Why are comparatively few rock avalanche deposits observed in NE Baffin Island? We hypothesize that (1) persistent permafrost in the region continues to act as a stabilizing factor, (2) overall rock mass competence is high in areas of most extreme relief contrast, and (3) some deposits remain masked underwater in deep and steep-walled fjords where bathymetric data is either lacking or too sparse for systematic mapping.

**Winner: AGS Sandra Barr Award for best graduate student oral presentation*

## Overprint magnetization in the Ratcliffe Brook Formation, Caledonia terrane, New Brunswick, Canada, and implications for paleomagnetic investigation of Appalachian orogenic evolution

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Paleomagnetism of Appalachian Paleozoic rocks offers potentially useful information regarding primary paleogeographic relationships between terranes and continents, if primary magnetizations can be demonstrated. Secondary "overprint" magnetizations commonly occur, however, and are usually related to later stages of orogenic evolution. We have collected a reconnaissance paleomagnetic sample suite from two localities in the Hanford Brook area of the Cambrian Ratcliffe Brook Formation, Caledonia terrane of New Brunswick to investigate its possible primary and/or secondary overprint magnetizations. Preliminary paleomagnetic results from the ca. 520 Ma Mystery Lake Member red-purple mudstone and siltstone strata carry a stable remanent magnetization that fails a fold test and has a combined in situ mean direction of $D = 165, I = 16°$, consistent with it being a Carboniferous overprint magnetization of 300–310 Ma age. The overprint is similar to "Kiaman" superchron Carboniferous overprint magnetizations in Paleozoic strata throughout the Appalachians and adjacent basins, thought to be associated with the Alleghanian orogeny. Regionally, the apparent late Carboniferous overprint age is slightly younger than ca. 315–326 Ma metamorphic ages along the Fundy coast, which are possibly related to the arrival of the Meguma terrane as it collided with and overrode Avalonia in New Brunswick. Locally, no metamorphic ages are reported in published $^{40}Ar/^{39}Ar$ work on detrital muscovite from the Ratcliffe Brook Formation, indicating that the remagnetization likely reflects low temperature formation of new magnetic minerals. Overprint paleomagnetic directions in the Hanford Brook area appear to be slightly younger than recently reported ca. 320 Ma overprint magnetizations in Meguma terrane, and also do not show as much counterclockwise apparent rotation. Kiaman overprint directions in the Appalachians offer a tool for both dating the overprint acquisition timing (with reference to the North American Apparent Polar Wander Path) and also to detect post-magnetization rotations of portions of the orogen during the final assembly of Pangea.

## Indicator mineral studies at the Brazil Lake LCT pegmatites, southwest Nova Scotia, Canada

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Indicator mineral research is currently being undertaken in partnership with the Nova Scotia Department of Natural Resources and Renewables at the Brazil Lake lithium–cesium–tantalum (LCT) pegmatites in southwest Nova Scotia as part of the Geological Survey of Canada's Targeted Geoscience Initiative (TGI) program. The pegmatites, discovered in 1960, are well known from previous detailed bedrock mapping and surficial studies and are informally named based on their relative geographic positions as the South and North pegmatites. The South pegmatite naturally outcrops, and both pegmatites are surrounded by spodumene-rich boulders on the surface of the thin till-covered (<4 m) drumlinized glacial landscape. For these reasons, the pegmatites are excellent sites to test indicator mineral exploration methods for Li and associated critical elements (e.g., Ce, Ta). Five pegmatite samples were collected for detailed study and analysis of potential indicator minerals. Close to the pegmatite and up to 13 km down ice (south-southeast), 87 bulk (10–14 kg), till sediment samples were collected for indicator mineral analysis. A total of 105 till samples were collected around the pegmatite and across the region for matrix geochemistry. A preliminary list of indicator minerals includes mid-density (e.g., spodumene, tourmaline, blue apatite) and high-density mineral species (e.g., columbite–tantalite, cassiterite) and this list is expected to expand as the detailed studies progress. Trenches dug in the Fall of 2022 to collect till samples on the proximal down ice (south) sides of both pegmatites revealed abundant spodumene pebbles and small cobbles in the till, indicating that the local till should display strong indicator mineral and matrix geochemical signatures derived from the pegmatites.

## Dating fault reactivation at the northern Appalachian structural front, western Newfoundland, Canada

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The Appalachian orogen developed during multiple microcontinent and terrane accretions resulting from episodic, Cambrian through Devonian, closure of the Iapetus Ocean. In western Newfoundland, preserved folds and faults formed during the Taconian and Acadian orogenies. The NW limit of deformation, or Appalachian structural front, extends along Newfoundland's west coast, and is defined by a tectonic wedge, the upper detachment of which is marked on the Port au Port Peninsula by the Tea Cove thrust. Stratigraphic relationships suggest west-directed wedge emplacement during the Early to Middle Devonian. The Tea Cove thrust is cross-cut by the basement-cutting Round Head thrust, the motion of which is bracketed between the Early Devonian and Visean according to stratigraphic relationships. Preliminary U–Pb geochronology data obtained from LA–ICP–MS of calcite slickenfibres collected from small but pervasive conjugate thrust faults, oriented parallel to the Tea Cove thrust with horizontal NW–SE shortening direction, show Late Devonian ages of ~366 Ma for fault slip. Major faults, parallel to the Tea Cove Thrust, preserve two generations of motion; a metre-wide fault zone with kinematic indicators indicating SE-directed back-thrusting and discrete, bedding-subparallel faults an opposite, normal sense of slip which bound the fault zone. U–Pb calcite slickenfibre ages from these discrete faults indicate latest Mississippian to Pennsylvanian slip at ~324 Ma. Later cross-cutting faults, with orientations consistent with post-Taconian basement faults, have sinistral sense calcite slickenfibres that yield late Pennsylvanian to Permian U–Pb ages of ~299 Ma. Future work will focus on dating early bituminous veins that are cross-cut by all major structures, to further constrain motion and reactivation on the structural front. These novel calcite slickenfibre ages, some of the first reported in the Canadian Appalachians, demonstrate fault reactivation during late and post-orogenic stages along the Appalachian front.

## Appinite complexes, granitoid batholiths and crustal growth: a conceptual model

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Appinites are plutonic rocks, ranging from ultramafic to felsic in composition, that are characterized by idiomorphic hornblende as the dominant mafic mineral in all lithologies and by spectacularly diverse textures, including planar and linear magmatic fabrics, mafic pegmatites and widespread evidence of mingling between mafic and felsic compositions. These features suggest crystallization from anomalously water-rich magma which, according to limited isotopic studies, has both mantle and meteoric components.

Appinites typically occur as small (~2 km diameter) complexes emplaced along the periphery of granitoid plutons and commonly adjacent to major deep crustal faults, which they preferentially exploit during their ascent. Several studies emphasize the relationship between intrusion of appinites, granitoid plutonism and termination of subduction. However, recent geochronological data suggest a more long-lived genetic relationship between appinites and granitoid magma generation and subduction.

Appinites may represent aliquots of hydrous basaltic magma derived from variably fractionated mafic underplates that were originally emplaced during protracted subduction adjacent to the MOHO, triggering generation of voluminous granitoid magmas by partial melting in the overlying MASH zone. The hydrous mafic magmas from this underplate may have ascended, accumulated, and differentiated at middle-to-upper crustal levels (ca. 3–6 kbar, 15 km depth) and crystallized under water-saturated conditions. The granitoid magmas were emplaced in pulses when transient stresses activated favourably oriented structures which became conduits for magma transport. The ascent of late mafic magmas, however, was impeded by the rheological barriers created by the structurally overlying granitoid magma bodies. Magmas that form appinite complexes evaded those rheological barriers because they preferentially exploited the deep crustal faults that bounded the plutonic system. In this scenario, appinite complexes may be a direct connection to the mafic underplate and so its most mafic components may provide insights into processes that generate granitoid batholiths and, more generally, into crustal growth in arc systems.

## In situ sensor-based monitoring strategies for biogeochemical reactions in circumneutral Au tailings environments

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Natural resource exploitation and ore processing have significant environmental impacts, such as wastewater, waste rock and tailings. These wastes continue to cause a detrimental effect on surface and groundwater bodies decades after production at the site is completed, requiring long-term management and remediation efforts either from the site managers, or the government. Existing approaches to characterize site chemistry involve extensive field sampling, lab-based analysis for pH neutralization and metal precipitation, and mass spectrometry techniques. However, substituting with in situ methods can provide rapid, accurate results and address inefficiencies in the traditional methods. Specifically, recent advances in sensor-based monitoring have created the opportunity for directly measuring redox species in the field, cutting the time for laboratory processing and analysis. There is evidence of specific microbial geochemical activities/pathways linked to open-circuit sensor-based potential measurements. In situ characterization of these pathways provide an improved spatial- and temporal resolution than can be achieved by the conventional methods.

Here, we will use open-circuit potential measurements from a collection of sensors to study the remediation of circumneutral gold tailings laden with arsenic and mercury. Carbonate minerals dominate circumneutral mine waste and the dissolution of these minerals leads to the mobilization of heavy metals into tailings pore water and subsequently into surface and groundwater bodies.

We will perform specific microbial metal reduction experiments relevant to mine waste remediation using a series of lab-based microcosms. These microcosms will follow a known geochemical pathway (iron, sulphate reduction, etc.) and monitor the microbial metabolites using ion-selective electrodes and electrochemical sensors (pH, dissolved oxygen, etc.). The knowledge from these experiments will support the development of new, in situ methods for monitoring contaminated mine sites and provide better data quality to managers and regulators. This information is critical to managing contaminated mine sites effectively and long term.

## On the discovery of fossil land snails (*Dendropupa sp.*) from the Minto Formation of central New Brunswick, Canada

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The Pennsylvanian-aged (late Bashkirian–early Moscovian) Minto Formation of central New Brunswick was previously studied for its diverse paleoflora, rare invertebrate fauna (trigonotarbid) and rare disarticulated vertebrate fauna. The Minto Formation has been interpreted to represent a peat-forming wetland that experienced occasional euryhaline influence within back-barrier or delta-front depositional settings. A recently discovered fossil locality situated along the southern shoreline of Grand Lake, yields a diverse array of plant fossils, vertebrate trace fossils, and invertebrate body fossils. Two new terrestrial gastropods (NBMG 21521) are described that broadly conform to the genus *Dendropupa*, with a similar apex and post-apical whorls. However, they differ in morphology from *Dendropupa* by possessing axial (longitudinal) sculpture on the shell. Species of *Dendropupa* exhibit either fine axial lirae or pronounced axial lirae along their shell that are not preserved in the Minto Formation specimens. This is possibly because of the preservation as the shells as internal molds with only fragments of the original shell remaining. Both Minto Formation specimens exhibit the same morphology but differ in size, suggesting one is an adult and one a juvenile. The diminutive size of the shells suggests that they may represent the smallest known Carboniferous land snails in the fossil record. These two gastropods are associated with invertebrate ichnofossils (*Gordia*, *Helminthoidichnites*, and cf. *Helminthopsis*). These traces are similar in width to the body fossils, and trail behind them implying a trace and trace-maker relationship, broadening the tracemaker interpretations for those ichnogenera.

## Later stages of a right lateral strike slip zone: Pennsylvanian to Permian (and Triassic) tectonism along the Fundy coast of New Brunswick, Canada

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The role of tectonism associated with right lateral strike-slip faults, and related salt movement is well-documented along the eastern part of Fundy coast of New Brunswick and adjacent parts of Nova Scotia. They relate to the Yeadonian–Langsettian (early Pennsylvanian) evolution of the Cumberland basin. Transpressional flower structures of similar age are seen from the Saint John area west to Lepreau. More recent structural mapping and related stratigraphic research between Saint John and Alma has defined more transpressional flower structures affecting lower Pennsylvanian strata, and transtensional structures involved in lower Pennsylvanian deposition (Tynemouth Creek Formation), and Permian–Triassic sequences from Quaco Head, Martin Head, and Waterside. Some of these structures involved salt movement, with candidates for salt welds and diapirs now identified from Quaco Head, Martin Head, Waterside, and Alma. Timing remains an issue, but early–middle Pennsylvanian salt movement is most probable around Alma and Waterside (comparable and contiguous with structures seen on the Maringouin Peninsula and at Joggins), while the gypsum (and salt?) diapir at Martin Head could be as young as Triassic (depending on the age of the hanging wall rocks (currently correlated with middle–upper Triassic formations around St. Martins, viz: Echo Cove Formation). Refinement of the Permian and Triassic stratigraphy is underway and will further help to elucidate a detailed tectonic history, but the persistence of the right lateral strike-slip regime from the early Pennsylvanian through the Permian into the lower to

middle Triassic seems probable. This begs the question of when the post-Alleghenian adjustments related to major orogen-parallel faults gave way to regional extension associated with opening of the mid-Atlantic ocean basin. With which regime should the half-grabens of the Fundy Basin (and its continuation to the southwest to the Hartford and Newark basins) be considered related?

## Controls on sandstone diagenesis, Scotian Basin, eastern Canada: basinal fluids and salt tectonics

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Sedimentation and diagenesis in the Scotian Basin were strongly influenced by salt tectonics. Thick Upper Jurassic–Lower Cretaceous deltaic sandstones are important reservoir rocks. Published fluid inclusion data provide a record of changing salinity and temperature of migrating formation water, with the most saline fluids at times of active salt deformation. Recognised high temperature events correspond to high regional mantle heat flow in the middle Cretaceous and the Paleogene release of over-pressured fluids known from apatite fission track studies. Geographic variations in timing of salt deformation resulted in variable diagenetic conditions along the strike of the basin. In reservoir sandstones, albitization of detrital K-feldspar and plagioclase resulted from the high Na+ content of formation waters that migrated through permeable pathways at the time of silica and carbonate cementation, with strong albitization coinciding with transport-controlled dissolution of K-feldspar. Such saline fluids recorded in fluid inclusions created widespread dissolution of silica and carbonate grains and cements and this secondary porosity was host to a variety of late diagenetic minerals including minerals transported by halogen-rich fluids such as sphalerite and titania ($TiO_2$) minerals. Among the titania polymorphs, anatase is mostly early diagenetic whereas brookite is usually late diagenetic and is abundant in reservoir sandstones above the free-water level. Detrital Ti-bearing minerals are unusually abundant in the Scotian Basin and provide a source of Ti for chelation by organic acids. Early diagenesis of titania minerals is related to humic acids in meteoric water at marine lowstands. Late diagenetic mobility of Ti and precipitation of brookite is enhanced by Ti complexing with organic acids in saline, hydrocarbon-rich fluids.

## High-level emplacement of the Cape Chignecto pluton, Cobequid Highlands, Nova Scotia, Canada

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New field work at Refugee Cove in the southern Cape Chignecto Pluton shows evidence for inflation of the granite pluton by multiple sub-horizontal gabbro sills. These sills show igneous intrusive relationships with the granites and include xenoliths and rotated blocks of granite, with local evidence of digestion of granite. East of Refugee Cove, the stacked gabbro sills are cut by a 60 m-wide zone of mixed lithologies bounded by sub-vertical faults. This zone includes 60% granite, 35% gabbro, a metre-scale block of faintly layered feldspathic rhyolite, and polymictic breccia of irregular cm-scale fragments of rhyolite and bedded tuff in a mafic matrix. At the margins of the zone, clasts in the undeformed breccia are aligned parallel to the bounding fault. The zone is interpreted as a small high-level volcanic pipe or diatreme where eruptive products have fallen back into a volcanic vent. There, solidified granite and fragments of rhyolite and tuff were intruded by irregular bodies of gabbro. The cross-cutting untectonized relationship between the vent zone and the gabbro sills demonstrates that both are related to the latest Devonian–earliest Carboniferous plutonism. There is no evidence for co-existence of immiscible mafic and felsic magmas, which is demonstrated in the coeval Wentworth Pluton by lobate, mutually chilled contacts at the margins of gabbro sills. Explosive rhyolite eruptions in modern volcanoes result from emplacement of hot mafic magma into partly crystallized fractionating magma chambers. The Wentworth Pluton outcrops record such processes in an active magma chamber. At Refugee Cove, the rising volcanic products of such a magma chamber cut through the fully crystallized host granite to form a volcano at the surface. The Geopark would welcome further field and lab research on these remarkable rocks.

## Measuring crustal thickness variations with muons

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Understanding topographic relief evolution and its changes over hundreds of thousands to million-year timescales remains challenging. Recent approaches usually combine numerical modelling of terrestrial cosmogenic nuclide (TCN) exposure ages on strath terraces, exhumation histories based on thermochronology, drainage basin evolution, and basin stratigraphy. However, even when combined, these methods are unable to measure the rate changes with precisions needed to differentiate climate from tectonic drivers over multiple glacial cycles and longer timescales.

Muon-paleotopometry is a new approach that may address the methodological gap of determining relief generation. Muon-paleotopometry utilizes the dependence of cosmic ray muon flux on crustal shielding depth. The spatial pattern of concentrations of multiple muon-induced TCN measured along a near-horizontal transect under valleys and peaks relates directly to the history of changes (positive or negative) in crustal thickness. It enables paleotopometry above the sample datum over an isotope-specific monitoring duration. By sampling at depths of hectametres, long-lived TCNs are not sensitive to minor short-term ($<10^5$ yr) changes owing to cut and fill terraces or transgressions for instance, but short-lived isotopes may provide constraints on this. The method uses concentrations differences among samples, so is not significantly impacted by limitations in knowledge of muon flux and interactions at those depths. Early proof of concept investigations at Dalhousie by student thesis work in 2017 provided encouraging results to allow for the current large-scale relief investigation of the European Alps.

## Microbial lipidomic and geochemical survey of newly discovered hydrocarbon seep site 2A-1, of the deep-sea Scotian Slope, Nova Scotia, Canada

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Cold seeps occur globally along active and passive continental margins, expelling deeply sourced hydrocarbon and sulphur-rich fluids from the seabed. These sites sustain oasis-type ecosystems, hosting a unique microbiome. Microorganisms extract metabolic energy by oxidizing the carbon in sedimentary organic matter though a series of electron acceptors creating a distinct biogeochemical zonation in the sediment profiles. Cold seep studies have traditionally focused on the vertical distribution of microorganisms and porewater profiles, ignoring the lateral influence of fluid seepage on the microbial communities and sediment geochemistry. Newly discovered Scotian Slope seep site "The Hole" (2A-1), was sampled along a 1000 m transect at a water depth of 2725 m, spanning the gas discharge point out beyond to the surrounding ambient seafloor. Six push cores, subsampled at 2 cm thickness, representing 76 total sediment samples, will be analyzed through lipidomic and porewater surveys to reconstruct the microbial and geochemical seep architecture. Lipid extracts will be collected through a modified Bligh and Dyer protocol and analyzed using ultrahigh performance liquid chromatography-time of flight mass spectrometry. Porewater profiles will be generated through ion chromatography and photometry. The lipidomes of these sediments will then be interpolated across the transect to resolve the underlying shallow sediment microbial community structure. This sampling strategy will resolve microbial and geochemical changes as a result of the transition from macroseepage to unconstrained microseepage. We therefore hypothesize microseepage will result in greater alteration of the ebullition of gas and result in a larger perimeter of methanotrophy. We will also test whether the microbial community occupying the seep sediments have some communication that extends past the geochemical defined boundary of the seep.

## Is Gold where U find it in Nova Scotia, Canada – a brief exploration guide

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Nova Scotia possesses a varied and complex geology with many distinct formations in a distinct metallogeny containing many metallogenic units, some of which have a rich and diverse mineral endowment. One such unit would be the Meguma Zone that contains several active mines and prospects with gold and associated minerals of economic interest including several prospects either planned or

about to enter production. This paper relates some of the experiences and observations completed during a 15-year period as the provinces' geochemist. My duties included supervising and designing several geochemical databases to assess this rich mineral endowment for economic potential. Several geochemical surveys completed at different scales and in different media facilitate a review of the gold potential within the Meguma Zone lithologies with new areas identified for additional consideration for exploration work presented in the accompanying talk.

Presently much interest is held in the traditional Meguma targets of saddle reef quartz-vein systems now eclipsed by the more recent interest in sediment-hosted targets with a similar geology to the Moose River deposit of Atlantic Gold. Another gold environment makes up the three potential target areas in the Meguma – that of shear zone-hosted deposits within the intrusive granitic suites. Several case history examples are given for cost-effective methods for exploration in the Meguma Zone, including soil, till, vegetation, and lake sediments ranging in scale from reconnaissance to prospect scale studies.

## Vanadium partitioning between apatite and biotite in magmatic rocks – potential for a novel oxybarometry method for Fe-poor granitoid rocks

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Vanadium is a multivalent element, present in the terrestrial magmas as $V^{3+}$, $V^{4+}$, $V^{5+}$ in proportions dependent on the oxidation state of the system. Biotite and apatite as trace minerals are ubiquitous in a wide variety of felsic and mafic rocks. The two mineral structures are expected to have a diverging capacity of accommodating the vanadium species. Based on lattice strain theory, $V^{5+}$ is anticipated to preferentially enter the apatite structure alike $Nb^{5+}$ and $Ta^{5+}$, whereas $V^{3+}$ and $V^{4+}$ are expected to favour the partitioning into biotite, substituting for $Fe^{3+}$ and $Ti^{4+}$. Total vanadium partitioning between apatite and biotite is expected to change as a function of the magmatic $fO_2$. The hypothesis is tested by analyzing the V abundance in coeval apatite and biotite from five well-described rock suites: Fish Canyon tuff (Colorado, USA), Mascota minette (Jalisco, Mexico), Revancha rhyodacite (Peru), Toba tuff (Sumatra, Indonesia), Umiakovik granite (Newfoundland, Canada). The group represents various compositions, emplacement depths, and oxidation states (previously determined range of FMQ-3.1 to +4.3 log, which represents the majority of oxidation states found in Earth's upper crust). Over the represented $fO_2$ range, vanadium partition coefficient between apatite and biotite ranges from ~0.002 to ~0.4 in a positive correlation with $fO_2$. However, vanadium content also covariates with Ti abundance in the minerals. Results imply a potential for an empirical oxybarometer with account for T, P, and mineral compositional effects. Previously published V data in apatite and biotite of South Mountain Batholith (Nova Scotia, Canada) suggest a low $fO_2$. This illustrates a potential of a vanadium oxybarometer for reduced, Fe-poor peraluminous granitoid rocks, which often lack Fe–Ti minerals essential for the conventional oxybarometry. A novel, broadly applicable two-mineral oxybarometer could greatly contribute to the research on the redox evolution of plutonic systems and aid redox-sensitive ore mineral exploration in peraluminous granitoid rocks.

## Early Jurassic organic matter preservation intervals (OMPI) in the central and north Atlantic conjugate margins

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Lower Jurassic sedimentary successions in many central and northern Atlantic basins include relatively thick

organic-rich intervals. Despite intense research, it is still unclear which mechanisms led to the deposition of these sediments during the Early Jurassic. In this talk, we will (1) present a detailed temporal and geographical framework of Sinemurian and Toarcian organic matter preservation intervals (OMPIs; subdivided into local, regional, and superregional) and (2) broadly constrain the relationship of OMPIs with the Early Jurassic $\delta^{13}C$ record. For this, we combine an in-depth analysis of the distribution of organic-rich facies in the Sinemurian and Toarcian with new geochemical data [total organic carbon (TOC) and organic matter pyrolysis] from Portugal, Spain, and Morocco.

The developed OMPI framework suggests a strong local control on organic matter preservation during most of the Sinemurian. Regionally widespread organic-rich facies are associated with the most negative $\delta^{13}C$ values of the broad Sinemurian–Pliensbachian negative carbon isotopic trend (including the Sinemurian–Pliensbachian Boundary Event). Pliensbachian OMPIs are expressive in the areas bordering the proto-Atlantic Ocean and are often linked with positive $\delta^{13}C$ excursions and short-lived warm intervals, but OMPIs are also observed for the Late Pliensbachian cool interval. Toarcian maximum TOC content occurs with the positive $\delta^{13}C$ (recovery) trend following the $\delta^{13}C$ negative shift typically linked to the Early Toarcian Oceanic Anoxic Event (T-OAE). However, superregional OMPIs predate and postdate the T-OAE, indicating that conditions favouring the preservation of organic matter (increased productivity and/or enhanced preservation) were not restricted to the T-OAE interval.

We will also briefly discuss how future research should aim to disentangle (1) the complexities in estimating original TOC and organic carbon accumulation rates, (2) temporal and spatial variability in environmental or Earth system feedback mechanisms driving sedimentary carbon sequestration, and (3) their combined impact on the global carbon cycle.

## Geological carbon storage modelling: looking for tigers, not mice

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In 1976, British statistician George Box wrote "All models are wrong, some are useful. Since all models are wrong, the scientist must be alert to what is importantly wrong. It is inappropriate to be concerned about mice when there are tigers abroad." Models are ubiquitous in Earth science, depicting objects or processes that cannot be fully observed or described. For geoscientific outputs to provide useful insights, the assumptions and uncertainties need to be defined. Geological Carbon Storage (GCS) research uses models to support decarbonization by identifying and evaluating subsurface storage locations for captured $CO_2$. GCS can be assessed using modelling processes developed in other disciplines and applying them to predict the capacity, containment, and injectivity of reservoirs for permanent $CO_2$ storage. $CO_2$ is highly soluble and, when supercritical or gaseous, it readily dissolves in other reservoir fluids (e.g., saline water, hydrocarbons). It can be trapped in rocks for storage by four mechanisms (ordered in increasing time required): structural, residual, solubility, and mineral. Effective GCS modelling requires integration of $CO_2$ fluid properties and reactions. Models should be designed to assess for centuries to millennia since GCS reservoirs are intended to be permanent. The fluid behaviour and timescale introduce assumptions into GCS modelling that are not adequately addressed in petroleum modelling, which GCS models have so far been based on. This study reviews existing and unique assumptions and uncertainties in GCS modelling, proposing what parameters are more important (the tigers) versus those with less importance (the mice). Alignment on GCS modelling inputs, assumptions, and uncertainties will allow for more standardized approaches and therefore results from different basins will be more comparable.

## Tectonic setting of the Devonian Park Spur pluton, central Cape Breton Highlands, Nova Scotia, Canada

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Field, petrological, dating, and structural studies in the central Cape Breton Highlands have led to new understanding of the complex history related to convergence between the Aspy and Bras d'Or terranes along the Eastern Highlands shear zone in the late Devonian. The Park Spur pluton (PSP) was emplaced in the Aspy terrane in the early Late Devonian (ca. 375 Ma, U–Pb zircon). Its age combined with S-type petrological characteristics and abundant pegmatite and aplite show that it is co-magmatic with the Black Brook Granitic Suite and satellite plutons that characterize the northern Aspy terrane. These widespread plutons may have formed by crustal melting caused by subducted slab failure. On its northern margin the PSP intruded high-

grade Ordovician–Silurian metamorphic rocks of the Cape North Group at mesozonal depth (>10 km), consistent with its petrological features and abundant pegmatite and aplite dykes. On its southern margin the PSP was synchronously deformed in the east–west-trending Park Spur Road shear zone and juxtaposed in a southerly direction over the low-grade metasedimentary and metavolcanic rocks of the Ordovician–Silurian Calumruadh Brook Formation (CBF). Ongoing dextral transpression between Aspy and Bras d'Or terranes reactivated the north–south-trending Central Highlands shear zone, on which the higher- grade Middle River metamorphic suite and Silurian Taylors Barren pluton to the west were transported upward relative to the adjacent CBF and PSP. By about 365 Ma, convergence had mainly ended, as evidenced by shallow emplacement of the ca. 363 Ma Margaree pluton in an extensional setting.

## Geochemical and mineralogical changes during soil development: preliminary study of a brunisolic soil from Nova Scotia, Canada

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Soils develop at chemical and physical gradients at the geosphere/atmosphere/biosphere/ hydrosphere interface. Their horizons are commonly poorly understood because they tend to be thin, poorly crystalline, and fine-grained, making their geochemistry and mineralogy difficult to characterize. Historic pedogeochemical investigations have employed small sample numbers, restricted element suites, and limited digestion methods, largely ignoring heterogeneity in the parent material. Thus, historical attempts to characterize horizon development have provided marginal geochemical and mineralogical insight.

Fifty 360 $cm^3$ soil samples within a 2 m thick vertical profile through a dystric (<5.5 pH) elluviated (w/Ae horizon) brunisolic soil developed in a homogeneous, ~5 m thick, fine-grained glaciofluvial sand in Nova Scotia's Annapolis Valley were collected to investigate soil profile development. This site is accessible via an excavator, lacks historical disturbance, hosts old-growth species consistent with a mature Acadian forest, and displays a simple mineralogy (quartz, feldspar, biotite, and muscovite derived from the peraluminous South Mountain Batholith). Variables measured include soil density, moisture, texture, Munsell color, pH, conductivity, magnetic susceptibility, ICP–ES/MS geochemical analyses of $LiBO_3$ fusions (10 major/33 trace elements), aqua-regia (36 trace elements) and deionized water (30 major/trace elements) digestions, LECO total carbon and sulphur analyses, Penfield $H_2O^+$ analysis, and smear-mount XRD analysis on the –63 um sample fractions.

Results indicate that parent material heterogeneity persists despite all efforts, as different textures and modal mineralogy were encountered at various depths. However, molar element ratio analysis could model/circumvent this variability, providing an understanding of chemical reactions involving quartz, alkali feldspar ($Or_{90}$), apatite, Na-phengite, and ferroan kaolinite within the soil profile. The depths where Na-phengite breakdown took place (via Fe oxidation), apatite dissolved, and kaolinite replaced albite in a sub-soil aquifer could be identified. Surprisingly, only small amounts of feldspar hydrolysis occurred, likely due to limited weathering since the glacial retreat from Nova Scotia.

## Petrology and lithogeochemistry of the Wildcat Brook Mo–W deposit, Charlotte County, New Brunswick, Canada: insights into log-ratio analysis

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The Wildcat Brook Mo–W deposit is located approximately 9 km east of the former Mt. Pleasant Sn–W–Mo mine in Charlotte County, New Brunswick. It is hosted by a leucocratic, quartz–feldspar porphyritic-to-aplitic, peraluminous, EW-striking, moderately north-dipping dyke intruding turbiditic metasedimentary wackes/argillites of the Fredericton Trough north of the Saint George batholith. High-grade Mo mineralization to 4 % (per metre) occurs in two niches: (i) molybdenite blebs to 4 mm disseminated in miarolitic cavities within albite- and muscovite-altered dyke, and (ii) medium-grade Mo mineralization at the margins/cores of 2–5 cm wide quartz veins cutting altered/unaltered dyke and adjacent metasedimentary rocks. The mineralized dyke has been intersected by 17 diamond drill cores spanning approximately 250 m along both strike and dip. Dyke thickness ranges from 17 to 42 metres (27 m average), with a length-weighted average grade of 0.27 % Mo.

Two styles of hydrothermal alteration occur in the

dyke: albite and muscovite–quartz. Molar element ratio (MER) analysis of 110 drill core samples, constrained by petrography, reveal the addition of Na and loss of K and Ca during albite alteration: Microcline + $Na^+$ = >Albite + $K^+$, Anorthite + 4 Quartz + 2 $Na^+$ = >2 Albite + 3 $Ca^{+2}$, and the addition of K and loss of Na during muscovite plus quartz alteration: 3 Albite + $K^+$ + 2 $H^+$ = >Muscovite + 6 Quartz + 3 $Na^+$.

Because hydrothermal alteration recognized in the dyke can be described by balanced chemical reactions, these processes are mathematically linear. Furthermore, when plotted on MER diagrams the data continue to form linear trends. Unfortunately, when plotted in logarithmic space, as log ratios, patterns become decidedly non-linear, significantly complicating data interpretation. Additionally, the use of linear statistical procedures, such as principal components or regression analysis, on such log-transformed data is numerically invalid, and so is not an appropriate way to understand the causes of compositional variations in rocks.

## Sinistral displacement along the Minas Fracture Zone

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Observations from a wide variety of sources across Mainland Nova Scotia and abroad are integrated to focus on the mapping of the eastward displacement of the Meguma terrane relative to adjacent terranes to the west and north. Sinistral displacement along an east–west transform fault is most evident from the drag fold exhibited at Cape Split and the linear southern coastline of Chedabucto Bay. Precise location control for shear planes between Cape Split and Canso were derived from bathymetric and geophysical surveys, mineral occurrence observations and drilling. This eastward shift of 42 km for the Meguma terrane probably occurred soon after the emplacement of the North Mountain Basalt but the age estimate and mechanism are hypothetical. Latitudinal mantle energy transitions are hypothesized for propagating and reactivating latitudinal, transform, upper crustal fractures. Crustal underplating related to the Central Atlantic Magmatic Province provided axial tensional uplift to the upper crust while the ancient terrane boundaries on the southern margin of Laurasia crossed an upper mantle latitudinal shear plane. The eastern Bay of Fundy would have required a spreading center and/or crustal thinning over a 23 kilometres width to accommodate the eastward dilation of the Meguma terrane. Surficial geology, bathymetry, backscatter, and aeromagnetic surveys contribute to the hypothesis. Similar spreading displacement of a terrane block including Grand Manan Island is also indicated in the offshore data. The westward extension of the Minas Fracture Zone across paleo-continents by mantle-tapping intrusions containing Critical Minerals is presented for the consideration of the undiscovered Critical Mineral potential in Nova Scotia.

## Why are there undiscovered critical mineral deposits in mainland Nova Scotia?

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Observations from across mainland Nova Scotia and a career in mineral exploration internationally are integrated to focus on the scientific aspects of this question with a very high-level view. Initially the key processes involved in naturally concentrating Critical Minerals into a deposit are briefly reviewed. Evidence for these processes having occurred in Nova Scotia are presented. The history of mineral exploration science in the province and the significance of current exploration geoscience best practices are reviewed. An analysis of what we know and what we don't know leads to some Critical Mineral research opportunities for consideration.

## The first evidence of terrestrial vertebrates from the Lower Mississippian Albert Formation of New Brunswick: Implications for the invasion of continental lacustrine ecosystems and biodiversity during Romer's Gap in Atlantic Canada

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The Early Mississippian (known as 'Romer's Gap') marks the beginning of a critical point in tetrapod history as they transitioned from dominantly aquatic to more terrestrial ecosystems. This paleoecological expansion set the stage for the radiation of all terrestrial tetrapod crown groups. The exact timing for the transition into freshwater continental environments is poorly understood. However, new discoveries in Scotland, England, and Nova Scotia, represent rare exceptions; offering a glimpse into coastal terrestrial ecologies during 'Romer's Gap'. These sites have evidence for a marine-water connection suggesting a coastal paleogeographic position. In contrast, Early Mississippian sedimentary deposits of the Moncton Subbasin in southern New Brunswick (NB) are interpreted as freshwater intra-continental conditions (lacustrine, wetland, fluvial, alluvial settings). A single stratigraphic horizon in the Albert Formation (Hiram Brook Member), exposed near Norton, NB, has yielded abundant tetrapod footprints. Preliminary assessments suggest at least four trackway ichnogenera: cf.*Characichnos*, cf.*Matthewichnus*, cf.*Hylopus*, and cf.*Batrachichnus* and a fifth trackway that may represent a new ichnogenus. Footprints range in size from 1 to 3 cm, suggesting that tetrapods were smaller than those documented from near time-equivalent sites in Nova Scotia, but are comparable in size to skeletal fossils described from younger strata in Scotland. These footprints are interpreted to be preserved in interfluvial crevasse splays associated with wetland forests dominated by *Lepidodendropsis* lycopods and *Aneimites* ferns preserved in their ecological context. The relatively large sample size of footprints suggests that a community of tetrapods were present and part of a diverse ecosystem, adapted to terrestrial and semi-aquatic continental environments in the earliest Mississippian. Additional trackways from slightly younger redbed playa lake deposits in the Sussex Group suggest tetrapods were also venturing into semi-arid continental environments. The ichnofossil assemblage from NB demonstrates considerable variation in ichnotaxa morphology and paleoenvironmental context from sites of approximately equivalent age.

## Petrography and chemistry of Early Carboniferous volcanic rocks in the northeastern Cobequid Highlands, Nova Scotia, Canada*

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Volcanic rocks of the lower Mississippian Fountain Lake Group and related plutonic rocks form a linear belt trending NW–SE through the northeastern Cobequid Highlands of northern mainland Nova Scotia. The volcanic rocks, with an exposed stratigraphic thickness of about 7 km and strike length of 35 km, include basalt and minor intermediate rocks but are dominated by rhyolite. Ten previously reported U–Pb zircon ages range from about 358 Ma to 353 Ma. LiDAR imagery shows topographic features that are useful to identify individual flow units and faults. Petrographic study of 88 thin sections showed that the rhyolite displays a diverse spectrum of spectacular textures, from welded to non-welded lithic, crystal, and ash tuff, and from spherulitic to flow-banded in the welded tuff samples. Texture has no apparent correlation with flow unit or chemistry. Silica contents in 14 basalt samples and 62 rhyolite samples range from 45 to 52% and 70 to 78%, respectively. The basalt is subalkalic and has chemical characteristics, including REE patterns, typical of continental tholeiite. The rhyolite is metaluminous to peraluminous, but not peralkaline, with chemical characteristics typical of within-plate A-type magma derived from crustal melting. Chondrite-normalized REE patterns in rhyolite samples are relatively flat and high, ranging from 100 to 1000 times chondritic values with variable but large Eu anomalies. As reported in earlier work, the rhyolite can be divided based on chemistry into low Zr and high Zr groups, the latter with higher REE contents, but correlations with most other chemical characteristics, stratigraphic position, magnetic susceptibility, or texture have not yet been recognized.

**Winner: AGS Rob Raeside Award for best undergraduate student poster*

## First melt inclusion data for South Mountain Batholith, Nova Scotia, Canada, with relevance to magmatic and mineralizing processes

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The South Mountain Batholith (SMB) outcrops over a significant portion of Nova Scotia and has been extensively researched. However, no studies exist that focus on the metal and volatile "fertility" of magmas associated with dominantly barren Stage I (granodioritic to monzogranite) and commonly mineralized Stage II (leucomonzogranite to leucogranite) plutons in the SMB. This study, the first of

its kind in the Appalachians, is characterizing silicate and sulphide melt inclusions (MI) in zircon to quantify and compare magma metal contents, state of sulphur saturation, and other related parameters (e.g., oxygen fugacity) in the SMB. Cathodoluminescence imaging provides textural constraints on the timing of MI entrapment relative to zircon growth stages (e.g., antecrystic vs. autocrystic). LA–ICP–MS analyses of MI (and host zircon) from ten SMB plutons reveal several emerging themes: (i) MI show a wide range of compositional variation based on total alkali (MI range = 5–12 wt.% $Na_2O + K_2O$) vs. silica content, with many MI plotting significantly above the sub-alkaline/alkaline line, in contrast to whole rock analyses (all sub-alkaline) suggesting early alkaline parentage modified by magma mixing and/or contamination; (ii) key SMB ore metals occur in similar concentrations (~2–30 ppm Sn, ~1–20 ppm W, ~1–10 ppm Mo) in both stages, except for the New Ross and Davis Lake plutons (Stage 2 mineralized) that show higher maximum concentrations (up to ~100 ppm Sn, up to ~400 ppm W in the most evolved MI, based on Cs proxy) similar to MI from Sn–W deposits in arc settings (e.g., porphyry); (iii) all plutons show evidence of co-entrapment of sulphide melt (possibly sourced from country and basement rocks) and silicate melt during zircon growth. Fe–S melts were enriched in Cu, Zn, As, Bi, Mo, and Te, suggesting sulphides may play some role in retaining select ore metals during volatile exsolution and subsequent mineralization.

## Exploration for Guysborough County near-surface mineralized pegmatites, Part 1: Justification

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Natural Resources Canada identifies a suite of elements associated with so-called LCT pegmatites, (Li, Be, Mo, B, Cs, Rb, Ta, REE) as critical minerals. The petrogenetic affinity of these elements with granite-associated mineralized pegmatites suggests northeastern Meguma is a potential host of raw materials required for decarbonization. The regional-scale map pattern of discrete Devonian granitic plutons intruded into Cambrian–Ordovician passive-margin metasedimentary rocks presently exposed in Guysborough County bears an obvious resemblance to the small-scale bedrock maps of Devon and Cornwall counties in southwest England, the latter a centuries-old mining district and present British Geological Survey target for pegmatite- and granite-hosted rare metals. Similar tectonic and metamorphic histories are inferred yet cannot be directly linked to mineralization. In both Nova Scotia (NS) and SW England, the protracted emplacement (>10 million years) of a texturally diverse suite of granitic rocks, ranging from granodiorite to B- and Be-pegmatite, evokes fractional crystallization of crustal magmas. Relative to other Meguma multi-phase granitic intrusions, such as the South Mountain Batholith, primitive granodiorite scarcity, abundance of evolved muscovite-leucocratic phases and Si-rich rare-metal pegmatites, substantiate the exploration potential of 30+ multi-phase plutons and greenschist–amphibolite-facies host rocks underlying the eastern extent of NS mainland. Bulk geochemistry assessment of the sulphur-poor Sangster Lake and Larrys River plutons suggests Paleozoic felsic intrusions and contact zones preserve a potentially fertile magmatic system (i.e., low Na/K, low Fe/Ti, lithophile element (Li, Cs, Rb, U) enrichment). Past and current bedrock mapping verifies post-granitoid emplacement of mineralized pegmatites, including the largest known Be-dyke in the province. A model of late-stage ore-forming igneous processes initiated by apical zone development culminates in the emplacement of mineralized pegmatites.

## 3D Geological modelling of the southern Bathurst Mining Camp, New Brunswick, Canada

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The southern part of the Bathurst Mining Camp is host to at least 13 mineral occurrences (including Chester, Sheephouse Brook, Lead Pond) and geological mapping has constrained the distribution of the main lithological units and faults at surface. However, the geometry of contacts at depth are complicated by multiple deformation events. Given the vast amount of geophysical data, as well as recent geological mapping results, this is an ideal area to integrate geological and geophysical data to produce a 3D geological model for a subset of the Bathurst Mining Camp. This project also involves the creation of a database of rock properties, including magnetic susceptibility, density, dc-resistivity, chargeability and remanent magnetization. During 2021 and 2022 we have been able to collect ~520 samples from hand sample and drill holes from across

the study area, with a minimum of 20 samples from each representative lithological unit. With these data, histograms for each property and geological unit have been constructed. Cross-plots between properties as well as Henkel diagrams of magnetic susceptibility vs density allow for better separation of the variability of each rock property and unit. The Henkel diagram allows for a quantitative mineralogical mixing model that involves estimates of quartz–feldspar–calcite (QFC), ferromagnesian silicates, and magnetite. The 3D geological modelling is being based on a series of 29 cross-sections distributed over the entire area of study, mostly across significant contacts and structures. Initial sketches were constructed for each section, and then the gravity and magnetic data were used to adjust each section. Sections were constrained by boreholes and other ancillary datasets like airborne electromagnetic data. Finally, some of the main contacts and structures will be interpolated in 3D between sections, forming the skeleton of a litho-structural model for the area.

## UN framework for classification of resources

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The United Nations Framework Classification for Resources (UNFC) is a resource project-based and principles-based classification system for defining the environmental socio-economic viability and technical feasibility of projects to develop resources. The UNFC was designed to meet the needs of project applications including: (1) Policy formulation based on resource studies; (2) Resources management functions; (3) Corporate business processes; and (5) Financial capital allocation.

The UNFC provides a consistent framework to describe the level of confidence of the future quantities produced by the project. A project is a defined development or operation which provides basis for environmental, social, economic, and technical evaluation and decision making. A project may be detailed or conceptual but must have enough info to allow an appropriate assessment. Resources (primary and secondary) meant for projects include solar, wind, geothermal, hydro-marine, bioenergy, injection for storage, hydrocarbons, minerals, nuclear fuels, and water.

The UNFC is aligned with the UN Sustainable Development Goals (SDGs, also referred to as the Global Goals) and are the blueprint to achieve a better and more sustainable future for all. As a key element of UN 2030 Agenda, the SDG's address the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. The Goals interconnect and, in order to ensure a just transition that leaves no one behind, it is important that we achieve each Goal and target, by 2030.

## A major Nova Scotia hurricane in the Little Ice Age

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Natural climate variability is important for modelling midlatitude hurricane risk under a warming climate, yet models focus on the brief instrument-based record. Given their destructive impact, it is important to define how Atlantic cyclones fit into longer trends. Historical and proxy data have the potential to extend the record by centuries. The violent 1757 Louisbourg Storm off Nova Scotia during the Seven Years' War was characterized by extracting quantitative attributes from historical observations preserved in the logs of naval vessels caught in the hurricane. The storm struck as a British fleet was blockading a French fleet moored in Louisbourg Harbour, providing a unique opportunity to assess multiple, independent weather records measured hourly on vessels scattered across the cyclone path. Peak wind speeds and storm surge calculated at two coastal sites support wind and wave estimates that the storm's intensity at landfall was that of a major hurricane and may have reached Category 4 on the Saffir Simpson Scale. This exceeds any midlatitude hurricane on the northwestern Atlantic since modern record keeping began in 1851 (HURDAT). This is at odds with the Little Ice Age's colder climate and cooler sea surface temperatures yet is consistent with other extreme midlatitude hurricanes for this historical period. It shows that short-term natural variability can depart from annual to multidecadal climate trends targeted by the recent instrumental record and that an understanding of the forcing mechanism behind extreme historic storms and assessing if these longer cycle trends may help to improve modeling coastal risk under projections of global warming and rising sea level.

## Geochronology, meet GIS: reconstruction of detrital zircon data using Euler poles and implications for Appalachian terrane interactions

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Detrital zircon data for the Appalachian–Caledonide Orogen comprise tens of thousands of analyses from several hundred samples that span the Neoproterozoic and Paleozoic eras. These data provide extraordinary insights into the history of terranes in the orogen, because the candidate source continents Laurentia, Gondwana, and Baltica display contrasting histories. For example, the varied arrival of Ganderia-derived terranes at the Laurentian margin is constrained by the influx of abundant ~1 Ga zircon from the Grenville Orogen of Laurentia. These large data sets can be managed by handling the data in a geographic information system (GIS). An initial spreadsheet compilation of data incorporated locations and estimated depositional ages (Ma, with errors) for each sample, and used standardized concordancy cutoffs and isotopic system selections. Samples were assigned to terranes based on published information, or by spatially joining them with a terrane map. Data were binned into time intervals corresponding to known potential source orogens. Colours were assigned to each bin so as to be distinguishable by those with diverse colour vision. The resulting tables were displayed as pie charts sized in proportion to the number of dated grains using free GIS software (QGIS). An overall trend from Laurentia- to Gondwana-derived is immediately apparent across the orogen from NW to SE. The entire data set was saved in shapefile format. The free software GPlates allows import of shapefiles. Usually, these are polygons describing continents and terranes in paleocontinental reconstructions. GPlates transforms these using Euler poles, according to plate rotation models. It was found that GPlates would also import the detrital zircon point data and transform it using the same rotations. The resulting paleocontinental models, exported back to QGIS, were used to display detrital zircon data sets in their reconstructed positions at their depositional ages, providing a powerful test of proposed reconstructions.

## The Number Nine Mountain inlier of northern Maine: new mapping, new thoughts, and new questions about northern Maine Appalachian tectonics

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New mapping in the Number Nine Mountain (NNM) inlier and vicinity in northern Maine improves current maps, prompts new questions, and generates new thoughts about the tectonic evolution of the Northern Appalachians. The inlier comprises three unconformable components: Cambrian (?) mélange basement (redefined Nine Lake Formation); a Silurian green phyllite section (redefined Burnt Brook Formation); and a Silurian Fe–Mn-bearing volcanic–sedimentary sequence. The last consists of conformable Spruce Top (pillow basalt), Dunn Brook (pyroclastics), and Maple Mountain (slate/sandstone with Mn ironstone) formations that may be related to the final collision of Laurentia and the leading edge of Ganderia (Brunswick Subduction). The Nine Lake mélange, reported here for the first time, is similar to the Chase Brook mélange of the Laurentian Munsungun massif. The two are nearly on strike and only 19 km apart at their closest point. If they are correlated, is the NNM mélange also part of the Laurentian? The NNM inlier is not part of the Weeksboro-Lunksoos Lake belt (WLB) as previously reported, but rather separated from it by a major fault. The WLB contains a Cambrian basement that lacks mélange (Grand Pitch Formation), overlain by strongly sheared bimodal volcanic rocks of the ca. 481–485 Ma Shin Brook Formation. It is geochronologically and geochemically more similar to the Ganderian Miramichi than to the Laurentian Munsungun. If the WLB is related to the Miramichi and the NNM to the Munsungun, the Laurentia–Ganderia suture separates both belts, leaving no room for the Popelogan Balmoral phase. Recent mapping shows that the entire region has experienced multiple generations of regional-scale, pre-Acadian, Acadian, and post-Acadian, dominantly southeast-directed reverse/thrust faulting and imbrication. Several northwest-striking and dominantly strike-slip and reverse faults have significantly displaced the northeast-trending tectonic belts. Thrust imbrication and horizontal displacement caused the current structural pattern and tectonic framework of the northern Maine Appalachians.

## Air photo surveys of the Chignecto Isthmus between Nova Scotia and New Brunswick during the 1930s and their potential value today

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After the First World War, Canada emerged as an early adopter of aerial photography to support civilian surveying and mapping. Small experimental projects were carried out initially. Larger and more ambitious activities followed during the 1920s and 1930s, including missions in the Maritime Provinces. Centred on the boundary between New Brunswick and Nova Scotia, the 1931 and 1939 aerial surveys of the Chignecto Isthmus are little known legacy sets of that period. The original air photos captured the situation on the ground in fine spatial detail, matching that of modern high-resolution satellite imagery. This study presents the results of a search, assembly, and analysis of two air photo mosaics. Individual frames were selected from different film rolls archived at Canada's National Air Photo Library. The uncontrolled mosaics were re-assembled digitally using recent Sentinel-2 satellite imagery as a reference data set. The study suggests that the 1931 and 1939 air photo mosaics encapsulate detailed spatial records of natural land cover and anthropogenic land use of the Chignecto Isthmus during that decade. In terms of area coverage, the southwestern portion includes the intertidal salt marshes, wetlands, and spruce bog areas of the Tantramar Marshes; the northeastern portion includes the Northumberland Lowlands. Aside from their national legacy and local heritage value, the old air photos represent a potential source for environmental, geographical, and historical studies today. While individual photos may have occasionally been used for local inquiries, their ultimate value becomes most apparent in mosaic form. It can reveal a wealth of contextual information across provincial boundaries and administrative divisions. In combination with more recent geospatial data, such as the Sentinel-2 satellite image used as backdrop for the mosaics, the 1930s air photos of the Chignecto Isthmus offer rare glimpses into the past from an unusual aerial perspective.

## Remote sensing evidence for determining the Holy Grail Fault of north-central Manitoba as a post-glacial fault in Canada

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Post-glacial faults (PGFs) have been studied in Scandinavia for over 50 years but no such features been verified in the deglaciated terrane of Canada. We suggest that exploratory analyses of archival aerial photographs and satellite imagery can provide possible evidence of PGFs in Canada. As part of an air photo search more than half a century ago, renowned photogeologist Jack D. Mollard came across a "fault-line scarp" in north-central Manitoba, since dubbed the Holy Grail Fault (HGF), at 55°05'55"N / 99°06'38"W. This N26oE trending, remarkably youthful-looking, linear escarpment of at least 20 km length drew only a specialized engineering audience at the time. Meanwhile, a broad range of satellite imagery available over the area and subsequent analysis may strengthen the interest in validating the HGF as a significant post-glacial fault. Isolation and accessibility of the HGF area of north-central Manitoba pose significant logistical problems for conducting field work. The remote sensing component of our work has several objectives: to re-examine the photo-geological extent and expressions of the suspected PGF; to review seasonal environmental conditions along the fault; and to determine sites for further field work. For this study we review previous work and focus on optical and radar imagery taken at different illumination angles, during various seasonal hydrological conditions and at a range of spatial scales. We also rely on old aerial photography of the area as a source of information. Preliminary image analysis indicates that the HGF feature is unique in its linearity and physiographic characteristics. The fault appears to extend tens of kilometres beyond the initial scarp. Our conclusions to date indicate that remote sensing data collection and analysis can benefit significantly from taking into account varying seasonal environmental conditions to highlight and characterize the Holy Grail Fault as a PGF.

## Exploring Nova Scotia, Canada, with the 2022 edition of the Atlantic Geoscience Society's Geological Journey Map of Nova Scotia

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The first "Geological Highway Map of Nova Scotia" was published by the Atlantic Geoscience Society (AGS) in 1980, with subsequent revised editions published in 1990 and 2005. Like earlier editions, the fourth edition shows the current road system of Nova Scotia superimposed on underlying bedrock geological units. The map is intended to encourage people to observe and better understand the diverse geological features that are responsible for the renowned scenic beauty of the province, evident as they travel around the province or visit viewpoints, parks, and coastal sections. In addition to a significantly updated and revised geological map at a scale of 1:620 000, the front side of the map includes a legend (Table of Rock Units) that uses a simplified version

of the 2021 International Chronostratigraphic Chart as the time scale. Units are divided into four areas: southern mainland, northern mainland, southeastern Cape Breton Island, and northwestern Cape Breton Island. Also included is information on how to use the map, a symbols key, representative block diagrams, and a long list of geological sites of interest. Current and past mining and quarrying activities with commodities are also highlighted. The reverse side provides more detailed maps and site descriptions for selected areas that are well known and publicly accessible, including Joggins, the Cabot Trail, the Parrsboro–Five Islands area, Scots Bay–Burntcoat Head, Yarmouth–Cape St. Marys, Arisaig, Halifax, and Louisburg. The descriptions emphasize rock types, minerals, fossils, structural features, landforms, and glacial history. In addition, the map highlights sites that are more hazardous than others where caution should be exercised and where special collection permits are required. The map is a traveller's companion to a second new AGS Special Publication "Journey Through Time – Places of Geological Significance in New Brunswick and Prince Edward Island".

## Along-strike variations in Furongian through Ordovician sedimentation and diachronous deformation within the northern Appalachians: Role of inherited margin geometry and colliding arcs

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Within the northern Appalachians, the deformed Laurentian margin and foreland basins show lateral variability in basin geometry, sediment provenance, and deformation timing. Although the margin is well-studied, inconsistencies in time scales, tectonic nomenclature, and sparse geochronological datasets have rendered it difficult to achieve an orogen-wide synthesis of the margin and overlying forelands' variability. To remedy this issue, biostratigraphic and isotopic data are placed on a common timescale. Using the replotted geological data, we focus on Cambrian through Ordovician orogenic events recorded in the Northern Appalachians to generate orogen-scale correlations.

Earliest Taconian deformation is associated with arc-continent collision at off-margin microcontinents, confirmed by simultaneous margin deformation (recorded in the peri-Laurentian realm) and passive margin sedimentation (recorded in autochthonous and allochthonous rocks of the Laurentian realm). This deformation was strongly diachronous, occurring in the Furongian in Newfoundland and the Early to Middle Ordovician within the Québec Embayment, as was subsequent Taconic Seaway closure. In Newfoundland, closure began at ~ 470 Ma, resulting in obduction of allochthons above the margin. In Québec closure began at ~ 461 Ma and allochthon emplacement continued until ~450 Ma. In New England the seaway closed ~ 455 Ma. Pro-arc foreland basins developed in the Middle Ordovician in Newfoundland, but not until Late Ordovician in Québec. Diachronous subduction polarity reversal, occurring first in Newfoundland (~460 Ma) and later in Québec (~450 Ma), resulted in simultaneous westward and eastward subduction at different places along the margin leading to a unique hybrid basin (pro and retro-arc) in Newfoundland, analogous to the current position of the Akimeugah Basin on the northern Australian Plate.

All major episodes of deformation, attributed to the Taconian orogeny in the northern Appalachians, were diachronous. Diachronous deformation resulted from irregularity of the Laurentian margin, distribution of off-margin microcontinents, and/or geometry of colliding arcs and microcontinents.

## Regional-scale trends in the composition of late Pennsylvanian palaeobotanical communities from Atlantic Canada

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The late Pennsylvanian of Atlantic Canada records a major transition in the evolution of fossil plants. This transition, broadly characterized by the replacement of the arborescent Lycopsida (giant club mosses) and Cordaitales (early gymnosperms) by Mariattales (tree ferns) and Coniferales (early modern conifers), has been known globally as the "Carboniferous Rainforest Collapse", and is commonly associated with widespread aridification amid fluctuations between glacial and interglacial climate regimes. In recent years it has become apparent that there are significant regional differences in the tempo of floral turnover, while studies of single locality sequences have revealed significant cyclical changes in plant community composition over short timescales. What remains unclear is the specific tempo of floral turnover within Atlantic Canada. This study

explores the transition in fossil plant community structure at the regional scale, focusing on the late Pennsylvanian localities from Nova Scotia, New Brunswick, and Prince Edward Island. Fossil macrofloral occurrence data were compiled from museum repositories and records from the published literature, representing plant fossil occurrences spanning the middle Bashkirian through the end of the Kasimovian. Species and genus presences and absences were used to conduct multivariate analyses of similarity between localities. Preliminary results show a gradual shift in species composition over time, with the greatest degree of turnover occurring in the late Moscovian. Conversely, analysis of community composition at the genus level revealed little change in composition between time bins, but an increase in variance between sites within time bins. These results indicate that the shift in palaeofloral community composition in Atlantic Canada may be best described as a gradual increase in the breadth of uniquely composed communities as opposed to a turnover pulse, as assemblages similar in composition to those of the middle Bashkirian persist throughout the studied interval.

## Zircon compositional systematics from Devonian oxidized I-type granitoid rocks: examination of porphyry Cu fertility indices in the New Brunswick Appalachian orogen

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Zircon is a common and widely distributed accessory mineral in igneous rocks. Its refractory nature can record magmatic oxygen isotope ratio, U–Th–Pb isotopic chemistry, and trace element content that reflect the physiochemical evolution of the magmatic systems in which it crystallized. Accessory minerals like zircon form in close association with the crystal/liquid interface. Zircon compositions are commonly used as an indicator for porphyry Cu ± Mo ± Au systems. To further characterize oxidized I-type granitoid rocks in New Brunswick (in particular, those associated with porphyry Cu ± Mo ± Au systems), LA–ICP–MS analysis of zircon from 13 different intrusive systems was conducted. The zircon grains examined were similar in terms of texture (patchy zoning, homogeneous cores, oscillatory zoning, and unzoned zircon); however, they display an extremely large range of trace- and minor- element (Hf, HREE, Th, U) compositions. Specifically, Zr/Hf ratios in these magmatic zircons range between 24 and 60, whereas Th/U ratios range between 0.15 and 5.37. The presence of inherited zircon can affect the concentrations of certain elements, such as Th and U in zircon. Estimated temperatures for zircon crystallization in these I-type granites were calculated using the Ti-in-zircon geothermometer by making corrections for reduced oxide activities of $TiO_2$ and $SiO_2$. The positive relationship between Th/U and Zr/Hf indicates that higher temperature crystallization in less fractionated magmas is associated with high zircon Th/U ratios. Zircon Zr/Hf and Eu/Eu* and (Eu/Eu*)/Y ratios, as well as zircon (Ce/Nd)/Y and Dy/Yb ratios, are some of the best fertility indicators. If Eu/Eu* in zircon is ≥0.4 (high redox), it may fingerprint ore-forming porphyry Cu associated with these oxidized I-type granitoid rocks. The Ce/Ce* values in the zircons examined are in the range of 1.1–590; higher Ce/Ce* implies more metallogenically favourable oxidizing conditions (diminished Eu anomaly); lower Eu contents reflects reducing conditions, where $Eu^{2+}$ does not substitute into the zircon lattice.