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ABSTRACTS

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Abstracts from the Atlantic Universities Geoscience Conference (AUGC) are published annually in *Atlantic Geology*. Such publication provides a permanent record of the abstracts, and also focuses attention on the excellent quality of the oral presentations and posters at the conference and the interesting and varied geoscience topics that they cover. In the pages that follow, poster presentations are indicated at the end of those abstracts, and award winners are noted below the relevant abstracts.

THE EDITORS

Redox state of the South Mountain Batholith, Nova Scotia, Canada: a reconnaissance study

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The late Devonian South Mountain Batholith (SMB) of southwestern Nova Scotia is the largest plutonic igneous body emplaced in the Appalachian orogen, with a current surface expression of 73 000 km². The batholith is composed of 13 distinct plutons that are broadly peraluminous in composition, ranging from tonalite to syenogranite. A parameter that has been particularly difficult to quantify for the SMB is the redox state, as measured by the oxygen fugacity (fO_2), which exerts a profound control on magmatic phase stability, element partitioning, and importantly, the potential for economic mineral deposits. Here we present a redox state survey of mineralised and unmineralised units of the SMB using the newly calibrated Ce-in-zircon oxygen barometer. This method combines bulk rock and zircon compositions to calculate apparent zircon/melt partition coefficients for Ce, a parameter which varies with the Ce^{4+}/Ce^{3+} in the melt, and hence oxygen fugacity.

A total of 23 samples were collected and 13 were selected for whole-rock major and trace element analysis and zircon separation based on spatial distribution, mineralogy, and preliminary geochemical data acquired by X-ray fluorescence spectroscopy. We obtained 13 samples from the spatially zoned Halifax pluton. From these, 2 samples were taken near the contact with the metasedimentary country rock (Halifax Group of the Meguma terrane) to assess how assimilation might influence fO_2 . The remaining 11 samples were taken from a contact-to-contact traverse, yielding information on fO_2 evolution during increasing differentiation from contact to core. An additional 7 samples were taken from the adjacent Sandy Lake pluton from a traverse along Highway 103. The remaining 3 samples were obtained from the New Ross pluton, which hosts uranium, molybdenum, and copper mineralization, and will provide information on the relationship between ore formation and magma redox state. Individual zircon crystals will be selected for trace element analysis by laser ablation ICPMS, following detailed textural characterization. Preliminary results for the New Ross pluton indicate an abundance of euhedral zircons, exhibiting well-developed igneous zonation, but also clear evidence for multiple growth events and the likelihood of inherited cores from older zircon-forming episodes.

Evaluation of hercynite and gittinsite as indicator minerals, Voisey's Bay area, Labrador, Canada

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The use of indicator mineral surveys has become a standard mineral exploration tool in surficial sediment-covered regions. The concept for this method is that robust minerals exhibiting distinctive physical and chemical features associated with mineralization, or from alteration associated with mineralization, can survive weathering and erosion. Identifying and examining these minerals, with the knowledge of the direction of sediment transport, may provide a vector back towards the source of mineralization. In this study I am examining two potential indicator minerals; hercynite and gittinsite in till and stream sediment samples collected around the Voisey's Bay (VB) Ni-Cu-Co deposit in northern Labrador in a previous study. Hercynite has previously been identified as a common spinel phase associated with the country rock assimilation that ultimately led to the formation of the Voisey's Bay (VB) troctolite-hosted massive sulphide deposits. Hence determination of its presence in a surficial sediment might suggest that the sediment was derived from the erosion of a VB-like deposit. The other indicator mineral to be examined in this study, gittinsite, has been identified as the most common rare earth element (REE) phase in the Strange Lake REE deposit over 100 km to the west of the VB deposit. Hence its presence in surficial sediment may point toward potential REE mineralization. The 31 samples for this study have been analysed using Scanning Electron Microscope - Mineral Liberation Analysis (SEM-MLA) techniques to map and identify any examples of these two indicator minerals and to examine any textures or relationships present. These MLA maps will be used to further examine the mineral chemistry of these grains will be analysed using both the Electron Microprobe Analyzer (EPMA) and the Laser Ablation Inductively Coupled Plasma - Mass Spectrometer (LA-ICP-MS). To confirm that these phases mapped by the MLA minerals in the surficial sediment are "indicator" minerals, hercynite in whole rock samples from the VB deposit and gittinsite in whole rock samples from the Strange Lake REE deposit will be analysed by SEM-MLA, EPMA, and LA-ICP-MS. [Poster]

Linking remotely sensed reflectance to suspended sediment stratification in tidal channels in southwest Korea

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Satellite imagery can provide information on the spatial distribution of surficial suspended sediment over broad scales in coastal environments. An outstanding challenge is to determine the extent to which surficial sediment distributions can be linked to sediment processes occurring near the seabed. Recent research indicates that dense sediment suspensions at the bottom of tidal channels off the southwest coast of South Korea limit upward turbulent mixing of sediment to the sea surface. The goal of this project is to determine whether this sub-surface sediment process is detectable with reflectance at the sea surface measured by the Landsat 8 satellite. The overall hypothesis is that the magnitude and variance of sea-surface reflectance will be lower in channels than in ridges. This is due to the presence of dense suspensions in channels that limit vertical mixing. On the ridges, this process would not occur, because dense suspensions would flow into adjacent channels under the influence of gravity. As a result, reflectance would be higher and more variable. To assess this hypothesis, Acolite processing software was used to perform atmospheric corrections on Landsat 8 images, and sea surface reflectances at 655 nm and 865 nm were used as proxies for suspended sediment concentration in a total of 15 cloud-free images collected over the years 2013–2018. Reflectance in both bands was extracted over a tidal channel and over an adjacent tidal ridge using SeaDAS. The reflectances from these two points were assessed for statistical correlation with depth and with other environmental variables, including sea level, wind speed, recent precipitation levels, and stage in the tidal cycle. Results indicate that the depth exerts primary control on mean and standard deviation of the reflectances, consistent with my hypothesis. Secondary controls on reflectance are wind speed and sea level. I propose that higher windspeeds are associated with larger reflectances due to resuspension over fringing tidal flats and that the correlation of higher water levels with reduced reflectances is caused by sediment supply limitation.

Tectonic evolution of the northern block Phyllite Quartzite Group, South Portuguese Zone, Spain

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The evolution of sedimentary rocks associated with oro-

genic development potentially records changes in regional tectonics and deformation with time. The geology of Southern Iberia is dominated by rocks that record the amalgamation of Pangea, which formed during the late Paleozoic with the collision between Laurussia and Gondwana. The middle to late Devonian Phyllite Quartzite Group contains the oldest exposed rocks in Southern Iberia. These rocks are thought to be continental shelf deposits deformed during Pangean orogenesis. Therefore, the Phyllite Quartzite Group is an ideal candidate to study the relationship of sedimentation to the evolution of the collision. In order to study these processes related to the formation of the Phyllite Quartzite Group, two field sections were studied in detail. The first section is in the core of the Iberian Pyrite Belt and is considered to represent a classic example of Phyllite Quartzite Group deposition. The second section is poorly studied and crops out in the northern section of an unmineralized part of the Iberian Pyrite Belt. By studying these sections, we hope to: (i) record the final stages of ocean closure and deformation associated with the formation of Pangea; and (ii) provide important insight into the development of the coeval Iberian Pyrite belt (host to some of the world's largest copper, lead, and zinc deposits). Field observations and detailed structural analysis are complemented by detrital zircon geochronology of various samples and clasts to constrain the potential sources of the metasedimentary rocks and to assess potential changes in deposition with time. Preliminary results suggest that the metasedimentary unit of the northern section is lithologically distinct from the classic Phyllite Quartzite Group, and indeed may have a genetic link to units not exposed in the Iberian Pyrite Belt. Taken together these observations and data may greatly improve our knowledge of one of the most contentious geologic areas in the world.

Geophysically constrained microplate fragmentation model and terrane-controlled evolution of Mesozoic basins – rifted North Atlantic borderlands, offshore Newfoundland, Canada

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The continental shelf offshore eastern Newfoundland comprises a collage of fault-bounded microplates, assembled during the closure of the Iapetus Ocean and the formation of the Pangea Supercontinent during the Mississippian. These inherited terranes and structural fabrics were later reactivated through multiphase rifting of the North Atlantic between 237–66 Ma. Rifting along offshore Newfoundland occurred in three to four transtensional phases which increased basin accommodation space and sediment infill. Each rift phase is represented by distinct tectonostratigraphic packages displaying: (1) Basal rift onset unconformities (ROU)

underlying syn- tectonic clastic units which thickening into active fault zones; (2) Back-stepping shore proximal deposits formed during tectonic and thermal subsidence; and lastly (3) Waning post-rift basin deepening often associated with capping carbonate marker units (e.g., Petrel, Marker-A, Rankin, Iroquois carbonates). These rifting phases were driven by global plate motions including: (1) Late Triassic to Early Jurassic rifting of Africa away from North America; (2) Middle Jurassic rifting away of Iberia; (3) Late Jurassic to Early Cretaceous oblique rifting of Baltica from the margin including Ireland; and (4) Early Cretaceous to Late Cretaceous extension associated with the opening aulacogen between Baffin Island/Labrador and Greenland.

Recent peer-reviewed dynamic tectonic publications modeled in the [®]GPlates freeware package led to interest in the development of an original 4-D dynamic micro-plate model for the MAGRiT geophysical group. This thesis project will provide a needed dynamic tectonic model that can simulate the microplate motion, and deformation patterns along the North American borderlands of offshore Newfoundland. The model is constructed to be infinitely expanded upon by future researchers as interpretations become more refined, and future datasets become available. This model will improve visualization and constrain the timing and distribution of structures, providing better control on the spatial-temporal relationships for of hydrocarbon source units, reservoir facies, and evolution of structural and stratigraphic traps, aiding future hydrocarbon exploration along the margin. This study focuses on the deformable North American plate margin with implications for Mesozoic basin evolution and contributes key detailed spatial – temporal tectonic stress information to refine global plate motions across relevant conjugate margin pairs (e.g., Ireland and Iberia).

****Winner of the Canadian Society of Petroleum Geologists Award for the best petroleum geology-related presentation***

Origin of epithermal-style gold mineralization in the eastern Cobequid Highlands, Nova Scotia, Canada: constraints from S isotopes and pyrite trace element chemistry

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In the eastern Cobequid Highlands, Nova Scotia, recent bedrock mapping, bulk rock geochemistry, and prospecting have identified a potential low-sulphidation epithermal Au system in Late Devonian to Early Carboniferous bimodal, rift-related felsic (Byers Brook Formation) and mafic (Diamond Brook Formation) volcanic and volcanoclastic rocks. The Warwick Mountain area located in the northwest por-

tion of the Diamond Brook Formation shows the most potential for gold mineralization, with two zones of intensely silicified and sulphidized basalt present. Assays show anomalous Au concentrations up to ~660 ppb, as well as anomalous As, Sb, Cd, W, and Hg.

This research aims to (i) characterize the ore mineralogy of the Au occurrences; (ii) determine what generation of pyrite is associated with the Au mineralization, and (iii) utilize the trace element and S isotope chemistry of pyrite to establish key events in the paragenesis of the mineralization. Petrographic and scanning electron microscopy (SEM) results document the mineralogy and textural characteristics of pyrite and representative grains of pyrite were investigated further by secondary ion mass spectrometry (SIMS), electron microprobe (EMP), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). SIMS data for Nuttby Mountain showed distinct differences from rim to core with arsenic-poor pyrite cores having a $\delta^{34}\text{S}$ ranging from -1.8 ‰ to -0.6 ‰ and As-rich rims having a $\delta^{34}\text{S}$ between -3.0 ‰ and -6.8 ‰. SIMS data from Warwick Mountain showed indistinct differences with arsenic-rich cores having a $\delta^{34}\text{S}$ ranging from -1.5 ‰ to 0.7 ‰ and As-poor rims had $\delta^{34}\text{S}$ between -1.9 ‰ and 0.6 ‰. Pyrite from Nuttby Mountain is oscillatory zoned with respect to As, with the highest concentrations of As occurring on the rims of pyrite. Oscillatory zoning is also present in the Warwick Mountain pyrites. Gold maps show some elevated concentrations near and along the rims of pyrite from Nuttby, which together with the S isotope data, suggests that fluid boiling was a key mechanism for gold precipitation. Further additions to this study will include the use of similar methods and techniques to analyze drill core and an additional surface sample from other areas in the Cobequid Highlands.

****Winner of the Frank S. Shea Memorial Award for best economic geology presentation***

Analysis of precious metal mineralization within the Bald Hill Antimony deposit, New Brunswick, Canada: a portable X-ray fluorescence study

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The volcano-sedimentary rocks of the Annidale Group in the Bald Hill area of south-central New Brunswick have been actively explored for base metals and gold in recent years. As a result of this exploration, a significant amount of antimony and anomalous gold has been discovered along a northwest trending fault zone. To better understand the characteristics of the gold mineralization in the Bald Hill area, pXRF analysis and petrographic examination was completed on core samples. Samples were collected from drill core stored at the New Brunswick Department of Energy and Resource

Development's core storage facility in Sussex and chosen from intervals that were enriched in gold based on drill hole assay data. These samples were then analyzed using an Olympus Vanta VMR model pXRF spectrometer. Analyses were run with a count time of 120 seconds to ensure the reliability of the collected data. The certified reference standards CD-1, DS-1, MA-2C, NIST-2710a, NIST-2711a, SY-4, and a silica blank were analysed at the start and end of work sessions to ensure the accuracy and precision of the collected data over multiple days. The data quality assurance and control (QA/QC) was completed on the data to determine a linear correction factor to correct the data. Since accepted concentrations for standards are recorded in databases, the accepted concentrations can be compared with the recorded concentrations to determine the correction factor. This correction factor was then applied to correct the data for each desired element. With the data corrected, further analysis and interpretation of the data can now be completed to attempt to better understand the gold and silver mineralization within the area. [Poster]

Investigating the potential for economic mineralization in the Jumping Brook Metamorphic Suite, Cape Breton Highlands, Nova Scotia, Canada

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The Jumping Brook Metamorphic Suite (JBMS) underlies a large part of the western Cape Breton Highlands east of the village of Cheticamp. It consists of the mainly metavolcanic Faribault Brook Formation overlain by the main metasedimentary Dauphinee Brook Formation. Numerous mineral occurrences are known to occur in the JBMS, including native gold, silver and sulphide minerals including chalcopyrite, arsenopyrite, galena, and sphalerite. The rocks are strongly deformed and hence stratigraphic relationships between the formations of the JBMS and the nature of the mineral occurrences that they contain are poorly understood. The purpose of this study is to further investigate these relationships by examining in detail core from two drill holes, GM-08-08 drilled at 45 degrees to a depth of 50 m by Globex Mining Enterprises Limited in 2008, and FB-01-86/08 drilled vertically to 128 m by Selco BP Resources Canada Ltd in 1986 and deepened to 277 m Globex Mining in 2008. The core will be logged and magnetic susceptibility measured. Representative samples will be taken for thin section preparation and petrographic study to enable definitive identification of rock types. A portable XRF instrument will be used to obtain detailed analysis of chemical variations in the core, and igneous samples will be submitted for whole-rock chemical analysis to investigate chemical affinity and tectonic setting in which the rocks formed. Previous studies have suggested that the mineralization is syngenetic poly-

metallic volcanogenic massive sulphide (VMS) mineralizing event in MORB-type basalt associated with turbiditic sediments in a back-arc basin, but there is also evidence of epigenetic vein-related mineralization. The area will be compared mineralized rocks units of similar Cambrian-Ordovician age in Newfoundland and New Brunswick. Ultimately, the implications of this research may provide new exploration targets and/or genetic models for the Jumping Brook Metamorphic Suite. [Poster]

Validation of a recently proposed method for coda wave inversion: a comparison between real and synthetic data

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Seismograms and the information that they provide are of crucial importance for understanding the nature of seismic sources and the media through which the waves travel. These waves, in particular coda waves, contain details about the half-space through which they propagate, important for both industry and research purposes. Coda waves make up the tail of seismograms and are typically ignored regarding them as noise as a consequence of unmodelled physics. However, these types of waves are extremely important because they contain information about scattering attenuation which deals with how energy is redistributed when seismic waves interact with heterogeneities within the propagation medium. Understanding this physical phenomenon is fundamental in seismic hazard analysis as well as in the study of rock properties. In addition, they also contain information about intrinsic attenuation which may be used, with other physical measurements, for characterizing important rock properties such as fluid saturation, lithology, permeability or porosity, making attenuation estimation valuable for different areas such as mining or geothermal exploration. Here we apply an inversion linear process, proposed in 2014 by Fielitz and Wegler based on the radiative transfer theory (RTT), to both real and synthetic data to recover parameters related to scattering and attenuation. We show the challenges in the application of this method to a database of hundreds of earthquakes recorded in southwestern Iceland from 2010 to 2011, and how we partly overcome these challenges. We also show how closely we recover the parameters from the synthetic data created by researchers at the MIT Earth Resources Laboratory and the proper changes required to apply the inversion process.

**Fluid inclusion systematics of the polymetallic
(Co-Ni-As-Au) veins of the Nictaux Falls Dam
occurrence, Annapolis Valley, Nova Scotia, Canada**

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A polymetallic (Co-Ni-As-Au) vein system is located in the Nictaux Falls Spillway (44°51'12.5"N, 65°02'01.5"W), Annapolis Valley, Nova Scotia. Variably mineralized, fault-hosted quartz veins occur metasedimentary rocks of the late Silurian Kentville Formation near their contact with the Devonian Cloud Lake Pluton of the South Mountain Batholith. Field work and sampling was conducted in late August 2018, resulting in a collection of representative vein samples as well as field observations of vein form and orientation. Multiple generations of subparallel and crosscutting veins were observed hosted within the main fault zone of the property, an east-west striking brittle-reactivated shear zone. Mineralization (predominately cobaltite, CoAsS) is restricted to early, laminated quartz veins surrounded by a later thick vein of milky white quartz breccia containing clasts of metasedimentary rocks.

Now that suitable vein samples have been obtained, the project will characterize the P-T-X-t characteristics of quartz-hosted fluid inclusion assemblages (FIA) within representative vein styles using (i) hot cathodoluminescence imaging to determine the relative timing (e.g., primary vs. secondary vs. pseudosecondary) of the FIA, (ii) microthermometry to determine minimum entrapment temperatures, bulk salinity, and isochores for P-T modelling, (iii) Raman spectroscopy to identify volatile components within fluids, and (iv) laser ablation inductively-coupled plasma mass spectrometry to quantify major and trace elements (including potentially metals) content in fluids. The results of this study will aim to (i) determine the conditions before, during, and after mineralization, (ii) constrain the source of fluids (e.g., metamorphic vs. magmatic vs. meteoric waters) and metals, and (iii) classify the occurrence through comparison with similar polymetallic deposits worldwide. [Poster]

**Synthetic 3D CSEM forward modeling for
hydrocarbon exploration applications**

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The Marine controlled source electromagnetic (CSEM) method is an exploration tool that is occasionally used

within the oil and gas industry to help delineate possible hydrocarbon reservoirs. Marine CSEM is a geophysical method which utilizes Faraday's and Ampere's laws to induce currents within the subsurface allowing the resistivity of the subsurface to be measured. This is done by deploying receivers on to the seafloor which measure the secondary electric and magnetic fields that are induced due to the currents that are generated in the subsurface by a high current, low voltage oscillatory waveform source being towed above the seafloor. Marine CSEM is an additional de-risking tool that can be used to determine if a possible target reservoir contains gas or hydrocarbons due to different resistivity response between the two. This tool can be helpful as the typical technique used in reservoir mapping is seismic reflection, which is useful for determining possible reservoirs but lacks in determining if the reservoir is hydrocarbon saturated or gas saturated due to similar amplitude response seen in the seismic data.

Three 3D EM forward modeling will be used to determine possible CSEM data based on an Earth Model. My primary focus will be building the appropriate Earth model for a hypothetical hydrocarbon reservoir to be able determine a possible resistivity reading for a typical hydrocarbon reservoir. This Earth model will be designed based on similar reservoirs seen in the Jeanne d'Arc Basin offshore Newfoundland and will be built and refined using the FacetModeller software tool. [Poster]

**Reconstructing paleoproductivity in the North Water
polynya employing diatom microfossils**

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The regional climate of the Arctic and North Atlantic is directly influenced by the properties of ocean water masses. Changes in the sea-surface oceanic conditions can influence marine phytoplankton production, which leaves a biological signature in the underlying seafloor sediments. This project investigates the features of this biological signature through the lens of diatoms; diatoms are the dominant primary producers in many aquatic ecosystems on Earth. Specifically, we are examining this biological signature in the largest and most biologically productive region of the Arctic: the North Water polynya. Polynyas are typically defined by seasonally ice-free conditions in an area bounded by ice. The North Water polynya is recurrently ice-free and in concomitance with its immensity, functions as a refuge for diverse biological communities that have sustained human populations for millennia (e.g., Dorset, Thule, Inuit). Located at the entrance to Nares Strait, between Greenland and the Canadian Arctic Archipelago, the North Water Polynya fosters large seasonal diatom blooms that are the base of the Arctic food web. This project will explore changes in the diatom abundance

and species composition during the past 8000 years, using a marine sediment core collected from the region. This project will contribute to estimate temporal changes in primary producer biodiversity, identify tipping points in primary producer communities and infer the parameters under which drastic changes occurred. This project represents the groundwork in understanding how changing climate affects Arctic phytoplankton communities.

***Winner of the Science Atlantic Presentation and Communication Award for best overall presentation**

Characteristics of epithermal-style gold occurrences at the Goldy and Irene showings, Dawson Range, Yukon Territory, Canada: towards a first model

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The objective of this study is to characterize and compare epithermal quartz-Au-sulfide vein mineralization that occurs on Triumph Gold Corporation's Goldy and Irene showings in the Dawson Range, Yukon Territory. Specific goals of the study will be to (i) determine if the two showings constitute part of a single hydrothermal system that had several mineralizing centers along common structures or in relation to a common heat source, (ii) to determine the fluid characteristics and crustal depth of the gold mineralizing process(es), and (iii) to characterize the mineralogy expressed at the showings leading to a classification of the P-T regime of the mineralization.

Both mineral showings contain economically significant concentrations of gold in quartz-sulfide veins that are focused along fault-modified contacts between the metamorphic rocks of the Yukon Tanana Terrane and intrusive bodies that are Jurassic to Cretaceous in age. The Goldy showing comprises a roughly 160 × 160 m elliptical area of quartz-carbonate veining at a contact between biotite schist/gneiss and Jurassic syenite. The Irene showing, located 9.5 km NW of Goldy, comprises a greater than 3 m-thick quartz-sulfide vein exposed over 150 m strike-length at a contact between biotite schist/gneiss and biotite-hornblende granodiorite to granite of probable middle- to late-Cretaceous age. At both showings, roughly fault/contact-parallel quartz-feldspar-porphyry dykes are present and are interpreted to occur along segments or splays associated with the regionally important Big Creek Fault.

Preliminary petrographic microscopy, BSE-SEM, and electron probe analysis have identified the following key similarities between the two showings, suggesting a genetic kinship: (i) the mineralize assemblage consists of electrum-arsenopyrite-pyrite-boulangerite-tetrahedrite/tennantite-stibnite-galena, reflecting an ambiguous (both low

and high) sulfidation epithermal signature, and (ii) arsenopyrite thermometry (by electron microprobe) shows a very similar, and high, crystallization temperature for the earliest mineral assemblages in the veins (Irene: 380–430 °C; Goldie: 390–430 °C). This mineralogical work will be complemented by fluid inclusion analyses (petrography and microthermometry) of the vein-hosted minerals, in order to constrain fluid composition and origin, as well as the crustal depth and temperature of the mineralizing event(s). The value of this study will be to ultimately establish robust geochemical criteria to aid in mineral exploration within this under-characterized region. [Poster]

The mineralogy, paragenesis, and petrogenesis of the polymetallic (Co-Ni-Au-Ag-Bi) veins of the Nictaux Falls Dam occurrence, Annapolis Valley, Nova Scotia, Canada

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Mineralization of the Nictaux Falls Dam occurrence occurs in predominantly fault-hosted quartz veins that cross-cut Silurian metasedimentary rocks of the Kentville Formation, close to the contact with the Cloud Lake Pluton of the Late Devonian Southern Mountain Batholith (SMB). Fieldwork and mapping conducted in September 2018 indicates that barren quartz veins post-date the SMB; however, no crosscutting relationships were observed between the mineralized (predominantly cobaltite) veins and the SMB or other lithologies exposed on-site (felsic dykes, diabase sills, and gabbroic intrusions). Mineralization is constrained to the middle of the main fault zone where early, laminated quartz-cobaltite veins occur in quartz breccia veins that contain angular metasedimentary rock clasts. Drag folds were observed at the eastern (unmineralized) end of the fault, suggesting that the fault may have initiated as a ductile shear zone and was reactivated as a brittle fault zone during hydrothermal, mineralizing activity. The far western end of the fault diffusely disappears near the contact with the SMB. Samples were collected from representative areas (mineralized and barren veins, and exposed lithologies) for petrographic thin sections and bulk rock geochemical analysis, in order to characterize their mineralogy and geochemistry. Using field observations, petrographic methods, bulk rock geochemistry and microanalytical techniques (e.g., electron probe microanalysis for major elements and laser ablation inductively coupled plasma mass spectrometry for trace elements and absolute age dating) this project aims to resolve: (i) the mineralogical characteristics and paragenesis (including distribution of Au and relationship to Ni-Co) of mineralization, (ii) the timing of veins with respect to the SMB, and (iii) conditions (PTXt) of vein formation including the age of mineralization and source(s) of metals. [Poster]

**Comparing CO₂ sequestration experimental methods
and investigating CO₂ sequestration using Type I
and Type II serpentine groundwaters**

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In situ sequestration of CO₂ in tectonically exposed mantle peridotite is a potential long-term sink for atmospheric CO₂. Atmospheric carbon dioxide is a prominent greenhouse gas that can be sequestered when groundwater reacts with ultramafic rocks during a process known as serpentinization. This hydrothermal alteration occurs naturally in ophiolites; sections of ocean crust and upper mantle that have been emplaced onto a continental plate causing uplift and exposure above sea level. The Tablelands in Gros Morne National Park, Newfoundland is the site of investigation. The objective of this study is to determine the ideal experimental apparatus for CO₂-sequestering experiments. The accuracy of the LICOR Flux chamber and CO₂ gas analyzer will be compared to similar experiments performed in a sealed glass bottle whereby the concentration of CO₂ will be analyzed by a gas chromatograph (GC) with a Flame Ionization Detector (FID). Once the ideal apparatus is determined, CO₂ sequestering experiments will be conducted, comparing simulated Type I waters (i.e., Mg-, OH-rich waters with a pH of 10) and Type II waters (i.e., Ca-, OH-rich waters with a pH of 12) that occur at sites of serpentinization. Initial experiments with just Type II waters sequestered 349 ppm of CO₂ in 3 hours. The CO₂ sequestration rates and the mechanism of CO₂ sequestration will be determined using peridotite samples from the Tablelands. [Poster]

***Winner of the Imperial Oil Award for the best poster presentation**

**Using sulfur isotopes to determine the sulfur budget of
Brothers volcano, Kermadec Arc, New Zealand**

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Brothers volcano is an active submarine arc volcano on the southernmost section of the Kermadec-Tonga arc, northeast of New Zealand. The volcano caldera hosts hydrothermal systems in a volcanic arc setting that differ from those hosted in mid-ocean ridges in their fluid chemistry and mineralization due to the more felsic host rock and high magmatic volatile content. Brothers volcano hosts two distinct seafloor hydrothermal systems: a seawater-dominated system on the caldera flank and a system dominated by magmatic volatiles at the summit of a resurgent

volcanic cone within the caldera. Drill cores from Brothers volcano were collected at various sites within the caldera on the International Ocean Discovery Program (IODP) Expedition 376 from May 5-July 5, 2018. The objective of this study is to determine the sulfur budget in a hydrothermally active arc volcano and to understand mixing relationships between seawater, hydrothermal fluid, and magmatic volatiles. Drill sites from the seawater dominated Northwest Caldera were located near actively venting black smokers, and thus are believed to represent regions of hydrothermal upflow. Sulfur isotopes can be used to identify the source of the sulfur as well as sulphide mineral precipitation processes. Pyrite and anhydrite from drill core at these sites have been analysed for precise measurements of ³²S, ³³S, ³⁴S, and ³⁶S using isotope ratio mass-spectrometry in the Stable Isotope Geobiology Laboratory at the Massachusetts Institute of Technology. The isotope data show a clear distinction between the sulfur isotopic composition of sulfate and sulfide minerals. The combination of δ³⁴S and Δ³³S values suggest sulfur disproportionation of magmatic SO₂ as the primary control on sulfur cycling within this seawater dominated hydrothermal system.

**An experimental study of reaction textures of
volcaniclastic kimberlites to determine
their emplacement process**

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Some of the most famous diamond deposits are associated with Kimberly-type volcaniclastic kimberlite facies (KPK) located within the diatreme part of the kimberlite pipes. The emplacement process of this type of kimberlite is still highly debated around the world. The two contemporary models suggest either (1) explosive pyroclastic eruption with subsequent welding of the pyroclasts or (2) in-situ magma fragmentation without formation of a pyroclastic deposit. The latter model suggests that a reaction between silicate fragments of the country rock and carbonatitic magma exsolves CO₂ causing the magma fragmentation and freezing. The study will test the two hypotheses by examining the reaction of granitoid and basaltic xenoliths with carbonate-rich kimberlite magma, composition of which will be similar to that of Anaconda hypabyssal kimberlite dyke located on Ekati property, Northwest Territories, Canada. Experiments will be conducted at 0.1 MPa in a box furnace to explore the effect of temperature and cooling rate on the textures and the sequence of the reaction minerals. The developed reaction mineral phases, their textures, and the reaction with the xenoliths will be compared to the textures of natural KPK in BK1 kimberlite from Orapa kimberlite cluster, Botswana. [Poster]

Mineralogy, porosity, and provenance of Upper Jurassic reservoir sandstones in Mizzen F-09 drillcore, Flemish Pass Basin, offshore Newfoundland, Canada

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The Flemish Pass Basin is located 450 km east of St. John's and is a highly faulted, syn-rift area. The basin is thought to be of similar origin to the producing Jeanne d'Arc Basin but has been relatively unexplored in comparison. The aim of this thesis is to compare the Flemish Pass Basin to the Jeanne d'Arc Basin by studying the mineralogy, porosity, and provenance of the Mizzen F-09 strata. The evaluation of the Mizzen F-09 well will help to improve our understanding of the stratigraphy and reservoir quality of the Upper Jurassic strata in the Bodhrán formation (informal) located in the Flemish Pass Basin. The goals of this project will be to (1) describe and log the 60 m of core and to create a stratigraphic section, (2) prepare the samples from the core for further analysis, and (3) analyze the prepared samples using SEM-MLA techniques. The data that will be collected will be used to help evaluate the economic potential of the F-09 well and of the Bodhrán formation sandstones. A comparison will also be made between the Mizzen F-09 well and the K-19 well in the Jeanne d'Arc Basin. It is thought that the sandstone units of the Flemish Pass Basin are correlative with producing reservoirs of the Jeanne d'Arc Basin. The comparison will help to determine if the source areas have predictable mineralogical and porosity characteristics. [Poster]

Numerical and experimental observation of nonlinear responses from the interaction of two progressing waves at an interface

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The nonlinear response of sedimentary rocks has been an ongoing area of research in recent years due to information it can reveal about reservoir porosity, fractures, and pore fluids. We attempt to observe numerically and physically a nonlinear response, generated at an interface between two different nonlinear media (e.g., reservoir rocks) due to the interaction of two acoustic waves at that interface, proposed theoretically by previous authors. It is thought that this response could be used in the future as a new way of mapping the reservoir properties mentioned previously. We first model two waves interacting at an interface both to see if we can observe the response numerically, and also see what parameters to use in physical experiments. The nonlinear

response is demonstrated by numerical modelling and thus the project progressed to physical experiments. In the experimental aspect of the project, we use high-frequency transducers as sources for the waves with an interface made between several different nonlinear materials (e.g., gelatin, water, salt brine). Two different receiving mechanisms were explored, a vertical array of transducers identical to the sources and a Polytec laser vibrometer positioned on a motorized slider, programmed to incrementally traverse across the media. The magnitude of the response varied between different materials, as expected. We have met the objective of the project by observing this response physically, which opens up a new line of work to both characterize these waves when produced from different materials, and also to perform the experiment with sedimentary rocks for a more realistic analogue to hydrocarbon reservoirs. [Poster]

**Winner of the Canadian Society of Exploration Geophysics Award for best presentation of a geophysics-related paper*

Electron microprobe study of lapis lazuli to determine provenance

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The illegal mining of lapis lazuli, a bright blue semi-precious mineral aggregate, in Afghanistan is fuelling conflict in the region, with half of illegal mining revenue going to insurgent groups. Other lapis lazuli deposits are located in Chile, Tajikistan, and Russia, and depending on the origin of the sample, the ore contains differing quantities of lazurite, pyrite, and other minerals within the lapis matrix. This study is a pilot project to determine if the origins of the lapis lazuli can be effectively pinpointed using techniques such as transmitted and reflected light microscopy, X-ray diffraction, and electron microprobe. A Chilean sample was characterized and compared to samples sold as Afghan. The results from our X-ray diffractogram confirm our thin section analysis, in which the peaks for Chilean sample indicate the presence of lazurite, wollastonite, and pyrite, and the peaks for the Afghan sample indicate the presence of lazurite and diopside. Electron microprobe analysis of lazurite and pyrite from the two "Afghan" samples indicate they came from different mines within the same region. The lack of wollastonite demonstrates that they are not from Chile. Reflected light microscopy verified that the pyrite samples contain no alteration which is characteristic of Russian lapis lazuli. The nickel content in the pyrite, as analyzed by the electron microprobe, fit into the parameters for potential Afghan provenance; however, copper content was below detection limits, and therefore could not be distinguished as Afghan or Tajik. More work is necessary to characterize the

pyrite chemistry in order to determine potentially significant conflict origins. [Poster]

Fluid inclusion and textural evidence of boiling in epithermal veins in the Cobequid Highlands, central Nova Scotia, Canada

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Low-sulphidation epithermal Au mineralization has been the focus of recent bedrock mapping, geochemical, and geochronological studies in the northeastern part of the Cobequid Highlands, Nova Scotia. Mineralization is hosted in Late Devonian to Early Carboniferous bimodal, rift-related felsic (Byers Brook Formation) and mafic (Diamond Brook Formation) volcanic and volcanoclastic rocks. The Warwick Mountain area located in the northwestern part of the Diamond Brook Formation shows the most potential for gold mineralization, with two zones of intensely silicified and sulphidized basalt recognized. Assays show anomalous Au concentrations up to ~660 ppb, as well as anomalous As, Sb, Cd, W, and Hg. A key question in this epithermal setting is: "Has boiling occurred, what is the evidence for this potentially important mechanism for gold mineralization?" To answer this question, representative samples of epithermal veins were obtained from the only two diamond drill holes targeting this mineralization style (R and J Drilling Ltd for Sugarloaf Resources Incorporated). The specific goals of the research are to (i) characterize vein textures (quartz-carbonate intergrowths) using established criteria for boiling vs. rapid boiling (flashing) vs. non-boiling systems, and (ii) and utilize fluid inclusions to constrain conditions such depth, fluid salinity, and fluid temperature during, prior to, and after mineralization. Boiling textures are typically associated with the presence of ore elements (Au, Ag, Cu, Pb, Zn, As, Hg, and Sb). Mineral and fluid inclusion textures such as colloform and plumose quartz, lattice bladed calcite (\pm replacement by quartz), as well as coexisting liquid-rich and vapour-rich fluid inclusions are definitive characteristics of boiling. These will be investigated by petrographic microscopy. With fluid inclusion micro-thermometry, the P-T-X characteristics will be determined. This study will help refine ore exploration models in the Cobequid Highlands. From initial petrographic analysis, boiling textures have been identified in some areas of the drill core but not all, suggesting that distinct boiling "horizons" existed. The relationship between these and gold mineralization is unknown but will be investigated. [Poster]

Chemical signatures and cathodoluminescence of multiple generations of apatite within the Mactung W (Cu, Au) skarn deposit, Northwest Territories, Canada: implications for the evolution of skarn fluids

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In order to understand the evolution of the Mactung deposit, and constrain chemical signatures of mineralizing fluids, multiple generations of apatite were characterized using classical petrographic techniques, hot cathodoluminescence (CL), and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Representative skarn samples were collected from each stratigraphic unit of the deposit and examined for apatite. Apatite occurred in all stratigraphic units and skarn types studied, including pyroxene-pyrrhotite, garnet-pyroxene, pyroxene, pyrrhotite, and amphibole skarn. Textural evidence suggests that at least some apatite formed through the recrystallization of detrital colophane, as apatite is commonly distributed around partially dissolved phosphate nodules. Apatite was paragenetically early and coeval with scheelite and titanite. It exhibits five texturally distinct fluorescence colours under CL: (i) irregular masses at the cores of oscillatory zoned apatite fluoresced light to dark grey, (ii) the interior of oscillatory zoned apatite fluoresced blue, (iii) the interior and/or rims of oscillatory zoned apatite fluoresced green, (iv) the rims of oscillatory zoned apatite and entire unzoned crystals fluoresced yellow, and (v) small patches of altered apatite rims fluoresced orange. Preliminary LA-ICP-MS data show that the different coloured fluorescent apatite grains have different rare earth element (REE) abundances. Dark grey apatite shows relatively low total REE contents (~590 ppm Σ REE, La-Lu), with relatively high LaN/YbN = 33 and negative Eu anomaly ($\text{Eu}/\text{Eu}^* = 0.4$; where $\text{Eu}^* = \sqrt{\text{SmN} \cdot \text{GdN}}$). Green apatite contains moderate REE contents (average 1170 ± 180 ppm, 1σ ; $n = 14$), with LaN/YbN = $7 (\pm 3, 1\sigma)$ and $\text{Eu}/\text{Eu}^* = 0.6 \pm 0.1$. Yellow apatite contains high REE contents (average 2130 ± 640 , 1σ ; $n = 23$), with LaN/YbN = $4 (\pm 2, 1\sigma)$ and $\text{Eu}/\text{Eu}^* = 0.4 \pm 0.1$. Orange apatite shows the highest concentration of REE (average 4040 ± 130 ppm, 1σ ; $n = 2$), with LaN/YbN = $1.83 (\pm 1, 1\sigma)$ and $\text{Eu}/\text{Eu}^* = 0.1 \pm 0.0$. These preliminary results indicate that the breakdown of colophane likely influenced the HREE abundance of green apatite. As more data are collected, apatite compositions will be used to describe the evolution of skarn fluids. [Poster]

Investigating the Barra Volcanic Ridge System and overlying Paleogene sills in the Rockall Basin in the North Atlantic Ocean using seismic reprocessing and potential field modelling

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The conjugate Irish Atlantic and the Orphan Basin/Flemish Cap margins are both considered non-volcanic margins formed from continental breakup of North America and Europe during the Triassic-Cretaceous that resulted in the North Atlantic Ocean. The focus of this study is on the Irish Rockall Basin, which is one of several large, deep water sedimentary basins in this region. Although both margins are classified as non-volcanic, they both exhibit significant magmatism formed during late stages of rifting. The Barra Volcanic Ridge System is identified as a young Cretaceous volcanic structure having three large ridges and is suggested to be an important example of volcanism in the Rockall Basin. The Barra volcanic system includes Paleogene sills which make it difficult for sub-sill imaging due to the high reflectivity contrast between the sediments and overlying sills. New regional seismic reflection data were provided by the Petroleum Affairs Division of Communications, Climate Action and Environment, Government of Ireland. The reflection line will be seismically reprocessed to produce an enhanced understanding of the Barra Volcanic Ridge System and overlying sills. The line will be seismically interpreted with support from 2-D reflectivity, gravity and magnetic modelling. [Poster]

Geochemical and mineralogical dispersal in till from the East Kemptville Sn-Zn-Cu-Ag deposit, southwest Nova Scotia, Canada

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The aim of this study is to document the type and abundance of indicator minerals in till at varying distances down ice from the East Kemptville tin deposit, as an aid to tin exploration in glaciated terrain. Southwestern Nova Scotia is covered by a thick, nearly continuous sequence of till deposited by multiple ice-flows during the Wisconsinan glaciation. This sediment cover produced complex geochemical dispersal patterns and represents a challenge to mineral exploration in this region. The greisen-hosted East Kemptville tin deposit is one of many granite- and metasedimentary-hosted Sn, W, Mo, Zn, Pb, Cu, Ag, and In prospects that comprise the Southwestern Nova Scotia Tin Domain. Detailed knowledge of glacial dispersal patterns is required to

effectively plan and implement exploration strategies for mineral occurrences in southwestern Nova Scotia. In this study, indicator mineralogy and surficial geochemistry will be employed together with a re-examination of existing research to evaluate how regional and local ice-flow dynamics have influenced the dispersal of mineralization from the East Kemptville tin deposit. These data can be used to better understand and potentially locate occurrences both locally and elsewhere in similar geological settings. [Poster]

Characterization of three mineralization styles of the Revenue Au occurrence, Dawson Range, Yukon Territory, Canada: implications for a large-scale, intrusion-related system

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The Freegold Mountain Project in the Dawson Range of the Tintina Gold Belt hosts multiple gold showings, including the poorly characterized Revenue Au occurrence. At Revenue, three different mineralization styles are hosted in the Cretaceous (ca. 105 Ma) Revenue Granite: (i) early, Cu-Au quartz stockwork, named the Blue Sky Porphyry (BSP), locally overprinted by (ii) the polymetallic (Cu-Mo-W-Au-Pb-Zn) W-Au (WAu - wow) Breccia, which is crosscut by (iii) a diatreme Cu-W hydrothermal breccia. The ore and alteration mineral assemblages have been characterized with respect to paragenesis and mineral chemistry (including major, minor, and trace elements) in order to discriminate the different mineralizing events, fingerprint their chemical signatures, and interpret the processes that led to their formation. The BSP is characterized by early quartz-pyrrhotite-chalcopyrite-pyrite±gold veins with trace sphalerite and potassically altered (biotite, K-feldspar) margins, and late stage quartz-chalcopyrite-molybdenite±carbonate veins. The WAu breccia consists of clasts of phyllic altered Revenue Granite and coeval quartz-feldspar porphyry (QFP) dykes hosted in a sulfide-quartz matrix. The sulfide matrix contains massive pyrite-chalcopyrite with late pervasive molybdenite and local occurrences of Bi-rich galena, sphalerite, and pyrrhotite, and trace glaucodot and ferberite-scheelite. The diatreme-hosted hydrothermal breccia consists of a fine-grained chalcopyrite-pyrite ± scheelite matrix interstitial to weakly phyllic-altered diatreme clasts with diffuse boundaries. Trace element compositions of chalcopyrite, pyrite and pyrrhotite from the early and late Blue Sky Porphyry and WAu Breccia indicate that the sulfides from each location show unique chemical signatures, with respect to relative Co + Ni, Ag + Au + Te, and W + Sn abundances. Major elements of sulfides and sulfarsenides provided a basis to calculate crystallization temperatures: (i) sphalerite with pyrite and pyrrhotite from late stage BSP and WAu Breccia yielded high temperatures of 601°C to 613°C and 610°C

to 647°C, respectively, (ii) glaucodot from the WAu Breccia gave temperatures of 300°C to 465°C, and (iii) arsenopyrite in equilibrium with pyrite gave temperatures from 363°C to 491°C for mineralized QFP dykes. The overprinting mineralization styles of the Revenue occurrence were likely the result of an overpressured system due to the emplacement of granitic intrusions at depth. Similar intrusion-related mineralization styles in the Freegold Mountain area suggest that the granitic intrusions were part of a large cooling magmatic system at depth.

Cooling history of a failed rift margin – new insights from (U–Th)/He thermochronology along the Labrador passive margin, Canada

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The Labrador Sea is the result of a failed rift system between Labrador and Greenland. The initiation of rifting has been attributed to the Late Triassic to Jurassic (223–150 Ma) based on Rb–Sr and U–Pb dating of dike emplacements in southwest Greenland. Less magmatic activity from rifting has been found on the Labrador side with the oldest ages determined through fossil evidence of a diatreme yielding Early Jurassic–Early Cretaceous ages (197–145 Ma). There is still ongoing debate on the age of initiation of spreading, which represents the end of rifting. The oldest undisputed evidence of oceanic crust formation has been dated to 63.0 ± 0.7 Ma correlating to magnetic anomaly polarity Chron C27. Older ages have been attributed to 72.1 Ma (Chron C32) for southern Labrador and 66.0 Ma (Chron C28) for northern Labrador. Cessation of spreading has been determined stratigraphically to the late Eocene to early Oligocene. The asymmetry of magmatism, bathymetric/topography, sediment distribution, and crustal structure along both margins suggests a lithosphere-scale simple shear model of rifting. Low temperature thermochronometry includes a range of methods used to retrieve the thermal history of the uppermost crust, allowing dating and identification of tectonic, magmatic, and/or surface processes that have contributed to this thermal history. For this study, five bedrock samples were collected along a 200 km transect along the Labrador passive margin between Nain (56.5417°N, 61.6969°W) and Hopedale (55.4580°N, 60.2115°W). Samples will be dated using apatite and zircon (U–Th)/He thermochronometry, with closure temperatures of 70°C and 170°C, respectively. We expect to quantify the crustal cooling of the margin and identify the processes driving it. If rifting ages (Jurassic – Early Cretaceous) are obtained from our samples, we expect those to be consistent with diachronous rifting from

south to north yielding progressively younger ages northwards. Alternatively, if much younger ages (Quaternary) are obtained, we expect a more uniform distribution along the Labrador margin, which could be attributed to glacial erosion generated by the Laurentide Ice Sheet which covered most of Canada including Labrador. [Poster]

Decoupling sources of natural and anthropogenic impact using lake sediment archives: an example from Cecil Lake, Fort St. John, British Columbia, Canada

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Lake sediment archives are an established tool for examining environmental change over time. Cecil Lake is a productive shallow lake located in the Peace Region of Northeastern British Columbia and supports a variety of waterbirds, including a significant breeding population of eared grebes (*Podiceps nigricollis*). The Cecil Lake watershed was originally open grass prairie and muskeg and Bison herds fed on the new growth that was maintained through controlled burns by the Dane-Za. The region was first homesteaded in 1928, making this one of the last areas in North America to be populated by traditional European pioneers. These lands are now almost entirely agricultural and used primarily for the farming of canola and hay, conventional oil wells are also scattered across the countryside. Nearby Fort St. John is highly industrialized and supports a variety of petroleum-handling facilities. The environmental impact of these recent changes is unknown but recent study in other northern industrial centers (e.g., Fort MacMurray) suggests substantial regional and atmospheric contributions are possible. The bulk geochemistry of the lake sediment archive at Cecil Lake is being investigated to decouple the natural and anthropogenic impacts on the environment. Three sediment cores were collected in July 2018 using a Glew gravity corer. Stratigraphic variations in bulk geochemistry (metals, $\delta^{15}\text{N}$, $\delta^{15}\text{C}$, Total C, N, poly aromatic hydrocarbons) will be determined. X-ray fluorescence will be used to determine metal concentrations. These data will provide insight into change through time and the total Pb curve will provide temporal control. The results of the analysis will provide further insight into the significance of the impacts of long-range atmospheric transportation of contaminants and regional/local environmental changes. These data will be used to determine the risk to both humans and ecologically significant species such as the eared grebe.

***Winner of the Atlantic Geoscience Society Award for the best Environmental Science presentation**