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Atlantic Geoscience Society

ABSTRACTS

46th Colloquium & Annual General Meeting 2020

Truro, Nova Scotia

The 2020 Colloquium & Annual General Meeting were held at the Holiday Inn, Truro, Nova Scotia, on February 7th and 8th. On behalf of the society, we thank Colloquium organizers Robert Raeside and Chris White, as well the numerous student volunteers and judges, for facilitating an excellent meeting with about 100 submitted abstracts. AGS acknowledges support from the corporate sponsors and partners for the meeting: Nova Scotia Department of Energy and Mines (Geological Survey and Petroleum Resources), New Brunswick Department Natural Resources and Energy Development, Association of Professional Geoscientists of Nova Scotia, Association of Professional Engineers and Geoscientists of New Brunswick, Mercator Geological Services, Northern Shield Resources, EXP Services Inc., St. Mary's University (Department of Geology), Stantec, Anaconda Mining, Xterra Resources, and Acadia University (Department of Earth and Environmental Science).

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 presentations are recognized and indicated by an asterisk in the authorship. The meeting included several sessions: (1) Current Research in Hydrogeology and Environmental Geology in Atlantic Canada; (2) Recent Advances in the Carboniferous in the Maritimes; (3) Paleontology and Sedimentology in the Maritimes and Beyond; (4) Structure, Tectonics, and Magmatism of the Appalachian-Caledonides from Iapetus to Pangea; (5) Gold: an Atlantic Canada Perspective; (6) Geoscience Education; (7) Current Research in the Atlantic Provinces.

Also included with the conference was a day-long short course/workshop on "QAQC methods in geochemical research and mineral exploration with a focus on gold assay quality control" delivered by Dr. C. Stanley (Acadia University). In addition, a Special Discussion session was held on "Being a Woman in the Field" chaired by A.M. Arnott and K. Vogler. The guest speaker at Saturday evening's banquet and social was Danielle Serratos (Director and Curator, Fundy Geological Museum) who gave a talk entitled "Not all those who wander are lost".

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

THE EDITORS

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A gravity study of the Valentine Lake Gold Property, west-central Newfoundland, Canada

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The Valentine Lake Gold Property (VLP) is located in the west-central region of the island of Newfoundland and encompasses four significant gold deposits, which are structurally controlled and of orogenic origin. These deposits, which have proven challenging targets for geophysical exploration, occur proximal to a major thrust faulted contact between the Precambrian Valentine Lake Intrusive Complex (VLIC), which houses the majority of gold mineralization, and the Silurian Rogerson Lake Conglomerate. Hosted within the silicic quartz-eye porphyry and trondhjemite phases of the VLIC, the gold concentrations are associated with extensional and shear parallel quartz-tourmaline-pyrite (QTP) veining. The VLP has undergone multiple complex stages of deformation and contains many generations of mafic dykes. While geophysical techniques are commonly used for detecting and investigating mineral prospects, their use to delineate the ore zone at the Valentine Lake Property has met with little success. This is primarily because the gold is scattered throughout veins within the resistive, silicic host rocks and the relationship between the mineralization and the mafic dykes is unclear. Consequently, to date the primary methods for locating the ore have been soil sampling and drilling. This study employs the gravity method, a geophysical technique that has not previously been used over the property, to investigate the VLP. Although gravity methods are often used in mineral exploration, they are not usually applied to the type of gold deposits present at the Valentine Lake Property, where the density contrast between lithologies is small, topography is rough and overburden is thick and irregular. A 2018 proof-of-concept survey over the gold-bearing hydrothermal alteration zone revealed a small but measurable negative gravity anomaly. Encouraged by this, in August 2019, a 14.2 line-km broad-scale gravity survey, comprising 166 stations, was carried out over the property in an effort to map the subsurface extent of the alteration zone and delineate areas suitable for exploratory drilling. Preliminary results indicate that there is a measurable response from the alteration zone, which suggests that gravity is a suitable technique for assessing the mineral prospects at the VLP. Overall conclusions on the utility of this geophysical method, over a deposit type exhibited in belts across the island of Newfoundland, will be shared with the broader resource exploration community.

An ichnotaxonomic study of historical tetrapod footprint specimens from Wentworth Station, Nova Scotia, Canada

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In 1873, Dr. David Honeyman and his assistant Andrew Jack collected fifteen vertebrate footprint specimens at two distinct fossil localities near Wentworth Station, Nova Scotia. These fossil footprints have been curated in the Nova Scotia Museum for over a century without ichnotaxonomical review. Both sites are preserved within the Tatamagouche syncline of the broader Cumberland Sub-basin. The first locality, Amos Purdy Freestone Quarry, has been mapped as mid to late Pennsylvanian Balfron Formation, while strata of the second location exposed along the banks of Whetstone Brook (now Giles Brook) have been mapped as early Pennsylvanian Boss Point Formation. Strata of the Balfron and Boss Point Formations are considered to represent a complex system of continental, fluvial and braid plain deposits with intermittent swampy conditions. Well-drained lithofacies assemblages at both localities resemble that of the lithofacies observed at the UNESCO World Heritage Site at Joggins (specifically the Hebert Sandstone), interpreted to represent a dryland watering hole deposit. This interpretation is broadly applied to the Wentworth Station fossil localities.

Four ichnotaxa are represented in the specimens: *Baropezia sp.* (5–10 cm wide), *Limnopus heterodactylus* (6–8 cm wide), *Characichnos ichsp.* (2–3 cm wide) and a morphotaxa (6–8 cm wide) that may represent a new ichnotaxa. The trackways are preserved in fine-grained red sandstone that exhibits mudcracks, rain prints, graded bedding and cross-bedding. *Baropezia sp.* is the most common ichnogenera and has been interpreted to be produced by large baphetid stem tetrapods. Baphetids were likely the top predator and may have occupied a similar ecological niche to crocodiles today. *Limnopus heterodactylus* has traditionally been interpreted to represent the footprints of temnospondyl amphibians. *Characichnos ichsp.* are general tetrapod swimming traces that have no affinity to a specific tetrapod group but likely represent an ethological variant of the other ichnotaxa.

The fourth, potentially new ichnotaxa is preserved as a single manus and pes set. It displays characteristics that could be derived from temnospondyls or microsaurs (i.e., *Matthewichnus* or *Limnopus*) with short round digits. Features common in the seymoriamorph footprint *Amphisauropus* ichsp. are present such as a wide pentadactyl manus. However, the manus is smaller than the pes; a characteristic not attributed to *Amphisauropus* tracks but a defining feature of *Matthewichnus*. The differences in the manus and pes morphologies are here interpreted to represent a basal anthracosaur. The biodiversity of this dryland-watering hole shows the presence of at least three crown groups of tetrapods: temnospondyls, anthracosaurs and baphetids.

The Au-bearing, polymetallic (Co-Ni-As-Au±Ag, Bi), Nictaux Falls Dam occurrence of the Meguma terrane, Nova Scotia, Canada

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A unique style of gold mineralization associated with polymetallic sulfarsenide-quartz veins occurs in the northwestern Meguma Terrane, outcropping near the Nictaux Falls Dam, Annapolis County, Nova Scotia. This occurrence, as well as compositionally similar styles of mineralization in the area, are currently under study to resolve details of their formation and the potential for economic deposits. These showings represent an under-characterized and under-explored mineralization style in Nova Scotia and provide an opportunity to expand our understanding of the Au metallogeny of the Meguma terrane.

Mineralized veins are constrained to a reactivated fault zone that cuts late Silurian Kentville Formation slate near the South Mountain Batholith (SMB) and mafic intrusions. Crosscutting relationships between genetically related barren veins and the SMB indicate a maximum age of ca. 70 Ma. Two types of mineralization, both associated with chlorite alteration, characterize the showing: (i) laminated, sulfarsenide-quartz veins and (ii) sulfarsenide-mineralized wallrock clasts in quartz breccia. The sulfarsenides exhibit unidirectional zoning from Fe-rich (arsenopyrite), to Co-rich (Fe-rich cobaltite), to Ni-rich (Co-rich gersdorffite) rims. Gold mineralization occurs as small (<10 μm), Au-Ag alloy grains (Au_{76}) interstitial to gersdorffite rims. Sulfarsenide trace element abundances (LA-ICP-MS) correlate with major element zoning: Fe-rich areas are high in Sb (≤160 ppm) and Bi (≤1600 ppm), and Co-Ni- rich areas are high in Au (≤140 ppm), Ag (≤10 ppm) and Se (≤1100 ppm). Similar bulk $\delta^{34}S_{VPDB}$ of both types of mineralization (5.4–6.6 ‰ and 3.9–4.6 ‰, respectively) suggest a homogeneous source of S, likely the wall rock. Two fluids are preserved as quartz-hosted fluid inclusion assemblages: (i) NaCl-$CaCl_2$-H_2O±CH_4 fluids (~32wt% $NaCl_{equiv.}$; $T_{h\text{-}halite}$ from 175-194°C; n = 2), and (ii) $CaCl_2$-NaCl-H_2O±CH_4 fluids with an undetermined but likely high salinity ($T_{h\text{-}vapour}$ from 142 to 194°C, n = 10). Estimates of trapping conditions show that NaCl-rich fluids were trapped at high confining pressure (0.2 to 2.6 kbar). Decrepitate mound analysis suggests mixing of the two fluids in widely variable proportions as Ca/(Ca+Na) range from 0-1 (n = 184). Based on fluid P-salinity data and the post-Devonian paleotectonic setting, we suggest the fluids were marine in origin, possibly derived from the overlying Carboniferous Maritimes Basin. High Ca may reflect Ca-Na exchange between fluids and plagioclase-rich rocks deeper in the metasedimentary succession. We suspect mineralization was associated with either late Paleozoic regional shearing or Jurassic rifting during the opening of the Atlantic Ocean. Future work will constrain absolute timing of mineralization.

The first discovery of an ichnofossil assemblage from the middle Pennsylvanian Minto Formation of central New Brunswick, Canada: implications for paleobiodiversity

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The middle Pennsylvanian Period (late Bashkirian–early Moscovian) Minto Formation in central New Brunswick has been historically studied for its diverse paleofloral assemblages and coal potential. Deposited on a stable cratonic platform (New Brunswick platform), this formation is thought to represent a peat-forming wetland that experienced occasional euryhaline influence within back-

barrier or delta front depositional settings. Previous studies have reported plants fossils, rare invertebrate body fossils (Trigonotarpid) and disarticulated fish, shark and tetrapod remains from the lower Minto Formation limestones. The middle (Hurley Creek Member) and upper (Sunbury Creek Member) strata of the Minto Formation have not yet yielded fossils prior to this study.

A recently discovered fossil locality situated along the southern shoreline of Grand Lake has yielded a diverse array of plant fossils, tetrapod and invertebrate footprints and invertebrate body fossils from the Sunbury Creek Member of the Minto Formation. The tetrapod ichnofossils are represented by seven ichnogenera that include: *Baropieza sp., Batrachichnus sp, Characichnos cf. Gilmorichnus sp., Limnopus sp., Matthewichnus sp., Notalacerta sp.* Trackways provide ichnological evidence as a proxy for biodiversity of terrestrial amphibians (temnospondyls, microsaurs, stem tetrapods, anthracosaurs) and early amniotes (reptiles). A wide range in footprint size is observed in all identified ichnotaxa. This observation could be interpreted as a gradation of juvenile to adult growth stages confined to a single species, or a multitude of tetrapod species sharing similar manus and pes morphologies.

Tetrapod footprints are preserved alongside an equally diverse invertebrate ichnofaunal assemblage (8 ichnogenera). In the proximal floodplain grey shales, millimeter-scale surface traces (*Gordia sp., Helminthoidichnites sp., Helminthopsis sp.*) are found in association with small land snails (*Dendropupa sp.*). Small (2cm wide) examples of myriapod tracks (*Diplichnites cuthiensis*) are commonly preserved in the distal floodplain redbed shale facies alongside rare examples of scorpion tracks (*Stiaria sp.*). Rare xiphosuran trackways (*Kouphichnium sp.*) are interpreted as evidence of a distal open water connection, perhaps in back-barrier wetland environments as was previously interpreted from the petrography of Minto coal beds. *Rusophycus* and *Planolites* traces are found associated with tetrapod tracks in sandstone lithofacies. Rare blattoid (cockroach: *Archimylacris sp.*) and paleodictoptera (dragonfly-like) wings represent flying insect fauna in the Minto Formation. Cumulatively, these ichnofossils and invertebrate body fossils help to populate the previously unknown biodiversity of the Minto Formation.

Granitoid rocks in the eastern Meguma terrane, Nova Scotia, Canada

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Granitoid rocks are abundant in the northeastern Meguma terrane. The terrane is characterized by a thick succession of metasedimentary rocks that were intruded by abundant granitoid plutons at ca. 375 Ma. Granitoid rocks are the crustal legacies of thermal disturbances that initiate melting in the mantle and lower part of the crust. Buoyancy contrasts and the exploitation of favorable structures facilitate upward transport of magma to form granitoid plutons. In some cases, these plutons are associated spatially and temporally with rare-element mineralization including elevated concentrations of beryllium, lithium, tantalum, and/or rare-earth elements. Despite the recognition of several rare-element mineral occurrences in the northeastern Meguma terrane, they have received little modern academic study. This study aims to better understand the age, petrogenesis, influence of magma source(s), and the relationship to orogenic events of granitoid plutons and their relationship to the rare-element mineralization. The granitoid plutons are peraluminous and have "S-type" characteristics including high SiO_2 concentrations (>70 wt.% SiO_2), primary muscovite, and accessory garnet. Some plutons (e.g., Canso plutons, Trafalgar plutonic suite) are associated with volumetrically subordinate mafic-intermediate rocks. Geochemical data show that the granitoid rocks lack elevated concentrations of rare elements such as beryllium (<26 ppm), tin (<21 ppm), tantalum (<5 ppm) or cesium (<27 ppm) that are enriched in pegmatites located adjacent to some of the granitoid bodies. For example, the Lower Caledonia pegmatite comprises three pegmatite outcrops with abundant, euhedral beryl (>5 cm in length). In addition to beryllium (<650 ppm), the pegmatite also contains elevated concentrations of gold (<24 ppm), cesium (<391 ppm), and tantalum (<128 ppm). An unnamed pegmatite near Sherbrooke is enriched in beryllium (200 ppm) and tin (78 ppm). A small pegmatite in the Forest Hills gold district is also enriched in beryllium (960 ppm). Field work showed that the surface extent of the known granitoid-related mineral occurrences is limited but a new beryl-bearing pegmatite and other previously unrecognized pegmatites were located. These new pegmatite discoveries require further investigation.

A geostatistical approach to study the petrogenesis of Silurian–Devonian granitoid rocks: an example from the New Brunswick Appalachian orogen, Canada

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Principal component analysis demonstrates that the Silurian-Devonian granitoid rocks of New Brunswick divide into three groups (herein referred to as NB-1, NB-2 and NB-3) based on their Zr/Ce to TiO_2 values. Unmineralized Lost Lake and Juniper Barren granites plot as individual intrusions due to geochemical traits similar to unfractionated I-type granites. These NB-1 group granites are generally the least fractionated intrusions in the study (SiO_2 68–70 wt.%), vary from metaluminous to peraluminous, and show light rare earth element enrichment with small negative Eu anomalies. These granitoid rocks also have high Zr/Hf (30.85 as opposed to 37 for the crustal average) and Nb/Ta (10.69 compared to 17 for crustal average) ratios. These unfractionated I-type granites are interpreted to have formed by partial melting in an arc system subsequently contaminated by reduced crustal blocks.

The majority of the studied granites plot as NB-2, and form six subgroups based on REE patterns. These granites are metaluminous to peraluminous I-type granites characterized by SiO_2 contents ranging from 71 to 75 wt.%, K_2O>Na_2O, and LREE enrichment with pronounced Eu anomalies. Granites of the NB-2 group vary from unfractionated to weakly fractionated I-type granites produced by various degrees of partial melting of a mixed mantle – older crustal protolith with an igneous quartzofeldspathic composition. The NB-3 group granites include the most evolved intrusions examined and are spatially and temporally associated with Sn-W and Au mineralization. These granites are characterized by the highest SiO_2 (>75 wt.%), Gottini index (τ) >227, K/Rb <41, and the lowest Zr/Hf (<14), Nb/Ta (2.6–4.2), La/Sm (2.7–3.9), and Eu/Eu* (0.002–0.03) values. These intrusions have crustal A-type affinities, although they exhibit higher Rb/Sr and Rb/Ba ratios than typical A-type granites. Consequently, they are interpreted as highly fractionated I-type granites that formed in response to crustal thinning related to crustal delamination following the juxtaposition of crustal terranes during the Acadian orogeny.

More U–Pb dating (zircon, monazite) is needed to resolve the detailed magmatic and tectonic evolution of New Brunswick through the Silurian and Devonian, to fully relate these events to mineralization.

Integrated water resources monitoring/research program in Cape Breton Island, Nova Scotia, Canada

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A monitoring/research program has been developed over the last 15 years to investigate the water resources within the ~11 700 km^2 encompassed by Cape Breton Island. It has evolved to integrate between geological, hydrological, hydrogeological, geochemical and sedimentological disciplines, as well as across most of the 10 Hydrological Regions and 27 Hydrological Districts forming the island. Data collection focuses on answering two questions: (a) how do the natural hydrological, geochemical and debris cycles function in these various hydrological settings, and (b) when, where and how will the impacts of changing climate be felt, in order to facilitate adaptation? The program presently encompasses stations to monitor: sea level (1 station), climate (65), rivers (29), lakes (14), wetlands (11), barachois ponds (5), karst dolines (5), vernal pools (3), groundwater wells (61) and springs (33), as well as groundwater surface water interaction (9). The data are held in an ArcGIS database with associated attribute and graphic files. It incorporates select field data collected from various federal, provincial, municipal, first nations, industry, NGO and university databases and reports. It is augmented with our own monitoring and supported with NASA satellite imagery. To date the program has supported publication of four peer-reviewed journal articles and four conference papers.

Comparative chemostratigraphy of halokinetically influenced Cumberland Group (Pennsylvanian) strata, Joggins area, eastern Canada

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The Pennsylvanian stratigraphy of the western Cumberland Basin has been influenced by salt tectonics, specifically the formation of the Minudie Anticline, a salt wall. South of the Minudie Anticline, along the Joggins World Heritage shoreline, the post-Boss Point Formation succession comprises an ~3000 m conformable succession of strata assigned to the Little River, Joggins, Springhill Mines, and Ragged Reef formations. North of the Minudie

anticline, the Grande Anse Formation lies in angular unconformity on the Boss Point and basal Little River formations. Biostratigraphic studies could not discern whether the Grande Anse Formation is equivalent to one or all of the Joggins to Ragged Reef units.

To further investigate the relationship of the Grande Anse Formation with strata of the Joggins shoreline, forty sandstone samples from post-Boss Point Formation strata were analyzed using Inductively Coupled Plasma Mass Spectrometry to determine major element compositions. On a Herron diagram, sandstone of the Little River, Joggins, and Springhill Mines formations are classified as litharenite, where the sandstone of the Ragged Reef and Grande Anse formations plot as subarkose and sublitharenite. On a Roser and Korsch diagram, the provenance of Little River, Joggins, and Springhill Mines formation sandstone lie in the Intermediate Igneous Provenance and quartzitic fields, whereas the provenance of the Ragged Reef and Grande Anse formations are in the quartzitic field. Chemical Index of Weathering values shows that the Grande Anse Formation and Ragged Reef Formation have the highest rates (89.6 and 87.5, respectively), whereas Little River Formation, Joggins Formation, Springhill Mines Formation show the lowest (71.8, 72.7, and 73.8, respectively). Values for the Plagioclase Index of Alteration are Little River Formation: 68.1, Joggins Formation: 69.7, Springhill Mines Formation: 70.3, Ragged Reef Formation: 83.4, and Grande Anse Formation: 87.2. These latter values indicate that Little River, Joggins, and Springhill Mines Formations have undergone relatively low to moderate degree of chemical weathering, with quite intense weathering for the Grande Anse and Ragged Reef formations. Statistically, the data were subject to an F-test, which showed no significant variance between the Ragged Reef and Grande Anse formations, and a significant variance between the Grande Anse Formation and other units. This result suggests that the Ragged Reef and Grande Anse formations were deposited at the same time under the same depositional conditions.

Quantifying the influence of spatial resolution in identifying estuarine morphology using remote sensing methods; observations from Cobequid Bay, Nova Scotia, Canada

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Image processing methods can be used to classify land cover and phenomena within satellite imagery according to their spectral characteristics and "automatically" identify target features. These methods provide a relatively efficient approach to processing many images and to measure change of features and phenomena over time. Selecting an appropriate data source and classification method, however, requires considerations such as the scale of the process under investigation, spectral differences between target areas and their surroundings, and technical limitations for the analyst. The Salmon River estuary in Cobequid Bay was chosen to evaluate the impact of spatial resolution on the use of satellite imagery to identify tidal bars. This setting presents several environmental conditions (e.g., extreme tides, suspended sediment) that constrain the applicability of certain data types, while also containing target features (tidal bars) of appropriate size to investigate the impact of varied spatial resolution. Satellite images were acquired from several sources covering a range of spatial and spectral resolutions (e.g., Landsat TM/ETM+, Sentinel, ASTER, RapidEye). Both traditional pixel-based methods (i.e., supervised, unsupervised classification), and object-based image analysis techniques were used to identify sediment bars within the estuary, and then assessed for classification accuracy. While it may be tempting to simply select the imagery with the highest spatial resolution, similar results can be achieved even at a coarser resolution depending on the classification and parameter choices applied by the user. All image types could be classified to at least 80% overall accuracy using at least one method. However, the best results (>95% overall accuracy, κ >0.9) were obtained from Landsat-5 and RapidEye imagery. The appropriate method of classification differed between the two images; RapidEye did better under object-based identification, while the coarser-resolution Landsat-5 image did better under supervised classification. This difference is likely a function of spatial resolution; object-based methods apply better to images where single features are represented by clusters of multiple pixels and are less appropriate at spatial resolutions where single pixels contain multiple features. As well, the most reliable method overall, object-based identification, required more user input compared to the pixel-based methods; the consequence is greater processing times for projects with a large number of images. Due to similarities in overall accuracy and considering differences in cost (image acquisition, processing time, file storage), I recommend the use of Landsat imagery for studies of estuarine morphology at this scale.

Silurian carbon isotope excursions (SCIE) in the upper Silurian of Arisaig, Nova Scotia, Canada*

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Silurian Carbon Isotope Excursions (SCIE) are well-documented events in the stratigraphic record on the paleocontinents of Baltica and Laurentia. Published δ13C curves record large positive excursions suggesting global drivers with small shifts along the isotope curve representative of regional input. Generally thought to be partially due to an increase in carbonate production, the cause of these peaks is contested as a number of environmental factors may play a role. The upper Silurian section of the Arisaig Group provides a unique opportunity to examine the possibility of similar SCIE on the microcontinent of Avalonia. Forty-six fossiliferous beds of the upper Silurian were sampled along a 2 km thick section of the Arisaig coastline, corresponding to 20 million years of deposition. Brachiopods species *Rhynchospirina sinuate* and *Salopina submedia* were sampled as they occur throughout the section. Thin section petrography was used to identify relicts of primary growth structures in the brachiopods which were targeted for microsampling and electron microprobe analysis. Microprobe data revealed nearly pure calcite compositions of both brachiopod fossils and the matrix with minor diagenetic alteration indicated by the presence of Mg. The carbonate samples were then processed for stable isotope analysis in a thermo-gas bench and IRMS, with values normalized and plotted against PDB for $\delta^{13}C$ and SMOW for $\delta^{18}O$. Stratigraphic sampling focused on formations where expected SCIEs plot in the global stratigraphy. Twenty-seven samples were taken from Stonehouse Brook Formation, eight from each of the Moydart and Doctors Brook formations, one from McAdam Brook Formation and two from French River Formation. SCIEs with $\delta^{13}C$ above -5 ‰ have been documented at the upper boundary of Llandovery, the uppermost Wenlock, the highest peak in late Ludlow and finally at the uppermost Silurian strata in the Pridoli. Samples of carbonate matrix and associated brachiopods have also been used to examine oxygen isotopes in the calcite, post-diagenesis with $\delta^{18}O$ curves are expected to display trends with peaks occurring in episodes of lowstands. Although our data displays a positive correlation between $\delta^{13}C$ and $\delta^{18}O$ from both brachiopods and matrix sampling, the $\delta^{13}C$ excursions in the Arisaig samples range from only -3 ‰ to +1 ‰. There are four peaks, the largest of which occurs in Doctors Brook Formation. Global and regional input such as episodic cooling, freshwater input, and salinity factors will be further discussed as drivers in the Arisaig Group SCIEs.

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

Implementation of a 3D resistivity imaging system for seepage reconnaissance at an embankment dam abutment

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The Mactaquac Generating Station is a large (660 MW) hydroelectric facility on the Saint John River, approximately 19 km upstream from Fredericton, New Brunswick. Due to an alkali-aggregate reaction, the concrete structures on site are experiencing differential expansion. This has prompted the dam's operator, NB Power, to be proactive in monitoring for any signs of concentrated seepage that could arise where the dam's clay till core abuts a concrete diversion sluiceway.

Repeated or time-lapse resistivity surveys have proven to be an effective non-invasive approach for investigations of seepage in dam interiors although much remains to be learned about their capabilities, limitations and optimal configurations. We have installed a 3D resistivity imaging system at Mactaquac, involving an areal array of 100 electrodes on the downstream face of the dam targeting the interface between the embankment and its concrete abutment. The system has been operational since January of 2019, but challenges associated with wiring, cold winter weather, and high electrical noise levels took some time to resolve. In early June, 2019, we discovered an uncommon current regulation problem brought on by the effect of exceptionally high noise levels on the pole-dipole survey geometry that we had adopted for its favourable resolution and depth of investigation properties. Adjusting our measurement parameters to mitigate that issue and averaging consecutive surveys with a "smart stacking" approach to reject outlier measurements improved data quality dramatically.

Fully autonomous monitoring began in late November, 2019. Preliminary models obtained for the dam's resistivity structure are encouraging and consistent with expectations given the dam's design and materials. Divisions between the low resistivity (<60 Ωm) clay-till core and overlying resistive rockfill (>500 Ωm) are clearly seen. Comparisons

between June and October surveys show changes which relate closely to the internal structure of the embankment; these include resistivities increasing prominently within the filter/transition zone and rockfill overlying the inclined core in the upper half of the embankment while remaining relatively consistent at depth. We also observe two shallow temporal changes at roughly 6 m depth close to the abutment which are adjacent to a temperature anomaly measured in a borehole just inside of the concrete at the interface between the embankment and its abutment. Continuous monitoring of how resistivities evolve seasonally, and relative to water temperatures and total dissolved solids within the dam's reservoir, will be used to assess seepage conditions in the interface region.

Paleomagnetic study of the volcanic rocks in the Devonian Fountain Lake Group, Cobequid Highlands, Nova Scotia, Canada

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The Acadian orogeny is interpreted to have been initiated in the Middle to Late Devonian by the arrival of the Meguma terrane at Avalonia, which had already been accreted to Laurentia. The broader paleogeographic context for the arrival of these terranes at Laurentia has been difficult to define, partly due to the scarcity of worldwide paleomagnetic data for the Devonian. This work primarily aims to determine the paleolatitude of the Avalonian margin of Laurentia as a member of the larger continent Laurussia in the Devonian using paleomagnetic analysis of volcanic rocks formed immediately following the Acadian Orogeny. The ca. 355 Ma Fountain Lake Group, in the Cobequid Highlands in mainland Nova Scotia, is part of the pull-apart basin fill which formed during dextral strike-slip motion between Avalonia and Meguma. Paleomagnetic analysis of volcanic rocks in the Fountain Lake Group can offer both a paleolatitude estimate for the Laurentian accretionary margin in the Devonian and the paleomagnetic directions and can help to restore local block rotations during the subsequent relative strike-slip motion along the Cobequid Fault zone. Preliminary analysis of >150 specimens taken from 20 sites in three Fountain Lake Group localities across the Cobequid Highlands (Squally Point, West Moose, Wentworth exposures) shows a stable remanence in the volcanic rocks. Stepwise demagnetization was conducted using a combination of alternating field and thermal demagnetization techniques, revealing the remanence to consist of an easily removed component of probable recent origin, and more persistent components carried by magnetite and hematite. Petrographic and electron beam analysis using Energy Dispersive Spectra (EDS) on four representative thin sections helps to determine the context for characteristic remanence carriers for the collection: (pseudo-) single-domain titanomagnetite and to a lesser degree single-domain hematite appear to be of igneous and volcanic oxidation origins, respectively. Many sites record both normal- and reverse-polarity directions, with dominant tilt-corrected characteristic remanent magnetization (ChRM) directions towards the SW with moderate downward inclination in most sites. Three sites sampled from West Moose locality exhibit a SSW, moderate downward direction with mixed polarity, whereas two sites sampled from the Wentworth locality have typically NW, moderately down directions of dominantly the other polarity. Differences in declination between the three Fountain Lake Group localities likely represent relative rotations. The similar inclinations at all three localities imply a subtropics paleolatitude for the margin, in good agreement with the depicted location of Laurentia in Late Devonian reconstructions.

Developing a 3D model of the Stellarton Basin for the analysis of coal bed methane resource of the Pictou County coal field, Canada

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Recent demand for alternative energy resources has become a driving force in the investigation of unconventional gas and coalbed methane prospects in the Stellarton Basin, Nova Scotia, Canada. The Stellarton Basin is a Late Paleozoic (Late Carboniferous to Pennsylvanian) pull-apart basin, located in the Canadian Appalachians, near the Meguma-Avalon boundary. Since the early 19th century, this basin has been the subject of extensive coal mining and exploration. The basin is bounded by the Cobequid and Hollow Faults and extends ~20 km from east to west and ~8 km north to south, encompassing the entire Pictou coalfield. The Stellarton Basin contains ~3 km of rapidly deposited clastic sedimentary rocks of lacustrine and deltaic origin, including

shale, sandstone, oil shales and minor conglomerate which have been subdivided into 4 geological members; the Thorburn, Coal Brook, Albion and Westville members. Nearly 32 coal seams have been identified throughout these intervals, with the thickest, most abundant seams identified within the Albion Member. Identification of coal seams and oil shales in sub-surface data allow for stratigraphic correlation between boreholes across the basin. Archival subsurface data was derived from conventional mapping, historical drilling logs, subsurface mining reports and small amounts of seismic data. The integration of these data types has allowed for the development of a new 3D geological model using Petrel E&P™ and ArcGIS™ Software programs. Preliminary results of this integrated model resulted on highlight coal thickness, coal seam morphology and initial gas content estimates. These factors provide insight into the resource potential for unconventional gas in the Stellarton Basin.

Preliminary examination of gold and polymetallic mineralization at the Elmtree Deposit, Alcida area, New Brunswick, Canada

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The Elmtree deposit, located in Alcida, approximately 10 km west of the village of Petit Rocher, was discovered in 1984 and contains a gold resource of 294 000 oz (indicated + inferred). The deposit straddles the unconformable contact between the Middle Ordovician Elmtree Inlier and Silurian clastic and carbonate sedimentary rocks (Quinn Point Group) of the Nigadoo River Syncline. In addition to gold the deposit contains subordinate polymetallic (Ag, Zn, Pb, Sb) mineralization and is divided into three zones, namely: Discovery, West Gabbro, and South Gold zones. Work conducted in the summer of 2019 focused on the West Gabbro and South Gold zones, with the aim of determining the timing and source(s) of gold and polymetallic mineralization, as well as local to regional controls affecting distribution.

Gold mineralization at the West Gabbro Zone is hosted by a steeply north-dipping, 3 to 40 m thick, texturally zoned, fine- to coarse-grained propylitically altered gabbro dyke, which intrudes argillite of the Elmtree Formation and the Belledune River Mélange. Gold mineralization is associated with extensive quartz veining, brittle to ductile deformation, carbonatization, locally bleaching, and abundant arsenopyrite and pyrrhotite. Mineralization locally extends into the surrounding hornfels. Petrographic examination of the West Gabbro Zone identified the early (partial) consumption of Fe-Ti oxides to produce pyrite, followed by a change in conditions resulting in pyrite reacting to form pyrrhotite and arsenopyrite ± gold.

The South Gold Zone, which is a more recent discovery first drilled in 2006, is situated approximately 150 m east of the West Gabbro Zone. The South Gold Zone is hosted by calcareous siltstone of the La Vieille Formation and sandstone and conglomerate of the Weir Formation (Quinn Point Group). The South Gold Zone is intruded by multiple felsic and rare mafic dykes. Mineralization at the South Gold Zone occurs within approximately 100m of the locally sheared Ordovician-Silurian unconformity. Gold mineralization is intimately associated with pyrite-muscovite and Fe-carbonate alteration, contorted quartz-carbonate veins, brittle to ductile deformation, and acicular arsenopyrite in the host rock. Gold mineralization is primarily hosted in sedimentary rocks, although the dykes are commonly altered and locally carry mineralization. Polymetallic veins are present throughout the South Gold Zone, and contain variable quantities of sphalerite, stibnite, galena, jamesonite, and pyrite. Zircon grains have been recovered from the felsic dykes that will enable the dating of magmatic activity using U–Pb geochronology and assist with refining the sequence of mineralizing events on the property.

Awaiting two new UNESCO global geoparks for Atlantic Canada: communities in Newfoundland and in Nova Scotia embrace their geoheritage

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In April 2020, communities on the Bonavista Peninsula of eastern Newfoundland and along the Parrsboro shore of Nova Scotia will learn if their aspirations to become Canada's fourth and fifth UNESCO Global Geoparks will be realized. In July 2019, field evaluations of both aspiring geoparks were conducted by Global Geoparks Network evaluators, which included Global Geoparks President Nickolas Zouros. Their report was presented to the Global Geoparks Council in September 2019, and both Discovery Aspiring Geopark and Cliffs of Fundy Aspiring Geopark

were endorsed and forwarded to the Executive Committee of UNESCO for their ratification in March–April 2020.

The Cliffs of Fundy honours the indigenous knowledge and traditions of the Mi'kmaq, for whom this area is the land of Kluscap. The geological storyline is equally significant, recording both the assembly of Pangea in the late Paleozoic and its later breakup in the early Mesozoic Era. The name 'Discovery' alludes both to the historic events including the arrival of John Cabot in the late Sixteenth Century to recent discoveries of Ediacaran fauna. Both geoparks showcase their geoheritage in dramatic sea cliffs. Both aspiring geopark initiatives were championed by their local communities and in particular municipal governments, aided by their provincial geological surveys. In an age where UNESCO's Sustainable Development Goals are growing in importance, the conveyance of geological knowledge as geoheritage provides rural regions in particular with sustainable economic opportunity. Pending a positive outcome in April, the number of UNESCO Global Geoparks (UGGp's) in Canada will grow to five, with four in the Atlantic region of the Northern Appalachians: Stonehammer UGGp, New Brunswick (North America's first), Geoparque Percé UGGp, Quebec, Cliffs of Fundy, Nova Scotia and Discovery, Newfoundland. The support of geoscientists in the area served by the Atlantic Geoscience Society has been instrumental in this success story. Tumbler Ridge UGGp, British Columbia is Canada's sole representative in the west at present. Ten aspiring geoparks from British to Newfoundland are actively building their cases with community support and with the guidance of the Canadian Geoparks Network. Canada has now reached a threshold where continent-wide networks are encouraged and indeed expected by the GGN. To that end, discussions are underway with Geoparks in Mexico, Peru, Ecuador, Brazil and Uruguay to build a geoparks network of the Americas, while maintaining close ties to the European Geoparks Network, which have long been supportive of the growth of geoparks in Canada.

Surface and subsurface perspectives of freshwater concerns on Sable Island, Nova Scotia, Canada

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Small islands support unique ecosystems and often dense human populations. However, these environments are highly vulnerable to changing ocean, land, and climate conditions. The World Health Organization and the Intergovernmental Panel on Climate Change has identified small islands as one of four regions most vulnerable to climate change due to their limited adaptive capacity to accommodate rising seas and intensifying storms. For instance, low-lying islands are susceptible to seawater overwash during large storm events and concomitant salinization of freshwater resources. Sable Island, a Canadian National Park Reserve, is a small low-lying barrier island located in the Northwest Atlantic Ocean with a unique ecosystem of wild horses, endangered seabirds, and the world's largest grey seal population. This relatively pristine site has been established as an island groundwater observatory as it has a strong record of environmental data, and the freshwater resources are highly influenced by ocean processes and the changing climate. Freshwater ponds on Sable Island, which are the only surface source of freshwater, have declined dramatically in size in recent decades, raising concern for the island's ecosystem. Surface water and sediment temperature monitoring in the ponds is used to assess pond-aquifer connectivity and provide insight into pond dynamics to inform the observed long-term decline in pond volumes. Multiple 2D transects of subsurface resistivity inferred using a WalkTEM are compared to geophysical surveys from the 1970s to assess trends in the subsurface freshwater lens volume. Data collected from near-shore wave loggers and pressure transducers in groundwater wells are analyzed to characterize the effect of oceanic forcings on the island's groundwater dynamics. Finally, to investigate episodic salinization of freshwater resources, a transect of multi-level piezometer nests are installed and monitored in a low-lying area on Sable Island to capture the response of the aquifer to overtopping. Data from this newly established observatory will provide insight into episodic and gradual salinization of freshwater resources on Sable Island. These insights are critical to enhance our understanding of the future vulnerability of freshwater resources on small islands.

Preliminary assessment of lithological units related to the gold mineralization in the Cape Spencer area, New Brunswick, Canada

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The Cape Spencer area has been explored since 1965 with the assessment of a quartz vein system for silica potential moving through systematic gold exploration in the 1980s, the early 1990s, and during 2004–2006. Approximately 28 000 m of core have been drilled during the different exploration campaigns. The Cape Spencer area is located 15 km southeast of the city of Saint John, New Brunswick; the exploration efforts implemented in the area have identified two main gold-bearing zones, the Pit zone and Northeast zone. In addition, several other prospects have been located, namely: Road Zone, Birches Zone, Emilio Zone, and Zones A, C, and D.

Gold mineralization at Cape Spencer is mainly hosted within both the pervasively altered Millican Lake Granite (greyish-pink to green medium-grained granitoid rocks) and the Cape Spencer Formation (purple-green metasedimentary rocks, comprising well-foliated, fine-grained shale and siltstone, medium-grained sandstone and minor conglomerate), concentrated in illitized, pyrite-rich rocks along thrust faults and folds and associated illite + pyrite + quartz ± carbonate ± plagioclase ± sulphide (pyrite, galena, chalcopyrite, sphalerite, arsenopyrite) ± specularite veins, defining an orogenic-style of gold mineralization. Minor zones of illitic alteration occur within the Coldbrook Group rocks (green amygdaloidal basalt and sheared mafic feldspar porphyry) and the Lancaster Formation rocks (grey, medium- to fine-grained sandstone with interbedded dark gray mudstone and siltstone), however mineralization in these units is restricted to the development of local quartz ± barite veining.

Work carried out so far was focused on the analysis of polished thin sections and μXRF-EDS mapping for the characterization of the hosting mineralized units in the Cape Spencer area. The illitic alteration consists of illite, carbonate, quartz, chlorite, and specularite; Mn and Fe are ubiquitous constituents within the analyzed calcium carbonates. Illitization locally overprints earlier propylitic alteration (chlorite, albite, epidote, quartz, carbonate, hematite, pyrite), present only in samples from the Millican Lake Granite, as evident in illite replacing chlorite. Graphite aggregates and graphite-pyrite veins occur in the fine-grained sandstone along with silicification and brecciation in local mudstone conglomerate from the Lancaster Formation; neither gold-related mineralization nor illitic alteration were observed in rocks from this unit.

The project goals are to identify the source of the mineralization and its relative timing with respect to the local and regional controls. Upcoming studies will include U–Pb and $^{40}Ar/^{39}Ar$ geochronology to constrain the timing of the mineralizing events, and LA-ICP-MS trace-element analysis of pyrite to characterize the mineralization.

Geophysical and geological interpretation of a deep seismic refraction line across central mainland Nova Scotia, Canada

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Seismic refraction line 99-2 extends for 440 km from the Scotian margin in the SW across central mainland Nova Scotia to the Gulf of St. Lawrence in the NE. Nine ocean bottom seismometers (OBS) on the SW (Scotian margin) part of the line recorded air gun shots spaced at intervals of ~110 km. Seismic waves from these shots were received also at 4 land recorders. All 13 recorders, plus 2 more OBS on the NE part of the line, recorded shots in the Gulf of St. Lawrence. The hydrophone channel of the OBS and vertical geophone channel of land recorders generally gave best data quality for P-waves, whereas S-waves are better defined by horizontal geophones for both OBS and land recorders. A two-dimensional ray-tracing algorithm was used to model the data; the 450 km-long model was constructed with 16 boundaries, each containing up to 32 boundary nodes. The P-wave model provides a general fit to all the observed data, thus enabling effective modelling of the more limited S-wave data. The relationship between P-wave velocity (V_P) and S-wave velocity (V_S) is expressed as Poisson's ratio, which is known to stay constant with increasing depth but to increase with decreasing SiO_2 in the range from 75 to 55 weight %.

The model shows different velocity structure for the crust under the northeastern part of the line (Avalonia) compared to the southwestern part of the line (Meguma terrane). Depth to Moho, defined by V_P of 8 km/s, is about 41 km under Avalonia and 35 km under the outer Scotian shelf, decreasing to 32 km under the inner shelf and adjacent onshore area NE of Halifax. An area with anomalously high velocity lower crust (HVLC, V_P = 7.6) at a depth of 30 km separates the thinner Meguma lower crustal block (V_P = 6.75–6.85) from the Avalonian lower crustal block (V_P = 6.9–7). The area of HVLC underlies the onshore part of Meguma terrane, and terminates approximately at the Chedabucto fault, although the boundary between Meguma terrane and Avalonian upper crust is not as tightly constrained as the boundary between the corresponding

lower crustal blocks. The Poisson's ratios of 0.22 in Meguma crust indicate that it is more SiO_2-rich than Avalonian crust (Poisson's ratio 0.24). The Poisson's ratio in the underlying mantle is 0.27. Preliminary gravity modelling along the line is consistent with the seismic model, which demonstrates that Avalonian crust does not underlie the Meguma terrane.

Methane isotopologues geothermometer: a new tracer to understand offshore petroleum systems

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In sedimentary basins, methane is commonly produced by thermogenic cracking of higher molecular weight hydrocarbons (i.e., C_{2+}) in organic-rich source rocks and through the reduction of CO_2 by microbial methanogenesis. To resolve these pathways, the evaluation of compound-specific stable isotopic compositions ($\delta^{13}C$ and δD) of methane and hydrocarbon species are traditionally used to distinguish the origin and formation mechanism(s) of methane gas. However, the complex process of mixing, migration, and biological alteration of methane can result in changes to its initial isotopic composition making the identification of primary sources challenging. More recently, a new isotopic method involving the measurement of 'clumped' isotopologues of methane ($\Delta^{13}CH_3D$ and $\Delta^{12}CH_2D_2$) has been introduced that can determine if the gas is at thermodynamic isotopic equilibrium. This information provides insights into the formation temperatures and/or kinetic controls governing methane production. The ability to measure both $\Delta^{13}CH_3D$ and $\Delta^{12}CH_2D_2$, each being mass-18 isotopologue, makes it possible to differentiate thermogenic and biogenic formation temperatures when the associated gas is further impacted by disequilibrium effects. Therefore, we hypothesize that a 'clumped' isotopologue study of the methane will resolve the burial depths of methane producing source rock intervals. Methane samples will be collected from: (i) the ExxonMobil-operated Alma 4 well off Sable Island located on the Scotian Shelf, and (ii)the headspace-gas samples obtained from piston core sediments collected from the Scotian Margin during a cruise conducted in 2018 as well as with a future cruise slated for 2020, The 'clumped' isotopologue study is expected to enable a better understanding of the geochemical characteristics of the underlying gas-generating stratigraphy across the margin; as well, it is anticipated that this method will provide tighter constraints on the formation temperature of the underlying source rock. If successful, the results will improve the calibration of existing local heat flow models, which for this region is complicated by the presence of widespread salt tectonics.

The first discovery of tetrapod trackways from the Pennsylvanian (Westphalian C), Plymouth Member of the Stellarton Formation, Stellarton Basin, Nova Scotia, Canada

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The Maritimes Basin of Atlantic Canada is known for discoveries of tetrapod skeletons and their footprints that range from the early Mississippian Period to the early Permian Period. These Late Paleozoic tetrapod skeletal fossils are found at several locations in Nova Scotia, most notably at Minto in New Brunswick; Joggins, Cape Breton, East Bay, Horton Bluff, and Brule in Nova Scotia; and from Prince Edward Island. The first discovery of tetrapods from the Stellarton Basin was made by Sir John William Dawson in 1862 when he discovered a partial skull of *Baphetes planiceps*. Since Dawson's 19th century discovery, no further evidence of tetrapods (trace fossils or body fossils), have been encountered in the basin; with fossil material from the Stellarton Basin being dominantly comprised of plant material and coal balls.

A new discovery of tetrapod footprints from the Pennsylvanian (Westphalian C), Stellarton Formation represents the first tetrapod ichnofossil to be discovered in the Stellarton Basin. Preserved in the Plymouth Member of the middle Stellarton Formation, the tetrapod tracks are preserved in a fine-grained grey sandstone that represents a

fluvial environment. The trackway-bearing sandstone of the Plymouth Member is exposed in a private aggregate quarry that conformably overlies lacustrine shale of the Westville Member that outcrops just east of the quarry along a nearby river.

The tetrapod tracks are identified here as the ichnotaxon *Limnopus heterodactylus*. *Limnopus heterodactylus* is characterized as having footprints with a tetradactyl manus and a pentadactyl pes with short rounded digits, and is longer than 2 cm. *Limnopus heterodactylus* has traditionally been interpreted to represent the trackways of temnospondyl amphibians well known from time equivalent rocks in Nova Scotia, and is here the first evidence of temnospondyls in the Stellarton Basin.

In addition to vertebrate ichnofossils, abundant samples of invertebrate ichnofossils of *Monomorphicnus sp.* and *Rusophycus sp.* are preserved in the underlying Westville Member. These traces range from 1 mm to 5 cm in width and likely represent a diverse and undocumented crustacean faunal assemblage, burrowing or feeding in the sediment. The low-diversity ichnofossil assemblage presented above represents the first ichnological study in the Stellarton Basin documenting a marginal lacustrine depositional environment populated by temnospondyls and crustaceans.

Strontium as an indicator of Alewife (*alosa pseudoharengus*) moving from a marine environment into a freshwater system

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The discovery in 2018 of a strontium (Sr) anomaly in a fluvial lake sediment gravity core taken in the Avon River, Nova Scotia, has led to the hypothesis that strontium may be a proxy for anadromous fish movement into freshwater environments. Alewife (*alosa pseudoharengus*) are an anadromous species known to bioaccumulate Sr. Alewife were thought to have migrated up the Avon River to Mantletree Lake in thousands before the watercourse was altered by hydroelectric development. The 2018 study indicated that Sr concentrations in the fluvial lake sediment core declined after the installation of the dam in 1929 that impeded fish passage. Those results suggested that Sr is transferred by Alewife to freshwater environments and thus serves as a proxy indicator of marine derived nutrient transfer to freshwater environments. To test this hypothesis, two gravity cores were obtained from Mantletree Lake, a lake that was located at the headwaters of the Avon River prior to dam installation. X-ray fluorescence was conducted to determine metal concentrations in the Mantletree Lake sediment core, bankside sediment samples were used to determine geogenic Sr concentrations in soils that might have become available upon flooding.

Our study determined that atmospheric lead is a good time-stratigraphic indicator that can be used to provide some dating control for the sediment core from 1920 to Present. Variability in the metal data (Ti, Rb, K) indicates that flooding associated with the Forks River dam installation in 1929 produced considerable bankside erosion and watershed disruption. The strontium data is equivocal but does not to appear to show a strong trend associated with the potential cessation of Alewife visitation. Further investigation of the total carbon (C) and nitrogen (N) levels along with $\delta^{13}C$ and $\delta^{15}N$ stable isotopes will be used to determine the source of organic matter in the lake sediment core and may be used to more clearly interpret whether Sr concentrations in lake sediment cores can be used as a reliable indicator of anadromous fish residency.

Investigating the variability and dynamics of soil moisture beneath a tile-drained field using time-lapse electrical resistivity imaging (ERI)

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Three agricultural trial plots have been established on the southern slope of the Saint John River Valley at Fredericton to investigate the effectiveness of agricultural beneficial management practices (BMPs), including tile drains (used to accelerate subsurface drainage) and diversion terraces (earth berm structures used to intersect surface runoff). One of the questions being investigated is the effect of these features on the spatial variability and temporal evolution of soil moisture in the shallow subsurface. Given its sensitivity to water content, time lapse electrical resistivity imaging (ERI) is being tested as a tool to provide such information with high spatial resolution, complementing the more direct, but sparse measurements provided by soil moisture sensors

and drive point piezometers. Soils on the site are classified as sandy loam, sourced from an ablation including abundant clasts of local gray sandstone (Late Carboniferous Pictou Group). This soil overlies a compact, low permeability lodgement till at ~1 m depth that gives rise to intermittent perched water conditions.

We present results from a single ERI survey line, consisting of 48 electrodes at 0.5 m spacing, crossing over a diversion terrace structure, and two tile drains. Each survey consisted of 1830 apparent resistivity measurements using a combination of dipole-dipole and Schlumberger arrays. A smoothness-constrained time-lapse inversion algorithm was chosen to invert the resistivity data. Using Archie's Law, changes in resistivity obtained by time-lapse inversions were converted into changes in water saturation. A time-lapse series taken between August 29th and September 10th, 2019 illustrated that electrical resistivity surveys are capable of detecting changes in soil moisture caused by subsurface drainage, evapotranspiration and percolation. The results showed drying throughout the first 30 to 80 cm of the entire profile with dryer spots above each tile drain and the berm. The effect of the tile drains was clear five days after a heavy rainfall event on August 29th (56 mm) that had followed a relatively dry period. Their impact was evident even faster (the next day) after a second heavy rainfall event on September 8th (69 mm, from Hurricane Dorian). The faster response is attributed to higher antecedent soil moisture conditions. Diversion terraces appeared to have negligible impact on soil moisture due to low surface runoff during the time-lapse period. They would be expected to have more effect during the spring snow melt and following fall harvest when surface runoff is more likely to occur.

The Fogo Experience: a unique opportunity for wide-ranging geoscience outreach

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Fogo Island is located on the eastern side of Notre Dame Bay, north of Gander, Newfoundland. It is a prosperous community that has helped itself through cooperatives and the Shorefast Foundation, a not-for profit organization. Shorefast has helped build an economic infrastructure that includes the Fogo Island Inn, Fogo Fish, The Woodshop, cooperatives and other ventures. The Foundation has also invested in art and science through Fogo Island Arts and Geology at the Edge. Each program funds artists and geologists for residencies. Geologists-in-residence describe and interpret the rocks, landforms, and geological history to visitors and residents during their one-month residency appointment. With a Geology Centre staffed by a geology summer student, the resident geologists can use a variety of props to make geology and science accessible to people with various backgrounds and education. Seeing 'real' rocks is exciting and easy on the island. The exposures on the 14 × 25 km island are ready-made for interpretation. They show a cross section of a granitic magma chamber, 3 to 5 km of siliciclastic sediment, and voluminous pyroclastic flows. The bedrock is Silurian or slightly younger. The surficial deposits show the recent glacial and post-glacial history. The exposures allow an interpretation of a relatively uncomplicated geological story to help residents and visitors appreciate how geoscientists study rocks, interpret them, and provide information about past-history, mineral resources and geohazards. Each resident geologist leads interpretive walks three or four times a week for Fogo Island Inn guests. In addition, the geologists present two to three public talks, two or three interpretive walks for the public, and a weekly children's geology program. These activities offer an exceptional opportunity to help the public appreciate role of geologists and geoscience in education, public policy formation and risk assessment. Geologists-in-residence meet and talk to many visitors and residents who are influential through their positions in commerce, government, and education. The multiplying effect of these special contacts and the month-long growth of an audience creates a tremendous opportunity for geoscience outreach.

Fogo Island Model: occasional volcanic eruptions merging into massive eruptions of a possible supervolcano

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Fogo Island, north of Gander on the eastern edge of Notre Dame Bay, hosts detailed exposures of sedimentary rocks of the Silurian Fogo Harbour Formation (FHF) and overlying volcanic rocks of the Brimstone Head Formation (BHF). Intruding these units is the Fogo Island intrusion containing gabbro, ultramafic rocks, granitic plutons (one dated at 420 ± 2 Ma), and small granitic intrusions. None of the rock units appear to be penetratively deformed except adjacent to faults. Tilting to the north is evident in the FHF, BHF and presumably the Fogo Island intrusions. Folds have been mapped in the FHF. Interspersed in the siltstone and quartz wacke of the upper part of the FHF are six pyroclastic flows and several volcanoclastic, matrix supported units deposited over approximately 1 Ma. The contact with the

BHF appears conformable. An uncomplicated hypothesis suggests continuous deposition of quartz wacke and siltstone through approximately 3 myr by anastomosing streams with pyroclastic flows becoming more common and numerous in the upper part of the FHF. Near the top of the formation volcanoclastic debris flows, interpreted as lahars, may signal the impending heat flow and eruptions of a supervolcano. At the contact with the Brimstone Head, the greenish sandstone is conformably overlain by two, thin felsic pyroclastic flows, followed by more than 45 m of a third pyroclastic flow. One of the thin flows at the base of the BHF yielded zircon that was dated at 421 ± 0.6 Ma. Several E-W trending faults break the continuity of the units in the BHF so that a continuous section is not present. The pyroclastic flows in the FHF and the flow forming the bulk of Brimstone Head show excellent eutaxitic textures, suggesting hot flows that became welded. Younger units of the BHF do not show the very much welding. Instead, thin to thick zones of grey felsic fragments, slightly flattened, mark the dip of the units. The location of the supervolcano is not known. The estimate of volume of extruded material in FHF is 0.26 km^3. The flows in the BHF may represent more than 2 km^3. The postulated lahars may have 0.07 km^3. Previous workers have suggested an unconformity between the FHF and the overlying BHF, which would create two periods of volcanism. Clearly more field work and additional ages are needed to clarify the volcanic eruptions and their timing on Fogo Island.

Paleoenvironment reconstruction of the Cambrian–Ordovician boundary of western Newfoundland, Canada, using petroleum biomarkers and carbon isotope chemostratigraphy

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For this study, we have investigated marine carbonates and shales deposited as rhythmites from the lower Shallow Bay Formation and upper Green Point Formation of the Cow Head Group spanning the Cambrian–Ordovician boundary in western Newfoundland. Twenty-four carbonate and shale samples were collected and processed for their hydrocarbon biomarkers. The resulting solvent extracts were analyzed using comprehensive two-dimensional gas chromatography-mass spectrometry (GC×GC-MS). Several petroleum biomarkers such as n-alkanes, acyclic isoprenoids, steranes, hopanes as well as various aromatic hydrocarbons were quantified. These compounds are used as parameters to reconstruct the paleodepositional conditions of the depositional environment, the degree to which biodegradation has affected the preservation of the resulting sedimentary organic matter, and the thermal maturation of the extractable hydrocarbons. Pristane/Phytane (Pr/Ph) ratios of the sediment samples range from (~1.3 to ~3.4), indicating that the organic matter was deposited under oxic to suboxic conditions. A comparison of the Ph/n-C_{18} and Pr/n-C_{17} suggests the organic matter is derived from mixed Type II/Type III kerogen. The sediments also contain C_{27}, C_{28}, C_{29} αββ- and ααα-steranes 24(S+R) and αβ- and αβ- diasteranes in which the C_{29} stigmasteranes dominate. Gammacerane, formed from the biological precursor, tetrahymanol found in ciliated detritivores that commonly thrive in marine stratified water columns was also detected. Gammacerane Index (GI) values are low, ranging from ~0.82 to ~3.5, indicating there is no stratification in the water column during sediment deposition. The ratio of 25-norhopane and C_{30} αβ + C_{31} αβ 22(S+R) hopanes shows minimal biodegradation on the samples. Maturation of source rocks was assessed by monitoring the ratio of trisnorneohopane (Ts) and trisnorhopane (Tm) as well as C_{31} αβ homohopane S/(S+R). Ts/(Ts+Tm) and C_{31} αβ S/(S+R) values are 0 to ~0.68 and ~0.45 to ~0.54, respectively. These low values indicate the organic matter in most of the samples is early to moderately mature. Samples with the highest range of Ts/(Ts+Tm) 0.57 to 0.62 likely experienced the main phase of oil generation. The $\delta^{13}C$ profile across Shallow Bay Formation and Green Point Formation shows alternation of positive and negative $\delta^{13}C$ excursions (SPICE event, post-SPICE event, and HERB or TOCE event). Changes in organic matter ratios are observed by using steranes/hopanes and Pr/Ph ratios. Distinct negative shifts of values for the two parameters correspond to negative $\delta^{13}C_{carb}$ excursions during SPICE, post-SPICE, and HERB events. At the Cambrian-Ordovician boundary, an inverse relationship between these two parameters (high steranes/hopanes percentage accompanied by low Pr/Ph ratios) exists that may be linked to oxygen drawdown from increased productivity in the water column that effected redox conditions at depth.

Spatio-temporal tectonic controls on the transition from AMCG-type magmatism to silicic peralkaline magmatism in the Nain Batholith, Labrador, Canada

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The Nain Batholith is the younger of two extended periods of Proterozoic anorthosite-mangerite-charnockite-granite (AMCG) affinity magmatism in Labrador. The batholith comprises numerous discrete, overlapping AMCG-affinity plutons emplaced sporadically between 1362–1290 Ma. The youngest of these, the Notakwanon Batholith, is located at the southernmost extent of the larger Nain Batholith. The peralkaline Flowers River Igneous Suite to the immediate southeast marks the latest episode of these interrelated Mesoproterozoic magmatic events, having been emplaced at 1281 Ma within a satellite of the Notakwanon Batholith. A cogenetic relationship between the Flowers River granite and the AMCG-affinity augite-fayalite granitoid rocks it intrudes is indicated by the similarity of their major and trace element compositions. The Flowers River granite displays comparatively higher absolute concentrations of incompatible elements, higher Fe/(Fe+Mg) and Eu/Eu*, and a more pronounced depletion in Sr and Ba relative to the augite-fayalite granitoid rocks, suggesting that it is the more strongly differentiated product of a common source. A similar differentiation trend is observed in the augite-fayalite granitoid rocks relative to more northerly granitic constituents of the Nain Batholith. Furthermore, ferrogabbroic rocks spatially associated with this youngest suite of AMCG-affinity intrusions possess a mildly alkaline chemistry, contrasting with the more typical ferrogabbroic compositions present elsewhere in the Nain Batholith. Considered together, these factors suggest that localized, metasomatically imposed heterogeneity of the mantle source played a significant role in the resultant expression of magmatism in the overlying crust. The proximity of the Nain Batholith's southern limits to at least three major Paleoproterozoic lithotectonic boundaries provides a convenient means of introducing this heterogeneity. The confluence of several independent geologic controls may have been the ultimate factor governing the late transition from traditional AMCG-type magmatism to that of a peralkaline affinity within the Nain Batholith, and may similarly be responsible for cryptic occurrences of peralkalic magmas worldwide.

The Strativerse: an interactive collection of time-stratigraphic records of environmental change

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Since the mid-1960s, geoscientists have collected sediment-based trace metal records from lakes around the world. The combination of previous records of trace metal accumulation have an impressive spatial and temporal extent but are difficult to locate and/or evaluate together due to limited machine-readable information, particularly for earlier studies. The Strativerse (https://strativerse.org/) is a collection of geographic features and analytes that are associated with each publication, providing the ability to locate the collective literature for a given geographical region and/or analyte. The fundamental unit in the Strativerse is the record: records are samples (or collections of samples) that form a record of environmental change from a feature (e.g., a lake or glacier). Records list publications that refer to them, and parameters that were measured on them. At present, most records in the Strativerse are lake sediment cores, or clusters of sediment cores that could not be disambiguated from consulting the relevant publications. Metadata are stored as a collection of text files hosted on GitHub, compilied into JSON and HTML by Hugo, and served by Netlify. Building the collection of metadata is currently ongoing.

Seismic stratigraphy of Visean carbonate and evaporite rocks beneath the Gulf of St. Lawrence, Canada

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Synthetic seismic traces were calculated using average rock properties based on descriptions of outcrop and onshore drill core studies for marine carbonate and evaporite rocks assigned to the Windsor and Codroy groups in the Maritimes Basin. These synthetic seismic traces were compared to those generated from deep well bores in the Gulf of St. Lawrence, which were subsequently compared to regional seismic reflection data. A common, although not unique, seismic stratigraphy for the Windsor/Codroy marine rocks is as follows: one or two high amplitude reflections at the base of the section representing the basal sulfate and carbonate, which are overlain by low amplitude or chaotic

reflections representing lower Windsor salt; these are in turn overlain by three to four high amplitude reflections representing the middle Windsor, which are in turn capped by a series of continuous parallel reflections representing the upper Windsor. The latter reflections are typically of lower amplitude than the middle Windsor. Variations or departures from the "common" seismic stratigraphy were mapped using regional seismic reflection data in the Gulf of St. Lawrence, and a seismic facies distribution map of the lower, middle and upper Windsor/Codroy seismic facies was developed. The seismic facies map provides a basis to better understand the relationship between the Windsor/Codroy lithostratigraphy in the various onshore structural basins in eastern Canada.

Using sensor-based time series analysis to distinguish chemical and metabolic redox reactions in situ

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Potentiometric sensors have long been used to for in situ monitoring of groundwater. One limitation, however, of such sensors, is their inability to directly identify ongoing biogeochemical processes, often depending on supplemental microbiological and -omics data sets to infer microbial community composition and behaviour. Recent developments using the time series technique detrended fluctuation analysis (DFA) make it possible to determine whether a specific geochemical reaction is abiotically or biologically mediated. Here, this technique is applied to electrochemical time series from an oxic-anoxic cyclical bioreactor experiment. Measurements of EH, pH, dissolved oxygen (DO) were recorded by electrodes every 20 minutes for 74 days. The time series were divided by geochemical environment (aerobic respiration, NO^{3-} reduction, mixed $Fe^{(III)}$, $Mn^{(IV)}$, SO_4^{2-} reduction, and anoxic-oxic transition), and analyzed for correlation strength using DFA; change point analysis was used to verify the selected end points for each condition. The correlation strength of each parameter varied systematically by environment over five oxic-anoxic cycles; and the suite of measurements taken together successfully distinguished the dominant biogeochemical process. This pattern indicates that electrochemical sensor time series data carries important system information beyond simply recording the value of the sensor reading.

The results of this study in a well-constrained environment with a complex microbial community suggest that there is great potential to use galvanic and electrochemical sensor-based approaches in field settings for groundwater and surface water monitoring as a viable, cost-effective long-term strategy. This approach could be valuable in any application where remote, long-term monitoring of ongoing biogeochemical processes is desirable, such as agriculture, bioreactors, or in long-term remediation and monitoring programs where inexpensive, consistent data sets could provide valuable insight into contaminant degradation or transformation, and environmental stability.

History of Nova Scotian gold fields and the London International Exhibition of 1862

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Established in 1868, the Nova Scotia Museum is one of the oldest provincial museums in Canada. The early collection of the museum includes specimens and historic documents related to Nova Scotia's displays at the International Exhibitions of the nineteenth century. In response to the 1861 gold rush, Nova Scotia invested considerable effort and resources to promote Nova Scotian gold at the London International Exhibition of 1862. Historic specimens and new digital archives have been used to examine the impact of the London Exhibition for Nova Scotia geoscience. The Colony of Nova Scotia was represented at the London Exhibition by Rev. Dr. David Honeyman. Honeyman had been involved in organizing the geological displays which prominently featured the Nova Scotian gold fields. He represented Nova Scotia throughout the Exhibition, which had over six million visitors from May to November. Honeyman also participated in several geological excursions during this time, experiences that would be important for his future geology work in Nova Scotia and as the first Curator of the Nova Scotia Museum. Through his interactions with international geologists in 1862 Honeyman also advanced his personal scientific studies of Silurian strata of Nova Scotia. Results of this recent historic research include locating previously unknown maps and illustrations prepared by Honeyman within the archives of the Geological Society and examining the connections Honeyman established within the Society and Geologists' Association, including palaeontologists Murchison, Salter, and Etheridge, and the British mineralogist James Tennant.

A surprising result was the location of a sample of Nova Scotia gold in a mineral collection of the famous English art critic John Ruskin, a sample likely originally sourced from the 1862 Exhibition. The research of historic specimens and documents demonstrate Nova Scotia has a rich history of significant contributions to international geoscience. Museum collections continue to provide valuable specimens for new internationally significant research and exhibits, and historic collections in provide important opportunities to examine the history and culture of geoscience in Nova Scotia.

The geology of the College Grant area, Antigonish County, Nova Scotia, Canada

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College Grant is located approximately 30 km south of Antigonish, Nova Scotia. Most of the area is underlain by calcareous siltstone, mudstone, and shale of the Silurian Arisaig Group that was intruded by gabbro of an unknown age. To the south of College Grant lies the Chedabucto fault, a major fault within the larger Minas Fault Zone (MFZ) system. South of the fault zone are undeformed clastic sedimentary rocks of the Devonian–Carboniferous St. Mary's Basin. Copper mineralization at College Grant has been known since the late 1800s but the area has received little modern academic study. Traditionally, it was thought to be a porphyry system but more recent studies indicate an iron-oxide copper gold (IOCG) deposit type that is possibly related to other IOCG deposits located along the MFZ (e.g., Copper Lake). The mineralization is disseminated chalcopyrite, pyrite and sphalerite with minor bornite that is hosted in breccia and quartz-carbonate veins that intruded both the Arisaig Group and the gabbro. The coarse-grained gabbro contains plagioclase and highly altered ferromagnesian minerals. Geochemical data show that the gabbro is subalkaline and trace-element data indicate an enriched mantle source. Normalized rare-earth element slopes are relatively flat. Moderately positive europium anomalies with elevated strontium concentrations in most samples indicates plagioclase accumulation. An ore sample yielded >1% copper, and elevated concentrations of gold (15 ppm), molybdenum (145 ppm), and cobalt (78 ppm) relative to the host rocks. This project is still in its infancy and future work will include dating of the ore mineralization, dating and characterization of the ore fluids, and dating metamorphism and fault movement to develop a tectonic model for the formation of IOCG deposits in northeastern Nova Scotia.

Seismic stratigraphy and deep-water sedimentary evolution of the southern Mozambique margin: Central Terrace and Mozambique Fracture Zone

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Based on new seismic reflection data, this study reveals the development of a complex sedimentary system on the mid-slope terrace of the southern Mozambique margin. The deep-water sedimentary system clearly shows the interaction of downslope and along-slope processes. Downslope features include: a pronounced canyon, slope creep, submarine slides, and multi-stage mass-transport deposits. Along-slope features include: contourite drifts and sediment waves, erosional moats, valleys, erosive surfaces and a distinctive contourite terrace. We show an evolution through time as follows: (1) slope progradational clinoforms and hemipelagite drape were developed during the Early Cretaceous after the initial break-up, which indicates relatively quiet conditions; (2) the onset of a contourite depositional system characterized the Late Cretaceous; (3) downslope gravity deposits dominated sedimentation during the Paleocene-Eocene, including a canyon and a submarine fan; and (4) an along-slope contourite depositional system was re-established on the continental slope in the Middle Miocene, while turbidites (from a northern source) covered the Mozambique abyssal plain. The Mozambique Fracture Zone marks a distinct and steep slope beneath the contourite terrace, and has significantly influenced both contourite and turbidite deposition. Our study provides new insights into the onset and evolution of bottom current control on margin sedimentation, the interaction of downslope and along-slope processes and how these processes have jointly sculpted this part of the southern Mozambique continental margin.

Determination of magma emplacement and remobilization times using zoning of Sr, Br, and Pb in plagioclase phenocrysts, Galeras volcano, Colombia

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The Galeras Volcanic Complex in Southern Colombia has been active for approximately 1 million years. The complex comprises at least 3 edifices and a monogenetic cone. The most recent eruptive volcanic center is the Galeras volcano which began erupting at ~4500-years BP in the caldera produced by collapse of an earlier edifice. Galeras is one of the most active volcanoes in the world and has been designated as a Decade volcano by the International Association of Volcanology and Chemistry of the Earth's Interior. Eruptions threaten a population of approximately 526 000 inhabitants in 7 localities including the city of Pasto which is the capital of the Department of Nariño. Galeras is notable for its high explosive potential, characterized by vulcanian eruptions, emplacement and destruction of crater domes, lava flows, pyroclastic density currents, and pyroclastic falls, as well as lahars and debris avalanches. Gravitational column collapse is the most common origin of the pyroclastic flow deposits. The products are predominantly andesitic magmas rich in plagioclase phenocrysts. These phenocrysts show distinctive zoning defined by variations in anorthite content as well as in trace elements such as Ba, Sr, Pb and the REE. In this study, we use the zoned plagioclase to examine pre-eruptive magmatic conditions and residence times of magma. In a zoned plagioclase with an initially homogeneous distribution of a trace element, that element will undergo diffusion in order to reach its equilibrium distribution which, for the elements of interest, is a strong function of the anorthite content. With simple assumptions about the initial distribution of trace elements and experimental data on their equilibrium partitioning and diffusion rates, we can model the diffusive transport of trace elements in the crystal using a two-dimensional finite difference method. In the models, the initial profile of the trace elements is compared to the observed profile at each model time step, until model and observed distributions converge. Our preliminary results indicate that magma can reside in the subvolcanic system for as long as 4700 years before eruption. Further modelling on three layers at the base of the Galeras volcanic sequence which contain a variety of plagioclase phenocryst morphologies will allow us to examine the time scale of inputs of fresh magma into the subvolcanic system, and may allow us to identify the triggering mechanism for eruption.

PET rocks – a new lithology for the Anthropocene?

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Plastic is a widespread pollutant in marine and terrestrial environments and its presence in sediments may be used as an indicator of the onset of the Anthropocene. Plastic persists in oceanic environments for years/decades, but its behaviour in sediment remains unstudied. Experiments on plastic stability in sediment within the first meters of burial are impractical; low temperatures give very slow reaction kinetics. We have investigated plastic stability and interaction with sediment during diagenesis, in experiments using Bay of Fundy mud and discs of polyethylene terephthalate (PET) cut from a single use water bottle. The sediment (either dry or water saturated) and plastic are enclosed in Pyrex tubes and sealed in cast iron pipe, or with an autoclavable screw cap. The experiments were run at 80°C for between 1 day and 6 months. Macroscopically, the PET discs recovered from experiments in dry sediment show no change and have no sediment adhered to them. Discs in wet sediment experiments commonly have sediment adhered to them and in the 6 months experiment the plastic is brown with a lumpy surface. Examination of carbon coated samples using secondary electron imaging in the SEM shows that PET in dry experiments has a cracked and flaky surface texture whereas that in the wet experiments contains bubbles and in the 6 month run spheres of plastic containing core of mud.

Preliminary data that water plays a significant role in PET – sediment interaction. Under dry conditions surface cracking is possibly caused by a small volume decrease due to volatilization of a component of the plastic. Under wet conditions, PET appears to have undergone a viscosity decrease. The glass transition temperature (Tg) of amorphous PET is 67°C. Below Tg PET behaves as a brittle solid, whereas above Tg it is a viscous fluid. We suggest that in wet sediment, the PET does not lose material by volatilization but rather since it is at about its Tg is capable of flow which leads to the formation of plastic spheres with sediment cores. We suggest that these spheres develop because the viscous plastic and pore water in the sediment are immiscible.

Our results indicate that PET plastic may be incorporated into wet mud during diagenesis and over the long term may act as cement during lithification creating a new class of PET rocks that will be characteristic of the Anthropocene.

New petrological and age constraints for metamorphic rocks of the northeastern Aspy terrane, Cape Breton Island, Nova Scotia, Canada

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New geological mapping, petrological studies, and U–Pb (zircon) dating have been done with the objective of refining and better characterizing meta-igneous and metasedimentary rock units in the northeastern Aspy terrane as well as providing better constraints on their age and genesis. Revisions to the existing geological map so far include recognition of a new pluton (South Aspy), an expanded map area for the Glasgow Brook pluton, and reclassification of metasedimentary units in the study area. The South Aspy pluton is in an area previously mapped as Money Point Group. It consists of well foliated medium-grained biotite monzogranite that crops out in South Aspy River and Glasgow Brook. The sample yielded a U–Pb (zircon) age of 440.2 ± 2.2 Ma. A new U–Pb (zircon) age from the foliated Glasgow Brook pluton of 419.5 ± 2.3 Ma is consistent with the previously reported age of 416.0 ± 1.9 Ma. Additional U–Pb (zircon) ages from the Cheticamp Lake Gneiss of 415.8 ± 1.4 Ma and 410.1 ± 1.8 Ma, combined with mineralogical and textural similarities, suggest that the Cheticamp Lake Gneiss and Glasgow Brook pluton may be equivalent units. Both the South Aspy pluton and Glasgow Brook pluton have chemical characteristics consistent with calc alkaline affinity and emplacement in a volcanic-arc tectonic setting. These characteristics together with the new geochronological data suggest an extended history of arc magmatism in the Aspy terrane from the early Silurian through the early Devonian. The South Aspy and Glasgow Brook plutons are surrounded by metasedimentary rocks that were previously interpreted to be their host rocks. However, new U–Pb (detrital zircon) dating of a metasedimentary muscovite-biotite schist yielded a maximum depositional age of 412.3 ± 2.6 Ma. This age suggests that the metasedimentary unit was sourced primarily from rocks with the same age as the Glasgow Brook pluton, either from associated volcanic equivalent rocks (not preserved here) or the pluton itself. The sedimentary protolith was likely deposited in a restricted basin receiving immature volcanic/plutonic detritus from very proximal sources and was subsequently deformed and metamorphosed with the pluton. Further studies are required to determine the nature of the contact between the dated metasedimentary rocks and the older rocks that the plutons intruded. Preliminary gt-bt and plg-hbl thermometry indicates that metamorphic temperatures ranged from 600°C to 750°C at 4.5–5.5 kbars.

Storm frequency and extreme waves in Atlantic Canada during the Late Holocene

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Since 1951, twenty-three hurricanes and post-tropical storms have struck Canada resulting in minor to catastrophic damage costing hundreds of millions of dollars and, in some cases, leading to some casualties. Several studies have examined storm frequency across the US Atlantic margin by investigating the sedimentary record of coastal water bodies such as lagoons, marshes, and salt ponds. However, few efforts have been made in the Maritimes to reconstruct the frequency and climate influences of these major weather events, and no studies have explored the storm record looking at offshore sedimentary basins on the Nova Scotian shelf. Cyclones are well known to generate a great amount of wind shear, which, in return, induces the formation of extreme waves capable to resuspend and transport coarse sediment (sand to gravel size) on the seafloor into areas where the background sedimentation is much finer (mud). As a result, a layer of coarse-grained sediment spanning from few millimeters to several centimeters in thickness can be associated to a specific storm event, or to a period of enhanced storm activity in case the background sedimentation is limited. In this study, we investigated the sedimentary record of the Emerald basin by analyzing a piston core acquired by the Bedford Institute of Oceanography in a water depth of 190 m. We performed X-radiography, grain size analysis, X-ray fluorescence (XRF) elemental ratios, such as Si/Al, Zr/Al, Ca/Al, Mg/Al, and radiocarbon dating to detect the "storm-beds" and to constrain the chronology of the core. Four intervals of enhanced storm activity are observed in the last 3150 yr BP, specifically at 560 yr, 1600 yr, 2370 yr, and 2900 yr. The most three recent intervals correlate with storm-beds from a salt pond record in a Massachusetts and from a deep-sea record in the western Bahama Bank. The synchronicity of the events

suggests that as El Niño-Southern Oscillation influences the late Holocene storminess up to 45 °N. Our work is a preliminary step in developing a long-term record of storm activity in Atlantic Canada and highlights the potential of offshore shelfal basins as archives of past climates.

Current research at the Joggins Fossil Institute, Canada

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The Joggins Fossil Institute (JFI), a not-for-profit charitable organization, manages the Joggins Fossil Cliffs UNESCO World Heritage Site in partnership with the Province of Nova Scotia. JFI runs the on-site museum, daily tours of the site, and offers many educational opportunities to the community and beyond. But the JFI is also a research institution that strives to conduct world-class research, both in-house and in collaboration with scientists globally. Since the Institute's inception in 2008, over 20 papers have been published specifically on the Joggins site. This broad research includes evolutionary studies, taxonomy, stratigraphy, paleoecology and recent history on the coal mine and grindstone industry. While we do host scientists, the opportunity to study the collection housed at the institute is increasing as we move towards having it available on-line; we are a pioneer in the province to do so. Current research at JFI is focused on reconstructing the aquatic environment: we have recently published work on fish coprolites and the taxonomy of the little-studied shrimp fauna. Our coprolite research continues, and we are also beginning work on the fauna contained in the siderite concretions that are commonly found at Joggins. This research proceeds in collaboration with many partners, including Natural Resources Canada, Queen's University, Carleton University, and the Museum of Natural History (Paris).

Origin of volcanic-hosted Cu-Au-Ag-Bi quartz-carbonate mineralization crosscutting Neoproterozoic rocks of the Broad River Group, Caledonian Highlands, southern New Brunswick, Canada

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Vein-hosted Cu-Au-Ag-Bi mineralization in the Caledonian Highlands, southern New Brunswick, occurs within quartz-carbonate-rich shear zones cross cutting felsic lithic tuffs, minor sandstone, intermediate intrusive rocks, and interbedded felsic and mafic flows of the Neoproterozoic Broad River Group. Mineralization in the quartz-carbonate veins consists of chalcopyrite in deep veins (Vernon Mine locality) and bornite-chalcocite-hematite in shallower veins (Mile Brook-Roman Wolfe locality), with later supergene alteration of the ores to cuprite-malachite. Gold-Ag-Bi carriers, coeval with Cu sulfides, are electrum, empressite, and bismuthinite. Wall-rock alteration is characterized by sericitization, albitization, and paragonitization. Sulfide paragenesis reflects changes in fluid redox to more oxidizing conditions as mineralization progressed, ideal for efficient Au precipitation from bisulfide complexes.

Stable isotope and fluid inclusion data provide insight into the origin of the mineralizing fluids. Fluid inclusions are two-phase liquid-vapour at room temperature. Homogenization occurs by vapour bubble disappearance between 150–270oC (n = 70). Bulk salinities from final ice melting range from 4 to 13 wt% NaCl eq. Individual fluid inclusion assemblages show much narrower ranges in data. Later assemblages of hypersaline, Ca-rich brine inclusions in vein-infilling carbonate are observed.

Stable isotope data (bulk separates, and *in-situ* by secondary ion mass spectrometry [SIMS]) for quartz ($\delta^{18}O_{bulk}$ = 15.1‰); $\delta^{18}O_{SIMS\text{-}qtz}$ = 11.8±1.5‰, 1σ, n = 40) and chlorite ($\delta^{18}O_{bulk}$ = 6.9‰; δD_{bulk} = -60.1‰) predating sulfide and calcite postdating sulfide ($\delta^{18}O_{bulk}$ = 13.7-17.2‰; $\delta^{13}C_{bulk}$ = -5.3 to -4.4‰) combined with Sr isotope data (calcite: $^{87}Sr/^{86}Sr_o$ 0.70743–0.70902), LA-ICPMS and microthermometric data suggest that the metal-precipitating fluids were mixtures of magmatic fluid and evaporated seawater (calculated $\delta^{18}O_{fluid}$ ~1 to 6 ‰). Values of $\delta^{18}O$ decrease from early euhedral quartz to quartz adjacent to, or enclosed entirely within, bornite-chalcocite by ~ 4‰, reflecting the progressive incursion of evaporated seawater.

The host setting, vein assemblages and paragenesis, and fluid inclusion and isotope systematics of the mineralization are very similar to hydrothermal Cu sulfide deposits associated with basalt in the Keweenawan Cu district but those studied here have a distinct Au-Bi endowment and involved mixing of magmatic fluid with bittern brines rather than meteoric waters. Therefore, mineralization may significantly postdate the host volcanosedimentary sequence by at least ~200 myr, requiring overlying Carboniferous evaporitic basins as a brine source.

Epithermal gold mineralization in the northeast Cobequid Highlands, Nova Scotia, Canada: evidence for incursion of evaporated seawater into an active hydrothermal mineralizing system in the Late Devonian-Early Carboniferous

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Recent discovery of low-sulphidation epithermal gold showings in the NE Cobequid Highlands provides an opportunity to characterize mineralizing hydrothermal processes and define exploration criteria for a new style of gold mineralization for Nova Scotia. The studied rocks comprise silicified and sulphidized, Au-As-Sb-Hg-enriched, Late Devonian to Early Carboniferous bimodal volcanic rocks.

Quartz-carbonate textures typical of rapidly boiling ("flashing") epithermal Au-Ag deposits are abundant, notably lattice-bladed calcite, and colloform-banded, plumose-textured, and mossy quartz. Primary and secondary fluid inclusions ($L_{aqueous}$+V at room T) comprise two types: *Type A* inclusions occur in early, zoned, euhedral quartz and lattice-bladed calcite. Fluid inclusion assemblages (FIAs) also show evidence of episodic boiling or "flashing". Homogenization temperatures (T_h) and salinity values across all FIA are between ~150 and 320°C and 0 to ~10 wt% NaCl equiv. (variations up to 70oC and ~4 wt% NaCl equiv. within FIA). Entrapment depths are estimated at <250 m (lithostatic). *Type B* inclusions occur in massive calcite infilling vugs in earlier quartz and calcite. Salinity values are between 19.5 and 42.5 wt% $CaCl_2$ eq. and LA-ICPMS confirms abundant divalent cations (Ca-Mg-rich). T_h data are bimodal, with a high temperature group (T_h ~150-300°C) and a low temperature group (T_h ~70 and 100°C). The higher temperature inclusions have lower salinities. Whereas Type A fluid likely represents a magmatic-hydrothermal fluid that was transiently boiling, Type B fluid is consistent with a marine evaporate brine ("bittern").

Support for evaporitic brine incursion is provided by *in-situ* stable O and S isotope analyses of epithermal minerals from the study area and a recently correlated environment in the Antigonish Highlands (n = 300 analyses; calcite, quartz, barite, pyrite) by secondary ion mass spectrometry (SIMS). These analyses show: (i) ^{34}S-enriched ($\delta^{34}S_{VCDT}$ = 19.4-20.8‰) barite at the core of epithermal veins containing boiling Type A FIA; (ii) rare pyrite grains with late overgrowths showing very high $\delta^{34}S_{VCDT}$ values ~ 25‰ ; (iii) large decreases in $\delta^{18}O_{VSMOW}$ in zoned quartz and calcite in late growth zones, and in the shallowest epithermal veins. Both (i) and (ii) are attributed to sulphide derived from the high temperature (hydrothermal) reduction of seawater sulphate, while (iii), when combined with the fluid inclusion data, reflects the introduction of a marine bittern brine. The results reassert the presence of an overlying evaporitic basin during the waning stages of magmatism in the late Devonian-early Carboniferous, and suggest that basinal fluid incursion into underlying hydrothermal mineralizing systems may have triggered metal deposition.

U–Pb hydrothermal rutile age constraints on gold mineralization in the Belleisle Bay and Annidale groups, New Brunswick, Canada

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As a part of the Canadian Appalachians, New Brunswick hosts a number of different gold deposit types, which are related to various stages of Appalachian orogenic events. In southern New Brunswick, Ganderian rocks of the Belleisle Bay (New River belt) and Annidale (Annidale belt) groups host several important structurally-controlled gold occurrences, including orogenic and intrusion-related gold deposits/ occurrences. The highly mineralized rocks in these belts contain approximately 27 gold and base-metal occurrences. The timing and genesis of the mineralization are a matter of debate. The presence of hydrothermal rutile in quartz-carbonate veins as a possible geochronometer was investigated to determine the age of sulfide and gold mineralization in selected occurrences within the Belleisle Bay and Annidale groups. According to petrographic studies, hydrothermal rutile crystals show a paragenetic relationship with sulfide and gold mineralization associated with brittle and ductile deformation. The age data obtained from two occurrences in the Annidale group (North Fuchsite Zone and East Scotch Settlement) indicate a Late Cambrian to Early Ordovician age for the mineralization. This age range coincides with the Penobscot orogeny, which accreted the Miramichi, Annidale, and St. Croix belts to the New River belt on the edge of the Gander Zone by closing of the Penobscot back-arc basin in the Early Ordovician. The Devil Pike gold deposit of the Belleisle Bay Group is located

south of the northeast-trending Taylors Brook Fault, which separates rocks of the Cambrian-Ordovician Annidale Group to the north from the Late Neoproterozoic to Early Cambrian Belleisle Bay Group to the south. Preliminary ages obtained from rutile in the Devil Pike Brook samples are Late Devonian to Early Carboniferous, which coincides with the Acadian to Neoacadian orogenies that involved the collision of Avalonia with Laurentia.

The tectonic evolution of the Maritimes Basin complex of New Brunswick, Canada, and the eastern offshore area: regional cross sections

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Significant revisions have been made to the surface and subsurface geology across the Devonian to early Permian Maritimes Basin complex of onshore and offshore New Brunswick. Detailed seismic, borehole, and field interpretations have led to a greater confidence in the nomenclature, placement, and movement history of seven major fault systems throughout southern New Brunswick. These major systems, from oldest to youngest, include: the Belleisle, North Hill, Caledonia, Cradle Brook, Ratter Road, Clover Hill, and Kennebecasis faults.

One of the new interpretations include a new mid Devonian sedimentary unit, tentatively named the Killams Brook '*formation*', which was identified through field interpretations and palynology in the Killams Mills area, southeast of Havelock. From preliminary palynology results, the Killams Brook formation appears to predate the Horton Group and can be correlated in seismic profiles and field localities from the Smiths Creek to Cocagne areas; additional samples have been collected for palynological analysis. Nine regional cross sections across southern New Brunswick and Prince Edward Island (PEI) illustrate the potential existence of an older mid-Devonian sedimentary basin that, along with the late Devonian to Carboniferous Maritimes basin, has been compartmentalized by the regional fault systems. This older basin could be part of the pre-Horton Group basins postulated by Durling and Marillier (1990) within the Northumberland Strait, the offshore northeast of PEI, and the Gulf of St Lawrence.

Also, the relationship between the Clover Hill and older Caledonia fault systems is now better understood through field interpretations in the Prosser Brook area. Here, the Avalonia and Brookville terrane boundary (contact between the Coldbrook and Green Head groups) is marked by the Caledonia Fault, which is then bisected by the Cradle Brook and Clover Hill faults respectively. The surface trace of the Clover Hill Fault is near coincidental to the older Caledonia Fault throughout southern New Brunswick. This work will be submitted for two separate publications in Atlantic Geology and will serve as the foundation for future more detailed publications in selected areas across southern New Brunswick and PEI.

Setting and structure of Meguma gold deposits in Nova Scotia, Canada, constrain vein formation to a late-stage flexural slip model

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Over sixty past producing gold districts are scattered throughout the Meguma Group of southern Nova Scotia. These districts (Meguma deposits) share many similarities and, whereas various genetic models have been proposed, a common origin for all deposits is implied. All Meguma deposits occur in the hinge area and adjacent steep limbs of regional anticlines. The regional folds are characterized by chevon and box folds that develop by flexural folding and involve hinge migration throughout their development, thus gold mineralization concentrated in fold hinges occurred late in the fold history. Meguma deposits are dominated by bedding-concordant veins, including laminated veins, en echelon vein arrays and saddle reef veins that reflect flexural-shear on fold limbs and related dilatancy in fold hinges. Discordant veins show mutual cross-cutting relationships with bedding concordant veins, show increased concentration in gold deposits compared to regionally, and reflect hinge-parallel extension during vein emplacement. All veins of the "vein array" consist of similar mineralogy, including gold, consistent with synchronous emplacement. Documented flexural shear strain from displaced discordant veins and rotated en echelon veins records significant shear strain that is localized within the minor mudstone layers and reflects only minor changes in limb dip of steep limbs. Gold deposits occur throughout the entire stratigraphic sequence; however, stratigraphy may influence the charter of individual deposits. Documented gold distribution in many of the deposits is related to minor overprinting structures, including minor folds, vein intersections and fault intersections with veins suggesting remobilization of gold or introduction of late gold. A flexural-shear model for vein formation late in fold development provides an explanation for the distribution of Meguma deposits in fold hinges and steep limbs of regional anticlines and provides a model for exploration for new deposits and extensions of existing deposits.

The use of titania polymorphs as indicators of mesodiagenesis at hydrocarbon charge

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Although titanium (Ti) is typically considered immobile during diagenesis, large quantities of diagenetic anatase and brookite were observed in Cretaceous sandstone of known oil- and/or gas-producing fields of the Scotian Basin, eastern Canada. Diagenetic anatase was seen both during early diagenesis replacing phytodetritus and during late diagenesis precipitating as neoformed crystals with sharp, straight edges. Diagenetic brookite appears as a completely late diagenetic mineral occurring in pores as euhedral crystal clusters, as isolated crystals in secondary porosity in completely silicified sandstone, in secondary enlarged remnants of primary pores, and along enlarged intergranular boundaries. Brookite is the most abundant titania polymorph and was predominantly observed in sandstone reservoirs above the free water line. In contrast, anatase was mostly observed below the free water line. It is proposed that humic acids at lowstand resulted in the dissolution of Ti-bearing minerals and the mobilization of Ti in the shallow section of the basin, favouring the authigenesis of anatase as pH increased. Large amounts of halogens in the deep basinal fluids and the release of organic acids during hydrocarbon formation resulted in the complete dissolution of Ti-bearing minerals, transport of Ti in the form of chelate complexes with Ti^{4+}, and the precipitation of diagenetic titania in the deeper sections of the basin. The abundance of brookite, rather than anatase, in sandstone reservoirs is associated to decreasing pH at oil-water interfaces. In addition, the decrease in F^- ions and increase of Cl^- ions due to the precipitation of fluorapatite and absorbance of F^- in calcite cements, preferentially precipitated brookite, as Cl^--rich fluids favour brookite formation. The widespread occurrence of diagenetic titania minerals in Scotian Basin can thus potentially provide information on fluid flow and migration of hydrocarbon in the basin.

Modelling changes in internal pressure during the solidification of hydrous granitic intrusions: Implications for the crystallization of miarolitic pegmatites*

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Although volatile exsolution is widely recognized as an important trigger for eruptions of shallow magma reservoirs, relatively few studies have investigated the effect of volatile exsolution on internal pressure within deeper seated magma bodies. We present a model to predict the changes in internal pressure during the crystallization of haplogranitic melts containing 3 and 5 wt. % H_2O emplaced at lithostatic pressures of 200 and 500 MPa. Mass and volume relations between phases are used to calculate internal pressures assuming a closed, constant-volume system. Our results indicate that initial crystallization of alkali feldspar and quartz causes a decrease in pressure and the eventual separation of an aqueous fluid from the residual melt (i.e., resurgent boiling). Progressive crystallization inwards towards the core of the body, combined with a simultaneous increase in the volatile phase, results in a sharp increase in internal pressure. The model shows that in a closed, isochoric system, internal pressure during the crystallization of the H_2O-saturated melt will exceed lithostatic load. In nature, however, the maximum internal pressure is constrained by the permeability and tensile strength of the enclosing rock. In miarolitic granitic pegmatites, the crystallization of most pocket minerals occurs prior to pocket rupture at pressures that may be significantly greater than lithostatic. Extreme overpressure in the latter stages of crystallization adjusts the physical properties and chemical composition of the residual melt and coexisting aqueous phase. Such pressure-induced changes influence crystallization kinetics and provide insight into the composition of melt and fluid inclusion assemblages in pocket minerals.

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

Secrets of the Temple of Doom: 2. Messengers from the Deep

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The Western Gneiss Region (WGR) of Norway preserves large tracts of ultra-high-pressure (UHP) metamorphic rocks formed in subducted Baltican crust during the Scandian phase of the Caledonian orogeny. In

the Nordøyane UHP domain, the deepest and hottest part of the WGR, coesite and microdiamond are locally preserved in eclogite-facies assemblages. Along the north coasts of the islands of Haramsøya and Flemsøya, rafts of mafic eclogite within migmatitic orthogneiss are surrounded by dioritic "melt envelopes" containing abundant eclogitic enclaves and xenocrysts. At Arhaugen, in an outcrop informally referred to as the "Temple of Doom", intensely recrystallised eclogite with a steep lineation is separated from the adjacent melt envelope by a dioritic dyke that is highly contaminated with partly digested eclogitic material. The dioritic matrix consists largely of zoned plagioclase, quartz, biotite, hornblende, scapolite, and ilmenite/titanite, with abundant xenocrysts including embayed and fragmented garnet and spongy clinopyroxene-plagioclase intergrowths. Coesite is present in garnet xenocrysts from both the dyke and the adjacent melt envelope, but has not yet been found in situ in the coherent eclogite bodies. The coesite-hosting xenocrysts differ in texture, composition, and inclusion assemblage from garnets in the adjacent eclogites. In particular, they display an unusual patchy zoning pattern and contain quartz/coesite inclusions, along with omphacite, rutile, apatite, and kyanite, with rare phengite-biotite intergrowths and possible melt inclusions. Both the presence of coesite and PT estimates from garnet-inclusion assemblages in xenocrysts record UHP conditions, whereas the host diorite crystallised at amphibolite facies conditions. We conclude that the xenocrysts were not derived from the immediately adjacent eclogite bodies. By implication, their dioritic hosts were not locally derived but must have originated from a different, probably deeper, source.

Technical challenges using ground-penetrating radar: a case study from the Joggins Formation, Joggins, Nova Scotia, Canada

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The acclaimed Carboniferous Joggins Formation is famous for the complete succession of fossil-rich, coal-bearing strata, deposited in a fluvial meanderbelt depositional setting. Thus, the Joggins Formation is an excellent analogue for studying the 2D geological complexities associated with meanderbelt systems. A ground-penetrating radar system was employed for the first time with the purpose of imaging the dipping strata of the Joggins Formation, in addition to any potential mine adits or openings leftover from past coal mining days. A successful outcome would allow for the 2D outcrop to be extended into 3D space and perhaps lead to an increased understanding of the small (e.g., bedform baffles and barriers) and large (e.g., channel bodies) scale architectural elements, meanderbelt geometry, and aspect ratios. The study consists of an extensive ground-penetrating radar survey using a Sensors and Software pulseEKKO Pro SmartCart system, supplied by the Dalhousie University Basin and Reservoir Laboratory, combined with a real-time kinematic differential global positioning system for the georeferencing of survey lines. The survey consisted of 42 lines (a distance of 3.46 km) and used the 50 MHz antennae with a 1.0 m separation. A total of 6692 traces were recorded between elevations of 16.97 m to 47.47 m above sea level. Data was collected over four areas: (1) Hardscrabble Road (lines 09-39), (2) Main Street (lines 40-44), (3) Mitchell Street (line 51), and (4) a grassy area adjacent to Main Street (lines 45-50). The thick clay-rich soil and nature of the dipping strata are the main reasons for the inability to image the Joggins Formation. A byproduct of this study was the apparent imaging of the angular unconformity between the Joggins Formation and overlying glacial till/soil. Interestingly, the results show many lines contaminated with diffraction hyperbolae. The effects of surface objects, such as trees, utility poles, and utility lines, have been well-documented as being the culprits of many diffraction hyperbolae seen in the profiles. A variety of overburden and surface/sub-surface objects may also affect the GPR data collection. Other potential issues that may hinder the imaging of the subsurface include the uneven terrain, the compacted road surface, and edge effects from collecting data near the cliff edge.

Potential corrosivity of groundwater in Nova Scotia, Canada, and its association with lead in private well water

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Lead in drinking water is associated with a range of adverse health effects. The content of lead in plumbing materials has been restricted over the last 30+ years, but issues with respect to lead exposure from drinking water supplies persist, mainly due to the presence of lead in older plumbing materials. Although municipal drinking water systems in Nova Scotia are risk-managed for lead exposure, private well water supplies account for about 42% of Nova Scotia's domestic water supplies and are not regulated for drinking water quality. Lead exposure in private wells is therefore a significant public health concern. The potential corrosivity of groundwater in Nova Scotia was characterized

for seven major aquifer types using the chloride to sulphate mass ratio and langelier saturation indices, which were derived from available groundwater chemistry data. The relative risk map of the potential corrosivity of groundwater identifies areas where there may be a greater likelihood of waterborne lead in private well water supplies. Crystalline rock type bedrock aquifers, especially plutonic aquifers, and most of the province's surficial aquifers, showed a high potential for corrosive groundwater, whereas well water chemistry data from carbonate/evaporite aquifers and surficial aquifers in contact with these aquifers showed a lower potential for corrosive groundwater. Aquifer types associated with a higher potential for corrosive groundwater were also associated with a higher likelihood of lead in well water exceeding the new Health Canada guideline of 5 micrograms per litre. The relative risk map of the potential corrosivity of groundwater will be used to communicate risk to private well owners and to highlight the importance of routine water testing to assess the risk of lead in private well water supplies.

Fluid inclusion and microtextural evidence for efficient gold precipitation from Au-undersaturated fluids via coupled redox-pH change: Dufferin gold deposit, Nova Scotia, Canada

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The ~380 Ma metasedimentary rock-hosted Dufferin gold deposit in the Meguma terrane (MT), Nova Scotia, hosts several stacked, mineralized saddle-reef-type quartz veins along lithological contacts between metasandstone and black slate rich in carbonaceous material (CM) in the tightly folded Crown Reserve Anticline. The saddle-reef veins record multiple generations of veining, with early gold-poor laminated veins cut or incorporated into later gold-mineralized massive quartz. Locally, vugs in the late massive quartz contain undeformed euhedral quartz crystals that host two fluid inclusion types, both of secondary origin: (i) Type 1 – 3-phase, aqueous-carbonic (H_2O-NaCl-CO_2+N_2+CH_4), 1.3 ± 0.4 wt.% eq. NaCl fluid inclusions, and (ii) Type 2 – 2-phase, aqueous-dominated (H_2O-NaCl+CO_2+N_2+CH_4) 3.2 ± 1.0 wt.% eq. NaCl fluid inclusions. Type 1 inclusions are gold-bearing, but gold-undersaturated (i.e., 0.045 ± 0.024 ppm [n = 58] versus a calculated concentration of 0.1–2 ppm at 300°C) and also contain moderate concentrations of As (67.1 ± 50.1 ppm; n = 80) and Sb (31.6 ± 20.4 ppm; n = 80). Type 2 inclusions have lower average gold contents (0.025 ± 0.012 ppm; n = 7), as well as As (9.24 ± 8.28 ppm; n = 24), and Sb (5.66 ± 5.64 ppm; n = 23).

CM is ubiquitous as coatings on quartz in mineralized saddle veins within cavities and along mineral grain boundaries adjacent to vein laminations and vein margins. The occurrence of micro-inclusions (≤2 μm) of gold in CM-filled cavities strongly suggests the gold mineralization and CM are genetically related. Based on an integrated, microanalytical petrographic study, we propose that late gold mineralization at Dufferin proceeded through a coupled mechanism involving fluid reduction and pH increase. This led to the destabilization of soluble gold bisulfide complexes and gold precipitation from the type 1 aqueous-carbonic fluids. This conclusion is based on the following key observations: (i) the decrease in concentration of Au and redox-sensitive elements (As, Sb), and the increase in concentration of elements inherited through wall rock interaction (Mg, K, Ca, Sr, Fe) between the aqueous-carbonic (type 1) and aqueous (type 2) fluids, respectively; (ii) the decrease in CO_2 abundance between type 1 (X_{CO2} = 0.15) and type 2 (X_{CO2} = 0.02) fluids corresponding with CO_2 removal via reduction/respeciation and carbonate precipitation; and (iii) the occurrence of native gold within CM-filled cavities and fractures.

This work improves existing genetic models for metasedimentary rock-hosted "orogenic" gold systems in the MT and elsewhere by providing direct insight into the mechanisms responsible for at least some of the observed gold.

A unique aquatic fossil assemblage from the Albert Formation near Norton New Brunswick, Canada: implications for paleobiodiversity and paleoecology during Romer's Gap

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Romer's Gap represents a hiatus in the fossil record of terrestrial faunas. This early Mississippian (Tournaisian stage) interval is thought to be the time when tetrapods made the transition from aquatic to fully terrestrial habitats. Within the Moncton Sub-basin, the continental and lacustrine facies of the Hiram Brook Member (Albert Formation) synchronous with Romer's Gap and are exposed in outcrops along Highway 1 near Norton, New Brunswick.

New fossil discoveries from the Albert Formation have advanced our knowledge of continental and lacustrine paleobiodiversity in this time. New fish taxa have been added to the fossil record of the Albert Formation including an undescribed articulated sarcopterygian. Paleobotanical specimens including lycopsid trunks with articulated branches (*Lepidodendropsis*), articulated ferns and pteridosperms (i.e., *Anemites* and *Spenopteridium*), are all preserved in life position. At least one trunk with attached helical crown branches is of a unique fern belonging to the Cladoxylales, a group that is better known from the Middle to Late Devonian. The first evidence of tetrapod communities in the Albert Formation are recorded as fossil footprints (*Batrachichnus, Characichnos, Matthewichnus, Paleosauropus*) and putative disarticulated tetrapod bones (limb and mandibular jaw).

A horizon within the Hiram Brook Member near Norton, NB, yields a unique assemblage of enigmatic fossils otherwise uncommon in the Albert Formation. The first evidence of xenacanthiform sharks is represented by two morphologies of shark spines, a heteropolar microspiral coprolite (xenacanthid shark), and a small shark tooth. A rare eurypterid cuticle is found alongside abundant, yet enigmatic fossils all preserved in an organic rich siliciclastic shale. This unit is interpreted to have been deposited in a low energy shallow lacustrine depositional environment under dysaerobic conditions with abundant plant fragments and disarticulated paleoniscoid remains.

Within the assemblage are enigmatic spherical microfossils, which are 250 μm in diameter and consistently found in disc-like clusters of 60–100 spheres, with some examples of up to 12 clusters on a single bedding surface. The interstitial sediment within the discoid cluster is organic-rich compared to the quartz-rich silt in the surrounding matrix. Spheres often indent and deform around each other, implying that these were once soft deformable objects, likely biogenic in origin. Internally, each sphere has a distinct recurring pattern of a crescent-shaped void between the outer interface and a spherical, offset mass of phosphatic material, that is further permineralized with pyrite. The phosphatic preservation is a common taphonomy for the preservation of soft tissues.

Late Holocene sea-surface cooling in the North Water polynya region, northern Baffin Bay, Canada*

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The North Water (NOW) is located off the coasts of northwestern Greenland and Ellesmere Island in Canada and is the largest Arctic polynya (i.e., area of open water in a region with high sea ice concentration). It is an area of high primary production that sustains a diverse food web. Because the formation of the NOW relies on climate-sensitive factors, the polynya is susceptible to climate fluctuations. First, its formation is largely influenced upon the presence of an ice bridge that forms in Nares Strait, which blocks drift ice from being exported from the Arctic Ocean into northern Baffin Bay. Second are strong northerly winds that contribute to pushing sea ice away from the NOW region. Lastly, the maintenance of the polynya is facilitated by the advection of relatively warm and salty waters from the West Greenland Current into the area. However, there is limited data on the long-term evolution of the NOW polynya, and as such the response of this system to climate variations is not fully understood.

The main objective of this study is to reconstruct changes in the polynya's sea-surface conditions with respect to climate variations of the past. Here, we present preliminary results on changes in dinoflagellate cyst (dinocyst) assemblages in a long sediment core (5.43 m) collected in the central region of the NOW (77°17.097'N-74 23.214'W) at a water depth of 700 m and spanning the last ca. 4000 years. Our results suggest three important phases. First, the highest abundances of autotrophic species *Operculodinium centrocarpum* and *Spiniferites elongatus* between ca. 4000–3000 years BP suggest a longer open-water season and warmer sea-surface conditions during this interval. Second, an increase in the abundance of the sea-ice associated cyst of *Polarella glacialis* likely hints to increasing sea ice concentration between ca. 3000 to 1850 years BP. Lastly, the increase in abundances of the cold-water species *Islandinium minutum, Islandinium? cezare* and *Echinidinium karaense* suggests a colder and shorter open-water duration between ca. 1500 to 180 years BP. In general, the dinocyst assemblage composition suggests that from ca. 4000 towards ca. 180 years BP, the sea-surface conditions are becoming colder with a shorter open-water season within

the NOW polynya. Future work will involve the analysis of the corresponding box core which will allow us to capture the last ca. 180 years and have a continuous record of the late Holocene to present.

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

Meguma gold deposits, Nova Scotia, Canada: past, present and future

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The Meguma terrane of southern Nova Scotia, despite having a modest historical gold production (≈1.3 Moz) extracted during the late 19th and early 20th centuries, is well-known and studied for its slate-belt type orogenic quartz-vein gold deposits (i.e., Meguma deposits). Interestingly, this production from lower Paleozoic greenschist-facies metaturbiditic rocks contrasts markedly with other settings globally (e.g., Central Andes, Australia) where rocks of similar age, lithology, and deformation/metamorphism record significantly more historical gold production (i.e., 100s Moz Au); the same can also be said of older (e.g., Ashanti Belt, Ghana) and younger (e.g., Juneau Belt, Alaska) analogues. Although active mining of Meguma gold deposits has resumed (Q1/2018) at the Touquoy low-grade (ca. 1.2 g/t; ≈500 000 oz Au) disseminated-type deposit, there still remains a marked contrast in regards to the gold endowment of Meguma deposits with their counterparts. In order to understand this apparent discrepancy, the historical context of Meguma deposits is reviewed in terms of their geological setting, deposit features and various analytical datasets as a basis to re-evaluate earlier genetic models and revisit an alternative one. It will be argued that, whereas much of the data is equivocal in terms of models (e.g., fluid chemistry), the distribution of quartz veins and ore zones, which are localized to the most steeply dipping beds near anticlinal hinges, evidence of localized elevated geotherms around deposits, and timing of fluid flux (i.e., ca. 380–370 Ma) are more consistent with an intrusion-related model versus the classic regional metamorphic model. The former model instead relates ore-fluid generation to a punctuated thermal perturbation coincident with emplacement of large granitic batholiths in the region. This thermal event devolatized previously low-grade metamorphosed (low-mid greenschist facies) metasedimentary rocks of the Meguma terrane and mobilized its contained metals (e.g., Au, W). Inherent to the model is a lower fluid flux compared to longer sustained and higher temperature (to amphibolite facies) metamorphism which typifies orogenic gold provinces with large gold endowment. Going forward, it should be realized that although Au grades may be adequate, it is tonnages that determine endowment and for Meguma-type deposits this is likely limited to <1 Moz Au. Favourable geology and demographics do, however, make the Meguma deposits excellent exploration targets, as indicated by current defined ore reserves at several sites that ensure continued gold production into the foreseeable future.

Metallogeny of the Avalonian Mira terrane, southeastern Cape Breton Island, Nova Scotia

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The greater Avalon terrane (now known as Avalonia) originally developed as a consequence of volcanism and plutonism related to subduction on the margin of Gondwana beginning ca. 730 Ma and ending in the latest Neoproterozoic. In common with the Avalon Zone of Newfoundland, the Mira terrane records multiple episodes of arc-type volcanism during this time period. In the Mira terrane, our current study focuses on the ca. 620 Ma Pringle Mountain, East Bay Hills, and Coxheath groups, the ca. 575–560 Ma Fourchu and Main-à-Dieu groups, and their related intrusions. These two episodes of volcano-plutonism appear particularly prospective for mineral resources in the broad class of epithermal Au (-Ag) and porphyry Cu (-Au-Mo) deposits. Contemporaneous sequences in the Avalon Zone in Newfoundland are now recognized to contain numerous examples of these types of deposits.

Within the history of an individual arc, epithermal Au-Ag deposits may be intimately linked to the eventual re-extension of the subduction-related arc environment, with associated andesitic to rhyolitic volcanism, and concomitant subsidence, amplifying shallow hydrothermal circulation in a subaerial volcanic regime. Consequently, the most prospective horizons for these deposits may lie at or near the transition from predominantly volcanic-volcaniclastic lithologies to epiclastic rocks – the latter lithologies being characteristic of intracaldera fill during re-extension and erosion of the volcanic edifices. In this context, the recognition of silicified, sulphide-rich epiclastic sediments

at Big Hill Road Quarry has provoked a more detailed examination of the proximal lithologies of the Main-à-Dieu Group.

Other examples of mineralization discovered during our study include: (a) an occurrence of porphyry-style Cu mineralization several kilometres from the former Coxheath Mine (a Cu-Au porphyry deposit within dioritic rocks of the ca. 620 Ma Coxheath Hills Pluton), (b) Cu mineralization in veins hosted by volcanic rocks of the Pringle Mountain Group, which is possibly affiliated with plutonism of Sporting Mountain age (ca. 620 Ma), and (c) zones of intense hydrothermal alteration of volcanic rocks within other parts of the Pringle Mountain Group. Our continuing work has focused on: (a) narrowing prospection to lithologies characteristic of the intracaldera "extensional" phase where epithermal precious metals systems are most likely, (b) characterizing known occurrences of mineralization as to whether they have the mineralogical/textural attributes of porphyry-style or epithermal-style mineralization (including historically recognized auriferous mineralization at Park Brook), and (c) lithogeochemical and Sm-Nd analyses in support of determining whether the Fourchu and Main-à-Dieu groups can be constructively subdivided into two separate volcano-plutonic episodes.

Exposed on Fogo Island, Newfound and Labrador, Canada: the magmatic history of a mushy intermediate system

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Sorting out the magmatic history of a batholith is fraught with issues. Magmatic systems which produce batholiths are large, long-lived (a few to several million years), open and pulsed. The individual pulses of magma, particularly toward the late stages of batholith formation, may have experienced a tortuous path through a complex plumbing system and components within them may be sourced and modified at varied times and locations along the path. A pulse may experience further modification (mingling, mixing, fractionation, fluid alteration, recrystallization etc.) during and after emplacement.

Fogo Island, off the north coast of Newfoundland, is underlain by the suitably complex Silurian-Devonian 'bimodal' Fogo Batholith, which was emplaced over ~13 Ma during transtensional motion along a major lithospheric suture. Through a series of fortunate circumstances, Wild Cove East, on the northeastern coast of Fogo Island, provides a window into the magmatic history of part of the batholith. The well-exposed outcrops along the cove are mainly chemically similar tonalite to quartz diorite. The similar, intermediate compositions allowed a wide liquidus-solidus interval and no chilled margins between units. The units are nevertheless distinguishable based on colour or by the abundance of darker magmatic enclaves, allowing contacts to be mapped in detail. Based on field relations and petrography, we conclude that the oldest unit, 'enclave-poor tonalite' (EPT) was emplaced in a series of pulses under a warm granite roof, with venting and crystal compaction. A late diorite intrusion formed a small sill, which compressed the underlying EPT mush generating tube and ladder structures. 'Enclave-rich tonalite' (ERT) with a crystallinity of ~20% and including dark, rounded mush enclaves, intruded fluid pockets of EPT mush, with no chills and little chemical exchange, and did not vent. A slab of overlying granite stoped into the underlying mush, revealing the relative rheologies of the units. After ERT intrusions, the mushes cooled with little further motion. A few later intrusions cut the stiffer mushes as dykes. Distinct variations in the compositions of enclaves now in close proximity indicate magma mingling on or prior to emplacement. On a smaller scale, variability in crystal compositions and textures within single thin sections indicate complex mixing histories at deeper levels.

Heat as a tracer in coastal settings: quantifying pore water fluxes using temperature, pressure, and conductivity*

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In inland settings, hydrologists have built on seminal research from Stallman in 1965 and others to demonstrate that pore water fluxes in streambeds can be quantified via time series of multi-depth pore water temperature readings. In essence, groundwater flow advects heat and thus influences thermal environments. Heat offers advantages over other groundwater tracers because it is relatively inexpensive to collect and simple to analyze. In particular, the damping and lagging of sinusoidal, diel thermal signals in sediment underlying surface water bodies can be interpreted to reveal the direction and magnitude of groundwater-surface water exchanges. Also, the curvature of sediment temperature-depth profiles can be used to quantify vertical groundwater fluxes.

Although heat-as-a-tracer techniques have been widely

applied to inland environments, pore water exchanges in coastal settings are difficult to quantify with heat due to the highly dynamic nature of tidal environments. Complications arise because groundwater fluxes are periodic in response to the tidal forcing. This flux periodicity, which is not incorporated into any standard analytical approaches for determining pore water fluxes from temperature, may induce signal interference in the thermal diel signals. To address the challenging physics of pore water exchange in coastal settings, we are developing a novel, multi-level temperature-pressure-conductivity probe for quantifying porewater fluxes in coastal sediment. The pressure readings reveal the hydraulic gradient as well as the period and magnitude of the tidal fluctuations, which are important controls on groundwater flux. Having these hydraulic data available helps limit equifinality issues when interpreting the thermal data to quantify the fluid flux. The conductivity readings reveal whether discharging pore water is fresh or saline. Also, when the fluid flux is inferred from the thermal data, the hydraulic conductivity can then be estimated from the pressure data by rearranging Darcy's Law. Challenges in the design and implementation of this instrument are highlighted, and field data and future plans presented.

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

Evaluation of select metal concentrations in acorns and soils by X-ray fluorescence

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Traditionally, acorns have been used as a food source for indigenous peoples. With a number of mature oak trees on the Dalhousie Campus, the question arises as to whether it might be possible to harvest acorns for consumption, and more importantly, whether they might be safe to consume. In soil, differing contaminants and metals can be found and because of this, guidelines were created by the Canadian Council of Ministers for the Environment (CCME) to ensure limited quantities of contaminants are present in farmland, residential, and industrial soils. This has been done to ensure that metal concentrations in soils are low enough so that food is safe to consume, and that levels of contaminants and metals remain below recommended concentrations (in ppm). The purpose of this study is to systematically sample and analyze soil samples from an oak grove located on the Dalhousie campus in Halifax, Nova Scotia, which is separated into two parts by a construction site. We aim to determine what concentrations of select metals are present in the soils, and to provide knowledge on whether the acorns themselves have elevated levels of potentially toxic elements. Using desktop X-ray fluorescence, soils were analyzed to determine concentrations of potentially harmful metals. A random selection of acorns was collected, dried, mashed and then analyzed using the same method as for the soils to determine metal concentrations. We present our findings to date, together with recommendations for further work, and unanswered questions around acorn analysis and acceptable limits of metals in acorns.

Developing a second-generation in-situ cosmogenic ^{14}C quartz extraction system

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Advancements in in-situ produced cosmogenic ^{14}C extraction from quartz are allowing new geologic problems to be addressed. The short half-life of ^{14}C reduces issues of inheritance. Its rate of production by muons is also greater than other cosmogenic nuclides, permitting new applications hundreds of metres below Earth's surface. The foremost difficulty in extracting cosmogenic ^{14}C from quartz is high natural abundance of atmospheric and solid ^{14}C near Earth's surface, and the low concentration of ^{14}C in quartz (10^4 to 10^5 atoms per 10^{22} atoms of Si and O). The Cosmic Ray Sciences @ Dalhousie Lab is unique in Canada and among only eight labs worldwide that extract ^{14}C from quartz. The second-generation Dalhousie ^{14}C extraction line lab (DCELL2) is in the final phase of development. It will test a number of design changes meant to improve process and line blanks.

DCELL2 incorporates design improvements from extraction systems developed recently at University of Cologne, University of Wollongong, and ETH Zurich. It also adds innovations that will advance the technology. Major changes to the extraction system include an induction heating system with a sapphire sample heating tube, allowing higher extraction temperatures; ultra-high vacuum capabilities, reducing potential contamination during the cleaning stage; and a largely automated extraction procedure to improve processing consistency between samples. More specific developments include the replacement of an alumina boat, thought to contribute considerable ^{14}C to the process, with a platinum boat used for quartz heat extraction; replacement

of lithium borate flux and an inefficient tube furnace used to melt quartz with an induction system, heating quartz to the quartz-cristobalite phase change (above 1600°C), diffusing the C from the sample; faster heating and cooling capabilities with the induction system, increasing sample throughput; and an isotope dilution process, adding $^{12+13}CO_2$, reducing the current requirement that 100% of the ^{14}C must be extracted and carried through gas purification procedures.

Expected improvements to process blanks from our previous extraction system of ~7 x 10^4 atoms of ^{14}C to ~2 x 10^4 atoms in our new system will improve total internal error and enable new hypotheses to be tested. These improvements will open research into geologic problems that require higher resolution chronology, and geologic events that have occurred relatively recently, over shorter time scales.

Textbook cost is a barrier to accessibility in Geology courses; open textbooks are a viable solution

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In order to better understand how commercial textbook costs impact accessibility, and to test to the acceptability of free alternatives, Cape Breton University students enrolled in Engineering Geology were surveyed over two years (n = 27 and 45): before and after the replacement of a commercial textbook with an open one (*Physical Geology, 1st University of Saskatchewan Edition*). In both years, students reported frequently not buying required textbooks due to cost ('often' or 'very often' = 44%), with almost half believing that they at least sometimes received a bad grade as result. Notably, international student respondents were much more likely than domestic students to report 'very often' failing to purchase textbooks because of cost (28% vs 6%), in line with recent local media reports of financial stress in this group. Although only half of students purchased the required commercial textbook in 2018, most of those who did not purchase it reported reading at least parts of the textbook through other avenues (illegal download, from friends, or the library). Perhaps because of the inconvenience of these methods, 85% of respondents said they would be more likely to read a free online alternative.

Uptake of the open textbook (2019) was strong: 80% reported reading at least some chapters. Of these, 86% read an hour or more a week and 44% read for three or more hours. Most students read the textbook online (personal computer, phone, or library computer), with only 17% printing out pages. While half of respondents reported a general preference for printed textbooks, only a third would be willing to pay for the option of using a print copy of the open textbook. Those who would pay set acceptable rates well below commercial textbook prices (~$30/BW and ~$50/colour). Additionally, 92% of students agreed that the ability to access content digitally was a very important to them. Student evaluation of the open textbook content (writing, illustration, and information) was consistently very high, with the majority students rating it better than commercial alternatives and <10% rating it worse in any category except illustrations ('slightly worse' = 14%). One hundred percent agreed it provided good value, and 79% wished their other classes used open textbooks. Only 6% would have preferred a commercial textbook.

Experimental calibration of an apatite oxybarometer for felsic magmas*

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The range of oxygen fugacity (fO_2) in terrestrial magmatic systems is larger than any other intensive parameter. Quantifying fO_2 is important as this factor can as it controls the solubility and speciation of various metals and ligands, which will impact the minerals that form in the system. Unfortunately, there are few methods to quantify this parameter in felsic magmatic systems. Experiments are now in progress to develop a new method for determining the fO_2 of a felsic system utilizing the ubiquitous mineral apatite, which selectively accommodates the As^{5+} species relative to the As^{3+} species. Additionally, previous work on aqueous fluids and basaltic melts have shown that the relative proportion of the arsenic species is dependent on fO_2; thus, we are exploiting this relationship to develop an arsenic-in-apatite oxybarometer. Experiments were performed in a piston-cylinder apparatus at 1000°C and 0.75 GPa using metaluminous, peraluminous and peralkaline rhyolites doped with apatite. A combination of internal buffers and double-capsule techniques are utilized to control the fO_2 of the experiments. The analysis of the coexisting apatite and glasses from the initial experiments indicate that the apatite/melt partition coefficient for arsenic increases from <0.3 at low fO_2 (FMQ -1.0) to 7.4 at high fO_2 (FMQ +5.9). Additionally, these experiments also demonstrate that partitioning of arsenic into apatite changes as a function melt composition, with the partition

coefficient increasing from 2.6 for peraluminous rhyolites to 126 for peralkaline rhyolites when the system is at FMQ +7.5. Further experiments are underway to refine the fO_2-composition-partitioning relationships as well as explore the effect of temperature on partitioning.

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

The age and petrogenesis of the Donegal batholith: insights from titanite

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Titanite is a common accessory mineral in granitic rocks. It can incorporate uranium making it a useful mineral for uranium-lead (U–Pb) dating and other trace-elements that are important for understanding the petrogenesis of granite batholiths. Commonly, zircon is used for U–Pb dating, but with its high crystallization temperature there is also a high possibility of inheritance from source rocks. Titanite can remain closed to lead (Pb) up to temperatures of 750°C, which is within the crystallization temperature range of most granites leading to a lower possibility of inheritance. As a result, titanite may retain a more reliable crystallization age. Titanite also incorporates trace elements (e.g., Zr, rare-earth elements) into its crystal structure that can reflect the P-T conditions at time of crystallization and can be used as a thermobarometer. This project focuses on titanite in granitoid rocks in the Donegal composite batholith of the Caledonide orogen in NW Ireland; more specifically, it focuses on the older plutons (Ardara, Fanad, Thorr, and Main Donegal granites) in the batholith as they contain titanite. The Donegal batholith is composed of seven plutons that range in composition from granite to gabbro that intruded between ca. 435–400 Ma during the Caledonian orogeny. While the Donegal batholith is well mapped, the ages and duration of magmatism, the magma source(s), the relationship of magma production to mountain-building events, and the continuity of magma production remain poorly understood. Laser ablation inductively coupled plasma mass spectrometry was used to obtain U–Pb isotopic and trace element data from titanite to help discern the age, composition and petrogenesis of the Donegal batholith. The ages of two felsic samples from the Ardara pluton yielded ages of 429.0 ± 2.0 Ma and 429.0 ± 1.4 Ma while a mafic enclave yielded an age of 427.9 ± 1.6 Ma. A granodiorite sample from the Fanad pluton yielded an age of 421.8 ± 1.4 Ma while a mafic enclave yielded a younger age of 404 ± 15 Ma. Two samples from the Thorr pluton yielded ages of 417.1 ± 1.4 Ma and 419.2 ± 1.6 Ma. One sample of the Main Donegal pluton yielded an age of 417.5 ± 1.4 Ma. Taken together, the titanite ages are consistent with the zircon ages from the same samples which provides reliable age constraints on the crystallization age Donegal batholith.

Intra-salt palynological events in the Late Triassic-Early Jurassic of the southern Grand Banks, Canada

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The Late Triassic-Early Jurassic strata of the Scotian Basin represent the initial rifting and eventual drift tectonic phase of the Central Atlantic Ocean. It is a challenging interval to interpret due to relatively few well penetrations on the basin flanks, deep subsidence of the central basin below the TD of wells, and possible erosion of Early Jurassic from much of the area during continental breakup. By contrast, the southern Grand Banks experienced the same rift phase as the Scotian Margin, but was then abandoned, leaving shallower basins and less deformation. Biostratigraphic age control is especially challenging due to only terrestrial palynology (spores and pollen) being available.

Comparison between the southern Grand Banks and the Scotian Margin has demonstrated that the two-salt stratigraphy of the Grand Banks, with older, low-bromine, continental salt of the Osprey Formation overlain by the high-Br, marine salt of the Argo Formation, also occurs on the Scotian Margin. Whether due to contiguous parts of one basin evolving together, or isolated basins evolving diachronously is not yet established, but all available biostratigraphic control is consistent with the former hypothesis.

New palynological study of three wells (Sandpiper 2J-99, Osprey H-84, and Spoonbill C-30) on the southern Grand Banks has identified a distinctive ~100 m-thick rhythmically-bedded interval within the Hettangian-E. Sinemurian Argo Formation salt that contains marine dinoflagellates (*Dapcodinium priscum*), implying that the marine evaporite basin intermittently achieved more normal marine conditions. Correlative log signatures at 10–20 m scale likely indicate lateral continuity at 300 km scale rather than isolated basins at this time. Alternatively, they could indicate striking correspondence between separate basins controlled by outside factors such as climate, but this is

considered a less likely explanation. Within the continental salt of the Late Triassic (Carnian-Rhaetian) Osprey and clastic Eurydice formations, multiple wells have similar wireline log signatures and the occurrence of the freshwater alga *Plaesiodictyon*, again implying 300 km lateral continuity, but for the evaporite lake of this time, which must have intermittently achieved freshwater conditions.

Though neither of these events have yet been recorded on the Scotian Margin, correlation using Br geochemistry is possible and provides better constraints on the conditions and timing of the nascent Central Atlantic as it transitioned from continental rift lakes to narrow marine basin.

Tree's company: a new, Permian-like fauna within a single fossilized stump from the Carboniferous of Nova Scotia, Canada

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The fossil record of tetrapods from the Carboniferous of Nova Scotia has been central to understanding some of the earliest phases of tetrapod evolution, including the earliest records of the major groups of tetrapods alive today. Here we report on the discovery of a fossiliferous lycopsid 'tree' stump from the Sydney Mines Formation, upper Pennsylvanian, Cape Breton Island, that remarkably contains the remains of at least six taxa, both non-amniote and amniote, in various states of preservation and articulation.

Significantly, most of the preserved taxa are otherwise known only by representation in the later, Permian ecosystems of North America. Most notable among these is a virtually complete skull of a large, pantylid recumbirostran, as well as four partial, articulated skeletons of a varanopid synapsid. As such, the new material provides new, earliest records of these taxa and reveals several evolutionary events vastly predate currently known occurrences. For example, CT scanning of the pantylid reveals a highly specialized dental apparatus composed of opposing dental fields on the palate and coronoids. The low, conical teeth of these fields is suggestive of complex oral processing of a diet consistent with high-fibre herbivory, well advanced to that of any known tetrapod of equivalent age. Additionally, the presence of at least three partial, articulated varanopid specimens, and a fourth very small associated skeleton, represents evidence of extended parental – a behavior otherwise known from this clade in the middle Permian. The varanopid skeletons are consistent in many regards with mycterosaurine varanopids; however, they are recovered as a new taxon, *Dendromaia unamakiensis* gen. et sp. nov. Furthermore, a fragment of a large proximal femur is also attributable to a varanopid, and approaches the size and morphology of much later occurring varanodontines, such as the Permian *Varanops*. This latter specimen reveals that this early amniote clade had already become much larger, possibly taking on a role of apex predator, well before the start of the Permian.

Together, the implications of this discovery are numerous and include revisions to the tempo of evolution of major tetrapod clades and several new additions to the upper Carboniferous faunal record. Further detailed analyses of this material will contribute to revising our understanding of the ecosystem composition and dynamics of upper Carboniferous tetrapod communities.

Depositional environment and provenance of Early Carboniferous clastic sedimentary rocks at McIsaacs Point, Nova Scotia, Canada

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The Appalachian-Caledonide orogen formed by the accretion of peri-Gondwanan terranes to Laurentia and Baltica during the Ordovician–Devonian, followed by collision with Gondwana and the Carboniferous–Permian formation of the supercontinent Pangea. The two most outboard peri-Gondwanan terranes in Atlantic Canada are the Neoproterozoic Avalon terrane and the Cambrian-Early Devonian Meguma terrane. As Pangea formed, a large system of strike-slip faults developed. These regional-scale strike-slip faults resulted in the formation of syn-collisional basins, and the sedimentary rocks within them likely preserve a record of orogenic processes associated with this supercontinent formation. One such basin, the Antigonish Basin, contains late Devonian fluvial, marine, coastal, and lacustrine sedimentary rocks including sandstone, conglomerate, limestone and shale. LA-ICP-MS U–Pb detrital zircon data from three samples from the base, middle and top of the McIsaac's point section show that most zircons were derived directly from magmatic rocks in both the adjacent Meguma and Avalon terranes. Zircon from the base and middle of the section show a strong Silurian-Devonian (ca. 440 to 380 Ma) population whereas the top of the section lacks these age populations and is instead dominated by Neoproterozoic (ca. 630–550 Ma) populations. Taken together, detrital zircon data and field

observations show that sediments were likely deposited in a transitional braided meandering fluvial system to a proximal braided stream environment followed by an evolution to a more distal braided stream environment. During the onset of basin formation detritus was likely derived from a mix of both local Avalonian and more distal Meguma sources. As the basin evolved, the source of detritus became dominated by a more local Avalonian source. The lithological and depositional environment variability indicates complex depositional processes within this evolving syn-orogenic sedimentary system.

The effects of dolomitic limestone application on forest soil and tree nutritional status on two acidic sites in Nova Scotia, Canada*

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Decades of acid deposition from increased sulfuric and nitric oxide emissions have led to increased leaching of base cations (Ca^{2+}, Mg^{2+}, and K^{+}) and mobilization of toxic aluminum (Al^{3+}) in many northeastern forest soils. As a result, affected forests a nd aquatic ecosystems have seen decreases in productivity and health. Despite recent reductions in emissions, recovery of soils and aquatic systems have been slow. Therefore, soil amendments such as dolomitic limestone may be useful or necessary to speed up the recovery process on these sites. Dolomitic limestone was applied by helicopter at a rate of 10 tonnes/ha over acidic mature hardwood and softwood forests at the Otter Ponds Demonstration Forest (OPDF) in Mooseland, Nova Scotia. Long-term growth plots were established to measure tree growth, tree health, and regeneration. An in-depth analysis of forest floor morphology was performed. Foliage, bark, and wood samples of sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and red spruce (*Picea rubens*) as well as ground vegetation were collected for chemical analysis. Samples are being analyzed for total C, N, S, Ca, Mg, Al, Mn, K, Na, and P. Soil samples were collected from soil pits outside each growth plot and analyzed for pH; exchangeable acidity and Al^{3+}; exchangeable Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, PO_4^{3}, NH_4^{+}; available NO_3; and total C, N, and S. Chemical analysis data will be used to determine the short-term response to liming in the forest floor, upper mineral soil, and tree foliage. Upland catchment liming has the potential to improve forest ecosystem health by restoring base cations in the soil and decreasing toxic aluminum concentrations. This could also lead to improved water chemistry and fish habitat conditions in nearby surface water bodies. Upland catchment liming trials have yet to be performed in Nova Scotia. If successful, upland catchment liming may be a potential tool to help remediate forests, soils, and freshwater systems impacted by acid deposition in Nova Scotia.

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

The geological nature and possible origin of the "Enigmatic Mounds" on top of Orphan Knoll, offshore eastern Canada

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These features were unexpectedly discovered in 1970 as the Deep Sea Drilling Project's, Glomar Challenger, first crossed the 1.5-km high feature 550 km northeast of Newfoundland. Site 111 in 1797 m had been selected to prove that Orphan Knoll comprised continental rocks and had been left behind as the Northwest Atlantic began to open. Before we left Orphan Knoll for the next drillhole we had proved the continental origin of Orphan Knoll but the echo sounder 'peaks' up to 600 m high and barely 2 km in width were a real puzzle. The DSDP cruise developed a calibrated seismostratigraphy for Orphan Knoll using the Site 111 cores and this was available for future sub-bottom profiling.

Rock-dredge attempts in 1971, 1978, and in 2004 failed

to get definite bedrock samples; speculation ranged from possible erosional remnants of Triassic dykes, to massive bedded Palaeozoic sediments. The British crossed what they called "mounds" with their GLORIA low frequency sidescan in 1979 and 1981 and conclusively established that there were over 200 mounds and there was no feature linearity. Meantime to the east the Europeans had realized that many similar mounds comprised cold-water corals; Canadian speculation considered a similar origin for Orphan Knoll's mounds. In 2004 Michael Enachescu identified two possible organic fluid-escape 'chimney' mounds on the southwest edge of Orphan Knoll.

The North Atlantic Fisheries Organization assessed Orphan Knoll as a possible new fishing ground. The Canadian Department of Fisheries and Oceans sponsored a mid-2010 Hudson cruise with the deep-diving tethered ROPOS submersible. The ROV allowed one to observe several in situ bedded sediment outcrops but none could be sampled. Only two mounds had ROPOS dives. The ROV had a multibeam and these data did not show evidence of significant bioherms.

Canada had no multibeam bathymetry available to map Orphan Knoll. In 2000 USCGC Healy's multibeam on a test cruise mapped the northeast margin and in 2006 Canada contracted the Kommandor Jack for a series of UNCLOS zig-zag check lines of multibeam data across the northeast margin. In 2017 we were blessed by an unexpected visit to Orphan Knoll by the British RSS Discovery; its multibeam bathymetry systematically mapped what have become known as the "Enigmatic Mounds". However. our view is hampered by the fact that the multibeam transducers are in the order of 1600–1700 m distant above the mounds. The "Enigmatic Mounds" have been draped with in the order of 150 m of hemipelagic Quaternary sedimentation as well as a significant post-glacial covering of ice-transported debris that does not permit traditional coring. They remain as "Enigmatic".

Experimental determination of diffusion rates of major components in clinopyroxene: the first step in developing a generally applicable geospeedometer for zoned igneous clinopyroxene

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The timescale of magmatic processes is extremely variable. Explosive eruptions are initiated over hours to seconds, magma ascent may occur over hours to years and it may reside in subvolcanic chambers for hundreds or even thousands of years. Radiometric methods determine the absolute age of igneous bodies and in some cases, the time between eruptions in a volcanic system. However, these methods cannot give information on the rate of short-term processes volcanic systems which are vital to prediction of eruptive behaviour and hazard analysis. Zoned olivine has been used to extract timescales of mantle xenolith and xenocryst transport in alkaline basalts. The inter-relationship between zoning in anorthite and trace element content in plagioclase has been used to resolve magmatic timescales up to several thousand years, particularly in andesites. Not all igneous rocks contain olivine and/or plagioclase, and in those that do, zoning is not always present. Clinopyroxene is commonly present as a zoned phenocryst in a wide variety of igneous rocks. However, the zoning has not been widely exploited as a geospeedometer because we have very little information on diffusion in clinopyroxene. The current study aims to experimentally determine the diffusion rate of the major components in clinopyroxene. Preliminary data indicate that for Fe-Mg exchange, diffusion rates are of the order of 10^{-21} m^2/s (around three orders of magnitude slower than in olivine). The very slow diffusion rates make experiments and measurements of diffusion challenging. There are two options: (1) run diffusion experiments for months to produce measurable diffusion profiles; (2) use techniques that can measure very short diffusion profiles – the most commonly used technique is Rutherford Backscattering (RBS). There are problems and challenges with both methods, however, the analytical limitations of RBS mean that it is only usable for relatively heavy major components – it is ideal for Fe-Mg interdiffusion experiments, but not for Na-Al-Si interdiffusion experiments or for trace elements. We have chosen the long duration experiment approach. Diffusion experiments run for three months will be analyzed with three different methods: the standard RBS technique, energy dispersive spectroscopy on TEM foils prepared by focused ion beam methods and by stepwise laser ablation mass spectrometry. We will use the RBS measurements to validate the others. It is particularly important to validate the LA-MS technique since it is the only way to approach measurement of trace elements which is the next step in developing the geospeedometer.

Relative sea level change and coastal erosion of the Cocas Bay region, Trinidad, as observed through satellite imagery

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Changes in relative sea level control the landward and seaward migration of coastlines and this has implications for coastal communities and modern infrastructure globally. Islands of the Caribbean are under particular vulnerability to relative sea level change due to having dense populations in low-elevation coastal areas, having extreme economic dependence on coastal area tourism, and having limited landward migratory options. In an effort to mitigate and prevent changes to their coastlines, many coastal communities are implementing natural (planting of vegetation) and man-made (seawalls, sandbags, fencing) structures.

Here, we present part of an ongoing study of satellite and airborne imagery focused on the coastline of the Cocos Bay region of eastern Trinidad. We combine these images with literature on the stability of the Nariva swamp mangrove fringe, sand ridges indicating past shorelines, and GIS flood risk mapping, to provide a detailed account of coastal migration and geomorphological changes in land cover due to fluctuations in relative sea level. We also examine efforts being applied to mitigate the coastal erosion of these areas. This compilation of satellite and airborne imagery, coupled with evidence of modern coastal erosion, implies that the Cocos Bay region of eastern Trinidad is highly dynamic, having undergone previous progradation and retrogradation, and is most likely in a current phase of shoreline transgression.

A paleolimnological assessment of factors affecting metal deposition and productivity in upland hydroelectric reservoirs, Nova Scotia, Canada

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A 200-year paleolimnological study of two upland hydroelectric reservoirs in Nova Scotia provided insights into metal deposition and lake productivity associated with water level change. Black River Lake (BRL) and Gaspereau Lake (GL) were modified by dam installation beginning in the 1920's and are influenced by similar hydrological and ecological conditions but are morphometrically distinct. Flooding resulted in increased metals (Pb, As, Zn, Sr, Ti) which peaked around 1970 in BRL. GL records increases in most metals until present, however, Sr and other grain size dependent elements decreased with flooding. Chlorophyll-α data indicates an increase in productivity during flooding though productivity in BRL increased much earlier than GL.

These data suggest that the morphometry of the flooded surface strongly influences the timing of erosion, water column productivity and the composition and concentration of the metal load. The GL Sr record may also reflect the impact of damming on the transfer of nutrients and metals from marine environments to GL by alewife (*Alosa pseudoharengus*), an anadromous fish. Continuing research focuses on investigating the lake sediment isotopic record (^{13}C ^{15}N) to better resolve the mechanisms controlling metal flux and productivity into these two upland reservoirs.

Thermobarometry of eclogite from the Nordøyane UHP domain, western Norway: to melt or not to melt?*

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Exhumation of ultra-high-pressure (UHP) terranes, such as the Western Gneiss Region (WGR), Norway, may be facilitated by melting of subducted continental crust. During the Scandian phase of the Caledonian orogeny, the WGR was affected by UHP metamorphism at ca. 415–400 Ma resulting from subduction of Baltica beneath Laurentia. In the Nordøyane UHP domain, eclogite hosted in migmatitic orthogneiss underlies well exposed sections along the coasts of Haramsøya and Flemsøya. UHP conditions have been documented in nearby coesite-bearing eclogite, and there is abundant evidence for late-stage melting of the host rocks, but direct evidence of melting at peak pressure has not been observed. This study is designed to determine whether the peak pressure-temperature (P-T) conditions recorded in the eclogite bodies overlap with the UHP melting range for eclogites and their host rocks. The eclogite-facies mineral assemblage comprises omphacite + garnet + biotite ± rutile ± zircon, locally overprinted by retrograde amphibole + plagioclase ± biotite ± orthopyroxene ± clinopyroxene$_2$, with symplectite present along omphacite-garnet grain boundaries; quartz is rare and coesite has not been found in the studied samples. Garnet hosts inclusions of omphacite, rutile, zircon, apatite, and idioblastic biotite. The presence of biotite in the peak UHP assemblage is unusual and may

reflect the bulk composition of the sample. Temperature estimates based on Fe-Mg exchange thermometers ranged from 800–900°C at 30 kbar, assuming all Fe is Fe^{2+}, and 600–750°C if Fe^{3+} is calculated stoichiometrically; the same thermometers can also be affected by retrograde Fe-Mg exchange. Data from garnet and inclusions interpreted to be least affected by retrograde exchange yielded T estimates of 630–780°C in the P range of 28–32 kbar, using calculated Fe^{3+} values. The Zr-in-rutile thermometer yielded T of 770 ± 50°C at 20 kbar and 820 ± 50°C at 30 kbar. The inferred P-T conditions, ca. 750–800°C at ca. 30 kbar, overlap with the fluid-present melting range for UHP rocks. Fluid-present melting affected the host rocks during decompression, but we have found no direct evidence of fluid infiltration or in situ melting in the eclogite bodies at peak conditions. It therefore seems unlikely that melting at peak UHP conditions assisted exhumation of subducted WGR crust in the Nordøyane domain.

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

Predictive modeling of sandstone reservoir distribution in the Shelburne sub-basin, Scotian Basin, Canada*

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The Shelburne sub-basin is an active target for oil and gas exploration. However, little is known on the distribution and quality of sandstone reservoirs. This is due to the limited number of wells in the study area, the influence of salt tectonics, and inadequate amount of seismic data. The goal of the project is to produce a geologically accurate predictive sediment distribution model for the mid-late Jurassic (163-150 Ma) using the modeling software DionisosFlow™. This model tests the proposed sediment pathways from the literature, and the transport of clastic sediment into deep-water. The paleoriver systems responsible for delivering sediment into the study area are: (1) a river draining the area of Maine, (2) a larger river system draining the area of New Brunswick and possibly further back into the Appalachians and Grenville, and (3) small local rivers draining the southern Meguma terrane. Sediment supply and water discharge values for the different river systems have been calculated from the literature based on their respective river catchment area and amount of uplift that occurred.

Simulation results indicate that sand is mostly found on the shelf behind the carbonate reef, and bypasses in areas of the Shelburne Delta or where large canyon systems occur. The results also indicate that the provenance pathways defined from the literature are correct for the model, however, predicted sediment supply is underestimated for Georges Bank and in deep-water, as there is a lack of thickness in the basin. Sand found in deep-water tends to bypass the upper slope and spread out as toe of slope basin floor fans, or as complex turbidite deposits.

Although, the presence of clastic sediments in deep-water is significant, it remains uncertain whether it results from the initial parameters that were selected. For this reason, CougarFlow™, a statistical analysis software was used in order to assess the sensitivity of the model. Sensitivity analysis indicates that the most influential parameters on the location of sand in deep-water are the position of the Maine river source, the water discharge values for the Bay of Fundy river source, and the sand diffusion coefficients. Results of 350 CougarFlowTM simulations indicate that the best place to find sand in deep-water is immediately down-dip of the Shelburne Delta, just past the shelf edge.

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

Stratigraphic evolution of a submarine channel-lobe system in the ancient passive-margin Windermere turbidite system, Cariboo Mountains, southeastern British Columbia, Canada

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Deep-marine rocks of the Windermere Supergroup in the southern Canadian Cordillera show several km-thick succession consisting of intercalated, sheet-like, Dm-thick sandstone and mudstones (Upper Kaza Group) that upward change to Dm-thick channelized sandstone bounded by mudstone (Isaac Formation), which are correspondingly interpreted to represent proximal basin-floor and slope channel deposits accumulated in a Neoproterozoic passive-margin basin. Detailed stratigraphic architectural analyses within an up to 360 m thick interval of the Kaza and Isaac

succession reveals lithological heterogeneity and complex arrangement of deep-water stratal elements associated to distributary channel-dominated lobe, channel-lobe transition zone (CLTZ) and leveed channel, providing new insights of the spatial and temporal development of an ancient channel-lobe system.

Based on the abundance and distribution of stratal elements, three sharply bounded complexes are recognized to form the system. The lower and upper complexes are characterized by ubiquitous small and large scours that erode fine-grained deposits, localized sandstone-rich distributary channel fills and rare terminal splays. They are interpreted to illustrate the detachment of lobes from an upflow leveed channel, separated by well developed CLTZs, and were formed by highly efficient, siliciclastic and mixed siliciclastic-carbonate flows that mostly bypassed the CLTZ and deposited further downflow. These conditions coincide with falling and later highstand of relative sea level. In contrast, the middle complex comprises predominantly proximal basin-floor elements, including sandstone-rich distributary channels and terminal splays, separated by fine-grained turbidites and interspersed small scours, which collectively are overlain by the first leveed channel. This likely indicates an attachment between the leveed channel and lobe, as the CLTZ was poorly developed, reflecting less efficient flows were preferentially deposited in the proximal parts of the system, marking the lowstand and/or ensuing transgression.

The stratigraphic architecture and stacking pattern of the Kaza–Isaac interval reflect temporal changes in sediment supply and flow character and efficiency during the long-term progradation of the Laurentian continental margin.

Constraints on magma metal fertility from silicate and sulfide melt inclusions in mineralized volcanic and intrusive rocks in the northeastern Cobequid Highlands, Nova Scotia, Canada

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In the northeastern Cobequid Highlands, Nova Scotia, Canada, bedrock mapping and bulk rock and stream sediment geochemical surveying has identified a potentially large epithermal Au system in a thick sequence of Late Devonian to Early Carboniferous bimodal volcanic rocks along the Cobequid-Chedabucto Fault zone. Two Au occurrences have been reported and comprise zones of silicified and sulphidized volcanic rocks with up to 660 ppb Au reported. Anomalous concentrations of As, Sb, Se, and Hg are also reported, consistent with a shallow, low-sulfidation epithermal association. Melt inclusions (sulphide and silicate melt) are abundant in accessory zircon within both volcanic and broadly coeval intrusive phases. Analysis of melt inclusion compositions (major, minor, trace elements including metals) provides constraints on the magmatic reservoir chemistry as well as the metal tenor and volatile content of pre, syn, and post-eruptive silicate and sulphide melts.

LA-ICP-MS analyses of silicate melt inclusions show that the melts are generally poor in As and Sb but are variably enriched in Cu (up to 1 wt %; ~1130 ± 2190 ppm; n = 93), Mo (~5.2 ± 2.9 ppm; n = 55), and W (~2.4 ± 2 ppm; n = 85). No systematic correlations are present between metal concentrations and age of the host phases. A positive correlation is present between Cs and Mo concentrations suggesting that Mo is likely concentrated in the magma due to melt fractionation. However, Cu does not show any correlation with Cs indicating that Cu has likely been lost by fluid exsolution. LA-ICP-MS analyses of sulphide melt inclusions from the hybrid porphyry are modestly enriched in Cu (~2.04 ± 0.57 wt %; n = 19), Co (~700 ± 270 ppm; n = 19), Ni (~740 ± 190 ppm; n = 14), and Mo (~94 ± 51 ppm; n = 19), comparable to sulfide melt inclusions reported in other barren and mineralized magmatic-hydrothermal systems globally. However, As was only above detection in one inclusion (2.71 ppm) and Sb was always below detection with a minimum detection limit of 0.57 ppm.

The anomalously high concentrations of Cu in some silicate melt inclusions most likely represent the co-entrapment of a sulphide melt. The As- and Sb-poor nature of the silicate and sulphide melts could indicate that a metal-enriched volatile phase exsolved from the magma prior to silicate melt entrapment and/or sulphide saturation or the intrusive phases studied were not the source of As and Sb enrichment (and by association Au) observed in the volcanic units.

The mineralogy and petrogenesis of the Lower Caledonia pegmatite, Nova Scotia, Canada

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Northeastern mainland Nova Scotia hosts several rare-element granitic pegmatites in the Meguma terrane. These pegmatites have received very little academic study, including the Lower Caledonia Pegmatite, which was discovered in 1999. The pegmatite is situated on the periphery of an elongated leucogranite named the Kelly Brook pluton. Both the pegmatite and the Kelly Brook pluton contain metasedimentary xenoliths of the Meguma Supergroup and all units are sheared due to dextral transpressive movement along the Minas Fault Zone during the late Devonian and Carboniferous. The Kelly Brook pluton is dated to ca. 375 Ma and has recrystallized quartz, microcline, sheared muscovite, plagioclase, chlorite, garnet, zircon and apatite. The pegmatite contains large quartz and K-feldspar megacrysts along with plagioclase, muscovite, pyrite, tourmaline, apatite, garnet and abundant beryl. The beryl crystals are randomly oriented and up to 5 cm in diameter and >5 cm in length. The euhedral beryl is slightly altered and contains inclusions of quartz, plagioclase and muscovite. The Cs content of the beryl shows that the pegmatite is highly evolved but not as evolved as some other pegmatites (e.g., Tanco). Quartz is recrystallized and deformed. K-feldspar and albitic plagioclase are also deformed. Muscovite is deformed, altered and occurs as cm-sized books within small miarolitic cavities. Tourmaline is only observed near the contacts with metasedimentary xenoliths, commonly with the c-axis oriented normal to the contact of the xenolith. Mn and Fe-rich garnet is present in the pegmatite core as millimeter sized, euhedral crystals. Apatite is also present and will be used to date the emplacement age of the pegmatite. These geochronological data will help constrain the relationship of the Lower Caledonia pegmatite to the Kelly Brook pluton and place the origin of the pegmatite into the regional tectonic context.

Baseline compound-specific nitrogen ($\delta^{15}N$) isoscape of coastal Nova Scotia, Canada

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Anthropogenic nitrogen (N) loading in coastal marine environments causes eutrophication, alters food web structures, and degrades water quality. In Nova Scotia, anthropogenic N is introduced to coastal waters through multiple sources, including sewage wastewater outfalls, seafood processing, aquaculture, and agricultural runoff. Each N source has its own unique isotopic ($^{*15}N$) signature that can be traced using bioindicators to map the spatial variability of $^{*15}N$ along the coastline. Organisms such as the blue mussel (*Mytilus edulis*) integrate the $^{*15}N$ composition of their local environment by feeding on particulate organic matter and integrating it into their tissues over several months. Mussels are ideal bio-indicators for this study because they are sessile organisms that are found along the rocky intertidal zone of the coastline, preserving the biogeochemical variability of their collection sites. This allows us to map the spatial variability of $^{*15}N$ and identify sources of N in coastal Nova Scotia, which is a region with few previous N measurements. Specimens of *M. edulis* were collected in triplicate from 21 sites across the Nova Scotia's Atlantic and Northumberland coasts. The adductor muscle of *M. edulis* was isolated from the rest of the tissue, removed, and freeze-dried for $^{*15}N$ analysis. Within-site variability was considerably low (mean of standard deviation = 0.56‰), indicating narrow variability within specimens at each site. There was, however, a wide range of mean $^{*15}N$ values between sites, ranging from 5.74 ± 0.29‰ to 9.24 ± 0.42‰ (n = 21). To refine these baseline $^{*15}N$ estimates independent of trophic fractionation, 8 sites with the largest $^{*15}N$ ranges were selected for compound specific isotope analysis (CSI-AA). Amino acids were isolated for $^{*15}N$ analysis through acid hydrolysis, cation exchange and trifluoroacetic acid anhydride (TFAA) derivatization. Individual amino acid values ranged from -7.5‰ to 18.1‰ (SD = 5.5; n = 250). Phenylalanine (Phe) is the best amino acid proxy for baseline $^{*15}N_{Phe}$ values and range from 2.4 ± 1.2‰ to 7.8 ± 0.9‰; n = 22. This variability reflects similar trends in the bulk $^{*15}N$ values, indicating that the local variability seen in *M. edulis* $^{*15}N_{Phe}$ likely reflects inputs of different nitrogen sources specific to each sample site. Ultimately, this study pairs the novel CSI-AA approach with traditional nutrient data and bulk $^{*15}N$ analysis to generate the first baseline compound-specific nitrogen ($^{*15}N$) isoscape for the Northumberland and Atlantic coasts of Nova Scotia.

Integration of microbiological and geochemical tools for de-risking oil and gas exploration along the Scotian margin, Canada

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Nova Scotia may have vast untapped hydrocarbon resources in its offshore region. However, the exploration efforts needed to develop these resources are expensive and associated costs become multiplicative when applied to deep-water prospects. Major exploratory risks for the Scotian Margin include its size, distribution and quality of reservoirs, and the presence or extent as well as quality of its source rocks. New data are needed to de-risk exploration to meet these challenges and to ensure the next generation of discoveries. As a component of this effort, we are engaged in an ongoing, inter-organisational program to develop, and potentially implement, microbiological and geochemical-based tools to complement conventional geological exploration approaches with the aim of maximising the search of oil and gas in the offshore. Microbiological proxies are currently under development. These proxies utilize the power of genomics and lipidomics to resolve populations of hydrocarbon oxidizing bacteria and archaea in natural sediments as an indirect hydrocarbon indicator for active and inactive hydrocarbon systems. Thus far, from 101 cores collected during piston and gravity coring cruises spanning 2015-2018, over 400 samples have been analyzed for genomic, lipidomic, and geochemical signatures. Integration of these disparate data sets is now underway. This study is integrating these data with existing geological, geophysical, satellite oil-slick data, and generating composite maps of petroleum potential for locating active reservoirs on a dynamic GIS platform. This study also seeks to find new techniques to compare and correlate these new data types with a goal of creating an efficient and dynamic exploratory information tool. The results will represent a component of a future comprehensive, prospectivity data atlas (known as the Play Fairway Analysis), to further promote offshore exploration and encourage further interdisciplinary research in the Scotian Margin.

Re-appraisal of the Pennsylvanian on the southwestern New Brunswick Platform: a preliminary correlation of palynology, field mapping, and LiDAR analysis

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Historically, interest in the Pennsylvanian succession on the central New Brunswick Platform has centred on the Minto coalfield, the oldest mined coalfield in North America. Detailed mapping over the last century has used lithostratigraphic criteria to make correlations with the Cumberland and Pictou groups of SE New Brunswick and Nova Scotia. Palynological studies over the last three decades has refined this stratigraphy. Currently, the coalfield is considered to consist of a late Duckmantian to Bolsovian (Westphalian C) predominantly grey sequence, overlying a coarser conglomerate-sandstone assemblage assigned to the Minto Formation (Pictou Group). Red intervals exist throughout the sequence, with a particularly thick interval above the coalfield, named Hurley Creek Formation (currently downgraded to 'member' status within the Minto Formation). South of the Saint John River, the Minto Formation extends into the Tracy area, but previous researchers recognized older units variously attributed to the Boss Point Formation (Cumberland Group). Recent re-mapping and palynology confirms Langsettian (Westphalian A) preserved as enclaves along the line of the Fredericton fault, but their extent between Oromocto Lake and Blissville remained conjectural.

A recent discovery of Yeadonian-Marsdenian (Namurian C) spores south of Oromocto Lake, and remapping between this area and Blissville suggests the presence of two upward-fining sequences along the southern margin of the platform. These units range from boulder-conglomerate to mudstone channel-fill sequences to mudstone-shale-fine sandstone over-bank deposits with in situ tree stumps, root and plant beds, and paleosols with minor reddening. LiDAR imagery has permitted correlation of these units and identified channel-forms larger than outcrops suggest. Some cross-bedded units may represent point-bars. Preliminary palynology and paleontology imply two Marsdenian-Yeadonian-Langsettian successions, overlain by a third consistent with a Bolsovian age. The younger succession includes reddened intervals, paleosol, caliche and coals. The Minto coalfield most probably overlies all this sequence. North of Minto, previous palynology analysis identified Stephanian and possible Permian assemblages. Though no more than approximately 300 m thick, this Pennsylvanian succession clearly preserves a varied stratigraphic and sedimentological history of which the back-barrier coal swamp identified around Minto is only one element.

Interpretation of the geochemical variability of the Miocene Volcanic Complex of Lesvos Island, Greece

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High-K volcanism is common during the final closing stages of collisional orogens. Interpreting the petrogenesis of Paleozoic examples may be informed by study of near-modern analogues. The island of Lesvos, in the northeastern Aegean Sea, has early Miocene volcanism that is representative of a regional shoshonitic (K-rich trachyandesite) volcanic province. A chain of stratovolcanoes, with several calderas, extends NNE-SSW across central Lesvos, with pyroclastic flow tuffs onlapping basement both to the SE and NW. The oldest volcanic rocks are ~21 Ma andesitic domes of the Eressos Formation. These are overlain by several hundred metres of Sigri Pyroclastic Formation comprising pyroclastic flow tuffs (unwelded ignimbrites) interbedded with fluvial conglomerate and volcaniclastic sandstone. Hundreds of petrified trees are entombed in the tuffs. The orientation of fallen tree trunks indicates NW to N movement of pyroclastic flows, implying a source to the south near the younger Tavari caldera, which formed during the eruption of the 25 m thick welded Antissa ignimbrite. Following the Sigri Pyroclastic Formation at ca. 18 Ma, a rapid increase in the pace of volcanic activity produced thick lava sequences in the central stratovolcanoes, deposited of several thick welded ignimbrites (30–50 m thick) to the east, and dykes and laccoliths were intruded in SW Lesvos with inversion of the Sigri basin. Ignimbrite flow directions show that at least two more calderas were formed by the ultra-Plinian eruptions. Minor basalt and andesite flows and dykes in SE Lesvos include primitive lamproites. By 16.5 Ma, volcanic activity had ended, and the modern tectonic regime has dissected the volcanic rocks along E-W trending graben.

Shoshonite and lamproite samples show continuous trends of trace elements and their Pb isotope compositions show both were derived from subcontinental lithospheric mantle enriched in LILE in the Paleozoic, in part from subducted carbonate-bearing pelite. Lack of variation in K with Mg# or SiO_2 for individual shoshonite formations suggests trace element variation is due to inhomogeneous mantle sources rather than fractionation. Triassic rift-related volcanism and formation of Jurassic small ocean basins produced extreme depletion of parts of the mantle. Lamproitic magma was derived from melting of enriched refractory harzburgite, whereas enriched lherzolite, wehrlite and pyroxenite partially melted to supply larger volumes of shoshonitic and related magmas. The trigger for partial melting was slab detachment and heat from asthenospheric upwelling following closure of the Pindos Ocean in the Paleogene.

Palinspastic reconstruction of the Cobequid Highlands in the Late Paleozoic: local details and broader implications

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The Cobequid Highlands of northern Nova Scotia lie at the intersection of two major dextral intra-continental shear zones developed during closure of the Rheic ocean. The Cobequid Shear Zone was an ENE–WSW transfer zone in a NE–SW-trending orogen-parallel shear system in the late Devonian–early Carboniferous (Neo-Acadian phase). It formed under conditions of voluminous supply of mantle-derived magma in a back-arc setting. High heat flow and emplacement of dykes along deforming strike-slip faults lubricated fault motion, which created space for the emplacement of shallow plutons from 370–355 Ma. Restraining bends in the major Rockland Brook–Kirkhill fault system and variable rheology of cooling gabbro and granite plutons resulted in complex compartmentalization of the larger plutons and rotation of the volcanic carapace to almost vertical during the Early Carboniferous. A previously unrecognized fault system, the Lynn Mountain Fault, forms a link between the Kirkhill Fault and the Rockland Brook Fault. It may have accommodated tens of km of dextral slip, separating the Na-rich rocks of the early Wentworth pluton from those of the West Moose River pluton. The sequence of vein filling minerals suggests that this slip took place after the emplacement and cooling of the smaller plutons but before the onset of the Alleghanian Minas Fault Zone.

The Rockland Brook–Kirkhill fault system was the bounding fault of the syn-tectonic Horton Group basin south of the Cobequid Highlands. Explosive felsic volcanism in the Fountain Lake Group largely or entirely pre-dates Horton Group sedimentation. During deposition of the lower Horton Group, rhyolite domes and basaltic flows were the supracrustal expression of the ongoing pluton intrusion. There is no requirement for >100 km of strike slip displacements to juxtapose the Fountain Lake Group and the Horton Group.

The Alleghanian Minas Fault Zone parallels inferred

Acadian faults resulting from Avalon-Meguma convergence. Deformation took place principally along the Cobequid Fault, with thrusting predominating both to the north on the northern edge of the amalgamated Cobequid Block and to the south in the Kennetcook basin. The differing styles of the Cobequid Shear Zone and the Minas Fault Zone are a consequence of the availability of magma and the relationship of the regional stress field to pre-existing lineaments. Analogous patterns of magma-lubricated strike-slip faulting adjacent to extensional basins are found in other orogens and reflect regional softening of the lower crust facilitating extension adjacent to rigid upper crust stitched by plutons.

Teaching Earth Science to primary education students: how to build an engaging field trip program for schools

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The Johnson Geo Centre is one of many institutes in the Atlantic provinces that seeks to provide in-depth education on geology and related topics to people of all ages. The Geo Centre has seen significant and growing success with structured educational field trip programming for over a decade, with new programs being developed every year to meet the growing demand for high-quality education on a topic with which many school teachers may be unfamiliar. With a local population of only 260 000 within less than 2 hour's drive from the centre, the Johnson Geo Centre manages to fully book up and see an average of roughly 6000 students for structured educational field trips every year. By tailoring programs to meet specific educational outcomes with materials and props that are often not available to schools, combined with the expertise of its science and exhibit interpreters, It provides an exciting space for children to learn in a multitude of different styles, many of which are very hands on.

In this talk I will provide a breakdown of how programs are run at the Johnson Geo Centre, what leads to their success and how other institutions might learn from them, how the Geo Centre compares to other comparable institutions, and where the Geo Centre could innovate or expand on what it has already accomplished.

Geochemical gold exploration in Nova Scotia's Meguma Zone, Canada

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The Meguma Zone (MZ) presently hosts 1 active mine with 4 others permitted as the economic driver for many exploration plays. Several geochemical studies define 3 Au-bearing environments within vein systems or sediment facies. The sediment-hosted deposits are lower in grade but support most active bulk mining operations such as Moose River. New bulk mineable deposits will mostly likely be found as an adjunct to known MZ vein systems. Most existing vein deposits have not been exploited beyond 350 m depth and have a huge untapped potential when compared to the Bendigo corollary that has working mines to depths of 1800 m. Large-scale structures play an important role in the MZ like the Tobeatic Fault Zone and many NW linears noted as distinct geochemical trends in several sampling media. An integrated exploration strategy is recommended for the MZ incorporating GIS technology and geochemical methods to intersect the signal from an undiscovered deposit. Studies from 20 years of MZ geochemical experience are presented to show that some methods are far more desirable than others in terms of cost and effectiveness. A ny m ethod's effectiveness is controlled by fusion of spatial characteristics within the physical and landscape. Greater anomaly contrast definition, size and detection are governed by the combination of appropriate sample spacing and chemical analysis to ensure the intersection with the signal from the type of deposit sought. Each geochemical method must be considered in terms of its area of influence. The MZ model is predicated by the larger the area of influence then the greater the area of ground which can be assessed at the lowest cost. The most cost-effective solution uses only vector media at the reconnaissance scale that include drainage lake sediments, vegetation and water. Vector methods have the additional advantage of having a large defined area of influence which makes sampling other digital layers in a GIS through a polygon much more efficient. The proposed geochemical Au model is as follows: (1) First pass reconnaissance geochemistry using lake sediments, vegetation in the interfluve areas with surface water if the budget allows; (2) Second pass follow-up is achieved using detailed vegetation sampling to narrow the target. At this point till trenching to bedrock contact, mapping, Au grain counts and geochemistry is recommended; and (3) Third pass concerns target drilling of target subject to obtaining sufficient Au bedrock values.

Strength evolution of a crustal-scale shear zone on the example of the Himalayan Main Central Thrust*

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The brittle-ductile transition zone, and therefore location of greatest strength in the crust, can be determined through construction of a stress profile. To produce this profile, one needs to calculate the flow stresses for a sequence of rocks collected at different crustal depths and to calculate the frictional flow envelope for the brittle crust. Grain microstructure and texture reflects the variations in pressure and temperature, and therefore flow stresses, during exhumation through the aseismic ductile regions at depth until the brittle upper region of the megathrust. Quartzite mylonites of the Lesser Himalayan Sequence were sampled along a 3 km-thick transect across the footwall of the Main Central Thrust (MCT) in Bhutan. The quartz crystallographic preferred orientations (CPO) were obtained through electron backscatter diffraction. The orientation maps indicate that the quartz microfabric contains two grain size populations. The large relict grains display grain boundary migration and straightening, indicative of a partial foam texture. The smaller grain population demonstrate subgrain rotation recrystallization. The quartz CPO is characterized by a transition from type-I to type-II cross gridles with increasing structural distance from the MCT, which correlates to the decrease in deformation temperature. Orientation maxima of c- and a-axes indicate a dominant rhomb <a> slip system. A grain size piezometer was applied to determine the flow stresses that were combined with independently determined deformation temperatures and pressures to calculate strain rates. The large grain population presented only slight variation in flow stress, but the strain rates in the middle of the shear zone were two orders of magnitude higher than at its boundary. The maximum flow stress obtained from the recrystallized grains was approximately 110 MPa, which was assumed to be the stress at the brittle-ductile transition. Construction of the stress envelope for the brittle part of the crust indicates that the pore fluid pressure along the MCT of $\lambda = 0.85$ with a friction coefficient of 0.4 is required to allow a slip along the thrust. Our data indicate that the Himalayan crust is strongest at 11 km with the peak differential stresses at approximately 110 MPa. However, the geothermal gradient varies across the MCT due to overthrusting of hot over colder rocks. Therefore, the generated strength profile is only applicable to the shear zone, not to the encompassing continental crust. Finally, because the calculated stresses were not effective coevally, the strength profile is actually a strength history of the shear zone.

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

New Brunswick's online well log system: an essential hydrogeological tool

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Since the introduction of the *Potable Water Regulation* of the *Clean Water Act* in 1994, the New Brunswick Department of Environment and Local Government has published a provincial database of municipal, domestic, and industrial well information. This information is regulated under the *Water Well Regulation*, which ensures that all wells are constructed and developed to an appropriate standard, providing for water resource protection. Between the two regulations, information is produced that includes water chemistry, pump test results, well construction details, and "driller's log" stratigraphy. These data also serve as important background information: stakeholders have used the data to conduct municipal aquifer exploration, establish environmental baseline conditions, and enhance regulatory submissions. This submission will review (1) how past projects have used the data; (2) limitations of the data, and (3) potential ways to address limitations. Provincially recorded well information prior to the *Potable Water Regulation* will be discussed. This work is being done to help implement goal #1 of New Brunswick's Water Strategy for 2018–2028: understanding and sharing knowledge about water. This submission also describes how the data was used to inform a shallow groundwater investigation plan in response to a recent industrial event in New Brunswick.

Investigation of submarine landslides and geological hazard assessment of Pangnirtung Fjord, eastern Baffin Island, Nunavut, Canada*

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Recent research efforts have highlighted that current climate warming is reducing the thickness and extent of glaciers, causing permafrost instability, and increasing river runoff in high-latitude regions. However, due to the lack of seafloor and sub-seafloor data, the effects of a changing climate on submarine environments and its impact on geological hazards in this region is still poorly understood. This project aims to determine the recurrence of geohazards including submarine landslides, floods and tsunamis in Pangnirtung Fjord, eastern Baffin Island to test the hypothesis that the cumulative effects of climate change increases the frequency of these events in the Arctic. A nine-day research cruise on the R/V Nuliajuk with the Geological Survey of Canada collected sub-bottom profiler data, multibeam bathymetric data, sediment cores, and topographic data of the flanks of the fjords to address the factors responsible for sediment transport processes and margin instability in high latitude fjords. Multibeam bathymetry and 3.5 kHz sub-bottom profiler data will be used to identify submarine landslide deposits, while Unmanned Aerial Vehicle (UAV) data of the high-relief fjord sidewalls will help determine possible subaerial areas of failure. Surficial sediment cores were collected to quantify the age of the landslides and estimate the stability of the seafloor through geotechnical analyses. Combined, these analyses will aid in identifying potential trigger mechanisms of landslide generation in the fjord. The results will also be used to drive future field investigations aimed to collect new sediment cores in lagoons and low-lying environments along the fjord deltas to assess the tsunamigenic potential of these hazards. Short-term outcomes for this project include: (1) informing northern communities of marine geological hazards by providing local geohazard maps and (2) understanding the potential hazards for infrastructure development on the seafloor and low-lying coastal zones.

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

What is most important – education or experience?

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Global climate change, evolution, and deep time are all topics that are central to a holistic understanding of the history of Earth and yet the validity of these topics is debated widely throughout the world. Not having a comprehensive knowledge of Earth's history, the causes and effects of mass extinctions on biodiversity, and the influences that humans have had on global climate during the previous 300 years as compared to climate change as seen in the rock record is a severe lack of information that could negatively influence the sustainability of diverse ecosystems on our planet. How best to approach, educate, and create a lasting and positive impression on people is a question that is constantly being revisited and evaluated by STEM (science, technology, engineering, mathematics) museum educators as well as other informal and formal educators. Education is a broad term that covers multiple methods of gaining knowledge including but not limited to reading (exhibit displays, books, scientific literature, online articles), hearing (audio presentations, podcasts, classroom lectures), watching (television, online videos, films), and social learning (tour guides, debates, community presentations). Science museums are at the center of where this information should be accessed, made easily digestible, and where the public should have a high confidence in the accuracy of interpretation. In the last few decades, museums (both science and others) have refocused their efforts on being places that are more engaging by providing hands-on experiences that can have a reduced educational impact by providing a more entertaining experience. It is widely accepted that the more involved a person is in an activity, the more likely it will have a long-lasting impact on them which they are more likely to share with others. So, the question arises – which component of our responsibilities as informal science educators is most important? Is it more imperative to provide a foundational knowledge of these incredibly complex topics on our planet's history, or should we focus on providing an engaging experience that will inspire a curiosity-driven need to explore these topics on their own after leaving our institutions? Academic studies abound that provide evidence that supports both methods as primary educational approaches. We will share the latest in pedagogical studies as well as first-hand experience in geological informal education and outreach in Nova Scotia and as well as select locations in the USA.

Watch where you're stepping: evaporites and sinkholes in Nova Scotia, Canada

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The large and deep Maritimes Basin is filled with dominantly late Paleozoic non-marine clastic sedimentary rocks. The Viséan Windsor Group, comprising limestone, siltstone, and significant evaporites, represents the only fully marine incursion into the basin. The evaporites include gypsum, anhydrite, halite, and potash deposited in repeated sequences that can be traced across many sub-basins within the Maritimes Basin. In most sub-basins, the Lower Windsor Group is characterized by a thick interval of halite, preserved only in the subsurface. These evaporites were likely active soon after deposition and continue moving at the present day. Evaporite expulsion likely kinematically controlled sedimentation during deposition of the higher Windsor Group and later strata.

Where salt is near the surface, areas of subsidence and karst development are common. Two examples in Nova Scotia include Cheverie in the Windsor-Kennetcook sub-basin, and the newly formed Oxford Sinkhole, in the Cumberland sub-basin. The distribution of near-surface evaporites leading to sinkhole development can be seen on recent LiDAR data near Oxford, which lies on the crest of a diapiric salt wall developed between two downbuilt minibasins, 4–5 km deep, that developed as evaporites were expelled into the wall. Core from wells drilled in the vicinity of the Oxford sinkhole show gravel-bearing sediments, probably either Quaternary deposits or younger Carboniferous rocks, in the top 37 m. However, below this depth, siltstone breccia is present, similar to that found in outcrop elsewhere in the Maritimes Basin, wherever halite-bearing evaporites have approached the surface. The breccia contains slickensides that strongly suggest it formed as a residue from solution of salt that had undergone halokinesis. These observations suggest that a range of processes should be considered in the interpretation of sinkhole development, including both ductile flow and solution of both halite and gypsum.

Till fabrics in southwest Nova Scotia's ice-marginal environment: new insights from improvements to data collection and presentation

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Glacial flow directions are not commonly determined using till clast fabrics because a full day of collection is required to amass enough measurements to determine flow direction confidently. Fortunately, smart-phone apps can now make structural measurements and transcribe verbal notes, speeding up data collection to >350 measurements per day and providing a safer working environment by allowing geoscientists to keep three points of contact on steep till escarpments. During the summer of 2019, >2000 till fabric measurements were collected from ten escarpments along the 'French Shore' of southwestern Nova Scotia, and >500 till fragment orientations were measured from the expansively exposed upper lodgement till at Mavillette Beach. The dips and dip directions of each clast's long-intermediate plane were measured, and the clast lithology and the clast length, width, and height were recorded.

These data were evaluated graphically and statistically using 'combination tests' of means and variances to evaluate appropriate parameter limits for till clast measurements. Results demonstrate that: (i) pedoturbation likely distorts till clast fabrics at shallow depths, (ii) ablation tills have neither consistent nor reliable till clast orientations, (iii) lodgement till clasts with steep dips (>30o) have unacceptable till clast orientation variances, and (iv) larger till clasts (>25 cm) can display evidence of slumping, despite efforts to avoid such displaced clasts. Analogous tests of randomly selected measurement subsets reveal that ~100 measurements are generally necessary to obtain less than ±3o (1σ) error on mean orientation estimates.

Other 'combination tests' fail to demonstrate significant differences (in replicate measurements, different clast lithologies, and different clast eccentricities defined by long/short dimension ratios >2). Consequently, till clast fabric measurements in this study were collected only from the lower portions of lodgement tills, and till clast measurements were made using ~100 clasts with long dimensions from 5–40 cm, long/short dimension ratios >2, and dips <30o.

Data were interpreted using both conventional and smoothed rose diagrams, the latter produced using a Von Mises distribution kernel algorithm. Results indicate that all lodgement till units measured have a reasonably uniform flow direction from the WSW onto southwestern Nova Scotia from the Gulf of Maine. Classification of the tills measured in this study is under way but is neither easy nor quick due to the large stratigraphic variability of tills in the ice-marginal environment of Nova Scotia, a characteristic that prevents easy recognition of mappable units. Further analysis and the collection of additional data from southwestern Nova Scotia next summer may provide more constraints on the complicated glacial history of Canada's Atlantic Provinces.

Petrography, geochemistry, and Pb-Zn-Cu-As-Au mineralization in drill core from the Faribault Brook area, western Cape Breton Island, Nova Scotia, Canada

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Mineral exploration has been ongoing in the Faribault Brook area of the western Cape Breton Highlands, Nova Scotia, since the 1890s when adits were dug in areas enriched in sphalerite, galena, chalcopyrite, and arsenopyrite. Since then at least 15 significant mineral occurrences have been reported and more than 50 exploration holes have been drilled. However, details of the age, structure, and tectonic setting of both the mineralization and its highly deformed metavolcanic and metasedimentary host rocks remain enigmatic. This study focuses on core from three holes drilled in 1978, 1990, and 2008 and archived at the Nova Scotia Department of Energy and Mines core library. Core logging included magnetic susceptibility measurements, petrographic study of 39 thin sections, and 120 portable X-ray fluorescence (pXRF) analyses. Whole-rock chemical analyses were obtained for 17 samples and assays for 6 mineralized samples. PXRF analyses facilitated recognition of rock types in these mainly fine-grained, deformed and metamorphosed rocks: Zr/TiO_2 ratios over 100 ppm characterize metasedimentary rocks whereas ratios less than 100 characterize metavolcanic rocks. Hole AMC-06-78 (177.3 m) from near the Core Shack occurrence north of Faribault Brook consists of interlayered mafic metavolcanic, calc-silicate and garnet-rich metasedimentary rocks; the abundance of metavolcanic rocks increases with depth and metasandstone with blue detrital quartz clasts occurs at the top of the hole. Hole RB-90-01 (102.4 m) from near the Rocky Brook occurrence 7 km south of Faribault Brook also contains interlayered metasedimentary and metavolcanic rocks but metasedimentary units dominate in the upper and lower sections. Hole GM-09-08 (50 m) from near the Fisset Brook occurrence in the western part of the area consists of metasandstone with blue quartz clasts and interbedded mudstone with local gossan zones. All 3 holes contain much more mineralization than recognized in company assessment reports. Elevated Pb-Zn occur mainly as stratabound layers in metasedimentary rocks whereas Cu and As are in quartz-carbonate veins parallel to foliation. Anomalous Au was found in two holes, in both quartz veins with arsenopyrite (up to 6 ppm Au and >10 000 ppm As) and in metawacke with elevated Pb and Zn (e.g., 1236.3 ppb Au, 2464.7 ppm Pb, and 6086 ppm Zn). Although previous studies have suggested that the mineralization in the Faribault Brook area is VMS-style, most mineralization in the three drill holes is in metasedimentary rocks, suggesting sedimentary exhalative (SedEx)-type with related epithermal veins.

Permian to Triassic tectono-sedimentary evolution of the Mahu sag, Junggar Basin, Western China: implication for the transition from post-collisional rifting to tectonic inversion

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The Mahu sag in Junggar Basin is located at a critical tectonic position at the bend in the Kazakhstan orocline of the Central Asian Orogenic Belt. The Permian to Lower Triassic terrestrial successions constrain the tectonic evolution of the Junggar basin during and after the final stages of oceanic closure in the Orogen. This study proposes a new reconstruction of the tectono-sedimentary evolution of the Mahu sag at the northwestern margin of the basin based on detailed analysis of drill cores, detrital zircon U–Pb geochronology, geophysical well logs and 2D seismic reflection profiles. Sixteen lithofacies are grouped into three facies associations: fan delta, fluvial delta and lacustrine. Detrital zircons in Lower Permian sandstone were locally derived from Carboniferous and syn-depositional volcanic rocks in Central West Junggar to the west, with minor input from the Luliang uplift to the east in the Junggar Basin. The Central West Junggar source remained dominant but in the upper Permian and lower Triassic there was increased input from the Boshchekul–Chingiz and Zharma–Saur arcs to the northwest, and from Southern West Junggar to the southwest. Sedimentary data from drill cores and seismic reflection profiles are integrated into a second-order transgressive-regressive sequence stratigraphic framework, with regional unconformities, supported by isopach and paleogeographic maps. The sedimentary infilling processes of the Mahu sag during early Permian to early Triassic is mainly controlled by movement on the NE–SW trending Wu-Xia, Ke-Bai and Hong-Che fault zones. Two stages of tectonic evolution are recognized: (1) the transition from syn-rift to post-rift during early–middle Permian; and (2) late Permian to early Triassic tectonic inversion. The early to middle Permian dynamic mechanism may have been induced by regional post-collisional intra-plate adjustment along large-scale shear zones after the final closure of Paleo-Asian Ocean at the end of Carboniferous. Counterclockwise rotation between West Junggar and Junggar Basin relative to the western part of the Chingiz Arc since late Permian provided the dynamic mechanism for the late Permian to early Triassic tectonic inversion.

Re-examining faults as primary and secondary salt welds in the late Paleozoic Antigonish sub-basin of Nova Scotia, Canada

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The Antigonish sub-basin, part of the late Paleozoic Maritimes Basin, extends from the Antigonish Highlands into western Cape Breton Island. Strike-slip faults inherited from the late stages of Appalachian orogenesis border the late Devonian to late Carboniferous basin-fill. Clastic sedimentary rocks dominate the contents of the sub-basin, with the exception of the marine carbonates and evaporites of the Visean Windsor Group. Existing maps of the region show several surfaces that are mapped as faults. The largest of these is a discordant surface spanning most of the sub-basin, which was first mapped as the Antigonish Thrust. This surface was later considered to be a low-angle extensional fault and renamed the Ainslie Detachment. Closer examination and the known presence of salt and salt structures in the local stratigraphy, such as salt walls found on seismic lines through St. Georges Bay and salt diapirs exposed in coastal outcrops, lead us to suggest that these surfaces are instead salt welds.

A combination of field mapping, UAV photogrammetry, core logging, and seismic interpretation was used to examine the sub-basin for evidence of salt movement and its timing. Salt movement in the salt-dominated Lower Windsor Hartshorn Formation began in the Visean during the deposition of the middle Windsor Group, causing lateral thickness variations. Contemporaneous salt diapirs around the sub-basin margins prevented the local deposition of middle and upper Windsor strata. A primary salt weld in the Hartshorn Formation is exposed in outcrop at Lakevale on Cape George. A previously unrecognized Middle Windsor salt unit (MWS) was identified in the sub-basin. Locally the MWS began to move during upper Windsor Group deposition, but the majority of the salt remained immobile until after the deposition of the Bashkirian Mabou Group. Several structures originally mapped as faults are re-interpreted as surficial expressions of MWS diapirs. At Little Judique Harbour on Cape Breton Island, steeply dipping strata with different younging directions on either side of a breccia zone are interpreted to record a secondary salt weld.

The presence of salt structures in both the previously known Hartshorn Formation and the newly recognized MWS shows that salt movement has had a larger and more complex role in the history of this sub-basin than was previously thought. Salt may also have played a similar role in the development of other regions in the Maritimes Basin.

An overview of gold mineralization in New Brunswick, Canada: our current understanding

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In the New Brunswick segment of the Appalachian orogen, various stages of orogenesis led to the development of a variety of geological environments favorable for the deposition of several styles of gold mineralization within Neoproterozoic to Carboniferous host rocks. Many of the occurrences comprise gold-bearing quartz veins concentrated along structural features and are commonly located peripheral to felsic intrusions, as is characteristic of orogenic and intrusion-related deposits, respectively. Other gold deposit types found throughout the province include epithermal, porphyry, skarn, gold-rich volcanogenic massive sulphide (VMS), placer/paleoplacer and iron oxide-copper-gold. Classification of the recent gold discoveries in an emerging gold belt in Ordovician metasedimentary rocks in northern New Brunswick is ongoing as exploration activities progress.

Although there is no current gold production in the province, much of the historic gold production was from Au-enriched gossans capping the VMS deposits of the Bathurst Mining Camp (e.g., Murray Brook). In addition to this, gold was also produced from the orogenic-type deposit at Cape Spencer in southern New Brunswick. Much of the province's known gold endowment is contained within the orogenic and intrusion-related systems, which are the focus of the majority of current gold exploration activity; however, the potentially very large gold resource contained within the VMS deposits (and tailings piles) of the Bathurst Mining Camp could become economically viable with technologic advances. Recent exploration successes extending known gold deposits and identifying new gold zones in the Clarence Stream gold district in southwestern New Brunswick, have expanded the gold inventory thereby increasing the potential for future development of these intrusion-related deposits.

Nova Scotia's LiDAR coverage and its potential for geoscientists

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The Nova Scotia government has over the past 9 to 10 years invested significantly through the Department of Internal Services in the airborne acquisition of Light Detection and Ranging (LiDAR) technologies. These generally use infrared laser pulses that can penetrate the gaps in the ground vegetation cover to return energy from at, or very close to, the actual ground surface with centimetre accuracy. The Digital Elevation Model (DEM) that can be produced by LiDAR is without comparison to other methods used in the past and is combined with GPS positioning for extremely accurate horizontal positioning. LiDAR elevation maps will soon make the traditional "topo sheet" obsolete.

Seventy-five percent of the Province has been flown and is now available under an open license via the Nova Scotia "Open Data Portal" (https://data.novascotia.ca/). This means that anyone in the world can access these data without charge. Nova Scotia has partnered with Natural Resources Canada and these data are being made available with an "unrestricted data licence". The Provincial 2017 release states that the new "Datalocator allows users to easily find and download elevation data for free," Thus these data are ours to use for flood mapping, topographic mapping, or forest inventory, or any use we can conceive of. If you are mapping, or re-mapping, bedrock, or glacial deposits, which may have been subject to the forces of erosion which may have emphasized a geological formation and geological structures differentially think "LiDAR" as a possible data assistant that is close at hand.

We greatly appreciate Colin W. MacDonald of the Nova Scotia Department of Internal Services, who has been one of the Province's key participants in a multi-jurisdictional LiDAR Working Group established by the GeoNOVA Steering Committee, in providing our poster. It is a LiDAR composite digital image stretching from 'downtown' Oxford, Nova Scotia to the southwest through the 2018 doline (sinkhole) that developed in the parking area of the now-former Lion's public park. The large LiDAR image continues on across the TransCanada Highway 104 and well on towards Springhill in what may earn the name "Doline Alley".

This image will speak to you on the potential use of LiDAR in geoscience. If it does not then you are not listening.

Petrology, age and tectonic setting of the Gunshot Brook pluton, eastern Cobequid Highlands, Nova Scotia, Canada

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For decades the Gunshot Brook pluton has been an enigmatic component of the eastern Cobequid Highlands in northern mainland Nova Scotia. The name and boundaries of the pluton were different on every previously published map, and age estimates ranged from Devonian back to Late Neoproterozoic. This project sought to resolve these problems by clarifying field relations, petrology, age, and tectonic significance of the pluton. Mapping in the summer of 2019 showed that pluton intruded the ca. 750–735 Ma Mount Ephraim plutonic suite on its southern margin and the Dalhousie Mountain Formation of unknown age on its western, northern and eastern margins. Petrographic study revealed that the pluton consists mainly of granodiorite gradational to monzogranite and tonalite, with minor co-mingled dioritic rocks, all cut by mafic and felsic dykes. Whole-rock chemical data from about 40 samples display trends consistent with a comagmatic relationship among the tonalitic, granodioritic, and monzogranitic rocks, and a compositional gap between them and the mingled dioritic rocks. They are calc-alkalic and likely formed in a continental margin subduction zone together with the associated dioritic rocks. U–Pb zircon LA-ICP-MS ages of 630.6 ± 2.7 Ma and 631.9 ± 3.3 Ma for granodiorite samples from the northern and southern parts of the pluton are consistent with petrological similarities which suggest that the cross-cutting Millsville fault does not have significant offset. Granitic and dioritic rocks from the southeastern part of the pluton have chemical characteristics which indicate that they are part of the Mount Ephraim plutonic suite rather than Gunshot Brook pluton, resulting in a revised map of the pluton. A dacitic tuff sample from the Dalhousie Mountain Formation gave an age of ca. 750 Ma, consistent with ages of ca. 735 Ma from the co-magmatic Six Mile Brook pluton. Because these plutons all differ in age from the ca. 620–600 Ma plutons typical of the Jeffers and Bass River blocks of the Cobequid Highlands, the Gunshot Brook pluton, Mount Ephraim plutonic suite, and Six Mile Brook pluton, together with their host rocks of the Mount Thom and Dalhousie Mountain formations, are assigned to a separate Mount Ephraim block, with as yet uncertain relationships to the rest of the Cobequid Highlands and to other parts of Avalonia where rocks of similar ages are rare.

Changing northern Appalachian geology, one U–Pb zircon date at a time

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Cape Breton Island has a lot of complex geology compressed into a small area – it provides a cross-section of the northern Appalachian orogen over an across-strike distance of only 140 km. Although differences in volcanic, sedimentary, and plutonic rock types, structure, and metamorphic grade have been known for decades, and interpreted in terms of Appalachian terranes, it is only with recent acquisition of numerous accurate and precise U–Pb zircon dates that the scale of the complexity has become clear. Also clear is the need to have well defined field relationships through detailed mapping and petrographic work in order to understand which ages are "real". For example, some igneous samples (e.g., Gillanders Mountain syenogranite, Salmon River rhyolite porphyry, Sporting Mountain pluton) contain large populations of inherited zircon grains that are significantly older than the true age, which may be represented by only few or no zircon grains. Inherited populations can be recognized by knowing the ages of other units in the terrane; for example, the Broad Cove diorite contains a ca. 500 Ma population (the actual age, matching nearby Cape Smoky granite) and a large 550 Ma population, matching ages from plutons hosting gold mineralization near the Eastern Highlands shear zone. The latter plutons contain large populations of ca. 566 Ma grains inherited from the ca. 560–570 Ma plutons characteristic of the Bras d'Or terrane. In complex terranes where successor volcanic arcs are emplaced within previous arcs and their associated sedimentary basins it becomes hard to unravel the individual arc histories. Age predictions based on degrees of alteration, metamorphism, or deformation are fraught with difficulty as well – the petrographically pristine Morrison Brook quartz monzonite is the same age (ca. 566 Ma) as the nearby "older-looking" altered and foliated Birch Plain Granite (569 Ma) which it intruded, indicating that strain localization in adjacent units can be a misleading factor in determining relative ages. Another example of potentially problematic U–Pb zircon data is found in metasedimentary rocks, illustrated in the MacMillan Flowage Formation of the Highlands. Here several quartzite and gneiss layers from a continuous section have radically different detrital zircon populations even though one can walk from one quartzite to the other. Correlation of rocks based on detrital zircon "signatures" without well-constrained field relationships is a problematic approach. These results have broad implications for equivalent terranes in Newfoundland and elsewhere in the Appalachian-Caledonide orogen, underlining the need for careful, systematic field mapping.

Towards a kinematic model for Iapetus Ocean closure

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Since the earliest days of plate tectonics, the evolution of the northern Appalachians and the Caledonides of the British Isles has served as a type example of the 'Wilson cycle' of ocean closing and opening. Orogen development has been illustrated using cross-section time-slices. This approach is valuable, but it leads to implicit assumptions that: (i) subduction was initiated at previously 'passive' continental margins; (ii) convergence was mainly orthogonal; and (iii) terranes and zones had ribbon-like geometry extending parallel to continental margins.

Although the Iapetus is often compared with the Atlantic, the post-Pangea tectonic evolution of continents and oceans provides little support for these assumptions. We propose to use the software GPlates to suggest alternative kinematic models for the Northern Appalachians and the Caledonides of Britain and Ireland that operate on the surface of a sphere. We will first restore the effects of Mesozoic extension and late Paleozoic strike-slip using previous estimates. We will then review the extensive data sets relating to (i) detrital zircon geochronology and (ii) paleomagnetism. This work will involve collation of data collected by different labs and using different criteria for the inclusion and exclusion of measurements. We will instead use a constant set of criteria in a review of the existing data. We will then attempt to reconstruct possible Ordovician to Silurian terrane paths that honour: the paleomagnetic data; provenance evidence of terrane linkages; and the stratigraphic records from various terranes. Preliminary results suggest that terranes

attributed to Ganderia and associated peri-Gondwanan arcs crossed the Iapetus in at least four pieces. Portions of "Ganderian" and "Avalonian" continental crust may have travelled together after being juxtaposed during Monian/ Penobscottian interaction on the margin of Gondwana, travels that involved along-margin strike-slip, transpression, and/or transtension.

Feasibility study for the application of riverbank filtration on the Shubenacadie River, Nova Scotia, Canada

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Riverbank Filtration (RBF) is an approach to water supply which, in some settings, meets high demands that a conventional well field could not. Although several municipal water supplies in Nova Scotia are known or suspected to be sustained in part by groundwater under the direct influence of surface water, intentional application of RBF has not been applied at the municipal or industrial scale. A feasibility study for an RBF system was completed at a site on the bank of the Shubenacadie River, Nova Scotia

Application of an RBF system would require that a continuous unit of sand and gravel is present under the river and at the adjacent bank where a RBF well would be installed. A successful well would draw water from the river, through aquifer material, and into an RBF collection system. Regional mapping shows granular material under and adjacent to the river in some areas. Exploratory boreholes helped to identify a local sand and gravel aquifer, extending from the study site and under the Shubenacadie River. Water level and conductivity data provided evidence of a direct connection between the tidally influenced river and the aquifer.

Aquifer testing and numerical modelling were used to estimate the efficiency and yield of a potential RBF system. The investigation suggested that relatively high yields could be achieved by installing a horizontal production well parallel to the river, similar to those reported by successful municipal RBF supplies. The quality and quantity of water available would be dependent on the tidal nature of the river.

Progress report on bedrock mapping in Munsungun Inlier, Maine in 2019: a completely revised Ordovician volcanic stratigraphy in Bald Mountain region

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Significant progress towards understanding the geology and tectonic history of Munsungun-Popelogan Arc has been made based on detailed bedrock mapping in Munsungun Inlier since 2016. In 2019 the mapping effort was focused on Bald Mountain-Bull Hill mineral district where the Bald Mountain VMS deposit (discovered in 1977 by John Cummings) and Bull Hill VMS occurrence are located. The district was mapped by Superior Mining and Chevron Resources in early-middle 1980s and then by USGS in late 1990s. As a result, a three-phase stratigraphic sequence was established. In this report, we present a completely revised stratigraphy based on new mapping results, which does not support the three-phase model. Mapping demonstrates that the Norway Bluff - Jack Mountain - Bald Mountain Mid-Ordovician volcanic arc belt is significantly vertically and horizontally displaced by a number of E-W-striking, NEE-striking, and NWW-striking post-Acadian transverse faults. As a result, the volcanic belt is crosscut into multiple faulted blocks. In Bald Mountain block, the volcanic sequence includes substantial submarine basalt with minor andesite, followed by thick pyroclastic tuff and lapillistone. The VMS deposit is hosted by the pyroclastic rocks. In Bull Hill block, the volcanic sequence consists of thick submarine basalt flows, a rhyolite layer, and a voluminous package of interbedded pyroclastic tuff (including maroon tuff), lapillistone, and breccia. The Bull Hill VMS occurrence is hosted by the lower part of the pyroclastic sequence. In previous studies, major part of the pyroclastic rocks at Bull Hill were mistaken as "graphitic slate" and "conglomerate" (of "Phase 3"). The west side of both Bald Mountain and Bull Hill sequences are underlain by Early Ordovician Chase Brook Formation mélange and slate which were mapped as part of "Phase 3" at Bald Mountain or "younger sediments" at Bull Hill in the "three-phase" model. Both Bald Mountain and Bull Hill volcanic sequences are structurally homoclinal, dipping gently to the west. They are stratigraphically and structurally different from the volcanic sequence in Greenlaw Mountain - Orcutt Mountain area in the south where the sequence was built initially by thick pyroclastic tuff, lapillistone, and breccia and followed by voluminous basalt flows with minor rhyolite, and structurally the southern area is synclinal. Comparably, all the eruptive sequences in the region were substantially intruded by dikes, sills, and stocks of dominantly comagmatic diabase and gabbro with a few of them being granodiorite and granodioritic porphyry. The differences in the eruptive sequences that all belong to the middle Ordovician Munsungun Lake Formation, demonstrate along-arc variation typical for arc volcanism.

Characterization of Co-Ni-bearing polymetallic vein occurrences of the Meguma terrane, Nova Scotia, Canada*

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Three polymetallic (Co-Ni-As-Sb-Pb-Zn-Cu-Bi-Ag-Au) vein occurrences, with a suspected but unproven genetic link, occur in the northwestern Meguma terrane of Nova Scotia. Considering the elemental assemblage, these occurrences may be of the "five element (Co-Ni-As-Bi-Ag) vein" association. This project aims to understand how the occurrences formed, including the timing of mineralization, source of metals and fluids, and mechanism(s) for mineralization, within a regional and global context (e.g., comparison to other five-element style deposits). Many world-class five-element deposits occur in the Variscan orogen in Europe, which is contemporaneous with the Appalachian orogen, and were mineralized during the opening of the Atlantic Ocean. In spite of the similarities in geological history of Meguma terrane rocks with those across the pond, there has yet to be a concerted exploration effort for deposits of this unique elemental association in Nova Scotia. This project aims to direct these efforts forward by providing geological constraints and exploration vectors for this type of mineralization.

Preliminary field work conducted at Cape St. Marys (CSM), Digby County, documented multiple generations of quartz veins, two generations of carbonate mineralization, and Fe-rich chlorite alteration crosscutting slate of the Bear River Formation and a mafic dyke. The veins crosscut an earlier ductile shear zone. The samples that were collected are mostly barren with minor pyrite. Fieldwork in 2020 will focus on mineralized zones (reportedly Sb-Pb-Ni-Co-Zn-Bi-Ag±Au) and determine the relationship between mineralization and the afore-mentioned alteration.

Drill cores of the Lansdowne Occurrence, Digby County, exhibit mineralized quartz-carbonate veins containing early stage arsenopyrite-pyrrhotite, followed by sphalerite-chalcopyrite and later jamesonite-boulangerite-pyrite. These veins crosscut mafic dykes which intruded metasedimentary rocks of the Bear River Formation. The host rocks are pervasively altered by carbonate.

The Nictaux Falls Dam Occurrence, Annapolis County, is characterized by arsenopyrite, cobaltite, gersdorffite, and gold-silver alloy hosted in quartz veins and stockwork, which crosscut metasedimentary rocks of the Kentville Formation. Mineralization is structurally controlled by a fault zone, proximal to mafic sills and the South Mountain Batholith. Mineralization is not associated with carbonate.

The association of mineralization with mafic dykes and sills, brittle deformation zones, carbonate alteration and Co- and Ni- sulfarsenides may indicate a genetic link among these occurrences. Future work (e.g., petrography/paragenesis of mineralization, fluid inclusion microthermometry, mineral chemistry of alteration minerals, stable isotopes of mineral pairs, radiometric age dating, trace element signatures of ore minerals) will constrain the timing and conditions of formation during the mineralization, and evaluate whether these occurrences share a similar genetic history.

**Honourable Mention: AGS Graham Williams Award for best graduate student poster*

A methodological approach to dating landslides along the Eastern Denali and Duke River faults, Kluane Lake, Yukon, Canada

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The Denali Fault system is an intracontinental, dextral strike-slip and thrust system that extends southeast from Alaska, through Yukon, into northwestern British Columbia. The Yakutat terrane is accreting into the North American plate at ~50 mm/year where strain is accommodated along these fault lines. As the system progresses eastward through southwestern Yukon, strain is prominently displayed as strike slip faults between the St. Elias Mountains and the Shakwak Trench, southwest of Kluane Lake. The Kluane Lake study area is prone to debris flows, rockslides, rockfalls, slumps, and complex landslides due to factors such as steep slopes, sporadic permafrost activity, fractured bedrock, copious amounts of surficial material available for remobilization, and seismic activity produced along the Eastern Denali and Duke River Faults. The purpose of this project is to determine the ages of rockslides in the area to help resolve which of these contributing factors initiated the landslides. To accomplish this, four rockslide sites were sampled and will be analysed through the use of terrestrial cosmogenic nuclides (TCN), radiocarbon dating, and dendrochronology to determine the ages of the

events. Three of the sites were chosen for their potential in ^{10}Be and ^{36}Cl TCN analysis, and a fourth site was selected for dendrochronology based on recent scarring and leaning coniferous trees. Previously conducted research by others on one of the four sites, the Sheep Mountain Landslide (SML), examined the composition and timing of events that occurred in this area; this research will be expanded upon through the use of structure from motion photogrammetry, drone imagery, and radiocarbon dating to more precisely examine and age the multi-phase event. White River Tephra, approximated to be A.D. 833–850, found at the SML corroborates the presence of at least two events as evidenced by the deposition of tephra between the rockslide deposits. Although the Denali Fault system has similar characteristics to the San Andreas Fault, the ages of landslides throughout this northern system have not been extensively dated. This project will serve as a basis for the cataloguing of landslide ages in the Kluane Lake area. As well, this project will facilitate future research into the frequency of landslide hazards in this economically viable area.

Zircon and apatite geochemical constraints on the formation of the Huojihe porphyry Mo deposit in the Lesser Xing'an Range, northeastern China

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Northeastern China is an important Mo resource region in China, with more than 80 Mo deposits and occurrences. The Huojihe deposit located in the Lesser Xing'an Range represents one of the many Mesozoic porphyry Mo deposits in NE China. In this study, magmatic zircon and apatite from the causative intrusions (biotite monzogranite and granodiorite) of the Huojihe deposit have been analyzed to reveal their chemical and isotopic compositions, which provide insights into the nature of the source magmas and attempt to clarify the possible mechanisms controlling Mo mineralization.

The zircon U–Pb dating shows that ore-bearing biotite monzogranite from the Huojihe deposit was emplaced in the early Jurassic (ca. 181.6 Ma), which is consistent with the previous molybdenite Re-Os age and granodiorite U–Pb age. The intrusion samples share homogeneous geochemical and Sr-Nd isotopic compositions, which indicate a uniform magma source. The Sr-Nd-Hf isotope results from whole-rock, apatite, and zircon samples suggest that the primary magmas associated with the Mo mineralization could have been generated from a dominantly Mesoproterozoic lower crust source, with rare contribution from the depleted mantle. The low Ga, Ce, but high Eu contents in the magmatic apatite demonstrate that the a relatively oxidized magmas, which is also supported by the high zircon Ce_N/Ce_N^* and Eu_N/Eu_N^* values.

Estimates of absolute sulfur concentrations in the mineralization-related melt using available partitioning models for apatite return relatively low magmatic sulfur concentrations in Huojihe (20–100 ppm), indistinguishable from those of larger or smaller deposits or even barren magmatic bodies. Using the sulfur concentrations, a minimum volume of 10–50 km^3 magma has been suggested to be necessary to produce the Huojihe Mo deposit based on mass balance modelling. The Mo concentrations in the original magma have also been roughly estimated based on magma volume and Mo content in Huojihe (0.275 Mt). The magmatic Mo concentrations (2–10 ppm) are similar to many other porphyry Mo systems (e.g., Climax-type), and are also comparable to subeconomic to barren magma systems. This study suggests that pre-degassing enrichments of Mo and S in the original magma were not necessarily important in the formation of the Huojihe Mo deposit; rather, factors other than melt composition may be more critical in forming a porphyry Mo deposit. This understanding might also apply to other porphyry Mo mineralized systems worldwide.

Metamorphism and tectonics of the Hunt River Greenstone Belt in Labrador, Canada

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The Hopedale Block of the North Atlantic Craton comprises primarily 3300–3100 Ma tonalitic to trondhjemitic gneiss and hosts two Archean greenstone belts, the Hunt River belt (HRB) (interpreted to be 3105 Ma old) and the Florence Lake belt (FLB), which is 2980–3003 Ma old. The HRB is well preserved and comprises heterogeneous mafic metavolcanic rocks with interlayered ultramafic and metasedimentary schist metamorphosed at upper greenschist- to lower amphibolite-facies. The present study constructs a detailed lithostratigraphic section of the

HRB and the immediate underlying Archean basement rocks with a specific focus on clarifying the relationships between mineral growth, deformation and metamorphic conditions in order to understand the evolution of the HRB. U–Pb dating by LA-ICP-MS of zircon in the underlying gneissic rocks records magmatism between 3300–3100 and 2898 ± 28 Ma. The contact between the basement gneissic rocks and the HRB is marked by a thin metapsammite layer, the lowermost and oldest rocks in the belt. U–Pb detrital zircon geochronology shows that this unit contains a unimodal age distribution ranging from 2950 to 2800 Ma with a weighted mean $^{207}Pb/^{206}Pb$ age of 2886.8 ± 3.3 Ma. The detrital zircon peak matches the age the 2898 ± 28 Ma orthogneiss. We identify the orthogneiss as a source for the detritus. The youngest cluster of detrital zircons (n = 5) at 2843 ± 18 Ma suggests that the maximum depositional age for the metapsammite is <2843 Ma. The HRB was therefore emplaced <2843 Ma. This means that the Hopedalian meta-deformational event interpreted to have taken place at ~3100 Ma is not recorded by the HRB lithologies. Deformation and metamorphism are, however, recorded by episodic growth of titanite in metabasaltic schist and gneiss. In situ U–Pb dating of titanite reveals multiple periods of growth between 2869 ± 19 Ma to 2667 ± 14 Ma within individual grains. LA-ICP-MS mapping reveals discrete compositional domains that can be related to syn-deformational amphibolite-facies conditions as well as younger greenschist-facies metamorphism associated with plagioclase breakdown and the growth of titanite with positive Eu*Eu anomalies. This new information can aid in the reconstruction of Archean-Paleoproterozoic orogenic belts as well as make connections to similar belts in Western Greenland.