

Geological Association of Canada Newfoundland and Labrador Section

ABSTRACTS

2018 Spring Technical Meeting

ST. JOHN'S, NEWFOUNDLAND AND LABRADOR

The annual Spring Technical Meeting was held on February 19 and 20, 2018, in the Johnson GEO CENTRE on scenic Signal Hill in St. John's, Newfoundland and Labrador.

This year Monday morning started with a session on Environmental Challenges followed by an afternoon session on Economic Resources and Tuesday featured an all-day session on Solid Earth. These sessions included oral and poster presentations from students and professionals on a wide range of topics. The Keynote Speaker was Dr. Peter Hollings from the Department of Geology, Lakehead University, Ontario, who presented a talk entitled "Using igneous petrology to unravel the tectonic triggers for porphyry mineralization". Dr Hollings is the 2017–2018 Geological Association of Canada's Howard Street Robinson Medal Winner and Lecturer. On Tuesday evening a Public Lecture entitled "Where does our 50% discount on global CO2 emissions come from and how might it respond to climate change?" was presented by Dr. Sue Ziegler, Professor and Canada Research Chair in Boreal Biogeochemistry, Department of Earth Sciences, Memorial University of Newfoundland and Labrador.

As always, this meeting is brought to you by volunteer efforts and would not be possible without the time and energy of the executive and other members of the section. We are also indebted to our partners in this venture, particularly the Alexander Murray Geology Club, the Johnson GEO CENTRE, Geological Association of Canada, Department of Earth Sciences (Memorial University of Newfoundland), and the Geological Survey of Newfoundland and Labrador, Department of Natural Resources. We are equally pleased to see the abstracts published in *Atlantic Geology*. Our thanks are extended to all of the speakers and the editorial staff of the journal.

JAMES CONLIFFE, STEFANIE LODE, ANNE WESTHUES, AND ALEXANDER PEACE
TECHNICAL PROGRAM CHAIRS
GAC NEWFOUNDLAND AND LABRADOR SECTION

Developing an algorithm for predicting stream dissolved organic carbon concentrations from UV-visible light absorbance

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The export of carbon from terrestrial ecosystems may constitute a significant and climate-responsive carbon loss from forests, impacting downstream aquatic ecosystems. However, the magnitude of terrestrial carbon mobilized from the landscape is difficult to accurately capture during typical sampling campaigns. Therefore, accurate and high-resolution determination of dissolved organic carbon (DOC), the major transport medium of carbon from terrestrial to aquatic ecosystems, is imperative.

To better determine DOC export from forests to headwater streams within Newfoundland and Labrador, we explored the relationship between light-absorbing chromophoric dissolved organic matter (CDOM) and bulk DOC. Such a relationship would allow for rapid prediction of DOC concentrations based on absorbance characteristics, and through usage of an in-situ spectrophotometer, high-resolution determination of exported DOC.

We modeled the CDOM-DOC relationship from 4 headwater stream catchments across the province, using ~240 discrete samples collected over 5 years. Due to the heterogeneous composition of DOC within headwaters, which can alter this relationship, we included samples representative of sources to our streams, including nearby soil and groundwater inputs. Parameters used in multiple regression models were varied in each iteration to capture potential spatial and/or temporal differences potentially affecting DOC prediction accuracy. The ability of each model to successfully predict future observations was assessed by calculating $R^2_{\text{Predicted}}$, while validation sets were further used to confirm model accuracy.

The most robust model ($R^2_{\text{Predicted}} = 0.90$, validation $R^2 = 0.83$) included a combination of all sample types (soil, stream and groundwater). However, prediction accuracy was reduced when the model was applied to samples from an additional forest catchment outside of the training sample set, suggesting a sensitivity of predicted DOC to catchment characteristics. Therefore, our results indicate the need for a catchment specific establishment of a CDOM-DOC algorithm before high-resolution estimates of carbon exports from terrestrial to aquatic environments can be accurately determined.

Recent advancements in scanning electron microscopy-mineral liberation analysis (SEM-MLA)

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Scanning Electron Microscopy-Mineral Liberation Analysis (SEM-MLA) has become an important and versatile analytical tool in mineralogical research. This project will present some recent advancements in sample preparation and analytical methodology, which contribute to increased accuracy, precision and throughput of SEM-MLA data.

The first advancement is the development of a single-step trans-vertical method for preparing epoxy grain mounts. Traditional round mounts can be affected by density stratification: heavier minerals sink through the epoxy as it cures, causing an over-abundance of heavy minerals on the analysis surface of the sample. The trans-vertical mounting method eliminates this density stratification bias and is less labour intensive than other multi step trans-vertical mounting methods. This method also leads to increased throughput as more unique samples can fit inside the SEM chamber than traditional 30 mm round mounts.

Another recent development is the ability to distinguish between hematite and magnetite via SEM-MLA. Typically, SEM-MLA used X-ray spectra to identify minerals based on reference spectra. However, in the case of hematite and magnetite, their X-ray spectra are virtually identical. Instead, a method is presented to distinguish between them based on their brightness in backscattered electron (BSE) images. Accurately distinguishing between hematite and magnetite in an economic iron ore deposit can lead to more accurate estimates of the grade of the deposit.

Taconian subduction zone paths of metamorphosed mafic rocks west of the Red Indian Line in Vermont, USA

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A north-south-trending swath of metamorphosed mafic rocks embedded within peri-Laurentian rift clastic rocks and slope-rise deposits west of the Red Indian Line in Vermont preserve the latest Cambrian–Early Ordovician (Taconian) subduction zone metamorphism. In northern Vermont, high pressure facies series subduction zone metamorphism is preserved between the Tibbit Hill volcanic rocks and the Burgess Branch fault zone, the southern extension of the St. Joseph fault/Baie Verte-Brompton Line in southern Quebec. Eclogite/blueschist of the Tillotson Peak Complex (TPC) marks the northernmost limit of subduction zone metamorphism and preserves the highest metamorphic

pressures in Vermont. The TPC is perhaps correlative with eclogite within the Fleur de Lys Supergroup on the Baie Verte Peninsula. South of the TPC, subduction zone metamorphism is inconspicuous and preserved only in the cores of zoned amphibole grains retained in greenstones and amphibolites. Electron microprobe studies show that amphibole cores are barroisite/winchite in composition, whereas amphibole rims are greenschist facies actinolite. In general, conditions of metamorphism for these barroisitic rocks are not well constrained. However, some insight into subduction zone conditions has been gained from barroisite-bearing greenstone within a tectonized ultramafic-mafic-pelitic package in central Vermont that marks the known southern limit of the Taconian subduction swath. Thermodynamic modeling and amphibole isopleth calculations show that barroisite/winchite in the tectonized package grew at ~ 0.95 GPa (~ 32 km) and $\sim 425^\circ\text{C}$ prior to penetrative greenschist-facies overprint; peak conditions are interpreted as lower blueschist facies.

Exhumation mechanisms for these mafic subduction zone rocks are still in question. Local geologic and structural relationships suggest that a serpentinite-rich channel above the subducting slab may have facilitated exhumation at the greatest depths, whereas a sediment- and fluid-rich subduction channel may have played a major role at shallower levels.

Hunting unconformities on Fogo Island and Change Islands, Newfoundland, Canada: stratigraphic constraints and preliminary U–Pb geochronological data

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Detailed mapping by students from Cambridge University (UK) in 2013 suggested that an important formational boundary on Fogo Island might instead be a cryptic unconformity. The strongest evidence is that upright volcanic rocks of the Brimstone Head Formation locally rest topographically above structurally inverted sandstones of the underlying Fogo Harbour Formation. A stratigraphic gap between the two formations also resolves some previously noted inconsistencies in their mutual contact relationships, and also with granites of the nearby Fogo Island Intrusion. To test this idea, U–Pb zircon ages (CA-TIMS) were obtained from the basal Brimstone Head Formation and from a felsic tuff unit close to the top of the Fogo Harbour Formation. The 421 ± 1 Ma age from the Brimstone Head Formation confirms that it is Silurian, and contemporaneous with at least some granites of the Fogo Island Intrusion. The zircon population from the Fogo Harbour Formation is more complex. Variably

discordant Precambrian ages (from 544 Ma to 1775 Ma) imply inheritance and/or a detrital component, but the youngest grains, superficially of magmatic appearance, are concordant at 440 ± 1 Ma. Such results imply a 20 m.y. time gap between the two formations, consistent with the cryptic unconformity hypothesis, but they are not fully diagnostic. Further work using methods with high spatial resolution (e.g., LA-ICPMS) is needed to better characterize the younger population and any detrital age spectrum, but this has so far proved difficult to facilitate.

On Change Islands, there is angular discordance at the contact between turbiditic sandstones assigned to the early Silurian Badger Group and subaerial volcanic rocks and terrestrial sedimentary rocks assigned to the younger Lawrenceton Formation. Deformed and altered diabase dykes are prominent within the Badger Group, but cannot be traced across this contact. Outcrops are obscured by later brittle faulting in many places, but sedimentary breccia-like rocks containing greywacke fragments exist locally beneath the pyroclastic flows. The features support previous interpretation from GSC mapping as an angular unconformity. This location has obvious potential for geochronological studies using both U–Pb and Ar/Ar methods, and interest in such research is invited. As the Lawrenceton Formation sits *beneath* rocks assigned to the Fogo Harbour Formation, this might be a discrete older unconformity, subject to the validity of stratigraphic correlations between the islands. An alternative interpretation is that the Brimstone Head and Lawrenceton formations are correlative (despite lithological contrasts) and that parts of the Fogo Harbour Formation should be reassigned. This less interesting option requires only one unconformity. There remain more questions than answers on both islands, but more investigation could give valuable insights into the timing of tectonic events and magmatism in this fascinating part of the Newfoundland Appalachians.

A new strategy for higher resolution time – lapse velocity inversion

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Time lapse seismic methods have been extensively used over the past two decades to monitor oil reservoirs under production. Time-lapse changes can result from amplitude changes and/or time shifts. Amplitude changes can be caused by new structures in the target area or reflectivity differences at interfaces. Time shifts are usually the result of physically shifted geological boundaries or velocity perturbations along the wave path. Understanding which of these two mechanisms control the observed time shifts

is important to better estimate and interpret the time-lapse changes. Full Waveform Inversion (FWI) is a promising tool for time-lapse seismic imaging and shows promise for this type of imaging. However, for a successful application of FWI, low frequency data and large offsets are required; these prerequisites are difficult to meet when we are interested in a small region. FWI is robust in recovering amplitude changes but is often not able to resolve the kinematics. Image Domain Wavefield Tomography (IDWT) is a method that uses migrated images along with a warping function to deliver a velocity model of the subsurface. This method is better at recovering time-shifts and can be applied without long offset data. In real case scenarios, the 4D signal is a complicated combination of time shifts and amplitude changes. This can result in a decrease in performance in both methods, depending on the nature of the complication. In this study, we present a form of time-lapse waveform inversion that we call Dual Domain time-lapse Waveform Inversion (DDWI), in which we combine FWI and IDWT in a single inverse problem. We test DDWI on several synthetic examples, and we observe that the method delivers more accurate results when compared to each of the methods used separately.

Provenance and porosity of onshore reservoir sandstones of the Anticosti Basin, western Newfoundland, Canada, using scanning electron microscopy combined with mineral liberation analysis (SEM-MLA)

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The Anticosti Basin of Atlantic Canada contains numerous conventional and unconventional hydrocarbon plays. This project applies an integrated field and laboratory approach to investigate the provenance and porosity evolution of Cambrian rift-drift and Ordovician foreland basin reservoir sandstones of the southern and central Anticosti Basin in the Port au Port peninsula and Bay of Islands areas of western Newfoundland. Polished thin-sections of the sandstones were analysed using SEM-MLA, which produces high-resolution digital maps that quantify the modal mineralogy, effective porosity, and grain-composition of the sample, including dissolution/precipitation reactions. This method was further successfully applied and tested on unpolished rock samples, such as thin-section cut-off blocks. The SEM-MLA is non-destructive and results simultaneously provide information regarding provenance and porosity without having to perform petrophysical procedures on the core, or detailed petrographical point-count methods on thin-sections.

SEM-MLA showed that the foreland basin sandstones contain chromite and mafic volcanic rock grains, which represent easterly-derived debris from ophiolite complexes, whereas the rift-drift sandstones typically have abundant lithic (igneous, metamorphic, sedimentary) grains and heavy minerals (e.g., garnet) with west-derived, Laurentian basement provenance. The high-resolution maps clearly delineate secondary dissolution porosity in K-feldspars and chloritized (ultra-) mafic volcanic rock grains, as well as carbonate cements that fill in initial macro pores. This feature allows the visualization of the spatial resolution of occurrences of porosity in relation to matrix, rigid, and ductile grains in the SEM-MLA maps.

These methods enable us to simultaneously identify the primary and secondary porosity textures and provenance characteristics of prospective rift-drift and foreland basin reservoir sandstones. The results of this study are of significance not only for petroleum industry and exploration of onshore sandstones in the Anticosti Basin, but also have exploration implications for other conventional sandstone reservoirs globally.

Computational modelling of geophysical data without meshing the physical models

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Geophysical data modelling involves synthesizing theoretical responses, i.e., measurements to be expected over a known physical model, namely, an Earth model with inhomogeneous physical properties in the subsurface. A key ingredient in the modelling is how to represent the geometries of the physical model, the so-called discretization, which will determine how much details of the model structure to be recovered and what might be the most suitable numerical mathematical method to do the modelling. This research focuses on modelling electromagnetic (EM) data for 3D Earth models with complex geometric structures. Complex Earth models can have arbitrary orientation and surface structure, and therefore are more realistic scenarios of the real world than simplified prisms and spheres. However, the discretization of such complex models in 3D is not a trivial task, since accurate geometric representation is not the only requirement; accuracy and efficiency of mathematical methods can also be significantly affected. Currently available modelling methods require the physical model meshed, and are sensitive to the structure of the discretization. These methods are hence called mesh-based methods. An alternative are meshfree modelling methods that do not generate meshes. An important advantage of meshfree methods is that numerical performance is much less dependent on the model discretization. Also, the creation of such discretization can be greatly simplified and

speeded up. We will introduce how one can apply meshfree methods to synthesize geophysical data, and present possible directions to the solution of EM data modelling with them.

Solid phase extraction of dissolved organic matter from across the terrestrial to aquatic interface

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Understanding the chemical heterogeneity of dissolved organic matter (DOM) originating from different land positions along the terrestrial to aquatic interface can provide insights into a poorly constrained global carbon flux. By applying holistic analytical approaches, such as nuclear magnetic resonance (NMR), the location and extent of transformation of terrestrial DOM in response to direct and indirect climate effects can be ascertained and contribute to our understanding of C-climate feedbacks.

Solid phase extraction via a styrene-divinylbenzene copolymer (SPE-PPL) is a chemical isolation method that is commonly used to prepare dissolved organic matter (DOM) samples for solution-state NMR analysis. Despite its growing popularity, SPE-PPL has been hypothesized to select against some major components of DOM; however, this is likely dependent upon how the SPE procedure is carried out. This study investigates how the methodological parameters used in SPE-PPL may affect extraction yields and selectivity of DOM sourced from different land positions along the terrestrial to aquatic interface (stream, soil and ground water). Quantitative analysis of dissolved organic carbon and nitrogen (DOC/DON) was used to assess the relationship between SPE-PPL yields and flow rate, sample volume and sample type. Solution-state hydrogen (H) NMR was performed to investigate how chemical selectivity may relate to DOC and DON yield and the SPE-PPL parameters used (e.g. sample volume and application rate).

Average SPE-PPL DOC yields ranged from 50–80%, while DON yields ranged from 15–40%. SPE-PPL yields and selectivity were independent of sample application rates. However, higher sample loading volumes of soil water DOM exhibited selective loss of O-alkyl C relative to aliphatic C. However, this volume dependent selectivity was not observed with groundwater where O-alkyl C represented a smaller fraction of the total DOM. This source dependency of volume-induced selectivity represents an important caveat for applying the SPE-PPL technique to DOM across the terrestrial-to-aquatic interface.

Mineralogical controls on carbon reservoirs across a boreal forest climate transect

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Boreal forests contain ~30% of global soil organic carbon (SOC) within a region that is predicted to undergo some of the greatest increases in temperature and precipitation over the next century, yet the controls on SOC reservoirs remain poorly understood. A considerable portion of SOC resides within the mineral soil, where mineralogy can play a significant role in its stabilization. The Newfoundland and Labrador Boreal Ecosystem Latitudinal Transect is a climate transect across boreal landscapes exhibiting increased temperature and precipitation similar to what is expected in the next century. The regions have common vegetation and soil type, but variable geological parent materials, allowing one to assess the impact of mineralogy and climate on C cycling in a natural system. In this contribution, the relationships between mineral soil characteristics and ecosystem parameters influenced by climate with SOC were assessed across this transect using an information theoretic approach. This method of model selection allows us to rank models by their ability to describe the response variable, an advantage here where multiple factors and their interactions potentially play a role. The strongest models, describing 81–83% of variance in SOC, included the poorly crystalline Al pool involved in podzolisation with either soil surface area or litterfall inputs. However, the Al pool was the stronger predictor variable, explaining 75% of the variance in SOC. The remainder variance of 17–38% may be described by dissolved organic carbon inputs, hydrology, or by temperature and precipitation, which were not included as they were captured in the regional effect. These results suggest that mineralogical mechanisms are more important for controlling SOC stocks in these mineral soils than forest inputs or climate effects. This may also be responsible for the observed maintenance of SOC stocks despite the increased fluxes into and out of these mineral soils across this climate transect.

Structural, petrological, and potential field analyses of the Mesozoic Notre Dame Bay intrusions, onshore Newfoundland, Canada, and their link to North Atlantic opening

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The magma-poor Newfoundland margin formed after a period of rifting, followed by breakup resulting in separation of the Grand Banks from Iberia, and northern Newfoundland from Ireland. Mesozoic–Cenozoic magmatic rocks have been documented on- and offshore Newfoundland that are contemporaneous with rifting and breakup, with further magmatism occurring offshore post-breakup.

One such occurrence of early rift-related igneous rocks is the group of Jurassic–Cretaceous intrusions near Notre Dame Bay, Newfoundland. Here, the Budgell Harbour Stock (BHS) is surrounded by multiple sets of lamprophyre dykes, in addition to the nearby, potentially related, Dildo Pond Intrusion and Leading Ticks Stock. Although exploration wells penetrate the BHS, it has minimal surface exposure, such that its deeper structure, magmatic evolution, and relationship to pre-existing structures remained unknown.

Here, the results of field-based geological mapping and petrological analysis, in addition to inversion of Full Tensor Gradiometry and aeromagnetic data, are presented to examine the deeper structure. Our results show that the lamprophyre dykes are located in clusters at the surface terminations of density anomalies, interpreted to be lobe-like magmatic conduits, contrary to earlier interpretations of the dykes as structures radiating from the BHS. Furthermore, the analysis demonstrates the irregular geometry and south-westward-dipping nature of the BHS, in addition to the presence of multiple, near-surface anomalies that may correspond to igneous bodies. The subsurface geometry of the BHS suggests emplacement was influenced by pre-existing structures. Structural analysis indicates that the dykes have both interacted with pre-existing structures and have been deformed post-intrusion, potentially via reactivation of pre-rift faults. In addition, lineation data from dyke margins and the potential field investigations suggest multiple dyke sources and bodies similar to the BHS may exist. Finally, this study demonstrates that margins considered to be non-volcanic may host significant rift-related magmatism, challenging the concept of a simple distinction between magma-rich and magma-poor margins.

Episodic lithospheric orogenic collapse of the Newfoundland Appalachian orogen

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The Appalachian orogen is a linear mountain belt formed by the early Palaeozoic closure of the Iapetus and Rheic oceans and is considered to be the classic example of an ancient accretionary–collisional orogen. In contrast to continent–continent type collisional orogens, the tectonic evolution of the Appalachians records a complex history resulting from the sequential accretion of a collage of numerous oceanic and continental arc terranes and microcontinents to the margin of Laurentia.

Continental convergence in arc–continental and arc–arc collision zones results in crustal shortening and elevated topography that is controlled by the mechanical balance between the horizontal stress of tectonic convergence and vertical compression caused by gravity. Any change in the regional stress equilibrium will disrupt the gravitationally unstable crust and cause the elevated surface to extend resulting in a loss of topography. Extensional tectonics as a mode of deformation in shortened and thickened lithosphere has been reported as a feature in several orogens: e.g., present Tibetan plateau; Miocene Alps; Palaeozoic Caledonides; and Proterozoic Grenville Orogen.

The model proposed focuses on the role of repeated extensional deformation in the Ordovician–Silurian–Devonian Appalachian orogen of Newfoundland; areas of brittle detachment have been previously attributed to Taconic faults reactivated due to collision-related thrusting during Acadian tectonism. I suggest that the Appalachian orogen in Newfoundland has undergone at least two episodes of extensional collapse in the Late Ordovician and Late Silurian, related to separate arc–continent and arc–arc collisions responsible for the Taconic and Salinic orogenies, respectively. The model accounts for many features in Newfoundland including—but not limited to—development and exhumation of metamorphic core complexes, prominent regional unconformities, tectonic reactivation of obducted ophiolite sequences, intrusion of bimodal plutons, eruption of subaerial volcanic rocks, extensional faulting, and rapid denudation of the uplifted orogen.

Aggregation of nTiO₂ and illite colloids: effect of co-presence of phosphate and calcium

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The stability and aggregation of nanoscale and colloidal-sized fine particles, which are commonly found in soil and

groundwater, have important implications to water quality and contaminant transport. Extensive studies have been conducted on the aggregation of nanoscale titanium dioxide particles ($n\text{TiO}_2$) and illite colloids under simple water chemistry conditions. In natural aquatic systems, however, water chemistry could be complicated and suspended $n\text{TiO}_2$ and illite particles could encounter multiple water components simultaneously, yet, the combined effects of some components have not been investigated. In this study, the aggregation of $n\text{TiO}_2$ and illite colloids was examined in the presence of phosphate (0.1 mM) and Ca ions (0.5 mM) at different pH and under low ionic strength conditions (1.5 mM). Results obtained from the batch experiments indicated that the hydrodynamic diameter of the $n\text{TiO}_2$ was strongly influenced by phosphate and Ca ions, which both modified $n\text{TiO}_2$ surface charges. Calcium cations also had a substantial effect on the zeta potential of $n\text{TiO}_2$ at pH 9 where the particles were positively charged for any phosphate concentration up to 0.1 mM. Illite aggregation was studied under the same water chemistry conditions. Results showed that illite colloids carried negative charge at pH 5 and 9 and the presence of phosphate and Ca did not have a substantial effect on the zeta potential and hydrodynamic diameter of the particles. This study revealed that the combined effect of Ca and phosphate on the aggregation of the $n\text{TiO}_2$ can be different from that of their individual influence. In addition, natural suspended particles, including illite, can be much less sensitive to the water chemistry compared to the engineered metal nanoparticles such as $n\text{TiO}_2$. These findings are important for understanding of the fate and transport of $n\text{TiO}_2$ and illite in natural aquatic systems where various anions and cations coexist.

Petrographic, geochemical, and sulphur isotope studies of the Montagnais Gabbro, the Labrador Trough, Canada – Implications for Ni-Cu-PGE exploration potential

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The Labrador Trough is a Paleoproterozoic (2.17 to 1.87 Ga) fold and thrust belt straddling the Québec-Labrador boarder. The Labrador Trough comprises the Kaniapiskau Supergroup, which was intruded by the Montagnais Gabbro sills (1884 ± 1.6 Ma). The Ni-Cu-PGE potential of the Montagnais Gabbro has been recognized since the 1950s. Recent exploration results from the Northern Shield Resources (NSR) Huckleberry Prospect in Québec have highlighted the potential for new discoveries in this underexplored region. Fieldwork was completed in 2017

and lithological samples collected from gabbro sills and sulphide-rich shales within the Howse Lake and the Moss Lake areas, as well as from the Huckleberry prospect, 100 km north along strike in Québec. Whole rock geochemical data, including Pt, Pd and Au assays, were used to quantify possible Ni-Cu-PGE enrichments in the sulphide-rich gabbro samples. In addition, the data were used to assess the potential of these gabbro sills to host economically significant base-metal occurrences. Mineralized gabbro samples from the Howse Lake and Moss Lake areas were analyzed by Scanning Electron Microscope-Mineral Liberation Analysis (SEM-MLA) to provide detailed petrographic information on sulphide minerals, to locate and identify platinum group minerals (PGMs), and to ascertain their relationship with sulphide and silicate minerals. Secondary Ion Mass Spectrometry (SIMS) microanalyses were used to determine the stable S-isotopic ($\delta^{34}\text{S}$) ratios of pyrrhotite and chalcopyrite within the mineralized gabbros and sulphide-rich shales proximal to the gabbro sills. Thus, the S-isotopic data provide insight into the S source and amount of contamination related to the melting of the host shales. Results obtained from the three areas will be compared to determine factors, which may have contributed to the mineralization, as well as to classify the occurrences within a deposit model.

A fresh perspective on the middle Cambrian trilobites from Manuels River, Conception Bay South, Newfoundland, Canada

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The trilobite-rich middle Cambrian strata at Manuels River, Conception Bay South (CBS), Newfoundland and Labrador, were originally described by B.F. Howell in 1925. Howell identified and described a sequence of 125 discreet beds through his study area, comprising the Chamberlains Brook Formation (beds 1–35) and the overlying Manuels River Formation (beds 36–125). These formations are dominated by green, grey or black shales interbedded with minor to massive limestone deposits, achieving a combined total thickness of just under 100 m. Howell also provided a detailed description of the fossil fauna associated with this sequence, which is dominated by trilobites from the Orders Redlichiida, Ptychopariida, and Agnostida. In 1962, R.D. Hutchinson re-examined the trilobite fauna of this sequence as a part of a description of Cambrian stratigraphy and trilobite palaeontology in southeastern Newfoundland. While there have been subsequent studies examining specific components of the middle Cambrian trilobite fauna from Manuels River and associated localities,

there has been no systemic overview of the trilobite fauna from this sequence in several decades.

The Manuels River Hibernia Interpretation Centre is located adjacent to the CBS Highway in Manuels, approximately 2 km southward from the end of Manuels River. Although the primary mandate of this facility is education, work has commenced there to re-examine the middle Cambrian trilobite fauna found on the river. Preliminary efforts will include a summation of the previously published literature relevant to the trilobite fauna of the area. Longer term goals include bed-by-bed collection of new material throughout the entire middle Cambrian sequence on Manuels River, followed by identification and description of this new material and reconsideration of the present fauna in regional and global contexts.

Constructing a crustal-scale 3D Earth model of offshore-to-onshore western Newfoundland, Canada, using seismic reflection, gravity, magnetic, and well data

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Western Newfoundland is characterized as a geologically complex zone. It records multiphase deformation of a Cambrian–Ordovician passive margin and Ordovician to Devonian foreland basins formed during the Taconian, Salinian, and Acadian orogenic events. Hydrocarbon seeps are known to occur in western Newfoundland and the area contains three main basins capable of generating oil: the Anticosti Basin, the Deer Lake Basin and the Bay St. George sub-basin. These basins have been important targets for petroleum exploration and they have proven oil accumulations and oil potential.

Geophysical studies in western Newfoundland have mainly focused on petroleum exploration and understanding the development of the Appalachian Mountains in the region. Seismic acquisition in this area was performed prior to 2000 and in many cases, the data are poor and difficult to interpret. However, potential field methods, such as gravity and magnetic methods can be useful for studying complex regions, as they can build a bridge between seismic studies. Constrained gravity and magnetic studies have been used before in different geological areas and they have provided interpretable results down to the lithospheric scale.

No comprehensive attempt has been made to incorporate gravity and magnetic data from Western Newfoundland into tectonic models. Accordingly, this research project aims to provide new information at a regional scale to better understand the complexity of the Appalachian structure and how it may have evolved by constructing a crustal-scale 3D Earth model of offshore-to-onshore western Newfoundland using seismic reflection, gravity, magnetic, and well data.

The Satellite gravity data from the WGM2012 model and the high resolution magnetic data were analyzed using mathematical tools such as Euler Deconvolution, Spectral Analysis, and Curvature. These results, along with a refraction seismic profile, are used as a first approach to build the 3D model. The interpretation of selected seismic lines and well data further constrained the model. The preliminary results show interesting geophysical behaviour offshore western Newfoundland that possibly are caused by crustal faults or fractures and which have not yet been investigated in detail.

Simultaneous in-situ U–Pb dating and Hf-isotope ratio determination of zircons with laser ablation ICP-MS

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Laser ablation inductively coupled plasma-mass spectrometry (ICP-MS) has become a common method for U–Pb dating of zircon, especially when large numbers of grains have to be analyzed. The same is valid for laser ablation multi collector ICP-MS Hf isotope determination in zircons. These two measurements are commonly done independently, leading to a potential mismatch of ages and Hf isotope ratios in heterogeneous grains. Recently, some laser ablation ICP-MS laboratories introduced a split stream approach, where the laser ablation aerosol is split into two parts. One part is used for U–Pb dating, commonly on a single collector ICP-MS, the other part is used for Hf isotope determination on a multi-collector ICP-MS. This method allows a simultaneous in-situ determination of both, the U–Pb dating and the Hf isotope determination. This split stream approach has been implemented at Memorial University and the performance of the setting is presented here.

The 91500 zircon is commonly used as primary standard for dating; however, over the past few months, secondary zircon standards (Plesovice, 02123, Temroa-2) were also analyzed. These yielded average $^{206}\text{Pb}/^{238}\text{U}$ ages of 336.5 ± 0.7 Ma for Plesovice (comparably, data obtained using isotope dilution-thermal ionization mass spectrometry (ID-TIMS) yielded 337.13 ± 0.37 Ma); 291 ± 1 Ma for 02123 (ID-TIMS: 295 ± 1 Ma); and 412.9 ± 2.1 Ma for Temora-2 (ID-TIMS: 416.78 ± 0.33 Ma). The accuracy of mass interference and mass bias corrections applied to $^{176}\text{Hf}/^{177}\text{Hf}$ are validated by analyzing synthetic zircons doped with Lu and Yb, along with natural zircon standards. Recent results include $^{176}\text{Hf}/^{177}\text{Hf} = 0.282302 \pm 38$ for 91500 (solution ICP-MS: 0.282308 ± 6) and $^{176}\text{Hf}/^{177}\text{Hf} = 0.282757 \pm 45$ for R33 (solution ICP-MS: 0.282764 ± 14).

New age constraints in the St. Alban's map area, southern Newfoundland, Canada

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The St. Alban's map area in southern Newfoundland (NTS 01M/13) is the focus of a bedrock mapping project and incorporates detailed magnetic and radiometric airborne geophysical data. A major feature of this area is the Day Cove Thrust that defines the boundary between the Gander Zone and the Exploits Subzone of the Dunnage Zone. The Little Passage Gneiss of the Gander Zone is intruded by the Gaultois Granite and Northwest Brook Complex in the southwest corner. The Baie d'Espoir Group of the Dunnage Zone is intruded by the North Bay Granite Suite in the west.

Litho-geochemistry of felsic to mafic metavolcanic rocks of the Baie d'Espoir Group shows distinct features of subduction-related processes, suggesting an emplacement of these rocks in an intra-oceanic island-arc volcanic environment. A metavolcanic rhyolite of the Isle Galet Formation was dated by isotope dilution-thermal ionization mass spectrometry (ID-TIMS) U–Pb zircon geochronology and yielded a Darriwilian age of 465.73 ± 0.46 Ma, which is slightly younger than, but overlaps within error of, a Dapingian age (468 ± 2 Ma), previously determined for a felsic metavolcanic of the Twillick Brook Member of the St. Joseph's Cove Formation. A non-foliated post-tectonic quartz monzonite is dated at 419.65 ± 0.46 Ma and provides a limit on the end of deformation during the Salinic orogeny.

Several sulphide- and Au-mineralized quartz veins and base-metal massive sulphides occur within the Baie D'Espoir Group, which has been a focus of exploration activity in the area for its base metal, Sb, As, and Au potential. New Au and Ag anomalies have been identified as a result of this mapping project.

MLA-SEM and fluid inclusion analyses – A twin-track approach to the study of cuttings from the Margaree A-49 well, offshore Newfoundland and Labrador, Canada

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This study is based on twenty-one cuttings samples from the Margaree A-49 well in the East Orphan Basin, offshore Newfoundland; eight samples were from the Upper Cretaceous limestone (Wyandot Formation equivalent) and thirteen from two different sandstone intervals, defined as Targets A and B, within the Upper Jurassic Tithonian-aged interval (Jeanne d'Arc Formation equivalent). Mineral liberation analysis–scanning electron microscopy (MLA-SEM) techniques were used to evaluate both stratigraphic relationships within well and detritus provenance in all samples, and aqueous and hydrocarbon-bearing fluid inclusions (FIs) were examined from the thirteen Jeanne d'Arc Formation equivalent samples.

The MLA-SEM analyses indicate that the two sandstone intervals were composed of well to moderately sorted, subangular to subrounded, high sphericity detrital quartz grains, but the intervals also exhibit distinctive mineralogical and physical attributes. Texturally, Target B sandstone appears to be slightly more mature than Target A sandstone as indicated by better sorting and grain sphericity in the former. Mineralogically, the Target B sandstone appears to contain an enhanced igneous input, as suggested by Heavy Mineral indices calculated for the samples from the MLA data. Also, Target B sandstone contains enhanced siderite cement compared to Target A sandstone, suggesting an increased availability of iron within the former interval. The MLA-SEM analyses suggest that the uppermost limestone sample (Wyandot Fm. equivalent) was hydrothermally altered, possibly in near surface conditions, as it is the only limestone sample that contains Mn-bearing mineral phases and the only one that experienced significant dolomitization.

FI studies identified the presence of aqueous (2–20 µm) and hydrocarbon-bearing (<2–15 µm) fluid inclusions. Microthermometric data from the aqueous FIs indicate the presence of two distinct fluids: a low salinity-medium temperature fluid (~1 eq. wt.% NaCl and ~118°C) and a medium salinity-low temperature (~4 eq. wt.% NaCl and ~82°C) fluid. The hydrocarbon-bearing FIs (HCFI) exhibit a yellow/green fluorescence colour indicating oil with an estimated API gravity of 30°–35°. They occur along grain boundaries and in annealed microfractures suggesting at least two hydrocarbon trapping events. In general, the HCFI-bearing samples were identified by the MLA-SEM as being more mature with significant remnant carbonate cement.

The twin-track approach adopted for this project facilitates the generation of data on provenance, stratigraphic relationships and oil charge history. The material used for this study was drill cuttings, which are typically very challenging to use for petrographic and textural studies due to their broken, fine-grained, disaggregated nature (in contrast to competent drill core). The MLA-SEM grain mounts and FI wafers offer an alternative, reliable means of generating quantifiable provenance, depositional environment, and oil charge data from such material.