Atlantic Geology
Journal of the Atlantic Geoscience Society
Revue de la Société Géoscientifique de l'Atlantique

Atlantic Geoscience Society Abstracts: 45th Annual Colloquium & General Meeting 2019

Volume 55, 2019

URI: https://id.erudit.org/iderudit/1060420ar
DOI: https://doi.org/10.4138/atlgeol.2019.005

See table of contents

Publisher(s)

Atlantic Geoscience Society

ISSN

0843-5561 (print)
1718-7885 (digital)

Explore this journal

Cite this document

(2019). Atlantic Geoscience Society Abstracts: 45th Annual Colloquium & General Meeting 2019. *Atlantic Geology*, *55*, 163–211. https://doi.org/10.4138/atlgeol.2019.005

Atlantic Geoscience Society

ABSTRACTS

45th Colloquium & Annual General Meeting 2019

Fredericton, New Brunswick

The 2019 Colloquium and Annual General Meeting were held at the Fredericton Inn, Fredericton, New Brunswick, on February 8th and 9th. On behalf of the society, we thank Colloquium organizers Jim Walker, Mike Parkhill, Rob Raeside, Reg Wilson, Anne Timmermans, and David Lentz, as well the numerous student volunteers and judges, for facilitating an excellent meeting with a total of 91 abstracts. AGS acknowledges support from the corporate sponsors of the meeting: the New Brunswick Department of Energy and Resource Development, Engineers and Geoscientists New Brunswick, Nova Scotia Department of Energy and Mines (Geological Surveys Division), Nova Scotia Department of Energy and Mines (Petroleum Resources Division), University of New Brunswick Fredericton, Quartermain Earth Science Centre, Osisko Metals Incorporated, Terrane Geoscience Incorporated, and Trevali Mining Corporation.

In the following pages, we are pleased to publish the abstracts of oral and poster presentations from the meeting, which included the following Special Sessions: (1) Mapping, Petrology, Geochemistry, and Mineral Deposits: In Memory of Dr. Trevor MacHattie (1974–2018); (2) Paleontology and Sedimentology in Atlantic Canada: In Memory of Dr. Ron Pickerill (1947–2018); (3) Current Research in Carboniferous Geology in the Atlantic Provinces; (4) Minerals, Metals, Melts, and Fluids Associated with Granitoid Rocks: New Insights from Fundamental Studies into the Genesis, Melt Fertility, and Ore-forming Processes; (5) Earth Science Outreach in the Maritime Provinces; and (6) Geohazards: Recent and Historical. As always the conference included a General Session on Current Research in the Atlantic Provinces.

Also included with the conference were two half-day workshops: (1) "Structural Controls on Gold Deposits" by Stefan Kruse (Terrane Geoscience Incorporated); and (2) "Creating Beautiful, Effective, and Reproducible Graphics for Geoscience using R" by Dewey Dunnington (Dalhousie University). A teacher's workshop and an evening Earth Science Café, organized by Anne Timmermans (University of New Brunswick, Quartermain Earth Science Centre) were also part of the weekend.

THE EDITORS

ATLANTIC GEOLOGY 55, 163 - 211
(2019) 0843-5561|19|00163-211 $8.35|0

doi: 10.4138/atlgeol.2019.005

Assembling granitoid batholiths: the petrogenesis of the Donegal batholith, Ireland

Donnelly B. Archibald[1], J. Brendan Murphy[1], Joseph Dunlop[2], and Robin A. Strachan[2]

1. Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia B2G 2W5, Canada <darchiba@stfx.ca> ¶ 2. School of Earth and Environmental Sciences, University of Portsmouth, Portsmouth, United Kingdom

Granitoid rocks (*sensu lato*) are the crustal legacies of thermal disturbances that initiate melting in the mantle and along the base of the crust. Buoyancy contrasts and the exploitation of favorable structures facilitate the upward transport of magma and the assembly of large, composite batholiths. Despite more than a century of research, their origin, melting duration, influence of magma source(s), mode(s) of emplacement, and the relationship to orogenic events remain poorly understood. Traditionally, the study of granitoid batholiths used a combination of field relationships, whole-rock geochemistry, and entire-mineral dating. However, important petrogenetic questions were not resolvable with the techniques available. The advent of new petrochronological (determination of how rocks or minerals grow with time) and micro-beam analytical techniques provide data with a high spatial resolution for unravelling the evolution of complex igneous systems. Micro-beam methods permit the rapid collection of "time-stamped", isotopic and geochemical datasets with the ability to document geological variability at the micron scale in minerals. Evaluating how the isotopic and trace element compositions evolve will elucidate the sources and processes operating during batholith emplacement. The Silurian to early Devonian Donegal batholith is a classic example in Ireland of a composite batholith emplaced over ca. 30 myr. Emplacement of the batholith resulted from episodic magma pulses following oceanic slab failure (break-off) after the Iapetus Ocean closed during the Ordovician. New in-situ LA-ICP-MS zircon U–Pb geochronological data and in-situ LA-ICP-MC-MS zircon hafnium isotopic data, in addition to complementary whole-rock geochemical and petrographic data, provide important petrogenetic information about the magma sources and processes that were active during the assembly of the Donegal batholith.

Carbonate cement within strata of the Pennsylvanian Grande Anse Formation, southeast New Brunswick, Canada

Fadel Bahr and Dave Keighley

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 9P3, Canada <fbahr@unb.ca>

The Grande Anse Formation comprises a Lower Pennsylvanian sedimentary succession deposited in the western Cumberland Basin of the regional Maritimes Basin complex. The succession is interpreted to have formed within fluvial channel, floodplain, and non-channelized environments. Sandstone and conglomerate beds contain carbonate cements, the distribution and origin of which are being investigated using optical microscopy, scanning electron microscopy (ESM), X-ray fluorescence (XRF), and cathodoluminescence (CL). The overall diagenesis of the Grande Anse Formation is characterized by dissolution and alteration of framework grains, and by crystallization of iron oxides, kaolinite, pyrite, and several generations of silica and carbonate cements. Broadly, three types of carbonate cements are identified: calcite, dolomite, and siderite. These cements are more abundant in the coarser grained beds from the lower part of the formation, with clay minerals and greater compaction more common up-section.

Several different carbonates have been identified. The abundance of floating grains and non-ferroan poikilotopic calcite cements that fill large pores indicate early precipitation prior to significant compaction. In the lower part of the section these cements have generally prevented further diagenetic alterations and mechanical compaction, except for a later stage partial dissolution of unstable detrital grains. These cements most likely precipitated from vadose waters during eodiagenesis before the transformations of the clay minerals and release of iron and manganese that substitute for calcium in later stage carbonate. The later, high Mn- and Fe-calcite cements fill fractures and secondary pores of leached k-feldspar. The Scanning Electron Microscope shows neocrystallization of high Mn- and Fe-calcite and variably Fe-rich dolomite in conglomerate and coarse sandstone units. In addition, chalcedonic silica and prismatic silica zoned by microcrystalline carbonate indicate an episode of chertification that may accompany dissolution of existing carbonate during late eodiagenesis and/or mesodiagenesis.

The source and fate of intact polar lipids in the hydrothermally altered sediments of the Cathedral Hill vent system, Gulf of California, USA

Jeremy N. Bentley[1], Carl A. Peters[1], G. Todd Ventura[1], Connor J. Dalzell[1], Stefan M. Sievert[2], and Jeffrey S. Seewald[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <jeremy.bentley@smu.ca> ¶
2. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, USA

Intact polar lipids (IPLs) are frequently used as biomarkers for living microorganisms in sedimentary environments. Therefore, these compounds can potentially be used to track the habitable range or thermal limits of the subsurface biosphere. Upon senescence of a cell, IPLs quickly lose their polar head groups, leaving thermally more stable core lipids (CLs) that can become further degraded and bound into the sedimentary organic matter. For this study, we are evaluating the source and fate of IPLs and CLs within the pyrolytic conditions naturally present at Cathedral Hill, a sedimented hydrothermal vent system, in Guaymas Basin, Gulf of California. Here, in situ petroleum formation may be occurring as organic-rich sediments are exposed to high temperature conditions that are projected to reach up to 155°C within 21 cm sediment depth. This study is tracking the distribution of IPLs and CLs to (1) assess the microbial community that inhabits these sediments at a chemotaxonomic level, (2) determine the thermochemical stability of these lipids, and (3) track the degradation pathways that may result from their pyrolytic conversion into hydrocarbons. Thus far, we have identified and quantified bacterial and archaeal IPLs and CLs in a core transect extending from the center of the vent complex to the exterior of an overlying *Beggiatoa* microbial mat. Identified compounds include archaeal IPLs and CLs, such as archaeol (AR, 1G-AR, 2G-AR, 1MeC-AR), glycerol dialkanol diethers (GDDs, OH-GDDs), and gycerol dialkyl glycerol tetraethers (1G- and 2G-GDGTs, iGDGTs, brGDGTs). Also present in the samples are multiple unknown phospholipids that are likely bacterial in origin. Some of the identified compounds have distinct stratigraphic trends. For example, 2G-GDGTs, possibly derived from methanotrophs, were extracted from sediments ranging up to ~50°C. The 1G-GDGTs, likely sourced from hyperthermophilic archaea, are observed in sediments reaching ~145°C, which sets a new record for the threshold of life. The abundance of core iGDGTs also decreases with sediment depth; however, only minor biphytanes (break-up products of GDGTs) have been found. This suggests that at high vent temperatures either more time is needed to crack the lipids into hydrocarbons, or there are microbial processes preventing breakdown.

The lower Paleozoic, offshore Labrador, Canada: insights into the paleoenvironments and depositional realms from core and thin section analyses

Nikole Bingham-Koslowski and Tannis McCartney

Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada <nikole.bingham-koslowski@canada.ca>

Lower Paleozoic strata encountered in seven wells in the Hopedale Basin (offshore Labrador) are commonly associated with Cretaceous syn-rift structures. These strata are not laterally continuous, and inadequate biostratigraphic data prevents well-to-well correlation of the Paleozoic section. This study presents a detailed lithological analysis of Paleozoic conventional cores and associated thin sections from the Labrador margin, provides preliminary paleoenvironmental interpretations, and assesses whether lithological comparisons are sufficient for determining possible relationships between the Paleozoic strata of the margin in the absence of reliable age data.

Of the seven wells, conventional cores were collected from Paleozoic strata in (from north to south): Gudrid H-55, Roberval K-92, Indian Harbour M-52, and Freydis B-87. The lithology and paleontology of six cores and 43 thin sections from the four wells have been documented. The cores range from solid dolostone to predominantly limestone; the degree of diagenesis decreases southwards. The cores from Gudrid H-55 (core 1) and Roberval K-92 (cores 6 and 7) have been pervasively dolomitized, resulting in the destruction of any original fossil content. An unidentified hydrocarbon is observed within fractures and pore spaces of both Roberval K-92 cores. The Paleozoic rocks at Indian Harbour M-52 (core 1) consist of a fossiliferous wackestone having a microbial mud matrix that contains a significant amount of dolomite, including hydrothermal dolomite. Core 1 from Freydis B-87 represents the only siliciclastic Paleozoic rocks in the Hopedale Basin, and consists of interbedded mudstones, siltstones, sandstones, and carbonate units. Ichnofacies, sedimentary structures (ripple cross-laminations and planar laminations) and fossils from the carbonate sections are characteristic of a shallow marine depositional environment for this interval. A fossiliferous wackestone exhibiting preferential dolomitization of argillaceous stringers comprises core 2 from Freydis B-87.

Despite the similarities in the composition of the cores from Gudrid H-55 and Roberval K-92, the high degree of alteration prevents any direct correlation between these wells. The strata from Indian Harbour M-52 is comparable in lithology to core 2 from Freydis B-87, and shares a similar fossil suite characteristic of a low-energy, shallow marine environment (*Girvanella*, shell fragments, bivalves, brachiopods, crinoids, gastropods, sponge spicules, bryozoans, dasycladacean

green algae, trilobites, and ostracods). This suggests that the two intervals can be correlated, although a biostratigraphic analysis is recommended to confirm this.

Electrical resistivity tomography to monitor for seepage at an embankment dam abutment

Daniel E. Boulay and Karl E. Butler

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <dboulay@unb.ca>

Concrete structures at the Mactaquac hydroelectric generating station, located on the Saint John River near Fredericton, New Brunswick, are experiencing an aggregate-alkali reaction, causing them to expand. It has been hypothesized that differential expansion of the concrete abutment to the embankment dam could lead to elevated seepage along that interface. We are developing a 3D resistivity imaging system, installed on the back of the dam, which will be used to monitor for anomalous seasonal and spatial variations in resistivity that may be caused by such seepage. The electrical resistivity of earth materials is sensitive to changes in water saturation, pore fluid temperature, and total dissolved solids, all of which may change seasonally inside the dam in response to changes in headpond temperature and solute load. To start, we will identify zones inside the dam where resistivity variation with the changing seasons is anomalously high, suggestive of changes in temperature, water conductivity and/or moisture content arising from concentrated seepage. Observed seasonal changes in resistivity within different parts of the embankment will be compared to those expected based on prior modelling of seasonal variations in temperature accompanying bulk seepage. The study will also investigate best practices for making automated reliable, repeatable measurements of resistivity year-round despite typical challenges associated with electrode installation, ground freezing and electrical noise at dam sites in northern climates. Repeated measurements of the annual cycle of resistivity within the dam will complement ongoing monitoring of temperature using Distributed Temperature Sensing (DTS), thereby strengthening seepage monitoring at the embankment's interface with the concrete Diversion Sluiceway.

The January 10th, 2019 Westfield earthquake and related seismicity in southern New Brunswick, Canada

Kenneth B.S. Burke[1] and Maurice Lamontagne[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <kbsb@unb.ca> ¶ 2. Geological Survey of Canada, Ottawa, Ontario K1A 0E8, Canada

A magnitude (m_n) 3.8 earthquake occurred on January 10th, 2019, with an epicentre close to the town of Westfield in southern New Brunswick. The earthquake was recorded on seismographs in Canada and adjacent USA. The presence of a strong Rayleigh surface wave (R_g phase) on most of the seismogram traces suggests a shallow source; a depth of 2 km is listed by Earthquakes Canada. The latter agency received close to 400 felt reports on their on-line questionnaire and assigned intensities on the Modified Mercalli scale ranging from I (felt) to VI (cracks, fall of objects) for this earthquake. The event was strongly felt (sharp jolt, felt vibrations) in Grand Bay, Rothesay, Saint John, and Westfield, all within 20 km of the epicentre. An earthquake in the same area on April 14th, 1909, had a felt area corresponding to magnitude (m_b) 3.4, but this event was reportedly felt only in Lingly, Welsford, and Westfield. Other earthquakes of similar and larger magnitudes have occurred in the region stretching from Saint John to Moncton. Although no focal mechanism study was available at the time of writing this abstract, it is probable that this earthquake is similar to others in the southern part of the province and will show thrust fault movement (reverse faulting). According to the scaling laws between magnitude and fault rupture, a magnitude 3.8 earthquake represents a rupture of a few centimetres on a fault surface of 100 metres or less. The earthquake probably occurred in the crystalline basement in response to the North American slow westward drift brought about by the Mid-Atlantic ridge push, or perhaps stress perturbations due to post-glacial isostatic readjustments.

Nomination of the Cliffs of Fundy (Parrsboro Shore, Nova Scotia, Canada) as a UNESCO Global Geopark

John Calder[1] and Marlee Leslie[2]

1. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada <John.H.Calder@novascotia.ca> ¶ 2. Project Coordinator, Cliffs of Fundy Aspiring Geopark, Bass River, Nova Scotia B0M 1B0, Canada

The community-led initiative to establish a UNESCO Global Geopark designation for the north shore of the Minas Basin in Nova Scotia reached several important milestones in 2018 and early 2019, including the evaluation mission of the Canadian National Committee for Geoparks in June, 2018, the submission of the formal application dossier to UNESCO in November, 2018, and the formation of a governing not-for-profit society in November, 2018-January, 2019. The governing society comprises representatives from the municipalities of Cumberland and Colchester, the rural communities of the geopark, the Confederacy of Mainland Mi'kmaq, the Fundy Geological Museum, Joggins Fossil Institute, Provincial Parks, and representatives with specific technical skills from the geoscience, tourism, conservation, and arts and culture sectors. Few members of the Atlantic Geoscience Society would be unaware of the scientifically significant and aesthetically breath-taking coastal geology of this region of Atlantic Canada. The geological storyline used to convey the truly global significance of the region to a wider public focuses on the assembly of Pangea along the Cobequid and Minas fault system, and Pangea's breakup at the end of the Triassic, marked by the flood basalts of the North Mountain Formation and Central Atlantic Magmatic Province. In total, 43 geosites have been identified, 20 of which are in a visitor-ready state. Pains have been taken to present the indigenous storyline of the Kluscap legends and the narrative of the Mi'kmaq people concerning the birth of the Bay of Fundy tides. At the request of the Confederacy of Mainland Mi'kmaq, the eastern boundary of the geopark has been extended eastward to include the Debert 'PaleoIndian' site, and the future site of Mi'kmawey Debert intepretation centre. The aspiring geopark will host the formal UNESCO evaluation team during the summer of 2019 and will be informed of the recommendation of the Global Geoparks Network and the formal decision of UNESCO by early 2020.

A synopsis of fossil vertebrate footprints from the latest Carboniferous and early Permian redbeds of northern Nova Scotia and Prince Edward Island, Canada

John Calder[1], Matthew Stimson[2], Laura MacNeil[3], Lorenzo Marchetti[4], and Howard van Allen[5]

1. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada <John.H.Calder@novascotia.ca> ¶
2. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada ¶
3. 901 Pownall Rd., Rte. 26, Alexandra, Prince Edward Island EC1 B0P, Canada ¶
4. Urweltmuseum GEOSKOP/Burg Lichtenberg (Pfalz), Burgstraße 19, D-66871 Thallichtenberg, Germany ¶
5. 58 Temperance St., New Glasgow, Nova Scotia B2H 3A7, Canada

Recent discoveries add significantly to the record of fossil vertebrate footprints from the Carboniferous-Permian red beds of the Maritimes Basin on Prince Edward Island. These new discoveries establish Prince Edward Island as an important locality in reconstructing the tetrapod biogeography of equatorial Pangea. Discoveries derive from the Egmont Bay, Kildare Capes, Hillsborough, and Orby Head formations, spanning the Gzhelian through Artinskian stages of the late Carboniferous (Pennsylvanian) and early Permian (Cisuralian). The tetrapod ichnofauna comprises the ichnogenera *Amphisauropus, Ichniotherium, Dimetropus* and putative *Gilmoreichnus*, and *Notalacerta*. This ichnoassociation belongs to the Gzhelian-early Cisuralian Dromopus tetrapod footprint biochron and reflects a reptile/reptiliomorph amphibian-dominant trackmaker fauna consistent with the transition to terrestrialization of equatorial Pangea which experienced increasingly arid conditions into the Permian. This Prince Edward Island ichnoassembage shares many ichnotaxa in common with those at Brule, Nova Scotia, with the notable exception of *Batrachichnus*, a diminutive temnospondyl amphibian print that is omnipresent there and which is very common in the Pennsylvanian and early Cisuralian. The Prince Edward Island ichnofauna provide an important midway point across equatorial Pangea between the famous and productive early Permian sites in the southwestern United States sites such as the Prehistoric Trackways National Monument, Robledo Mountains, New Mexico, and historical European sites such as those of the Thuringian Forest Basin, Germany. Candidate trackmakers include reptiliomorphs such as *Seymouria* (*Amphisauropus*), the herbivorous *Diadectes* (*Ichniotherium*), and the largest predator of the equatorial Pangean biome, the sail-back pelycosaur *Dimetrodon* (*Dimetropus*), first discovered in 1845 in a farmer's well in Spring Valley, PEI. and named *Bathygnathus*. From an educational standpoint, these discoveries incite the imagination of the public, and add to interpretive programming possibilities for Prince Edward Island National Park.

Assessing the effects of eutrophication on lakes in Nova Scotia, Canada, using subfossil midges

Julia M. Campbell and Joshua Kurek

Department of Biology, Mount Allison University, Sackville, New Brunswick E4L 1C9, Canada <jmcampbell2@mta.ca>

The mink fur farming industry of southwestern Nova Scotia is one of the top agricultural exports in Nova Scotia. This industry has sparked recent debate on water quality declines in surrounding lakes, such as Nowlans Lake, which has experienced reoccurring algal blooms and very high

measures of nutrients. Midges from Nowlans Lake were used as bioindicators of environmental change due to their sensitivity to dissolved oxygen concentrations (DO), which can be significantly depleted as a result of eutrophication. Midges were recovered from a lake sediment core spanning the ~1900s to present. Visible reflectance spectroscopy (VRS) chl-*a* was also measured from sediments as a proxy of whole-lake primary production. Preliminary results indicate that chironomid taxa associated with lower DO (e.g., *Chironomus plumosus* and *Glyptotendipes spp.*) show increasing trends coinciding with greater VRS chl-*a*. Taxa associated with higher DO (e.g., *Stempellina*) displayed decreasing trends from the ~1900s to present. This research will help fill the missing gap of long-term limnological data by using paleolimnological approaches to reconstruct past environmental changes and determine pre-disturbance conditions necessary to investigate mink farming's contributions to water quality declines in southwestern Nova Scotia.

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

Juan A. Chavez[1], James Brenan[1], and Trevor MacHattie[2]

1. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <juan.chavez@dal.ca> ¶
2. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada

The Late Devonian South Mountain Batholith (SMB) of southwestern Nova Scotia is the largest plutonic igneous body in the Appalachian orogen, with a current surface expression of 73 000 km^2. The batholith is composed of 13 distinct plutons that are broadly peraluminous in composition, ranging from tonalite to syenogranite. A parameter that has been particularly difficult to quantify for the SMB is the redox state, as measured by the oxygen fugacity (fO_2), which exerts a profound control on magmatic phase stability, element partitioning, and importantly, the potential for economic mineral deposits. We are attempting a redox state survey of mineralized and unmineralized phases of the SMB using the newly calibrated Ce-in-zircon oxygen barometer. This method combines bulk rock and zircon compositions to calculate apparent zircon/melt partition coefficients for Ce, a parameter which varies with the Ce^{4+}/Ce^{3+} in the melt, and hence oxygen fugacity. A total of 23 samples were collected; 13 of these were selected for zircon separation lithogeochemical analysis based on spatial distribution, mineralogy, and preliminary geochemical data acquired by portable XRF.

Zircons from the unmineralized Harrietsfield and Sandy Lake plutons, and mineralized New Ross pluton were imaged using CL to determine textural domains, which were a guide to subsequent analysis by electron microprobe and LA-ICPMS. Zircon cores, which were delineated based on CL response, display a large variation in shape (euhedral to anhedral) and pattern (zoned and unzoned), and are typically truncated by concentrically zoned rims. Data from LA-ICPMS analyses of cores and rims yielded two distinct patterns on chondrite-normalized REE diagrams. The first pattern depicts a continuous increase in REE concentration with increase in ionic radius (La to Lu), large positive Ce anomaly and negative Eu anomaly; these characteristics are typically associated with magmatic zircons. The second pattern also shows a negative Eu anomaly, but a subtler increase in REE concentration from La to Lu and a lack of Ce anomaly; these characteristics are typically associated with hydrothermal zircons. Most zircons in the mineralized SMB phase exhibit the hydrothermal pattern, whereas the unmineralized SMB phases display a combination of both patterns with a dominant magmatic component. Additionally, within the Sandy Lake monzogranite we observe a large range in inferred fO_2 values (based on calculated Ce^{4+}/Ce^{3+} in zircon) that is absent in other samples. The relationship between REE trends, other trace elements, fO_2, and textural characteristics of the analyzed zircons will also be discussed.

Trace element partitioning between apatite and kimberlite-like melts: implications for kimberlite melt composition and emplacement

Richard Chow[1], Yana Fedortchouk[1], and Phillipe Normandeau[2]

1. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <richard.chow@dal.ca> ¶
2. Northwest Territories Geological Survey, Yellowknife, Northwest Territories X1A 2L9, Canada

The original composition of kimberlitic melts is largely unknown because the complex nature of kimberlites involves contamination from country rocks, loss of volatiles from exsolution during emplacement, and the lack of any quenched melts. Additionally, kimberlite bodies have varied morphologies, but the exact emplacement mechanisms of the magma in different bodies remain elusive. Apatite is a common accessory mineral found in kimberlite and has a crystal structure that allows for the incorporation of trace elements. The difference in the partitioning of trace elements between apatite and kimberlite-like melts can reveal whether the carbonate or silicate phases in the kimberlite more closely represent the original melt. Apatite is also often used as an

indicator mineral of magma degassing in igneous systems. As such, it should be applied to kimberlitic systems to study the volatile behaviour during emplacement. However, two problems currently exist with partition coefficient data for apatite. First, there is controversy regarding existing data for carbonatitic melts, and second, no data are available for kimberlite-like silicate melts. Here, we examine kimberlite-like melt compositions ranging from carbonatitic to silicate in order to investigate the effect on apatite partition coefficients and the behaviour of fluids in kimberlite.

Partition coefficients for Nb, Sr, Rb, Zr, Sm, Cs, Hf, La, Yb, and Eu were examined using synthetic compositions and a piston cylinder apparatus at 1250–1350°C and 1–2 Gpa. The effects of melt composition, temperature, pressure, water, and oxygen fugacity have been tested. Four synthetic melt compositions representing evolved kimberlite melts were used: three lamproitic compositions with SiO_2 ranging from 17–23 wt.% and CO_2 from 9–33 wt.%, and a composition modelled after a magmatic kimberlite (Leslie, NWT) by subtracting 50% (volume) of the olivine component (with 14–29 wt.% SiO_2, 7–33 wt.% CO_2). The lack of sizable melt glass produced by the kimberlitic composition in our experiments restricted the partition coefficients obtained to the lamproitic run products. We present partition coefficients that address discrepancies observed in carbonatitic melts and more closely resemble those of kimberlites in order to model the possible melt composition of an original kimberlite melt. The variation of apatite stability at different run conditions allows for examination into crystallization conditions of different kimberlite bodies. Furthermore, textural and mineralogical phase relationships observed in the derived kimberlite run products are compared to natural samples. This will provide insight into the enigmatic stages of kimberlite formation that result in the variety of morphologic facies observed.

Application of geological laboratory techniques for insight into the geomechanical behaviour of skarn-related veined rocks

Matthew D. Clark, Jennifer J. Day, and Chris R.M. McFarlane

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada
<matt.d.clark@unb.ca>

The role of healed intrablock structures, such as hydrothermal veins, on rockmass behaviour has recently become a critical consideration in geotechnical engineering development of deep mines and other excavations, both in designing ground support and predicting rockmass failure behaviours. Observations of rockmass instability at these depths have shown that intrablock structures can have a significantly greater influence than conventional rockmass structures (interblock structures) such as joints, bedding, and other fractures. Conventional approaches of geotechnical engineering design, developed for homogeneous rockmasses, do not adequately represent heterogeneous complex rockmasses such as those that contain hydrothermal vein networks. Diamond drill core samples were selected from two historical exploration boreholes in the Legacy skarn deposit in northern New Brunswick and sorted into homogeneous (matrix) and heterogeneous (veined) categories for mineralogical and geotechnical laboratory testing. Hand sample observations, thin section petrography, micro-X-ray Fluorescence (micro-XRF) and powdered X-ray Diffraction were used for detailed mineralogical characterization. Three matrix (vein host rock) lithotypes were identified, and one lithotype was subdivided into three categories to account for alteration: (1) The matrix of the garnet-pyroxene skarn unit contains garnet, diopside, and albite. Stockwork veining was abundant in this unit, containing quartz with minor sulphide mineralization (2–10 mm thick). (2) The granodiorite unit matrix contains sodium-rich plagioclase and quartz with minor amounts of biotite. Hydrothermal alteration processes including saussuritization and sericitization, are considered to be responsible for the varying amounts of chlorite and amphibole in the granodiorite samples, resulting in three subdivisions. The veins within the granodiorite unit display little geometric variability (often single veins, 1–2 mm thick) and are composed primarily of calcite. (3) The calcareous mudstone unit matrix contains an abundance of muscovite with minor amounts of calcite. The veins in this unit display the greatest geometric variability, ranging from single to multiple calcite veins (5–25 mm thick). The compositions of these lithological units (both matrix and vein materials) identified during this study are consistent with results from laboratory analysis techniques as well as previously published studies on the Legacy deposit. Micro-XRF relative imaging, and its ability to map 2D locations (matrix and vein) of mineral abundance at that scale, has provided key insight to explain geomechanical failure behaviours. Accurate and detailed mineralogy characterization of hydrothermally altered rockmasses like this study, with correlation to geotechnical properties and rockmass behaviour, is becoming critical for the success of modern, numerical geotechnical design of particularly large and deep excavations.

Evidence of magma mixing recorded on a mineral-scale in the Halifax pluton section of the South Mountain Batholith, Nova Scotia, Canada

Richard A. Cox, Dana Thomsen, Sydney Stashin, and Derek Wongus

Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <richard.cox@dal.ca>

An investigation of magmatic growth recorded by K-feldspar megacrysts and co-existing plagioclase crystals in the Halifax pluton, a part of the Late Devonian South Mountain Batholith, has been carried out through a series of focused studies. Coastal outcrops at Peggys Cove, Prospect, and Sambro Head were examined, and evidence of magma mingling and mixing has been documented. Magma mixing is unequivocally recorded in the outcrops exposed at Sambro Head, where a mafic intrusion (a ~5 m-wide dyke) has been injected into the partially molten granitic host. Several outcrops at Sambro Head and Prospect contain large clusters of mafic enclaves that are texturally and mineralogically identical to the Sambro dyke. These enclaves appear to be entirely magmatic in origin. The presence of the Sambro dykes and mafic enclaves suggest that periods of magma mixing may have occurred within the Halifax pluton. Similar partial mixing zones have been described in other granitic intrusions of the same age in southwest Nova Scotia. Outcrops at Peggys cove differ in that mafic enclaves are significantly less abundant and are smaller than at Prospect and Sambro. Large K-feldspar phenocrysts (megacrysts) are present in the granitic rocks, in the Sambro dyke and in many mafic enclaves. Of note are enclaves that show megacrysts crosscutting their margins, suggesting that both the host granite and enclave were partially liquid during megacryst growth. Whole-rock major and trace-element analysis, and detailed examination and analysis of plagioclase and K-feldspar crystals has been carried out. The feldspars were characterized using a variety of petrographic methods, X-ray mapping, and electron microprobe analysis. All of the feldspars show some evidence of primary magmatic zoning. Variations in both major elements and Ba and Sr suggest periods of magmatic circulation and significant fluctuations in temperature during crystal growth. Contrastingly, feldspars from Peggys Cove have been strongly resorbed. These feldspars show similar textures, and zoning patterns recorded by Ba and Sr, to feldspars that have been incorporated into mafic exclaves and the Sambro dyke. This, along with the lack of mafic enclaves at Peggys Cove, actually suggests that there was more thorough mixing of mafic material with the host granite than at Prospect or Sambro. Thus, evidence of magma mixing recorded by zoning preserved in the granitic K-feldspar megacrysts and plagioclase crystals, especially where no obvious mafic enclaves occur, suggests that hybridization of the Halifax pluton may have been more widespread than previously documented.

Onshore-offshore comparisons of Cretaceous and Paleogene strata from Bylot Island and the western Baffin Bay margin, Nunavut, Canada

Lynn T. Dafoe[1], Jim W. Haggart[2], and Graham L. Williams[1]

1. Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada <lynn.dafoe@canada.ca> ¶
2. Geological Survey of Canada (Pacific), Vancouver, British Columbia V6B 5J3, Canada

The Labrador Sea and Baffin Bay formed during Cretaceous rifting and subsequent Maastrichtian to Paleocene seafloor spreading, which ended by late Eocene time. The age and nature of rift-related sedimentary strata along the western Baffin Bay margin are largely unknown due to limited sampling; accordingly, analogues must be drawn from nearby contemporaneous onshore exposures. The rift succession is also preserved onshore in Eclipse and North Bylot troughs on Bylot and northern Baffin islands, as well as in small exposures on southeast Baffin Island. Here, we compare Lower Cretaceous through Paleogene units between the onshore and offshore. The ichnology and sedimentology of 35 stratigraphic sections from Eclipse and North Bylot troughs were assessed, in conjunction with palynological analyses, to better understand their depositional environments and age. Along the western Baffin Bay margin, twenty-three shallow core-hole bedrock samples, in addition to bedrock material from three piston cores and two dredge samples, were assessed in terms of their sedimentological and ichnological characteristics, and palynological analyses were conducted for the few samples lacking previous age determinations. Lower Cretaceous strata from Eclipse and North Bylot troughs, as well as strata previously documented from southeast Baffin Island, generally considered non-marine in origin, also show several shallow marine, shoreface intervals characterized by the *Skolithos* or proximal *Cruziana* Ichnofacies. Comparable offshore, Lower Cretaceous samples from Cumberland Sound and northeast of Padloping Island, comprise shales and sandstones of non-marine to possibly shallow marine, deltaic origin based on palynology and sedimentology. Upper Cretaceous sections on Bylot Island include thick mudstones and lesser sandstones. The mudstones typically contain abundant *Phycosiphon*, consistent with a distal

marine, *Zoophycos* Ichnofacies, but outer to inner shelf transitions with sandstone intervals show a more diverse archetypal *Cruziana* Ichnofacies. The sandstones are storm-dominated, with interbedded fair-weather beds also containing an archetypal *Cruziana* Ichnofacies. A number of offshore Upper Cretaceous mudstone samples from Buchan Trough, Home Bay, and Scott Trough similarly contain a distal *Cruziana* to *Zoophycos* Ichnofacies consistent with outer shelf settings; some sandier intervals may reflect distal prodeltaic deposition. Onshore Paleocene mudstones contain a low diversity and low abundance of trace fossils reflecting shallow, brackish-marine deposition, with localized beds containing cone-in-cone structures that could be comparable to an undated core sample from Scott Trough. Overall, the onshore succession appears to compare closely with offshore samples, proving its value as a vital stratigraphic analogue.

Thermochemical oil formation in hydrothermal vent sediments at Guaymas Basin, Gulf of California, USA, and the search for a deep biosphere hydrocarbon fingerprint

C.J. Dalzell[1], G.T. Ventura[1], R.K. Nelson[2], C.M. Reddy[2], J. Seewald[2], and S.M. Sievert[2]

1. Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <connor.dalzell@smu.ca> ¶
2. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543-1050, USA

Accelerated petroleum production is occurring naturally at Cathedral Hill, a hydrothermal vent complex in Guaymas Basin, Gulf of California. At this site, high temperature vent fluids, projected to reach 155°C within only 21 cm sediment depths, are not only capable of pyrolyzing in situ organic matter to produce petroleum, but may equally begin to thermochemically break down these newly-cracked petroleum-forming compounds. In this study, we aim to elucidate how the hydrocarbon matrix is attenuated or added to by biodegradation, thermochemical degradation, in situ hydrocarbon production, and migration. To this end, a multi-molecular, chemometric survey using comprehensive two-dimensional gas chromatography (GC×GC) has been conducted on 34 samples collected from a four push-core transect extending from the center of the vent complex to the exterior of an overlying *Beggiatoa* microbial mat. Preliminary extract data and matrix compositional patterns resolved by hierarchical cluster analysis, and multi-way principal components analysis of stacked whole GC×GC chromatograms of the entire sample set, indicates a patchy distribution of elevated oil signatures. One of these is a thin horizon uniformly extending across the transect at ~6–10cm sediment depth. Subtracted GC×GC chromatograms also reveal elevated levels of high-temperature pyrolytic hydrocarbons, including relatively high abundances of higher molecular weight PAHs (pyrenes-coronene) and equivalent perhydro-PAHs, at ~6–10 cm depth consistently across-transect. This band corresponds to a wide range of sediment temperatures spanning 18 to 125°C, which for the outer perimeter of the vent is too low for active in situ pyrolysis. Furthermore, the presence of abundant archaeal *glycerol dialkyl glycerol tetraether* (GDGT) core lipids and a lack of significant biphytanes in the apolar fractions of solvent extracts, suggests sediment temperatures are too low to promote cleavage of isoprenoid skeleton ether bonded to glycerol of the core lipid. Collectively, these data indicate the oil derives from multiple charge events deeper within the basin. Lastly, ratios of low to intermediate molecular weight *n*-alkanes and acyclic isoprenoids show increasing levels of biodegradation (reaching 2–3 on the Wegner *et al.* 2002 biomarker biodegradation scale) down-core across the transect. An unknown pseudohomologous series of tetracyclic compounds, along with decoupled ratios of bacterial-sourced lipids C_{30} hopene and C_{30} hopane (indicating the hopene biomarker is not being thermally altered to hopane) implies that a living microbial community is hosted by the vent complex shallow sediments.

Active learning in Five Islands Provincial Park about dinosaurs, glaciers, and climate change

Howard V. Donohoe Jr.[1] and Martha E. Grantham[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <howard.donohoe@smu.ca> ¶
2. 26 Rockwell Drive, Stewiacke, Nova Scotia B0N 2J0, Canada

The Triassic and Jurassic rocks of Five Islands Provincial Park, 50 km west of Truro, Nova Scotia, offer an unparalleled opportunity to engage the public in geoscience explorations. This location was chosen because it presented spectacular scenery and important geological associations in the site of a former rift valley. A typical walk comprises an audience of 40 to 80 people of all ages, who begin their journey into the past gathered in a semi-circle for an active learning talk about Earth history. Participants are invited to represent important 'paleo-milestones' such as the colour red (enough oxygen), complex animals, Fundy rift valley formation, dinosaurs, flowering plants, humans, and the present. We move to the beach to clearly see the sedimentary and volcanic rocks, glacial till, and stratified outwash material. The rocks help us renew the discussion about dinosaurs, fish, and climate variations using sedimentary structures and rock types, rift valley formation, volcanic eruptions, and

ancient paleogeography. The audience then walks into the virtual past along the shore. For the present and near past, climate change varies from tundra to present day biomes; the audience examines the variety of rocks on the beach to explore deeper into glacial history. Bedrock provides the chance to talk about the implications of geoscience knowledge for geotechnical applications. The Jurassic sedimentary rocks show examples of seasonal river systems and their architecture. By this point in the walk, the audience is recognizing channels, point bars, and overbank deposits. An exposed fault that separates the sandstones and basalt is used to discuss fault movements, timing of movements, and risk management in geoscience. The basalt outcrop and feeder dyke offer an opportunity to describe large igneous provinces and their effect on life. At the oldest Mesozoic sedimentary rocks, the Triassic (225 Ma) formations contain fossils that are not found in the Jurassic (200 Ma) sedimentary rocks previously encountered, indicating that a major extinction (43%) occurred at this time. Now the audience can actively talk about extinction events, dinosaurs, and life on Earth. Throughout the walk, the group's confidence in using geological terms, making observations, expressing ideas, and discussing implications of their new-found knowledge increases. Choosing a location characterized by great scenery, good outcrops, and a "worthwhile story" usually ensures a successful walk. Encouraging dialogue, questions, and discussion involves the audience in active learning and provides 'ah-ha' moments. These possibilities may give individuals the impetus to become involved in geoscience as citizen scientists.

Mineralogical controls on rare metal enrichment in the Flowers River Igneous Suite, Nain Province, Labrador, Canada

Taylor A. Ducharme[1], Deanne van Rooyen[2], Christopher McFarlane[1], and David Corrigan[3]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <taylor.ducharme@unb.ca> ¶
2. School of Science and Technology, Cape Breton University, Sydney, Nova Scotia B1P 6L2, Canada ¶
3. Geological Survey of Canada, Ottawa, Ontario K1A 0E8, Canada

Mineralogical associations within rare metal-enriched igneous bodies provide insight into the late-magmatic cooling conditions and fluid evolution of these systems. Rare earth elements (REE) and high field strength elements (HFSE) collectively represent most of the elements known as rare metals. Highly differentiated peralkaline systems commonly achieve enrichment in rare metals sufficient to promote growth of exotic accessory minerals that are intrinsically composed of these elements. The REE-bearing fluorocarbonate mineral bastnäsite ($(Ce,La)CO_3F$) is one such accessory mineral commonly found in systems host to rare metal mineralization. The Flowers River Igneous Suite of north-central Labrador comprises an intrusive ring complex of rare metal-enriched alkali granites and their comagmatic volcanic equivalents. Both intrusive and extrusive Flowers River lithotypes exhibit the same geochemical and mineralogical hallmarks of other silica-oversaturated rocks that host rare metal occurrences. Bastnäsite (Ce) is the dominant repository of REE in the Flowers River Igneous Suite. The distribution of bastnäsite in Flowers River rocks displays three distinct associations: (i) as a pseudomorph of allanite in alkali granites; (ii) proximal to Fe-rich minerals interstitial to cumulate quartz and feldspar or within Fe-rich chloritized domains in plutonic and volcanic rocks, respectively; and (iii) filling elated exotic mineral phases such as parisite ($Ca(Ce,La)_2(CO_3)_3F_2$). Further, pervasive Na depletion in the Flowers River volcanic rocks has been observed to accompany the alteration of groundmass albite to chlorite. In-situ replacement of allanite by bastnäsite suggests a primary magmatic contribution to enrichment of rare metals that was followed by alteration and remobilization by CO_2-rich fluids. A sporadic association of bastnäsite with hydrothermal fluorite supports a high activity of F in these fluids, a property that would enhance the hydrothermal system's capacity to mobilize REE. These criteria, taken together, indicate a deuteric or secondary hydrothermal control on the alteration of primary host minerals and on the redistribution of rare metals within the Flowers River Igneous Suite.

Paleoceanography, sedimentology, and geochemistry of Middle Ordovician ironstone, Welsh Basin, United Kingdom

Sarah K. Dunn[1], Peir K. Pufahl[1], J. Brendan Murphy[2], and Kevin G. Taylor[3]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <sarahdunn@acadiau.ca> ¶
2. Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia B2G 2W5, Canada ¶
3. School of Earth and Environmental Sciences, University of Manchester, Manchester M13 9PL, United Kingdom

Middle Ordovician phosphatic ironstone (ca. 467 Ma) of the Welsh Basin, United Kingdom, provides new information about the cycling of bioessential Fe and P in this ancient

back-arc basin during the opening of the Rheic Ocean. Located on the northeastern margin of eastern Avalonia, this narrow fault-controlled basin received terrigenous clastic sediment from the emergent Irish Sea Horst Complex and the Midland Platform. Bimodal volcanism punctuated ironstone deposition along the northeastern margin of the basin.

Lithofacies stacking patterns indicate that deposition occurred in a distal to middle shelf environment, below fair-weather wave base. Ironstone occurs in a single aggradational parasequence composed of variably bioturbated, chamositic mudstone that is overlain by a packstone composed primarily of phosphatic intraclasts and coated chamosite grains. The top of the parasequence is a trough cross-stratified, coated grain grainstone capped by a submarine erosion surface interpreted as the regressive surface of marine erosion.

The Fe-silicate and phosphatic mineralogy of lithofacies suggests that ironstone accumulation was stimulated by upwelling of phosphate-rich ferruginous seawater on the distal shelf. Increased primary productivity in the surface ocean and degradation of this organic matter on the seafloor likely established an oxygen minimum zone allowing the establishment of a stable Fe-redox boundary just beneath the sediment-water interface. The mineralogy of cortical layers forming large, granule-size coated grains records vertical fluctuations of this boundary in the sediment. These changes in pore water Eh are interpreted to reflect variability in surface ocean productivity and the export of organic carbon to the seafloor.

Lithofacies associations support an emerging model of ironstone deposition where upwelling of anoxic ferruginous seawater drives Fe precipitation. An additional continental source of Fe is inferred from the major and trace element chemistry of associated Fe-rich mudstone and siltstone. Research results illuminate a possible connection between increased seafloor spreading and the development of ferruginous bottom waters as the Iapetus Ocean closed and the Rheic Ocean opened. Further evaluation of this relationship will help clarify longstanding questions regarding the oxygenation history of Ordovician seawater during the apex of the Great Ordovician Biodiversification Event.

Land-use controls on spatiotemporal trace metal accumulation in Maritime Canadian lakes

Dewey W. Dunnington[1], Ian S. Spooner[2], Joshua Kurek[3], Chris E. White[4], R. Jack Cornett[5], and Graham A. Gagnon[1]

1. Centre for Water Resources Studies, Department of Civil and Resource Engineering, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <dewey.dunnington@gmail.com> ¶
2. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada ¶
3. Department of Geography and Environment, Mount Allison University, Sackville, New Brunswick E4L 1A7, Canada ¶
4. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada ¶
5. Andreé E. Lalonde Accelerator Mass Spectrometry Lab, Department of Earth Sciences, University of Ottawa, Ottawa, Ontario K1N 6N5, Canada

Trace metals play an important role in freshwater environments: guidelines for the protection of aquatic life have been established for both water and sediment, and drinking water guidelines require low concentrations of many trace metals following drinking water and waste water treatment. As the "tailpipe of North America", many Maritime Canadian lakes were acidified as a result of atmospheric transport of USA emissions, a process which potentially introduced trace metals to these systems. Maritime Canada has experienced significant historic land disturbance through forestry, water-level change, and urbanization, and is thus an ideal place to investigate the relationship between long-term trace metal accumulation and catchment land-use change. Using ^{210}Pb-dated gravity cores from 22 Maritime Canadian lakes with varied land-use histories, we reconstructed trace metal accumulation and watershed disturbance at decadal resolution over the past ~200 years. Preliminary results from the greater Halifax region suggest that Fe, Mn, and As are particularly sensitive to oxygen conditions at the sediment-water interface, and that increased Cu was associated with the onset of urbanization in some urbanized watersheds. The mean timing of increased Pb deposition occurred at AD 1921 ± 42 in the Halifax region and was consistent with atmospheric deposition from the use of leaded gasoline; however, only in some lakes have Pb concentrations decreased since the phasing out of lead in gasoline. Collectively, our data suggest that that that historic sources of trace metals in Maritime Canadian catchments are still contributing to the contemporary trace metal load in lake sediments, and must be considered in the management of these systems.

Late Carboniferous contractional deformation and foreland-basin-style subsidence in the Maritimes Basin, Canada

Paul Durling[1], John W.F. Waldron[2], and Morgan Snyder[2]

1. Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia B2Y 4A2, Canada <paul.durling@canada.ca> ¶

2. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada

The Maritimes Basin comprises a number of structural sub-basins, which share similar stratigraphic and structural relationships, suggesting a common tectonic history. For example, initial sedimentation in many of the structural sub-basins began with clastic sedimentation in a rift-like setting (i.e. Horton Group), followed by marine and evaporite sedimentation (i.e. Windsor Group), which was in turn followed by deposition of clastic and coal bearing strata (i.e. Mabou, Cumberland, and Pictou/Morien groups). Similarly, structures mapped in one structural sub-basin may affect adjacent structural sub-basins (e.g., Belleisle, Hollow, and Long Range faults). Many of these structures exhibit a significant contractional component (e.g., thrusting and/or tectonic wedging) in addition to strike-slip relationships observed through surface geological mapping. In several places, this contractional component has inverted previous normal faults. A compilation map encompassing onshore structural sub-basins and the offshore Magdalen and Sydney sub-basins highlights that Carboniferous deformation, including tectonic wedging, is greatest adjacent to the Cobequid-Chedebuto Fault (CCF) and decreases northeasterly away from this fault; the exception being the Hollow-Aspy-Long Range fault system. Furthermore, both the Magdalen and Sydney sub-basins have similar cross-sectional profiles, showing that each basin is deepest in the south and shallows obliquely to the north away from the CCF. In addition to the plethora of tectonic models that have been proposed for the Maritimes basin, a model involving predominantly tectonic wedging and crustal shortening in the Late Carboniferous should be considered. In this model, Late Devonian to Early Carboniferous regional extension and thermal subsidence (Horton, Windsor and Mabou groups and equivalents) are followed by foreland basin-style subsidence associated with tectonic wedging and transpression during the Late Carboniferous (Cumberland and Pictou/Morien groups).

Determining subsurface suspended sediment mechanisms through surficial remote sensing techniques, South Korea

Catherine Evans[1] and Paul Hill[2]

1. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <catherineevans@dal.ca> ¶
2. Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada.

Satellite imagery provides information on the spatial distribution of surficial suspended sediment over broad scales in coastal environments. An outstanding challenge is to determine the extent to which surficial sediment distributions can be linked to sedimentary processes occurring near the seabed. Recent research indicates that dense sediment suspensions at the bottom of tidal channels off the southwest coast of South Korea limit upward turbulent mixing of sediment to the sea surface. This research investigates whether this sub-surface sediment process is detectable using sea surface reflectance as measured by the Landsat 8 satellite. The project's hypothesis is that the magnitude and variance of sea-surface reflectance will be lower in channels than in ridges due to dense suspensions in channels that limit vertical mixing. On the ridges, this process would not occur, because dense suspensions would flow into adjacent channels under the influence of gravity. As a result, reflectance would be higher and more variable at shallower depths. To assess this hypothesis, sea surface reflectance at 655 nm and 865 nm wavelengths were used as proxies for suspended sediment concentration in 15 cloud-free and atmospherically corrected Landsat 8 images collected from 2013–2018.

Reflectance in both bands was extracted over a tidal channel and over an adjacent tidal ridge. The reflectance from these two points was assessed for statistical correlation with depth and with other environmental variables, including sea level, wind speed, recent precipitation levels, and stage in the tidal cycle. Results indicate that depth exerts primary control on the mean and standard deviation of the reflectance, consistent with the project's hypothesis. Secondary controls on reflectance are wind speed and sea level. I propose that higher windspeeds are associated with larger reflectance due to re-suspension over fringing tidal flats and that the correlation of higher water levels with reduced reflectance is caused by sediment supply limitation.

In order to see if these methods can identify other areas with similar suspended sediment processes, two secondary sites – located in Gyeonggi Bay, South Korea and the Gulf of Khambhat, India have been analyzed. Preliminary results show that similar primary and secondary reflectance patterns appear in the Landsat 8 imagery. While further field work is needed to study the effects of tidally-dependant suspended sediment stratification on surface sediment concentration and associated reflectance, results indicate that remote sensing may be applicable to detection of subsurface suspended sediment processes.

Using high-throughput sequencing and quantitative molecular techniques to investigate ~3800 years of diatom diversity and sea-ice variability in the North Water polynya (Baffin Bay), Canada

Joshua R. Evans[1,2], Gary W. Saunders[2], Sofia Ribeiro[3], Guillaume Massé[4], and Audrey Limoges[1]

1. Department of Earth Science, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <joshua.evans@unb.ca> ¶
2. Centre for Environmental and Molecular Algal Research, Department of Biology, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada ¶
3. Department of Glaciology and Climate, Geological Survey of Denmark and Greenland, 1350 Copenhagen K, Denmark ¶
4. Department of Biology, TAKUVIK, Laval University, Québec City, Quebec G1V 0A6, Canada

Changes in global temperatures have a direct impact on oceanic and atmospheric processes, and at present, the Arctic is experiencing a rise in near-surface air temperatures. As a consequence, multi-year sea-ice extent has significantly declined in the last two decades. These changes have a direct impact on the pelagic and ice-associated (sympagic) photosynthetic communities that form the foundation of marine food webs. The North Water (NOW) polynya is one of the most productive areas in the arctic and therefore represents a critical site for studying the impacts of climate-induced environmental changes. Although recent monitoring of the area revealed important changes in productivity and microbial species composition, proxy datasets that span large temporal periods are required to place these environmental changes into a long-term context.

To reconstruct past changes in sea-surface conditions, biogenic proxies derived from diatoms and preserved in seafloor sediment are commonly used. These include microfossil assemblages, biogenic silica, and IP_{25}. However, limitations to the use of these proxies include low species-level resolution and the biased preservation of heavily silicified specimens. Sedimentary ancient DNA (*seda*DNA) is an emerging proxy which, in the light of recent advances in molecular biology, has the potential to become a very useful tool for paleoenvironmental reconstructions.

In this study, we will quantify and characterize diatom *seda*DNA extracted from twelve samples collected along a 5.43 m long sediment core retrieved from the NOW polynya in order to: (1) characterize past diatom diversity using genetic barcodes and high-throughput sequencing (metabarcoding) techniques. Diatom-specific primers will be designed to target short (~75 bp), variable regions of two gene markers (*rbc*L, 18S rRNA V4 region) that will be used for genetic species identification. These results will be combined with diatom abundances and assemblage determinations to reconstruct past environmental conditions; (2) investigate changes in sea-ice conditions during the last 3800 years. The absolute quantification of both diatom *seda*DNA and copies of a specific *rbc*L gene from two species representing pelagic and sympagic assemblages will be obtained using droplet digital PCR. The absolute quantification data will be compared to BSi and IP_{25} abundances for evaluating proxy reconstructions of productivity and sea-ice history in the NOW.

The evolution of the Iberian Pyrite belt: new insights from geochronology, geochemistry, and structure

Sean Freeborne[1], James Braid[1], and Lori Paslawski[1]

Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia B2G 2W5, Canada <x2015jjv@stfx.ca>

The geology of southern Iberia is dominated by rocks that record the amalgamation of Pangea, which was formed during the late Paleozoic by the collision of Laurussia and Gondwana. The Middle to Late Devonian Phyllite Quartzite Group, which are the oldest exposed rocks in Southern Iberia, underlie the volcanic and sedimentary rocks of the Iberian pyrite belt and are thought to be continental shelf deposits deformed during Pangean orogenesis. Despite being host to some of the world's largest ore deposits, the relationship of the formation of the Iberian pyrite belt to the evolution of the Variscan orogen remains enigmatic. Therefore, in order to better understand the formation of the Phyllite Quartzite Group and its relationship to the Pyrite belt, two field sections were studied in detail. The first section is in the core of the Iberian Pyrite belt, and is considered to represent a classic example of Phyllite Quartzite deposition. The second is poorly studied and crops out in the northern section of an unmineralized part of the Iberian Pyrite belt. Field work and structural analyses suggest that the metasedimentary unit of the northern section: (i) is lithologically distinct, (ii) had a different structural history from the classic Phyllite Quartzite Group, and (iii) may have a genetic link to units not exposed in the Iberian Pyrite belt. U–Pb laser ablation detrital zircon geochronology of the northern block supports these field observations. Geochronology and isotopic data from magmatic rocks suggest the Pyrite belt had a protracted evolution that was both pre- and syn-collisional to the main Variscan orogenic event.

The plumbing system of a DECADE volcano: field and petrologic studies of the Galeras volcano, Colombia

L. J. Gomez Gomez

Colombian Geological Survey and Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3C 1G1, Canada <Johana.Gomez@unb.ca>

Galeras volcano, one of the most hazardous volcanoes in the world, is located in the southern section of the Colombian Andes mountain range, near the border with Ecuador. It is an andesitic stratovolcano that represents the last stage of the Galeras Volcanic Complex (GVC). The

volcano's zone of influence encompasses the city of Pasto, which has approximately 460 000 inhabitants, as well as seven towns and some villages. The proximity of such a large population and its high level of activity makes Galeras one of the best monitored volcanoes in the country.

The GVC reaches an elevation of 4276 m above sea level; the active cone has a height of 150 m and a diameter of about 300 m. It is located inside the youngest amphitheater, which is horseshoe shaped and approximately 3–4 km diameter. This amphitheatre was created by partial collapses on the west flank of the volcano. The active cone is considered to be less than 4500 years old and the age of the complex is at least 1 Ma.

Galeras volcano has a high explosive potential. The most recent activity has been characterized by vulcanian eruptions, the emplacement and destruction of crater domes, eruptions of 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 historic eruptions at Galeras have been small to modest in size, generating an ash column as high as 10 km. Commonly, a large part of the material ejected with each explosion is not juvenile but includes country rock as accessory lithics. The most recent eruption phase started in 1988 after ten years of dormancy. It includes episodes of unrest ranging from weak fumarolic activity and ash emissions, to larger explosive eruptions and high seismic activity before the present-day reactivation. The well-recorded historic activity indicates numerous eruptions since 1580.

Despite the hazard presented by Galeras, there are very few petrologic data on the volcano and no information is available on the magmatic plumbing system. The purpose of my research is: (1) to determine the pressure and temperature conditions of magma storage using mineral – melt thermobarometry; and (2) to decipher, by using zonation in phenocrysts, the transport history of magma from three distinct eruptions that occurred early in the history of the currently active cone.

Structural analysis of West Bay, Parrsboro, Nova Scotia, Canada using UAV photogrammetry

Fayula Gordon[1], Stefan Kruse[2], and Sherene James-Williamson[3]

1.University of the West Indies, Mona, Kingston 7, Jamaica <fayulagordon@gmail.com> ¶
2. Terrane Geoscience Inc., Fredericton, New Brunswick E3B 1E3, Canada ¶
3. Geography and Geology Department, the University of the West Indies, Mona, Jamaica

UAV photogrammetry was used to augment traditional mapping techniques for a coastal section of the Carboniferous Parrsboro formation near West Bay, Nova Scotia. Two generations of folding (F_1 and F_2) were recognized in the study area, along with D_3 low-angle, apparent sinistral and dextral faults. Automated extraction of planar geological surfaces from the UAV-generated point cloud was effective in characterising bedding orientation from the cliff-side exposures. Point cloud-derived bedding orientations agree well with compass measurement and indicate upright, open F_2 folds with axial planes striking SE–NW. Tight, steeply-plunging F_1 fold orientations were not directly extractable from the point cloud, but could be observed and mapped in the UAV orthoimage. The trace and apparent offset direction of selected D_3 faults could also be observed in the orthoimage.

Geochemical and petrological analysis of precious metal mineralization within the Bald Hill antimony deposit, New Brunswick, Canada

Alexandra Gray[1], David R. Lentz[1], and Kathleen G. Thorne[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <Alexandra.Gray@unb.ca> ¶
2. Geological Surveys Branch, New Brunswick Department of Energy and Resource Development, Fredericton, New Brunswick E3B 5H1, Canada

The Bald Hill antimony deposit is located in the Late Cambrian–Early Ordovician Annidale belt in Ganderia in south-central New Brunswick. The Annidale belt comprises deformed, greenschist metamorphosed mafic volcanic rocks, felsic tuffs, rhyolite dome complexes, and sedimentary rocks. The area also contains two major thrust faults — the Albright Brook and the Taylors Brook — as well as shear zones that are commonly associated with gold, antimony, and base-metal sulphide occurrences hosted within quartz-carbonate vein systems and associated alteration zones. The Bald Hill deposit is primarily hosted within the Carpenter Brook Formation and associated with the Bald Hill rhyolite dome complex. The Carpenter Brook Formation is characterized mainly by sedimentary rocks comprising a sandstone-siltstone facies and a siltstone-shale facies, and intercalated felsic volcanic rocks of the peralkaline Bald Hill rhyolite dome complex (Bald Hill member) that are aligned parallel to a northeast-trending regional fabric. The complex contains extrusive felsic ash tuff, pyroclastic breccia, rhyolite flows, and intrusive microgranite. The Bald Hill system is also enriched in sulphides such as pyrite and arsenopyrite,

and local stibnite and gold. Previous exploration in the area suggests that there are northeast-trending gold anomalies that are perpendicular to northwest-trending antimony anomalies. Drill core samples were selected from intervals that were enriched in gold based on 2008 drill hole assay data. These samples were then analyzed using an Olympus Vanta model pXRF spectrometer. New assay data for the samples using the Aqua Regia digestion yielded values up to 2 g/t Au and up to 24.9% Sb. Spearman Rank correlation coefficients were calculated for elements determined from the geochemical analyses and the assay data (n = 14). There is a significant association between Au and S (r_s = 0.72), Au and As (r_s = 0.90), Au and Sb (r_s = 0.68), and Au and Sn (r_s = 0.50). Associations of elements were also examined by mapping polished thin sections using Micro X-ray Fluorescence Spectrometry-Energy Dispersive Spectroscopy, which aids in the petrographic analysis of polished thin sections using reflected light microscopy.

ArtScape: creating an artist-in-residence program at the Joggins Fossil Institute, Nova Scotia, Canada, to engage the public with earth sciences

Melissa Grey and Laurie Glenn Norris

Joggins Fossil Institute, Joggins, Nova Scotia B0l 1A0, Canada <curator@jogginsfossilcliffs.net>

Museums are critical institutions for furthering public education and can do so through creative means. The Joggins Fossil Institute (JFI) is a not-for-profit, non-governmental organization that manages the Joggins Fossil Cliffs UNESCO World Heritage Site. JFI aims to engage the public and create world-class educational experiences pertaining to earth sciences and natural history. In 2017, it unveiled its new artist-in-residence program, ArtScape, in order to further the educational and outreach components of the museum and its mission. ArtScape is open to visual artists, literary artists, and performing artists on a revolving basis in a 3-year cycle and provides the time, financial support, and space to enable them to better focus on their work. JFI looks for artistic proposals that engage with, complement, examine, and reflect the natural environment (flora, fauna, weather, water, geology, paleontology, cultural history etc.) of the Joggins Fossil Cliffs and Centre. The residency benefits artists who, through artistic creation and expression, wish to explore the myriad relationships between the human experience and the natural world. It provides the opportunity for artists to personally encounter nature in a unique rural setting. Now entering its third year, ArtScape has hosted a visual artist (2017) and a literary artist (2018), and will complete the cycle with a performance artist (2019). While each artist has time to create their own works, they also have a commitment to engage with the public and school groups through artist's talks, gallery openings, and workshops. ArtScape provides artists, visitors, and the JFI itself with new and exciting ways to consider the natural phenomena embodied in the Joggins Fossil Cliffs.

Multistage gold enrichment in the Menneval – Saint-Quentin district, northwest New Brunswick, Canada: a distinct, shallow quartz-carbonate gold style requiring an exotic (magmatic) fluid source?

Jacob Hanley[1], Glen Hodge[1], Brandon Boucher[2], Jim Walker[3], and Ryan Sharpe[4]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <Jacob.Hanley@smu.ca> ¶
2. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada ¶
3. New Brunswick Department of Energy and Resource Development, South Tetagouche, New Brunswick E2A 3Z1, Canada ¶
4. Department of Geological Sciences, University of Manitoba, Winnipeg, Manitoba, Canada.

The Maisie and Lavoie gold occurrences in the Menneval–Saint-Quentin region of NW New Brunswick are hosted by Late Ordovician, fine-grained clastic sedimentary rocks of the Whites Brook Formation (Grog Brook Group). Gold-bearing veins comprise two generations of quartz (early, laminated and later, massive to vuggy), and contain an assemblage of electrum and trace pyrite (rarely preserved, now hematitized), and rare chalcopyrite (at Maisie) and galena-sphalerite (at Lavoie). Electrum is unambiguously late in the vein paragenesis infilling vugs and fractures.

Cathodoluminescence imaging of the textural relationships of gold and accessory minerals, combined with fluid inclusion data, indicate that veins initially formed via conventional crack-seal mechanisms as in orogenic gold systems, but transitioned to a brittle deformation regime involving the brecciation of early, laminated quartz veins. Gold and pyrite were coevally precipitated during rapid boiling ("flashing") of low salinity (1–4 wt.% NaCl equiv.), CO_2-poor fluid, at temperatures of ~100–200°C at Maisie, and ~140–250°C at Lavoie. Isotope data (Sr-O-C-S) suggest that the sedimentary host rock had a major compositional influence on fluid chemistry. However, pyrite chemistry indicates two stages of gold enrichment: (1) early, low-grade stage where Au correlates with Zn-Sn-Ag-Cu enrichment, and (2) later, higher-grade stage marked by As-Ag-Bi-Pb-Te-Sb enrichment. Sulphides in the host sedimentary rocks show enrichment in only the earlier metal assemblage.

Combined with evidence for locally very high temperatures (400–≥500°C) along vein structures prior to any quartz deposition, the pyrite data suggest magmatic-epithermal fluid involvement.

At Maisie, ID-TIMS U–Pb geochronology of inherited magmatic zircon enclosed in quartz veins yielded an age of 370.03 ± 0.20 (n = 2) Ma. For comparison, a porphyry dike (immediately adjacent to the Maisie veining) gave ages of 367 ± 0.11 Ma (n = 5) and 368.15 ± 0.11 Ma (n = 1) for two zircon populations.

The results provide a maximum age constraint (Late Devonian) for gold mineralization and potentially links the most productive period of gold mineralization to a late fluid of magmatic-epithermal affinity, or some other exotic source rock.

Province-wide engagement of youth in the minerals industry: a New Brunswick gemstone contest

Tom H.A. Healy[1] and Jennifer J. Day[2]

1. Kamcot International Ltd., Fredericton, New Brunswick Canada <tom.healy@kamcot.com> ¶
2. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada

Community outreach for earth sciences and the minerals industry is a critical component of public education and the continued sustainable development of natural resources. New Brunswick in particular has a great wealth of mineral resources, which has been and is a key contributor to the development and prosperity of the province. While today's youth may be absorbed in, and demand, the many products of the minerals industry, they have little knowledge or awareness of who has produced them or how. At the same time, unaware of their dependence upon the mineral industry, they are acutely aware of the negative imagery surrounding it—images that seem to fly in the face of the "sustainable environment" language that they have learned in primary school. Youth are also taught that with a strong foundation of STEM, and a pocket full of smartphones and other technology, they will become the next generation of innovators, command high paying jobs, and become the new and effective leaders of society. In contrast, mineral industry experts and elders suggest a somewhat different reality, whereby it is our natural resources that provide the major threads that create the fabric of our society. It has been this way for the past 5000 years or more and will continue in the future.

It is suggested that there is a major knowledge gap in our education system; in society's quest for a sustainable future, it fails to explain that the needs of society and those of the minerals industry cannot be separated. Messaging to our youth needs to be elevated beyond the current STEM focus and the employment needs of industry, to include a better understanding of societal issues in the sustainability conversation around the minerals industry.

The New Brunswick Branch of the Canadian Institute of Mining and Metallurgy (CIM NB) is working on educational outreach initiatives to address this need. At the provincial scale in New Brunswick, CIM NB is engaging with the provincial government to develop a Provincial Gemstone Contest for youth to propose a gemstone that best represents the province. The criteria for the gemstone contest include significance of the gemstone to the province, as well as the social influence, impact, and interest of the gemstone on or by the public. The contest winners will be invited to and featured at the New Brunswick Energy, Mining, and Petroleum Conference where they will have the opportunity to meet members of the provincial mineral resource community. CIM NB hopes this contest will engage teachers and students across the province to get involved with learning about minerals from multiple perspectives and how they relate in a truly integrated way to the fabric of our society.

Petrographic and μ-XRF study of the gold in sulphide minerals from the Devil Pike Brook deposit in south-central New Brunswick, Canada

Hassan Heidarian[1], David R. Lentz[1], Christopher R.M. McFarlane[1], and Kathleen Thorne[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <Ha.heidarian@unb.ca> ¶
2. Geological Surveys Branch, New Brunswick Department of Energy and Resource Development, Fredericton, New Brunswick E3B 5H1, Canada

The Devil Pike Brook gold deposit, located in south-central New Brunswick, occurs 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. The gold mineralization is hosted by a sequence of mafic volcanic rocks interbedded with sedimentary rocks of the Grant Brook Formation. Based on previous research, gold occurs in fault-fill quartz-carbonate veins that formed in primary shear zones cutting greenschist-grade mafic volcanic host rocks. The type of mineralization, alteration, and mineral associations are similar to other orogenic gold deposits elsewhere in the Appalachians. Although pyrite is the most important sulphide mineral related to the gold mineralization at the Devil Pike Brook deposit, other sulphides are also present including sphalerite, chalcopyrite,

and galena. Pyrite, ranging from fine- to medium-sized subhedral grains, is widespread throughout the foliated host rocks.

This study investigates the distribution of gold minerals in polished thin sections of drill core collected from the Devil Pike Brook deposit. Petrographic studies show that gold grains vary in size between 20–100 microns. In order to investigate the existence of gold in the sulphide minerals, the polished thin sections were examined and mapped using a Micro-X-ray Fluorescence (μ-XRF) – Energy Dispersive Spectrometer. Scanned images from several samples confirm that gold mineralization occurs in association with sulphide minerals, mainly in pyrite and to a lesser extent in chalcopyrite. Arsenic concentrations are low in the sulphide minerals, indicating a lack of arsenian pyrite and arsenopyrite in the samples. Based on μ-XRF scanned images, zinc has a spectral overlap with gold; sphalerite can be separated from native gold by using iron and sulphur spectral analysis. Furthermore, the distribution of sulphur and iron in the μ-XRF scanned images can identify areas of hematitization around the pyrite minerals. These images show that the pyrite and chalcopyrite contain elevated concentrations of both cobalt and nickel. Carbonates in the quartz-carbonate veins, including calcite, dolomite, and ankerite, are represented by the distribution of calcium in association with iron, magnesium, and manganese. The distribution of chlorite alteration can be illustrated in the scanned images by combining the iron, magnesium, and manganese to aluminum ratios.

Comparison of field portable X-ray fluorescence (pXRF) results to certified laboratory geochemical analysis at the Nash Creek Zn-Pb-Ag deposit, New Brunswick, Canada: analysis of reproducibility and application of pXRF geochemical data

Shane J. Higbee[1], David R. Lentz[1], and Jim A. Walker[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <shane.higbee@unb.ca> ¶
2. New Brunswick Department of Energy and Resource Development, Bathurst, New Brunswick E2A 3Z1, Canada

Field-portable X-ray fluorescence (pXRF) is a well-established non-destructive analytical technique capable of rapidly collecting multi-element geochemical data. The heterogeneity of the volcanic rocks hosting the Nash Creek (Zn-Pb-Ag) sulphide deposit provides an excellent opportunity for the application of the pXRF analytical technique. It is capable of assisting with protolith identification, identification of alteration, sample selection, and assessment of geotectonic setting. Using an Innov-X X-5000 pXRF, thin section cut-offs have been analyzed to assess the accuracy, reproducibility, and applicability of pXRF geochemical data compared to geochemical data obtained from a certified laboratory. Prior to comparison and subsequent plotting of geochemical data, the data obtained from the pXRF were subjected to rigorous data quality assurance and quality control (QA/QC), by the assessment of consistently inserted procedural blanks and matrix-matched certified reference materials.

Of the elements analyzed, Ti, Y, Zr, Nb, Th, and Rb were determined because of their common use in trace element-based discrimination diagrams. The comparison showed that in the majority of the basaltic/andesitic rocks analyzed, Ti, Y, and Nb values were reproducible to within 10% and Zr to within 15%, whereas Th consistently returned an overestimated value leading to a >25% difference. Within the basaltic/andesitic rocks, the majority of element ratios assessed (Zr/Ti, Y/Ti, Zr/Y, Zr/Nb, and Nb/Y) were reproducible to within 10%, except for Zr/Y, reflecting the propagation of the Zr variation. Rhyolite trace element data showed that Rb was frequently reproducible to within 5%, Y within 10%, Ti and Zr to within 15%, and Nb and Th to within 20%; variations may reflect heterogeneities such as porphyritic textures, flow layering or mineral phase distributions. Within the rhyolites, the majority of element ratios (Zr/Ti, Y/Ti, Zr/Y, Zr/Nb, and Nb/Y) were reproducible to within 15%, reflecting the propagation of Zr and Nb variation. Despite the variations, plotting both the pXRF and certified laboratory geochemical data on appropriate trace element discrimination diagrams including the Ti-Zr-Y, Nb-Zr-Y, Rb-(Y+Nb), Nb-Y, Zr/TiO_2 –Nb/Y, and Ti-Zr diagrams showed that the data commonly plot within the same fields, leading to the same geotectonic and protolith assignments, including recognition of high- and low-Zr rhyolites. While the results are relatively comparable between the pXRF and laboratory, and the trace element discrimination diagrams comparable to previously conducted studies, caution should always be taken when assessing and interpreting pXRF data.

Secrets of the Temple of Doom: new coesite discoveries in western Norway

Luke Hilchie[1], Rebecca A. Jamieson[1], Colin D. Bryden[1], Michael Terry[2], and Glenn G. Chapman[1,3]

1. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <beckyj@dal.ca> ¶
2. P.O. Box 553, Naples, New York 14512, USA ¶
3. Present address: Department of Earth and Environmental Sciences, University of Portsmouth, Portsmouth PO1 3QL, United Kingdom

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. Large rafts of mafic eclogite hosted by migmatitic orthogneisses are exposed along the north coasts of the islands of Haramsøya and Flemsøya. Previous studies of eclogites in this area determined pressure-temperature (PT) conditions in the coesite stability field although coesite was preserved only as pseudomorphs. Recent field work suggests that most of the eclogite bodies are partly surrounded by enclave-rich diorite to granodiorite envelopes containing variably digested fragments of eclogite and amphibolite. Dykes continuous with these melt envelopes locally intrude the eclogite bodies, where they are associated with intense folding and incipient disaggregation of the eclogites. At Arhaugen, an outcrop informally referred to as the "Temple of Doom" consists of intensely recrystallised eclogite with a steep lineation, separated from the adjacent melt envelope by a dioritic dyke highly contaminated with xenocrysts of eclogite-facies minerals. We identified coesite in garnet xenocrysts from both the dyke and the adjacent melt envelope; the initial optical identification has since been confirmed by Raman spectroscopy. Coesite has not yet been found in eclogite from this locality, although preliminary PT estimates are compatible with UHP conditions. The coesite-hosting garnet xenocrysts differ in texture, composition, and inclusion assemblage from those in the adjacent eclogite body, and we infer that they were derived from a different, possibly deeper, source. Evidence for in situ melting of the eclogite bodies themselves is sparse, although there is abundant evidence for eclogite-melt interaction at the present level of exposure. These results have implications for current questions concerning the role of melting in exhumation of UHP rocks.

Investigating volcanogenic massive sulphide and vein mineralization and its host rocks in drill core from the Jumping Brook Metamorphic Suite, Faribault Brook area, Cape Breton Highlands, Nova Scotia, Canada

Garrett R. Hooey[1], Sandra M. Barr[1], and Chris E. White[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <144239h@Acadiau.ca> ¶
2. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada

The Jumping Brook Metamorphic Suite (JBMS) underlies a large part of the western Cape Breton Highlands east of Cheticamp. Although previously interpreted to consist of mafic metavolcanic rocks (Faribault Brook Formation) overlain by metasedimentary rocks (Dauphinee Brook Formation), based on field observations and detailed studies of drill core, the metavolcanic and metasedimentary rocks are interlayered, and the relative abundance of metasedimentary rocks increases with depth. The JBMS contains many occurrences of gold, silver, and sulphide minerals including chalcopyrite, arsenopyrite, galena, and sphalerite. The rocks are strongly deformed and stratigraphic relationships and the nature of the mineral occurrences that they contain are poorly understood. The purpose of this study is to further investigate these relationships by examining core from two drill holes, GM-08-08 drilled at 45 degrees to a depth of 52 m by Globex Mining Enterprises Limited in 2008, and FB-01-86/08 drilled vertically to 128 m by Selco BP Resources Canada Ltd. in 1986 and deepened to 278 m by Globex Mining in 2008.

Core logging by visual inspection combined with magnetic susceptibility measurements, petrographic study, 5 assay analyses, 18 whole-rock chemical analyses, and 132 portable X-ray fluorescence (pXRF) analyses enabled documentation of units of greenschist facies basalt, tuff, gabbro, wacke, and rhyolite, intruded by thin sills of unmetamorphosed amygdaloidal basalt. The mafic units are difficult to distinguish based on petrography as all are dominated by actinolitic amphibole, chlorite, epidote, plagioclase, and quartz, and have similar low magnetic susceptibilities. Hence, protolith variations were distinguished geochemically using immobile elements and elemental ratios, including Zr/TiO_2, Zr/Y, and Nb/Y. As in other studies of metabasic rocks in the Faribault Brook Formation, the mafic samples display depletion in Nb and light rare earth elements, and the overall chemical characteristics are those of mid-ocean ridge basalt erupted or intruded in association with turbiditic wacke in a back-arc basin. More mineralization was found in hole FB-01-86/08 than reported in previous studies, especially in the upper part. In addition to elevated Cu, Pb, Zn, and As in pXRF analyses in zones of disseminated and vein-hosted sulphides, whole-rock analyses from Bureau Veritas Commodities Limited showed elevated background Au mineralization of 139 and 83 ppb in two samples. The observations support the hypothesis that most of the mineralization is of syngenetic polymetallic volcanogenic massive sulphide (VHMS) type, overprinted by epigenetic vein-related mineralization related to the intrusion of Ordovician and/or Devonian plutons that contact the metamorphosed Cambrian host rocks of the Jumping Brook Metamorphic Suite.

Shock veins in paired lunar meteorites Northwest Africa 3163 and 4881

R. G. Hopkins and J. G. Spray

Planetary and Space Science Center, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <rhopkins@unb.ca>

Many lunar meteorite samples exhibit shock effects, such as shock veins, melt pockets, and associated high-pressure/high-temperature polymorphs. However, the mechanism of formation of shock veins and melt pockets is not well understood. These shock effects are a result of the extensive bombardment by projectiles that have impacted the Moon and modified its surface since formation. On Earth, in situ shock veins have, so far, only been identified in the central uplift structures of the Manicouagan (Canada), and Vredefort (South Africa) impact structures.

This study examines the paired lunar meteorites Northwest Africa (NWA) 3163 and 4881. They are classified as granulitic breccias (breccias that have been thermally metamorphosed at 1000–1100 °C). In thin section, the textures of both samples range from granoblastic to poikiloblastic, with larger grains of plagioclase enclosing smaller grains of pyroxene and olivine. Pyroxene occurs as orthopyroxene hosts containing very fine exsolution lamellae of clinopyroxene.

The meteorites were subjected to shock pressures of 28–34 GPa (shock stage S3), as inferred through the near entirety of plagioclase being converted to maskelynite. Multiple shock veins (≤100 μm wide) and melt pockets (≤400 μm wide) are present, possessing fluidal-glassy textures lighter than the matrix when observed via electron microscopy (FESEM) in backscattered electron (BSE) mode. Within the larger shock veins and melt pockets, small (~1 x 3 μm) elongate plagioclase crystals have grown within the glassy matrix. Clasts that have been assimilated into the veins as xenoliths are also common. Grains of olivine and pyroxene have commonly melted into the veins with fluid (melting) margins. With respect to the pyroxene crystals, the lamellae (clinopyroxene) appear to have preferentially melted into the veins. Thinner (≤10 μm) shock veins commonly branch off the larger veins and pockets, which may crosscut mineral grains and offset them in a fault-like fashion.

The shock veins of NWA3163 were analyzed using Raman spectroscopy at the Planetary and Space Science Center at the University of New Brunswick. The results indicate that the shock veins are amorphous, as expected. Interestingly, a small peak at ~1000 Raman shift/cm^{-1} was registering for shock veins ≥80 μm in width. This is interpreted as clinopyroxene crystals that are beginning to crystallize out of the melt of large shock veins. If this is the case it would contribute greatly to constraining the conditions experienced within shock veins during formation.

Stonehammer in the Classroom

Wanda Hughes

Inside Out Nature Centre, ORBIT Amusements and Go Fundy Events "Adventure in Travel", P.O. Box 27036, Saint John, New Brunswick E2M 5S8, Canada <Gofundy@gmail.com>

We love sparking curiosity about the Earth! With a landscape created by the collision of continents, the closing and opening of oceans, volcanoes, earthquakes, ice ages, and climate change, Stonehammer UNESCO Global Geopark includes geological stories from late Precambrian time a billion years ago to the most recent Ice Age, and almost everything in between. As North America's first Geopark, Stonehammer is about geology, but it is also about the people, society, and culture. After two years of community engagement and rigorous evaluation, Stonehammer was awarded Global Geopark designation in 2010, and revalidated in 2014 and 2018. In our first eight years of operation, Stonehammer has fulfilled our promise of: (1) raising appreciation for and improving education in earth sciences; (2) deepening global scientific knowledge of local geological features; and (3) stimulating the economy through increased tourism.

With a volunteer Education Committee and the hiring of a programme coordinator in 2011, we began creating educational assets according to need, including an earth sciences curriculum course for provincial educators. Building a network and working relationship with the school district and teachers has been very beneficial in terms of creating educational content relevant to curriculum outcomes and hands-on interactive learning. We have taught over 5000 students in over 200 classroom school visits with an average of 25 schools per year, and have trained 143 teachers through capacity-building workshops and materials.

Pilot projects at 3 major high schools in Saint John, best practices with Joggins, the New Brunswick Museum, and other Geoparks, teacher workshops and communications, private and public funding and grants over the past 8 years have been key in enabling Stonehammer to provide field trips, youth activity books, classroom workbooks for grades 4 and 7, and a teacher workbook for high school field trips.

Going forward, we intend to build on our strong foundation and expand our reach, sparking curiosity and teaching all audiences about the earth. Our goals are: (1) to interest more young people in studying geology; (2) to improve province-wide earth sciences outcomes; (3) to encourage scientific research; (4) to inspire deeper pride of place and encourage local people to stay; and (5) to prompt us to examine our consumer choices.

"These workshops were a key component of the delivery of the Science Unit. This speaks volumes about your volunteers and the commitment they have to the program and sharing

our history with our students!" (Sarah Blanchard, Principal, Hampton Elementary School).

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

Alexis Imperial[1], Georgia Pe-Piper[1], and David J.W. Piper[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <alexhimperial@gmail.com> ¶
2. Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B3Y 4A2, Canada

Diagenetic titania minerals are widespread in the Scotian Basin and can potentially provide information on fluid flow and migration of hydrocarbons in the basin. This is because Ti mobility in pore water is enhanced by organic acids and thus, diagenetic titania is most common (a) at lowstands during eodiagenesis and is (b) associated with petroleum maturation and migration. Representative samples at various depths from exploratory wells in the Scotian Basin were selected for detailed study of the distribution of diagenetic titania polymorphs. These polymorphs were identified by Raman spectroscopy as: rutile, anatase, and brookite. Sedimentary facies, burial depth, temperature, and salinity are investigated to evaluate their relationship to the different titania polymorphs. The texture and morphology of the polymorphs were analyzed using scanning electron microscope-backscattered electron (SEM-BSE) images together with transmitted and reflective light microscope images. In general, the abundance of diagenetic titania increases with depth and thermal maturity. Diagenetic rutile is rare and was only seen at shallow depths of approximately 1900 m where it rims detrital quartz crystals. At the same burial depth, detrital ilmenite disappears through dissolution and/or replacement by rutile. Ilmenite pedogenically altered to rutile is abundant in samples containing high concentrations of heavy minerals. Diagenetic anatase primarily occurs as a replacive mineral, usually replacing rutile and phytodetritus, and demonstrably of eodiagenetic origin. In some cases, neoformed euhedral diagenetic anatase appears to fill pores while anhedral-subhedral crystals of anatase have precipitated adjacent to rutile crystals. Diagenetic brookite is predominantly neoformed, occurring (1) in pores as euhedral crystal clusters, (2) as isolated crystals in secondary porosity in completely silicified sandstones, (3) in secondary enlarged remnants of primary pores, or (4) along enlarged intergranular boundaries. Similar to anatase, some diagenetic brookite has precipitated near altered or dissolved rutile crystals. Brookite is the most abundant titania polymorph and predominantly occurs in sandstones that show evidence of transit of deep basinal fluid based on fluid inclusion data and the presence of hydrothermal sphalerite. These observed regional distributions provide a background against which variability related to the effects of petroleum migration can be assessed.

Chemostratigraphic assessment of drill core S916 from the Heath Steele E Zone, Bathurst Mining Camp, New Brunswick, Canada

Josue Jimenez-Gonzalez[1], David R. Lentz[1], James A. Walker[2], and Jennifer J. Day[1]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <Josue.JimenezGonzalez@unb.ca> ¶
2. Geological Surveys Branch, New Brunswick Department of Energy and Resource Development, South Tetagouche, New Brunswick E3B 3Z1, Canada

The Heath Steele E Zone, located in the Bathurst Mining Camp of northeastern New Brunswick, is an economically important part of the complex Middle Ordovician volcano-sedimentary sequence dominated by (meta) quartz-feldspar crystal tuff and intercalated (meta) sedimentary rocks of the Nepisiguit Falls Formation (Tetagouche Group). Based on previous lithogeochemical work conducted on drill core S196, the volcaniclastic and associated sedimentary rocks mostly fall within a very narrow compositional range of calc-alkalic to transitional A-type rhyodacite to rhyolite that is variably affected by hydrothermal alteration and multiphase deformation.

Modern portable X-ray fluorescence (pXRF) spectrometry can measure the abundances of many key elements in concentrations of 10 ppm or less and are sufficient to identify minor changes in geochemistry. Consequently, pXRF is a useful tool to acquire quality in situ data analysis of over 30 elements, thereby providing at least 30 potential variables for use in chemostratigraphic characterization and correlation. The advantages of pXRF-based chemostratigraphy are that it can be applied to any lithotype, deposited in any environment, and may be applied to core, cuttings, and outcrops with equal effectiveness. Perhaps the greatest benefit of pXRF-based chemostratigraphy is that it offers a reasonably high-quality result in real time and a level of resolution that surpasses most other techniques.

The objective of this study is the application of chemostratigraphy in order to resolve rock units in the hydrothermally altered sequence intersected in drill core S916. To achieve this, 152 core samples were selected and analysed at approximately 2 m intervals. Thus far, 11

chemostratigraphic units have been defined in terms of an average or range of elemental values (e.g., Th, Cr, Nb, Zr, and Ta), or a combination of elements or ratios. These results will be used to identify and correlate units intersected elsewhere in the deposit area. It is hoped that the results will be useful in resolving the complex lithostratigraphic relationships that are a key component of mineral exploration in the Bathurst Mining Camp.

A note on the location of diamictite in the Ratcliffe Brook Group on Hanford Brook, southern New Brunswick, Canada

Susan Johnson[1], Malcolm mcleod[2], and laurin branscombe[3]

1. New Brunswick Department of Energy and Resource Development, Geological Surveys Branch, Sussex, New Brunswick E4E 7H7, Canada <susan.johnson@gnb.ca> ¶ 2. Malcolm J. McLeod Geological Consulting, 2 Stockton Street, Sussex Corner, New Brunswick E4E 3C1, Canada ¶ 3. Executive Council Office, Chancery Place, Fredericton, New Brunswick E3B 1E9, Canada

Mapping of the lower part of the Cambrian Saint John Group on Hanford Brook was recently conducted as part of a larger field mapping project in the western Caledonia Highlands. The classic Hanford Brook section is of regional significance as it contains a well-preserved and nearly complete succession of fossiliferous Cambrian rocks characterizing the Avalonian marginal platform. Of equal importance is the report of a muddy diamictite horizon in the lower part of the section that has been interpreted as a dropstone bed. This interpretation provides the only evidence for Early Cambrian glaciation in Avalonia and therefore has implications for paleo-reconstructions of peri-Gondwanan terranes during the Cambrian. Accordingly, the location of the diamictite bed is important. A slab of the dropstone conglomerate is housed at the New Brunswick Museum in Saint John (specimen NBMR 1788); however, the coordinates for the sample were not given.

The diamictite occurs in the Early Cambrian Ratcliffe Brook Group, which is composed of the basal Rencontre Formation and overlying Chapel Island Formation. The Chapel Island Formation is further subdivided into the lower Quaco Road Member and upper Mystery Lake Member. The stratigraphic level of the dropstone conglomerate is reported to be near the base of the Mystery Lake Member, almost immediately above the highest fluvial conglomerate, in an overlying olive-green mudstone-dominated interval. The detailed description and stratigraphic log show the dropstone at interval 173.95–174.35 m, only 5 cms above the highest fluvial conglomerate. The location and depositional context of the dropstone is depicted in a series of three field photographs showing the underlying fluvial conglomerate, the top of the dropstone bed and the dropstone itself. Although polymictic conglomerate was observed above the fluvial conglomerate near the reported dropstone interval it was mostly underwater in the stream bed and was not accessible for sampling. However, it was clear that the photographs depicting the top of the dropstone bed and the dropstone itself were not taken at this location. A careful examination of the entire section has revealed that these photographs show strata much higher in the Mystery Lake Member, approximately 70 m and 110 m respectively above the dropstone interval as shown on the detailed stratigraphic log, which brings the exact location of the diamictite into question. Additional field work will be required to confirm the location of the diamictite bed and to determine where the museum specimen was collected.

Ground-penetrating radar investigation of the fluvial meanderbelt strata of the Carboniferous Joggins Formation, Nova Scotia, Canada

Trevor B. Kelly and Grant D. Wach

Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <tbkelly@dal.ca>

The world-renowned Carboniferous Joggins Formation is known for its complete section of fossil-rich, coal-bearing strata, deposited in a fluvial meanderbelt depositional setting. This makes the Joggins Formation outcrop an excellent analogue for studying the geological complexities associated with meanderbelt systems. This area has been the subject of countless research studies, which can be placed into the broad categories of geology, paleobiology, and paleoecology. In this research, the Joggins Formation is used to study reservoir heterogeneity through small (e.g., bedform baffles and barriers) and large (e.g., channel bodies) scale architectural elements. The study employed an extensive ground-penetrating radar (GPR) 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 (RTK) differential global positioning system (DGPS) for the georeferencing of survey lines. GPR is a non-destructive geophysical method using radar pulses for subsurface imaging. The sedimentary strata of the Joggins Formation were imaged to demonstrate the internal sedimentary architecture of large channel bodies and to obtain a 3-D sense of these channel bodies beyond the two-dimensional cliff face. The survey consists of 42 lines, for a total distance of 3.46 km. A 50 MHz

antennae with a separation of 1.0 m was used for all lines. A total of 6692 traces were recorded between the elevations of 16.97 m to 47.47 m above sea level. GPR lines 09–44 and line 51 were conducted on gravel road surfaces; lines 09–39 on Hardscrabble Road, lines 40–44 on Main Street and line 51 on Mitchell Street. Lines 45–50 were completed on a grassy area just to the north of Main Street near a residential dwelling. Initial results from image processing show many of the lines contaminated by diffractions from buried objects near or under the survey lines. The thick clay-rich soil overlying the Joggins Formation probably contributed to significant signal attenuation and the nature of the strata (dip of the beds, pinching and swelling of the beds, bed thickness, etc.) also contributed to imaging difficulties. Further processing is required to fully determine the success of the survey.

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

Nicole Kennedy[1], Natalie McNeil[1], Erin Adlakha[1], Mitchell Kerr[1], Jacob Hanley[1], Geoff Baldwin[2], and John Wightman[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <nicole.judith@live.com> ¶
2. Nova Scotia Department of Natural Resources, Mineral Resources Branch, Halifax, Nova Scotia B3J 2T9, Canada ¶
3. Goldfields Group of Companies, Bridgetown, Nova Scotia Canada

Cobalt-nickel-rich sulfarsenide (cobaltite-gersdorffite-arsenopyrite) mineralization (+Au, Ag, Bi) is located in the Nictaux Falls Spillway, Annapolis Valley, Nova Scotia. Mineralization occurs in a zone of fault-bounded quartz veins, breccia and stockwork, which cross-cuts the late Silurian Kentville Formation in the central portion of the spillway. Mineralization is hosted by: (i) early, laminated, quartz-sulfarsenide veins (~1–2 cm wide) characterized by early sulfarsenide crystals, with interstitial wall-rock material (i.e., chlorite, rutile, biotite) and later anhedral (interstitial with respect to sulfarsenide) to euhedral (surrounding sulfarsenide) quartz; and (ii) sulfarsenide-mineralized wall rock clasts (~1 cm in diameter) in quartz breccia veins. Late quartz veins appear barren of mineralization and crosscut mineralization in the fault-bounded mineralized zone. These veins range from <1 cm to 20 cm in diameter, and are characterized by beige-coloured, coxcomb quartz, with miarolitic cavities and wall-rock clasts in the largest veins. Similar barren veins are exposed in the other areas of the spillway, crosscutting the metasedimentary rocks and the nearby Cloud Lake Pluton of the South Mountain Batholith.

Quartz-hosted fluid inclusions in both vein types are similar and classified into two types. Type-1 inclusions contain two phases (L+V), are <5 μm in size, and exhibit rounded to negative crystal shape. Type-2 inclusions contain three phases, are <14 μm in size and exhibit irregular to negative crystal shape. Despite cathodoluminescence imaging of the quartz, the fluid inclusion assemblages are of indeterminate origin as they occur as clusters in the core, or between growth zones, of the individual quartz crystals. The vapour bubbles of the fluid inclusions were analyzed using Raman spectroscopy and are water vapour-dominated (i.e., no CH_4, CO_2, N_2 detected). Homogenization temperatures of type-1 inclusions range from 167.2°C to 181.8°C. Type-2 fluid inclusions homogenize via halite dissolution between 163.2–227.2°C, indicating entrapment at high-pressure (e.g., 2.5 to 4 kbar at 300°C) assuming no post-entrapment modification. Based on microthermometric calculations, the range of salinities for type-2 fluid inclusions is 30.37–33.86 wt.% NaCl equivalent. The salinities of type-1 inclusions could not be determined due to analytical difficulties related to their small size.

Ongoing and future work includes: (i) continued microthermometric analysis of fluid inclusions, (ii) Ti-in-quartz thermometry to provide independent temperature constraints for P-T estimates using microthermometric isochores, (iii) decrepitate mound analysis to determine solute composition of the fluid inclusions, and (iv) determination of $^{18}O/^{16}O$ in mineralized and barren quartz to confirm their genetic relationship and constrain source(s) of fluid.

Preliminary evaluation of the use of bulk fluid inclusion volatile signatures for exploration of argillite-hosted disseminated gold deposits: a case study in the Meguma terrane, Nova Scotia, Canada*

Mitchell Kerr[1,2], Jacob Hanley[1], and Daniel Kontak[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <Mitchell.Kerr@smu.ca> ¶
2. Harquail School of Earth Science, Laurentian University, Sudbury, Ontario P3E 2C6, Canada

Contemporary exploration programs focused on gold mineralization rely on detailed lithogeochemical and structural data coupled with assaying of host rocks and vein material to define mineralized domains, with no emphasis on ore fluid chemistry. Predictive models for hydrothermal ore deposit formation should also consider how ore-bearing fluids are modified at a "deposit-scale" level, producing systematic variations in fluid chemistry potentially

discernable at strategic distances from mineralization. This is especially relevant in the exploration for disseminated gold deposits since gold in these settings is not hosted in obvious quartz-carbonate veins, and is often unidentifiable during routine core logging.

We evaluate whether the bulk volatile chemistry (speciation and abundances of volatile species) of argillite-hosted fluids can be used to identify proximity to mineralization or differentiate ore-bearing vs. barren parcels of metasedimentary rock at a strategic level, and whether a gas chromatographic-related (GC) exploration tool may be effectively integrated into exploration protocols. To evaluate these questions, the metasedimentary rock-hosted disseminated gold deposits associated with the Moose River Anticline (MRA; e.g., Touquoy), and the "barren" parcels of metasedimentary rock along the MRA (e.g., Otter Lake) have been sampled.

Samples of metamudstone (meta-argillite, slate) and of crosscutting quartz-carbonate veins (<5 cm) from along the MRA have been investigated in order to evaluate the occurrence and composition of fluid types that may constitute a "bulk fluid". In quartz veins from Touquoy, clusters of 2-phase aqueous-carbonic fluid inclusions (type 1) of indeterminate origin, and secondary inclusion trails that extend away from vein margins into the argillite host rock, have variable abundances of CO_2 (0.12–0.95 mol%), CH_4 (0.08–0.80 mol%), and N_2 (0–0.84 mol%) in the vapour phase. Conversely, 2-phase inclusions hosted in quartz within arsenopyrite pressure shadows in argillite, are vapour-rich and dominated by CH_4 (0–0.82 mol%) and N_2 (0.18–1 mol%). Vapour-only inclusions (type 2) in quartz veins are variable CO_2-CH_4-N_2-bearing, while type 2 inclusions in pressure shadows are dominated by CH_4 and N_2 only. Preliminary bulk volatile GC analysis of argillite/slate samples from mineralized (>0.1 g/t) and barren parcels (<0.1 g/t) has been performed. Understanding the differences in fluid chemistry in barren vs. mineralized regions of the Meguma may help improve gold models by determining if (i) pulses of auriferous fluids locally infiltrated regions of the Meguma and precipitated gold, or if (ii) a gold-bearing fluid broadly infiltrated the Meguma but only precipitated gold as a result of favorable mechanistic factors (e.g., host rocks, dilational settings, etc.).

Winner of the AGS Sandra Barr Award for best graduate student oral presentation

An ichnotaxonomic and paleoenvironmental study of the xiphosuran ichnogenus Kouphichnium from the UNESCO World Heritage Site Joggins Fossil Cliffs, Nova Scotia, Canada

Olivia A. King[1], Matthew R. Stimson[1,2], R. Andrew MacRae[1], John Calder3, Brian Hebert[4], and Len Reid[5]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <Olivia.King@smu.ca> ¶
2. New Brunswick Museum, Saint John, New Brunswick E2K 1E5, Canada ¶
3. Nova Scotia Department. of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada ¶
4. Main Street, Joggins, Nova Scotia, Canada ¶
5. Maccan, Nova Scotia, Canada

The fossil record at Joggins has long been studied for its body fossil record of plants, tetrapods, and rare invertebrates. The vertebrate ichnofossil record has acted as a template for Paleozoic vertebrate ichnotaxonomy dating back to the early 1900s when studied by G.F. Matthew and previously by Sir J.W. Dawson. Despite some of the earliest descriptions of invertebrate ichnofossils (*Diplichnites*) being noted by Dawson at Joggins, and Carboniferous 'xiphosuran' trackways having been recorded in the Cumberland subbasin dating back to the 19th century (*Protichnites carbonarius*), invertebrate ichnofossils have yet to be systematically studied at Joggins in a comprehensive way. We present here the preliminary results of a restudy of the ichnogenus *Kouphichnium* from the Joggins Fossil Cliffs, that are traditionally assigned to xiphosuran walking traces. *Kouphichnium* species are dominated by the ichnospecies *K. lithographicum*; however, 2 new morphologies have been identified.

Before this study, the ichnospecies *Kouphichnium aspodon* had only been recorded from an incomplete trackway from the Mississippian-aged Mauch Chunk Formation in Pennsylvania, and from the ichnospecies type section in the Pottsville Formation of Alabama. *Kouphichnium aspodon* has now been discovered in the Springhill Mines Formation at Denis Point along the Joggins Fossil Cliffs. This makes it the third occurrence in the fossil record and is here interpreted to be produced by either a eurypterid or synxiposurian. Like limulids, eurypterids are known to travel inland from the oceans to quiescent brackish conditions to moult and mate. Eurypterids at Joggins have only been described (by Dawson in the 19th century) from cuticle fragments that were found inside lycopsid trees, where they were associated with tetrapod bones, millipedes, and land snails. This interpretation may have paleoenviromental implications as the strata exposed at Dennis Point may have been at least distally connected to open-water conditions.

A unique morphology of *Kouphichnium* has been identified from this site. Several *Kouphichnium* specimens exhibiting double telson drags were previously considered to represent mating xiphosurid traces. The interpretation for this morphology is not new; however, the ichnotaxonomic

implications of this behavioral difference suggest that these traces represent a unique morphology and unique behavior (mating) compared to simple walking traces of xiphosurans. It is therefore appropriate that this unique morphotype of *Kouphichnium* be proposed as a new ichnotaxon in honour of its discoverer, the late citizen scientist Donald Reid ("The Keeper of the Cliffs").

Changes in dinoflagellate cyst productivity in the North Water polynya during the past ca. 4000 years

Kelsey Koerner[1], Audrey Limoges[1], Guillaume Massé[2], Nicolas Van Nieuwenhove[1], and Sofia Ribeiro[3]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <kkoerner@unb.ca> ¶
2. Department of Biology, TAKUVIK, Laval University, Québec City, Quebec G1V 0A6, Canada ¶
3. Glaciology and Climate Department, Geological Survey of Denmark and Greenland, 1350 Copenhagen, Denmark

Polynyas are areas of open water in a region that is otherwise covered by sea ice. Because they receive more light and the mechanisms involved in polynya formation can enhance nutrient supply to surface waters, polynyas are regions of high primary production that sustain unique food webs.

The North Water (NOW) polynya is located off the northwestern Greenland coast and Canada's Ellesmere Island. It is the largest coastal polynya in the Arctic. There are three main factors that aid the formation of the NOW polynya. The first is an ice bridge that forms in Nares Strait, which blocks drift ice from being exported from the Arctic Ocean into northern Baffin Bay. Second, strong northerly winds remove newly-formed sea ice away from the NOW polynya region. Last, the advection of warm and salty waters from the West Greenland Current into the area further inhibits the formation of sea ice. Due to changes in sea-surface conditions (e.g., sea ice cover, nutrient availability) associated with ongoing climate warming, the physical-chemical conditions that make the NOW polynya biologically productive are subject to change. The rate and magnitude at which such changes will operate in the future are unknown.

Here, we present preliminary results on dinoflagellate cyst (dinocyst) assemblages in a 5.43 m-long sediment core collected in the central region of the NOW polynya (77°17.097'N-74°23.214'W) at a water depth of 700 m. Our goal is to reconstruct changes in the polynya's sea-surface conditions and dinocyst productivity that may be related to climate variations of the past ca. 4000 years. Heterotrophic dinocysts dominated the core assemblages, with *Islandinium minutum* being the most abundant species (62 to 88%). The last ca. 1800 years covered by the core are marked by a decrease in the autotrophic species (most clearly expressed by *Operculodinium centrocarpum* and *Spiniferites elongatus*) and a slight increasing trend in the total dinocyst concentrations. Although in low abundances, cysts of the sea ice species *Polarella glacialis* are present throughout the core. Since the dinoflagellate *Polarella glacialis* completes its entire life-cycle in sea ice, our data indicate that seasonal sea ice was present during the last ca. 4000 years. Our preliminary results suggest: (i) generally more seasonally persistent sea ice in the NOW region between ca. 1800 and 200 years ago; and (ii) increased total dinocyst concentrations during times of higher sea ice concentrations.

An integrated fluid inclusion, quartz CL, LA ICP-MS, and SIMS $\delta^{18}O_{quartz}$ study of an auriferous vein quartz sample, Caribou gold deposit, Nova Scotia, Canada: insight into a paleo-hydrothermal fluid

Daniel J. Kontak[1], Brandon Choquette[1], and Mostafa Fayek[2]

1. Harquail School of Earth Sciences, Laurentian University, Sudbury, Ontario P3E 2C6, Canada <dkontak@laurentian.ca> ¶
2. Department of Geological Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

Integrated fluid inclusion (FI) and O isotopic studies provide insight into the PTX conditions of paleo-ore systems. More recently, cathodoluminescence (CL) imaging of quartz and LA ICP-MS analysis of FIs have also been used to constrain fluid evolution in ore systems. It is rare to find well preserved vein quartz in orogenic deposit settings due to overprinting deformation. Here, a clear prismatic quartz (+muscovite-carbonate-arsenopyrite) sample from a late-stage pocket in a bedding-concordant auriferous quartz vein from the Caribou gold deposit, Nova Scotia, is used to address fluid evolution in such a setting. CL imaging reveals that primary quartz is bright in CL and free of FIs. In contrast, overprinting dark-CL zines are inundated with 3D arrays of large (≤100 μm), negative-shaped H_2O-CO_2 FIs (type 1); lesser, halite-bearing aqueous (type 2) FIs are also present. Locally, type 1 FIs record decrepitate textures. Thermometry of type 1 FIs (n = 81 FIAs) indicates X_{CO2} = 0.1 ± 0.05 with some CH_4 (Tm_{CO2} = -58 ± 2 °C) and low salinities (<2–3 wt.% NaCl equiv.). Entrapment of these FI are constrained to ca. 250 to 350 °C, but variable P_{H2O} is suggested based on isochoric projections. Type 2 FI (n = 22 FIAs) are saline (30 wt.% NaCl equiv.) with T ranging

between 80 to 150 °C. Evaporate mound SEM-EDS analysis (n = 310) and LA data (n = 20) of mainly type 1 FIs indicate that Na:Ca and Na:K vary, as do the trace elements (in ppm): As = ND to 1500, B =100-3000, Ba = ND to 450, Fe = NS to 3000, Mn = ND to 2000, Pb = ND to 100, Sb = ND to 1500, Zn = ≤60, W = ND to 150, and Li, Cs, Rb all ND to <70. In situ SIMS analysis (n = 19) of $\delta^{18}O_{quartz}$ yields values of 9.1 to 15.1‰ (avg. = 12.3 ± 1.7), with no preference for CL zones; thus, the quartz was deposited from a fluid with $\delta^{18}O_{H2O}$ = 7 ± 2‰ (for 350 °C). The studied sample records early trapping of a fluid of mixed provenance that is not solely of metamorphic origin. The variable X_{CO2} and decrepitate textures for type 1 FIs reflect transient P (Δ2 kbars) during vein formation, whereas its chemistry reflects exchange with the host wall rocks. Type 2 fluid records ingress of a cooler and more saline fluid unrelated to vein formation.

Potential for porphyry- and epithermal-style precious metal deposits in the Mira terrane of Cape Breton Island, Nova Scotia, Canada

Graham D. Layne[1], Sandra M. Barr[2], and Chris E. White[3]

1. Department of Earth Sciences, Memorial University, St. John's, Newfoundland and Labrador A1B 3X5, Canada <gdlayne@mun.ca> ¶
2. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada ¶
3. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada

Numerous features indicate significant potential for precious metal deposits in the Mira terrane of southern Cape Breton Island, in particular, those in the broad class of epithermal Au(-Ag) and porphyry Cu(-Mo-Au) deposits. The Mira terrane is closely analogous to the Avalon zone of Newfoundland, which is experiencing increased exploration activity focused on these deposit styles, including extremely active exploration on the Burin Peninsula – notably at Big Easy (Cartier Iron) and Heritage (Puddle Pond Resources). Farther to the southwest, rocks of Avalon zone age host the Hope Brook Mine, the richest producing Au deposit in the late Neoproterozoic of North America to date. In the Newfoundland Avalon zone, metallogeny is clearly related to specific episodes of granitoid plutonism (at ca. 620 Ma, ca. 575–580 Ma and ca 565 Ma), and contemporaneous episodes of similar plutonism and associated volcanism are recognized in the Mira terrane (Coxheath Hills-East Bay Hills-Sporting Mountain belts, and Fourchu and Main-à-Dieu groups in the Coastal belt). Some workers have also made the analogy with more modern Andean or Cordilleran terranes with respect to the evolution of the broader Avalon terrane (Avalonia), an environment considered auspicious for these deposit types.

The Mira terrane hosts the former Coxheath Mine, a Cu-Au porphyry deposit within the ca. 620 Ma Coxheath Hills Pluton. This indicates strong potential for additional porphyry-style and related epithermal-type deposits, although affiliated epithermal-type Au-Ag deposits have remained unrecognized in the broader Coxheath Hills-East Bay Hills-Sporting Mountain belts to date. However, both low- and high-sulfidation epithermal-style deposits can be cryptic. For example, some styles of low-sulfidation veins (e.g., low vein density peripheral occurrences) can go unrecognized as such during prospection, and high-sulfidation systems can have substantial volumes of relatively Au-barren alteration surrounding a smaller auriferous core.

Our initial field and laboratory work deployed petrography, geochemical assay. and infrared absorption spectroscopy (NIR-SWIR) to characterize currently listed mineral occurrences that might have the hallmarks of these deposit styles. Our study is also directed at narrowing prospective host lithotypes and paleoenvironments for epithermal-style deposits, including, for example, epiclastic rocks characteristic of caldera-fill sedimentation during active shallow hydrothermal activity (low sulfidation deposits), and areally extensive zones of high-sulfidation hydrothermal alteration. These initial studies are designed as a first step in providing an improved framework for exploration for precious metal resources in the Mira terrane.

Analysis of limestone-marble syntexis reactions in the generation of some peralkalic magmas: reanalysis of Reginald Daly's insights 100 years later

David R. Lentz

University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <dlentz@unb.ca>

The theoretical analysis of how sedimentary limestone and marble could melt as a result of infiltrative contact metasomatism associated with silicate magma enables reconsideration of the limestone syntectic (complex assimilation) hypothesis for the origin of some peralkalic rocks. Reginald Daly's syntectic model published in detail in early 1918 fell out of favor because experimental evidence from the early 1960s suggested that: (1) limestone assimilation would increase $P(CO_2)$ and cause solidification of the silicate intrusion; (2) there is a thermal barrier between silica-saturated and undersaturated magmas that would inhibit extensive desilication of the magma; and (3) the endothermic decarbonation reactions would require

heat via magmatic crystallization of near-solidus magmas. However, these concerns were not as critical for high-T mafic melts relative to lower-T silicic melts, although most subsequent researchers dismissed syntexis because isotopic arguments also seemed robust. However, skarn-related limestone melts can interact much more easily with silicate magma, resulting in calc-silicate-forming (endoskarn-like) limestone syntectic (desilication-calcification-magnesification processes) decarbonation reactions with compositional evolution into the silica-undersaturated field. If originally mafic in composition when syntectically modified, then the CO_2-bearing derivative peralkalic melt may subsequently react with the dominant volume magma or fractionate separately into a more evolved composition. As well, an increase in $P(CO_2)$ within the modified silicate fraction coupled with compositional evolution to more silica-undersaturated compositions enhances the stability of the immiscible, extremely low viscosity carbonate melt fraction. In addition, dynamic interaction of these co-existing immiscible melts (analogous to the current hypothesis) would partition elements, as well as isotopic signatures, such that they would be virtually unrecognizable as having a crustal level syntectic origin, based on mass-balance principles and Rayleigh decarbonation isotopic equilibria, as they do in many infiltrative skarn systems. Rayleigh decarbonation significantly affects these key isotopic signatures such that they are almost indistinguishable from mantle magmas. Radiogenic and stable isotopic arguments against limestone/marble syntexis for the origin of some peralkaline magmas are shown to be equivocal. Other objections to syntectic processes are briefly re-examined, in particular the importance of these syntectic decarbonation processes in open versus closed subvolcanic systems. The syntectic scenario challenges the current (only) petrogenetic hypothesis of a mantle source for peralkalic-carbonatitic magma systems, while presenting evidence for a modified syntectic origin for some (hybrid) peralkalic magmas and associated secondary crustal carbonatites. This petrogenetic analysis supports the basic premise of Daly's limestone syntectic hypothesis for the origin of some peralkalic igneous rocks.

Glaciers and blueberries: development and analysis of a field-based earth science workshop designed for Nova Scotia teachers

Louise Leslie

School of Environment and Sustainability, Royal Roads University, Victoria, British Columbia V9B 5Y2, Canada <louise.leslie@hotmail.ca>

Glaciers and Blueberries was the title for a field-based earth science workshop conducted in partnership with the Fundy Geological Museum in May and October 2018 for grade 4 and 7 teachers within the Chignecto Family of Schools catchment area. The development and analysis of this workshop is the basis of a thesis for a MA in Environmental Education and Communication at Royal Roads University. The teachers' workshop was developed with an inquiry-based approach intended to provide insight into their views and experience of field-based learning, while meeting Nova Scotia, grade-specific curricula requirements. Quantitative and qualitative data consisted of questionnaires completed by an expert panel of 10 geoscientists and five teachers who participated in two separate workshops, as well as an analysis of the workbooks completed by the teachers. The field setting was a glacial environment situated along the Parrsboro River valley. Field trip activities included identifying rock types of pebble samples collected from a glaciofluvial terrace and a kame field, conducting an erosion experiment, and drawing sketches of four different glacial landscapes. The teachers' pre- and post-field trip questions showed an increase in their confidence and comfort with conducting a field trip. Overall, the expert panel responses ranged from neutral to strongly agreed and the teachers' ranged from agreed to strongly agreed to the same thirteen quantitative questions. There were slightly lower agreement levels from both groups to two curriculum-related questions. Expert panel results from five open-ended questions identified eleven common keywords, most related to logistics, field trip activities, and knowledge. Teachers responses referred mostly to logistics and activities. Analysis of the workbooks completed by the teachers demonstrated there is a lack of knowledge in rock identification and erosion processes. Despite adding a pre-teaching session, the teachers had difficulty distinguishing rock textures and consequently identifying rock types. The low teacher participation in the workshop can be attributed to several factors, some which are unavoidable. There remains much work in the future in recruiting teachers, improving the quality of professional development of the workshop, and persevering in this endeavour.

Polynya productivity in relation to climate-driven changes in Arctic and subarctic environments: a long-term perspective

Audrey Limoges

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <alimoges@unb.ca>

The rapidly reducing seasonal duration and thickness of Arctic sea ice caused by current climate warming raises important questions regarding the future resilience and function of polar marine ecosystems. In the Arctic, recurrent polynyas (i.e., open-water areas that develop within sea-ice-covered zones) are major contributors to the Arctic productivity budget: they constitute localized sources of high marine primary production that fuels wealthy food webs. They also act as important sinks of atmospheric CO_2 through brine rejection and biomass production. Because the onset and lifespan of polynyas is tightly connected to sea-ice conditions, continued sea-ice reduction may compromise their formation, predictable recurrence, and biological productivity.

Over recent decades, the scientific community has put tremendous efforts into documenting the physical and biogeochemical impacts of climate-driven environmental changes on some of the largest Arctic polynyas. In the North water (NOW) polynya, located in northern Baffin Bay, satellite observations have notably revealed a rapid decline in primary production over the past 30 years. The available datasets are, however, too limited in time to fully understand the long-term significance of the system's observed variability, limiting our ability to predict its future evolution under a scenario of continued warming. For most of the smaller polynyas distributed in the Canadian Arctic and subarctic, little to no such information is currently available.

Here, I present the results from the analysis of subfossil diatom assemblages and sea-ice biomarkers (IP_{25} and triene) preserved in two sediment cores covering the Holocene, collected from the NOW polynya and offshore Upernavik, northern Baffin Bay. Our results place the observed recent decline in primary production into a long-term perspective and highlight a strong link between changes in the polynya's diatom productivity, sea ice and ocean circulation. I will also present the outline of a new research collaboration that aims at characterizing productivity changes that occurred over the last 2000 years in polynyas located in northwest Hudson Bay.

Using permutational and multivariate statistics to understand inorganic well water chemistry and the occurrence of methane in groundwater from the Carboniferous Basin, New Brunswick, Canada

Diana Loomer[1], Kerry MacQuarrie[1], and Tom Al[2]

1. Department of Civil Engineering, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <dloomer@unb.ca> ¶
2. Department of Earth and Environmental Science, University of Ottawa, Ottawa Ontario K1N 6N5, Canada

Concerns over possible impacts from the potential expansion of unconventional oil and natural gas (ONG) resource development prompted a regional domestic well sampling program focusing on the Carboniferous Maritimes Basin bedrock in southeastern New Brunswick. This work applies recent developments in robust multivariate statistical methods to overcome issues with highly non-Gaussian data and supports the development of a conceptual model for the regional groundwater chemistry and the occurrence of methane. Principal component analysis reveals that the redox-sensitive species, DO, NO_3, Fe, Mn, methane, As, and U are the most important parameters that differentiate the groundwater samples. Permutation-based MANOVA and ANOVA testing reveals that geology is more important than geographic location and topography in influencing groundwater composition. Groundwater in two geologic units, the Mabou and Cumberland groups of the Maritimes Basin, displays geochemical characteristics indicative of rapid recharge and relatively short rock-water interaction times. In many instances, the groundwater chemistry of the Horton, Sussex, and Windsor groups cannot be distinguished from each other. Trends in the Pictou Group groundwater chemistry are discernible if the grouping is further differentiated by formation. The statistical inferences are supported by chemistry trends observed in relation to road de-icing salt and other saline sources. However, source differentiation between Carboniferous brines, entrapped post-glacial marine water and, for coastal wells, modern seawater cannot be made. Furthermore, Cl:Br ratios lower than those of seawater or regional brines suggest an origin related to the diagenesis of organic-rich sediment and that the source for elevated Cl concentrations in those samples may be local, low permeability units as opposed to distal brines.

Combined chemical, spatial, and statistical analysis shows that, while trace or low levels of methane, <1 mg/L, are found ubiquitously throughout the Maritimes Basin, elevated concentrations near the town of Sussex, >1 mg/L, are associated with the Horton Group, consistent with it being the host and inferred source of ONG resources in the province. The highest methane concentrations (14–29 mg/L) were detected in areas having a complex history of uplift and erosion cycles which, in some locations, resulted in the juxtaposition of the Horton Group with four of the five other groups of the Maritimes Basin at the surface. In two examples, proximity to the Horton Group resulted in high methane concentrations, >15 mg/L, in wells completed in non-ONG-bearing units, the Cumberland and Sussex groups.

Does Atlantic Canada need its own geology textbook? A proposal for a regionally-focused open textbook

Jason Loxton

Department of Mathematics, Physics, and Geology, Cape Breton University, Sydney, Nova Scotia B1P 6L2, Canada <jason_loxton@cbu.ca>

The Ontario Undergraduate Student Alliance's recent #TextbookBroke campaign made national headlines by highlighting the financial burden mandatory course materials place upon students. Students in Atlantic Canada are far from insulated from these pressures: a 2017 Maclean's national survey ranked St. Francis Xavier, Cape Breton University, and Memorial University at #2, #11, #12, respectively, for highest average textbook costs ($917.24–$876.11/year). Open textbooks provide an alternative to the traditional publishing model and a partial solution to the problem of high textbook prices. Open textbooks are produced and distributed under a Creative Commons license, making them freely available to use and modify. (They may be used free digitally or printed locally at cost.) In addition to savings, the ability to adapt textbook content to make it regionally relevant allows instruction to be consciously "place based", increasing student engagement by emphasizing community connections, highlighting local examples, and integrating local First Nations' traditional knowledge. This is of particular value in Atlantic Canada, a region often poorly represented in "Canadian edition" introductory geology textbooks. Building an open textbook from the ground up is labour intensive, but an up-to-date textbook already exists that could act as a foundation for an Atlantic edition: *Physical Geology*, released in 2015 by the BCcampus Open Textbook Project, and modified for use by the University of Saskatchewan in 2018. This presentation reports the preliminary results of a pilot project using the 2015 edition of *Physical Geology* to support a non-majors introductory geology course at Cape Breton University, as well as the results of a survey of current textbook use and instructor attitudes about open textbooks at Atlantic Canadian universities offering first year geology courses.

Choose your model carefully: comparison of two versions of the MELTS algorithm with sub-liquidus phase relations in mineral – melt equilibration experiments at 1 GPa and 1250°C

Shuai Ma and Cliff Shaw

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <sma2@unb.ca>

Complex petrologic problems can be approached by experiment or by thermodynamic approximation. The thermodynamic approach has helped in understanding phase relations and geochemistry of igneous and metamorphic rocks over a range of temperatures, pressures, and compositions. One of the most commonly used thermodynamic models is the MELTS algorithm. There are a number of versions of the algorithm, which apply to different compositions. pMELTS is used to model partial melting in peridotite and clinopyroxenite compositions, other versions apply to crystallization and melting in volatile-bearing, silica-undersaturated or silica-oversaturated compositions. We are interested in reactive transport of magma through the mantle, particularly the mineral and melt assemblages that result from prolonged flow of magma through closely-spaced vein systems in peridotite. On the basis of field studies, we expect that the vein – peridotite system should reach equilibrium, since magma was present in the fractures for at least a few thousand years. A number of previous studies of reactive transport in peridotite have used the pMELTS algorithm to replace experiments, though it is not clear if this is the most appropriate model.

Magma – mineral equilibration experiments were performed in which a silica-undersaturated alkaline magma is reacted with orthopyroxene, olivine and clinopyroxene in various proportions under mantle conditions (1250°C and 1 GPa). The experiment charges were finely ground before being sealed into graphite-lined platinum capsules and held at the desired conditions for two weeks. It was expected that the combination of small grains with large surface area and long reaction time should allow chemical equilibrium to be attained. The phase proportions and compositions of glass, olivine, clinopyroxene, and orthopyroxene in the experiments have been determined using imageJ and the electron probe; these data allow the appropriateness of two MELTS versions for modelling peridotite – melt interaction to be assessed.

The experimental results were compared to the outputs from pMELTS (the model appropriate for mantle compositions) and MELTS V 1.2.0 (appropriate for modelling phase relations in quartz-free, volatile-bearing magmatic systems). pMELTS consistently overestimates the silica and alkali content of the equilibrium magma and there are large differences between the observed and calculated phase proportions and mineral compositions. MELTS V 1.2.0 gives much closer agreement of mineral and melt compositions and proportions, though there are still some differences between the experiments and the calculated equilibria. These preliminary results show that great care is needed in choosing the most appropriate thermodynamic model for the system of interest.

Toward understanding the pre-Carboniferous geological evolution of the Cobequid Highlands, Nova Scotia, Canada: constraints from U–Pb (zircon) geochronology and geochemistry

Trevor G. MacHattie[1], Chris E. White[1], Sandra M. Barr[2], and Kevin Neyedley[1]

1. Geoscience and Mines Branch, Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada <Christopher.e.white@novascotia.ca> ¶
2. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada

Detailed 1:10 000-scale bedrock mapping in the Cobequid Highlands was initiated in 2010 by the Nova Scotia Department of Energy and Mines to follow-up on known and recently discovered rare-earth-element mineralization and gold anomalies. The new mapping, combined with U–Pb zircon geochronology and chemical data, shows that the oldest rocks in the highlands are mafic metavolcanic rocks interbedded with quartzite, metawacke, and minor marble and ironstone located in the faulted-bounded Bass River block along the southern margin of the highlands. Sections dominated by mafic metavolcanic rocks have traditionally been termed the Folly River Formation and sections dominated by metasedimentary rocks are assigned to the Gamble Brook Formation, but the rocks are locally interbedded and interpreted to be of similar age. The age is constrained by detrital zircons to be less than about 1 Ga and by U–Pb zircon from cross-cutting plutons to be more than about 750 Ma. The mafic volcanic rocks have chemical characteristics of continental tholeiite with εNd(t) values of +4.6 to +7.1. Associated gabbroic bodies are also MORB-like with εNd(t) of +6.9 to +7.7. These rocks may have formed in the Early Neoproterozoic during the breakup of the Rodinian supercontinent. Cross-cutting plutons of the ca. 765–735 Ma Mount Ephraim Plutonic Suite consist of calc-alkaline gabbro/diorite to granite that show more evolved εNd(t) values of +0.2 to +1.7. They indicate the initiation of subduction along the margin of Rodinia or a Rodinian microcontinental fragment, probably Avalonia. The most extensive Neoproterozoic units in both the Bass River block and the Jeffers block to the north are calc-alkalic, arc-related volcanic and plutonic rocks with more typical Avalonian ages of 640 Ma to 585 Ma and εNd(t) values between -1.5 and +3.7. Many of the dated samples also contain a significant inherited ca. 680–650 Ma zircon component, suggesting the existence of older volcanic/plutonic rocks similar in age to the Stirling belt in Cape Breton Island. The ca. 610–585 Ma ages are similar to those from Avalonian volcanic and plutonic rocks in the Antigonish Highlands to the east and in the Boston area. Small bodies of within-plate syenite to alkali-feldspar granite and gabbro along the southern margin of the highlands yielded zircon ages of 482–480 Ma, slightly older than similar Ordovician plutonic units in the Antigonish Highlands. Fossiliferous sedimentary rocks of the Silurian Wilson Brook Formation unconformably overlie the older rocks of the Cobequid Highlands and are similar to the Arisaig Group in the Antigonish Highlands.

Recent changes in diatom production and sea-surface conditions in the North Water polynya, northern Baffin Bay, Canada*

Liam MacNeil[1], Audrey Limoges[2], Guillaume Massé[3], and Sofia Ribeiro[4]

1. Department of Biology, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <liam.macneil@unb.ca> ¶
2. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada ¶
3. Department of Biology, TAKUVIK, Laval University, Québec City, Quebec G1V 0A6, Canada ¶
4. Department of Glaciology and Climate, Geological Survey of Denmark and Greenland, Copenhagen, 1350 Denmark.

Environmental conditions at polar latitudes are uniquely governed by the interaction of oceans, atmosphere, and ice. Changes in these parameters can occur rapidly and induce pronounced shifts across environments and food webs. The sensitivity of marine food webs provides an initial basis to examine environmental flux through time; a series of biogenic tracers (e.g., microfossils, biomarkers, etc.) preserved in the seafloor sediment can reflect changes in conditions at the sea-surface. This project investigates the features of this biological signature through the lens of (sub) fossil diatoms in the largest and most biologically productive coastal Arctic polynya, namely the North Water (NOW) polynya (77°16.756'N, 74°21.428'W), a recurrently ice-bound, open-water region located between Greenland and Ellesmere Island (Canada). The NOW has functioned as a natural refuge for diverse biological communities, including human populations (e.g., Dorset, Thule, Inuit), for millennia. Diatoms dominate seasonal phytoplankton blooms in the NOW and represent the most important contributor to marine primary productivity in this region. Additionally, diatoms are highly sensitive to sea-surface conditions (e.g., sea ice, temperature) and are generally well preserved in marine sediments. A decline in overall primary production has been observed in the NOW over the last two decades. Here, we examine the impact of climate-driven changes in environmental conditions on sea-surface conditions, diatom abundance, and assemblage composition using a sediment

core covering the last ca. 80 years collected from the North Water polynya. This project will estimate temporal change in diatom diversity and infer the drivers of such change, contributing to our understanding of how modern climate change affects high Arctic phytoplankton communities. ***Winner of the AGS Rupert MacNeill Award for best undergraduate student oral presentation***

Impact of the East African Rift System on the routing of the deep-water drainage network, western Indian Ocean

Vittorio Maselli[1], Dick Kroon[2], David Iacopini[3], Bridget S. Wade[4], Paul N. Pearson[5], and Henk De Haas[6]

1. Department of Earth Sciences, Life Sciences Centre, Dalhousie University, Halifax, Nova Scotia Canada <vittorio.maselli@dal.ca> ¶
2. School of GeoSciences, University of Edinburgh, Edinburgh, United Kingdom ¶
3. School of Geosciences, University of Aberdeen, Meston Bld., King's College, Aberdeen, United Kingdom ¶
4. Department of Earth Sciences, University College London, Gower Street, London, United Kingdom ¶
5. School of Earth and Ocean Sciences, Cardiff University, Cardiff, United Kingdom ¶
6. Royal Netherlands Institute for Sea Research, National Marine Facilities Department and Utrecht University, Netherlands.

The East African Rift Systems (EARS) has had a major influence on river drainage basins and the regional climate of eastern Africa during the Cenozoic. Recent studies have highlighted an offshore branch of the EARS in the western Indian Ocean, where the Kerimbas Graben and the Davie Ridge represent its seafloor expression. However, a clear picture of the impact of the EARS on the physiography of the continental margin, and associated sediment dispersal pathways, is still missing. This study presents new evidence for giant and supra-elevated canyons along the Davie Ridge that are now inactive and disconnected from the modern slope systems. Regional correlation of dated seismic horizons, integrated with sediment samples and high-resolution bathymetric data, proves that the tectonic activity driving the uplift of the Davie Ridge started in the Plio-Quaternary and is still active. Our findings contribute to placing the offshore-Tanzania Kerimbas Graben and Davie Ridge in the regional geodynamic context of the western Indian Ocean, show the effect of the offshore branch of the EARS on sediment distribution pathways, and underline the need for considering offshore tectonic activity in future tsunami hazards assessments in eastern Africa.

New data from old infrastructure: using modern methods to investigate historic development

Zachary McDougall[1], David Lentz[1], and Robin Adair[2]

1. University of New Brunswick, Department of Earth Sciences, Fredericton, New Brunswick E3B 5A3, Canada <mch.zach@unb.ca> ¶
2. Osisko Metals Incorporated, Montreal, Quebec H3B 2S2, Canada

Brownfield exploration and development can come with many challenges from both environmental and logistical standpoints. Legacy infrastructure often needs to be remediated or repaired to meet modern standards. Although these features may be inconvenient at first glance, they offer a great deal of geological information at minimal cost. Using modern remote sensing and digital cataloguing techniques, valuable data can be recovered from former open pit mines, historical core yards, and older databases. At the Osisko Metals Pine Point property in the Northwest Territories, legacy infrastructure was available from past production by Cominco Ltd. from the 1950s to 1988. In addition to the haul roads and hydroelectric infrastructure, core yards and extensive open pits allowed historical data sources to be re-visited and documented with modern technology. In this district, there were 50 small open pits excavated and very few were backfilled. This resulted in kilometres of outcrop exposure ranging from 1–30 metres or more in height. Using an Unmanned Aerial Vehicle (UAV) photogrammetry platform, and Differential Global Positioning System (DGPS), high-precision three-dimensional digital copies of the pits can be preserved. Analysis can be completed with Geographical Information Systems (GIS) to extract true-to-life geological and structural measurements. One major advantage to three-dimensional (point cloud) data is the ability to observe and predict complex structural patterns in real time and display these data more effectively to audiences. Despite the vandalism and neglect of Cominco's core yards, valuable assay and lithological data can be scavenged from the intact core. By using GIS and photographic cataloguing, over 1 million metres of core were documented and prepared for entry in a digital library. By taking inventory and comparing previously assayed, non NI-43-101-compliant data with re-assayed core, an increase in confidence in historical assays can be achieved. In addition to confirmation assaying, re-logging of key drill holes that delineate historic deposit cut-offs and high-grade intersections is a very low-cost confirmation tool. Interpretation and development of exploration targets is also enhanced. These benefits are greatly increased by importing resampled and logged core data into modern exploration programs. By integrating this legacy data into the working data, significant capital and effort can be saved while preserving the lithological and structural data indefinitely.

Potential new U–Pb geochronometers applicable to highly fractionated granitic systems

Chris R.M. McFarlane, Nadia Mohammadi, and Brandon Boucher

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <crmm@unb.ca>

Placing accurate dates on pulses of magmatic activity in mineral belts is a key component of regional exploration for fertile systems. Low solubility of zircon in typical granitic bulk compositions promotes the preservation of xenocrystic material that can hinder unambiguous assignment of Pb–U ages to magmatic crystallization. To avoid inheritance of this nature, targeting U-bearing minerals that crystallized directly from the magma (or from magmatic-hydrothermal fluids) is critical. To this end, the UNB LA ICP-MS facility has been testing a variety of U-bearing minerals from well-dated, traceable, locations. The goal of this study is to identify potential natural reference materials for in situ (e.g., LA ICPMS) geochronology in peralkaline (miaskitic) igneous suites, greisen vein systems, evolved LCT and NYF pegmatites, kimberlites, uranium deposits, and carbonatites. Geochronometers of interest are from mineral groups such as complex oxides and fluoro-carbonates that can be unambiguously related to crystallization from fractionated late-stage liquids or hydrothermal fluids. Minerals investigated so far include cassiterite, wolframite, bastnaesite, and parasite, the pyrochlore group, uraninite (and uranothorite), fergusonite, euxenite, zirconolite, and columbite-group-minerals. These minerals are normally considered "leaky" to Pb-loss owing to high actinide concentrations and, thus, high amorphous fractions. Our approach has been to empirically test these minerals for isotopic homogeneity and robustness. The time-dependent behavior during ablation at different laser fluence and pulse rate is assessed, as is common-Pb content and optimal crater sizes for intrinsic U and Th concentrations. Once these conditions are established, the material is 'dated' using NIST610 glass as an external standard. This step establishes whether the material is isotopically homogeneous. In some Phanerozoic age minerals we have explored (e.g., cassiterite, uraninite, bastnaesite, fergusonite), standardization against NIST610 yields concordant data within error of the assumed age of the material. In other cases (e.g., euxenite), upper intercept ages overlap with known pulses of magmatism. Demonstrating primary external standardization using NIST610 relieves us of finding an additional natural material to act as a secondary standard. Thus, in addition to uncovering a new range of potential reference materials, this study may ultimately allow us to more tightly connect the space-time relationships along the continuum of juvenile through highly fractionated melts and into the magmatic-hydrothermal transition.

Mineral chemistry and zoning of sulfarsenide minerals at Nictaux Falls Co-Ni-Au-Ag-Bi occurrence in the Annapolis Valley, Nova Scotia, Canada

Natalie McNeil[1], Nicole Kennedy[1], Erin Adlakha[1], Mitchell Kerr[1], Geoff Baldwin[2], and John Wightman[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <natalie_mcneil@msn.com> ¶
2. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada ¶
3. Goldfields Group of Companies, Bridgetown, Nova Scotia, Canada

The mineralogy of understudied polymetallic (Co-Ni-Au-Ag-Bi) quartz veins exposed in the Nictaux Falls Spillway, Annapolis Valley, Nova Scotia, has been investigated. Two styles of mineralization crosscut the Kentville Formation metasedimentary rocks in the spillway: (i) laminated sulfarsenide-quartz veins, and (ii) quartz breccia veins containing sulfarsenide-mineralized wallrock clasts. Laminated veins are heterogeneous with euhedral sulfarsenides and coxcomb quartz occurring on opposite sides of the vein. Wallrock clasts contain late net-texture sulfarsenides and quartz. Petrographic work identified a spatial relationship between sulfarsenides and wallrock material (e.g., chlorite, rutile) in both styles of mineralization, suggesting that the wallrock may have acted as a reaction site, or provided chemical components (e.g., S, As, Fe), for mineralization.

Compositional maps of mineralization were produced at a variety of scales, from an entire thin section (micro-XRF) to a single crystal (50 μm) (EPMA). Sulfarsenides in both styles of mineralization exhibit unidirectional zoning characterized by euhedral arsenopyrite cores (50 to 100 μm) mantled by a succession of overgrowths from arsenopyrite to cobaltite to gersdorffite. In laminated veins, gersdorffite is constrained to the middle of the vein at the sulfarsenide-quartz boundary. The direction of zoning and textures of laminated veins reflect a process whereby dense arsenopyrite precipitated from the hydrothermal fluid and accumulated at the base of the vein; the surface of the arsenopyrite accumulation reacted with the fluid to produce cobaltite and then gersdorffite overgrowths, followed by quartz. The early arsenopyrite cores are disseminated throughout both styles of mineralization and may have been inherited from the wallrock, serving as nucleation sites for sulfarsenide overgrowths. Future S-isotope work aims to confirm this relationship and the source of S for both generations of sulfarsenides. The compositional zoning may reflect either: (i) a decrease in pH over time, or (ii) Rayleigh fractionation of the fluid through the progressive removal of Fe and Co during mineralization. Future trace element work

will quantify and map the distribution of trace elements including Au and Ag. Interestingly, the sulfarsenide zoning patterns are opposite of that for classic "five-metals" deposits, such as Cobalt, Ontario, and Eldorado, Northwest Territories, which have similar elemental assemblages but grade from Ni- to Fe-rich.

The elemental assemblage of the polymetallic veins suggests a mafic source. Petrographic work on gabbro, diabase, and surrounding contact-metamorphosed metasedimentary rocks in the area identified primary cobaltite and Co-Ni-rich secondary minerals such as actinolite, chlorite, and sulfides, confirming these rocks as a potential source of metals.

Facies architecture, eruption history, and emplacement mechanism of subaqueous lava-carbonate succession in Bogda Mountain, northwest China*

Mehmut Memtimin[1,2], Zhaojie Guo[1], Georgia Pe-Piper[2], and David J.W. Piper[3]

1. Department of Earth and Space Science, Peking University, Beijing 100087, China <mehmud@pku.edu.cn> ¶
2. Department of Geology, Saint Mary`s University, Halifax, Nova Scotia B3H 3C3, Canada ¶
3. Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova scotia B3Y 4A2, Canada.

A subaqueous volcano-sedimentary complex in Bogda Mountains consists of various volcanic facies and coeval carbonates. Lava flows are basalts and grade from fragmented lava clasts and sedimentary rock in the lower part into coherent pillow lava and irregular massive lava bodies in the upper part of the succession. Four different facies are distinguished: (1) hyaloclastite; (2) peperite; (3) pillow lava with interpillow sedimentary rock; and (4) closely packed pillow lavas and huge irregular lava bodies. Hyaloclastites are closely connected with coherent lava flows and show jigsaw-fit texture and stepwise granulation from bigger clasts into smaller ones, indicating in-situ fragmentation and deposition during lava-water interaction, rather than reworking or collapsing of the succession after the eruption. Peperites are formed during the intimate interaction between hot lava flows and unconsolidated, water saturated carbonate rocks, which suggests the coeval volcanic eruption and deposition of carbonates in a shallow marine environment. In the upper part of the succession, the lava flux increases, producing massive, irregular lava bodies indicating an increased eruption frequency, and a thick accumulation of lava flows lacking interbeds. Vesicularity of the lava clasts decreases noticeably as the succession continues, pointing to an increase in ambient pressure as the basin subsided. Vesicularity of basaltic clasts, ambient pressure, and peperitic features indicate eruption depth at between 1500 m to 2500 m. A rhyolite intrusion in the upper part of the succession was dated at 308 Ma by using the LA-ICPMS zircon U–Pb method; it suggests that the subaqueous volcanic eruption and shallow marine carbonate sedimentation took place during the Late Carboniferous. Stratigraphy, facies architecture and vesicularity of the volcano-sedimentary succession in Bogda Mountain suggest that it was formed during subaqueous volcanic eruption in a progressively deepening and subsiding basin. Results of this study are supported by the evidence from previous findings, such as regionally well-documented bimodal volcanic rocks, faulting, and along-strike granitic intrusions in the region, all related to post-collisional extension in the Central Asian Orogenic Belt during the Late Carboniferous.
Winner of the AGS Graham Williams Award for best graduate student poster

High heat production Mount Douglas Granite and potential for geothermal energy resources in southwestern New Brunswick, Canada

Nadia Mohammadi

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <nadia.mohammadi@unb.ca>

The radiogenic heat production of the Mount Douglas Granite was examined to determine potential for Hot Dry Rock (HDR) geothermal resources in this area. The highly fractionated Mount Douglas Granite, which is located in southwestern New Brunswick, has characteristic features of high heat production (HHP) granites, in which the granites have elevated concentrations of K_2O, Rb, LREE, U, and Th. They produce anomalous heat generated by radiogenic decay of unstable isotopes, such as ^{238}U, ^{232}Th, and ^{40}K. The uraniferous nature of the granite is well established by a number of criteria, including whole-rock geochemical data, displaying high U and Th contents (≤ 22 ppm U; ≤ 71 ppm Th), which are significantly higher than the average continental crust (Th = 10.5 ppm; U = 2.7 ppm). The presence of U-, Th-, and REE-bearing minerals (e.g., monazite, zircon, xenotime, thorite, bastnaesite, and uraninite) and significant U and Th anomalies in some oxide and sulfide minerals (e.g., wolframite, hematite, and martite) support the uraniferous nature of the granite, along with previous airborne radiometric surveys and a recent gamma-ray spectrometry survey.

Assuming a density of 2.61 g/cm^3, the calculated average

weighted mean radiogenic heat production of the granite is 5.9 μW/m³ (14.1 HGU). This ranges from 2.2 μW/m³ in the least evolved unit, Dmd1, up to 10.1 μW/m³ in the most fractionated unit, Dmd3. They both are significantly higher than the average upper continental crust (1.65 μW/m³). The high radiogenic heat production of the Mount Douglas Granite, accompanied by a high estimated heat flow of 70 mW/m², identifies the granite as a "hot crust" (>7 HGU) HHP granite and highlights its potential for geothermal energy exploration. This could be a local, renewable and clean energy source associated with deep, hot crystalline rocks having temperatures generally higher than 150 ºC. Such high heat production is expected to result in local heat flow anomalies for the area, although further investigation, such as airborne radiometric surveys, seismic data, and satellite magnetic data, are required. The surface heat flow (a function of radioactive element content), the latest thermal event, and the intensity of tectonic activity are other important parameters that should be considered when evaluating potential geothermal resources.

Experimental study of reaction textures in volcaniclastic kimberlites

Kanwar Multani and Yana Fedortchouk

Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <kmultani@dal.ca>

Some of the most famous diamond deposits are associated with Kimberly-type volcaniclastic kimberlite facies (KPK) located within diatreme zones of kimberlite pipes. The origin of this type of kimberlite is one of the most debatable topics in kimberlite geology. The two contemporary models suggest either (1) explosive pyroclastic eruption with subsequent welding of pyroclasts; or (2) in situ magma fragmentation without formation of a pyroclastic deposit. The latter model suggests that a reaction between silicate fragments of the country rock and carbonatitic magma exsolves CO_2, leading to magma fragmentation and freezing. This experimental study tested the two hypotheses by examining the reaction of mafic (basalt) and felsic (granite, andesite, and rhyolite) xenoliths with synthetic analogues of evolved kimberlite magma. The experiments were conducted using a box-furnace and piston-cylinder apparatus at the Experimental Petrology Laboratory, Dalhousie University. Tests were conducted at 800–1100 °C and pressure 0.1 MPa and ~500 MPa to explore the effect of temperature, CO_2 and H_2O on textures and the sequence of reaction minerals. First, composition was modelled by removal of 50 vol% of olivine components and adding CO2 to the composition of a hypabyssal kimberlite (Anaconda kimberlite, NWT). Second, composition consisted of Na-Ca-carbonate in equal proportions. Experiments at 0.1 MPa were conducted in the absence of water, and at 500 MPa with 10 wt.% H_2O added.

The experimental run products were analyzed using the scanning electron microscope (SEM) to examine the textures, and energy-dispersive spectroscopy (EDS) was used to identify mineral phases. At 0.1 MPa and water-free conditions the reaction of kimberlite composition with mafic xenoliths at 1100 °C showed reaction occurring along the rims leading to xenolith fragmentation; the granitic xenolith reaction at 1000 °C showed melting of sheet silicates and reactions occurring along the rims. Rhyolite xenoliths melted at 1100 °C with no evidence of reaction to the kimberlite mixture. The reaction of carbonate melt with both basalt and rhyolite xenoliths exsolved CO_2, which ruptured both capsules due to the overpressure. At 500 MPa and 10 wt.% H_2O, kimberlite and mafic xenoliths at 900 °C showed no reaction, but with andesite xenoliths at 800 °C, melting and reactions along the rims were observed. Preliminary analysis shows dissolution occurring at a faster rate than the reaction between xenoliths and kimberlite mixture. The developed reaction mineral phases and their textures will be compared to the textures of natural BK1 KPK from Orapa kimberlite cluster, Botswana, in order to better understand KPK emplacement processes.

Predictive modelling of sandstone reservoir distribution in the southwestern Scotian Basin

Justin F. Nagle[1], Georgia Pe-Piper[1], David J.W. Piper[2], and Franky Saint-Ange[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <Justin_Nagle@hotmail.com> ¶
2. Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B3Y 4A2, Canada ¶
3. Beicip-Franlab Headquarters, 232, avenue Napoleon Bonaparte - BP 213, 92500 Rueil-Malmaison Cedex – France.

The southwestern Scotian Basin is an active oil and gas exploration target; however, it is the least explored part of the Scotian Basin. The major risks associated with exploration are the distribution, size, and reservoir quality of deep-water sands. The goal of this study is to generate a predictive model of sediment supply to the southwestern Scotian Basin, which tests the proposed paleo-river systems from the literature, and transport of sand into deep water. These river systems vary in extent from the Late Jurassic to Early Cretaceous due to changing tectonics and climate, and increases in precipitation. It is thought that the main river systems supplying sediment to the southwestern

Scotian Basin came from Maine, New Brunswick, and the Meguma terrane, and that minor amounts of sediment were transported from the Labrador Rift through the Bay of Fundy. Rates of sediment supply have been calculated from the literature for these source areas by examining the relationships between river catchment area, relief, and climate interpretations in SE Canada for the Mesozoic. Although the Meguma terrane delivered sediments to some wells in the central Scotian Basin, and Mohawk B-93 in the southwestern Scotian Basin, the particular river system that supplied Mohawk B-93 would have been small, based on the nearby carbonate banks. Sediment supply from Maine has also been constrained by previous provenance studies on the COST G-2 well. However, preliminary modelling indicates that sediment supply across Georges Bank is insufficient to account for sediment thickness in the deep basin. As there is no well control on sediments entering from the Bay of Fundy, stratigraphic thickness determined from seismic profiles has been used to constrain river supply through this route. Testing of these proposed paleo-river systems is done by using the modelling software, DionisosFlow. This software can simulate basin infill on a scale of tens to hundreds of kilometres over a time span of tens of thousands of years to hundreds of millions of years. The results of this project shed light on sediment delivery to this part of the Scotian Basin, as well as the transport of sand into deep water. It will also help to resolve uncertainties in the literature with respect to paleo-river systems, river catchment areas, sediment transport, and petroleum potential. This information is beneficial to energy and petroleum companies in potentially reducing petroleum exploration risk.

Preliminary constraints on magma metal fertility in the northeastern Cobequid Highlands, Nova Scotia, Canada

Kevin Neyedley[1, 2], Jacob Hanley[1], Trevor MacHattie[2], Alexandra Tsay[3], and Zoltan Zajacz[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova scotia B3H 3C3, Canada <kevinneyedley@gmail.com> ¶
2. Nova Scotia Geological Surveys Branch, Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada ¶
3. Department of Earth Sciences, University of Toronto, Toronto, Ontario, Canada

In the northeastern Cobequid Highlands, Nova Scotia, bedrock mapping and bulk rock and stream sediment geochemical surveying by the Nova Scotia Department of Energy and Mines has identified a potential epithermal Au system in Late Devonian to Early Carboniferous bimodal volcanic rocks. Two Au occurrences have been reported and comprise zones of silicified and sulphidized volcanic rocks containing up to 660 ppb Au. 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.

Preliminary electron microprobe analyses of exposed, homogenized silicate melt inclusions from various volcanic and intrusive phases indicate that the magma was subalkaline but very close to the alkaline discrimination boundary ($Na_2O + K_2O$ ~6–8 wt.%; SiO_2 ~67–80 wt.%). Volatile concentrations are variable across all phases with H_2O concentrations of ~2.7 ± 2.6 wt.%, Cl ~680 ± 380 ppm, and F ~1160 ± 940 ppm. Preliminary LA-ICP-MS analyses of silicate melt inclusions show that the melts are poor in As (<60 ppm) and Sb (<12 ppm) but are relatively enriched in Cu (up to 1 wt.%; ~1130 ± 2190 ppm; n = 93), Mo (up to 15 ppm; ~5.2 ± 2.9 ppm; n = 55), and W (up to 15 ppm; ~2.4 ± 2 ppm; n = 85). Sulphide melt inclusions are also relatively poor in As (<2 ppm) and Sb (<0.5 ppm) but are relatively enriched in Cu (1.6 ± 0.5 wt.%).

The extreme enrichment of Cu in some of the silicate melt inclusions could either represent the co-entrapment of a sulphide melt or a saturated Cu-enriched volatile phase, the latter being consistent with the wide range in volatile concentrations observed in homogenized melt inclusions. The As- and Sb-poor nature of the silicate and sulphide melts likely indicates that a metal-enriched volatile phase exsolved from the magma prior to silicate melt entrapment and/or sulphide saturation. Overall, silicate and sulphide melt inclusion metal tenors are comparable to similar melt inclusions from major Cu – Mo ± Au porphyry systems (e.g., Santa Rita, Bingham, and Climax).

Are submarine landslides an underestimated hazard on the eastern Canadian margin?

Alexandre Normandeau, D. Calvin Campbell, David J.W. Piper, and Kimberley A. Jenner

Geological Survey of Canada (Atlantic), Natural Resources Canada, Dartmouth, Nova Scotia B2Y 4A2, Canada <alexandre.normandeau@canada.ca>

Landslides and turbidity currents are known to present major risks to submarine infrastructure and to break fiber-optic submarine cables. Understanding the triggers, knowledge of the recurrence, and timing of these events is important in order to mitigate their impact. Here, we assess the recurrence of turbidity currents and landslides

at the offshore feature known as The Gully during the Holocene. Most turbidity currents affecting the eastern Canadian North Atlantic slope occurred between the Late Glacial Maximum (LGM) and 17 ka BP when glaciers were delivering sediment directly on the slope. Turbidite occurrence diminished greatly until ceasing completely at 13 ka BP. However, new multibeam bathymetry mapping and sediment core acquisition off eastern Canada indicate that three previously unidentified, large, submarine landslides and turbidity currents occurred during the Late Holocene, between 4 and 1.5 ka BP. The discovery of these three new gravitational events, in addition to the well-known 1929 Grand Banks earthquake-induced landslide, indicates that one major landslide per 1000 years has occurred offshore of eastern Canada within the past 4000 years, a much shorter recurrence interval than hitherto reported. This Late Holocene recurrence rate is also similar to active margins around the world. One of the newly-recognized landslides, located on the western levee of the Laurentian Fan, is among the largest Late Holocene landslides described for the western North Atlantic. The discovery of these new Late Holocene landslides was made possible through the detailed examination of Holocene cores in deep-water settings and demonstrates that the risk posed by submarine landslides has been underestimated on the North Atlantic margin, where a large coastal population resides and significant submarine infrastructure exists.

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

Yaisa D. Owino[1], Randolph Corney[1], Casey Hubert[2], and Todd G. Ventura[1]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <yaisadipna@gmail.com> ¶
2. Energy Bioengineering and Geomicrobiology Group, 2500 University Dr NW, University of Calgary, Calgary, Alberta T2N 1N4, Canada

Nova Scotia may have vast untapped hydrocarbon resources in its offshore. Exploration efforts to develop these resources are expensive and associated costs become multiplicative when applied to deep-water prospects. To encourage investment and to reduce the risk associated with drilling dry wells on existing block boundaries, an ongoing inter-organizational project is seeking to develop new microbiological and geochemical-based tools to complement conventional geological exploration models in optimizing the search of oil and gas in the offshore. 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. This study involves the analysis of disparate data types collected along the Scotian margin, integration of the data with existing geological, geophysical, and satellite oil-slick data, and generation of composite maps of petroleum potential for locating active reservoirs on a dynamic ArcGIS platform. This study also seeks to find new techniques to compare and correlate the new data types with the goal of creating an efficient and dynamic exploration tool. The results will represent a component of a future comprehensive, prospectivity data atlas (known as the Play Fairway Analysis), which will be shared with prospective bidders to promote new offshore exploration licences.

Petrography, geochemistry, age, and stratigraphic significance of the Boyd Creek tuff, Mississippian, New Brunswick, Canada

Adrian F. Park[1], Steven J. Hinds[1], Christopher MacFarlane[2], Matthew Stimson[3,4], and Perry Clark[2]

1. New Brunswick Department of Energy and Resource Development, Fredericton, New Brunswick E3B 5H1, Canada <Adrian.Park@gnb.ca> ¶
2. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada ¶
3. Department of Geology, St. Mary's University, Halifax, Nova Scotia B3H 3C3, Canada ¶
4. Natural History Department, New Brunswick Museum, Saint John, New Brunswick, Canada

The Boyd Creek tuff consists of a pair of pyroclastic flow deposits and a more widespread air-fall tuff within a Mississippian redbed sequence encountered in outcrop and boreholes around Weldon and Gautreau, Westmorland and Albert counties, New Brunswick. Long recognized as an important stratigraphic marker, this tuff has been placed in the Tournaisian Weldon Formation and Viséan Hillsborough Formation by previous workers, with a position in the upper Tournaisian Weldon Formation being the most recent understanding. However, U–Pb zircon ages obtained of 337.1 ± 1.9 Ma from the tuff place the unit firmly in the Viséan, suggesting that it is part of the Windsor Group in a fine-grained red sequence of the Hillsborough Formation. Palynomorphs from the sedimentary rocks beneath the tuff are Tournaisian, implying that the tuff lies on an unconformity. Petrography and geochemical analysis of the tuff confirms a rhyolite or dacite source, despite extensive alteration and the presence of abundant xenoliths and xenocrysts. Composition and age suggest

that the Boyd Creek tuff is contemporary with the rhyolite-trachyte lavas of Cumberland Hill, dated tuffs within the Windsor Group carbonate-evaporite sequence at Picadilly Mine (Penobsquis), and the red bed Shin Formation at Hurley Creek near Minto. Locating and dating other "ash beds" in the Windsor Group may offer a way to resolve longstanding issues of correlation in the Windsor Group of New Brunswick and Nova Scotia.

Review of cobalt within Ni-Cu-PGE and Ni-Cu-Co-Au sulphide occurrences in Silurian mafic intrusions in the New Brunswick Appalachian orogen

Sima Peyghambari[1], David R. Lentz[2], and Nadia Mohammadi[2]

1. Department of Geology, Payame Noor University, Iran <peighambari.si@gmail.com> ¶
2. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B5A3, Canada

Cobalt occurs as an important component in Ni-Cu-PGE deposits related to mafic or ultramafic intrusions and that formed by the segregation (liquation) and accumulation of dense immiscible sulphide liquids. The abundance of cobalt varies depending on the primitive character of the mafic magmas involved. Large world-class deposits have been found in intrusions related to intra-continental settings or rifted continental margins, and also in convergent environments such as arc settings, but those are typically small. Ni-Cu-PGE mineralization in Canada is associated with a wide range of rock ages, parental magma compositions, geologic settings, host unit geometries, and tectonic settings. Archean deposits (e.g., Abitibi, McFauld's Lake) in general have higher grades of Ni and PGEs, but are also smaller. Proterozoic deposits (e.g., Sudbury, Raglan, Thompson, Voisey's Bay, Lynn Lake) are not always high in grade but can be very large. Except for Norilsk, Phanerozoic deposits (Wellgreen, Turnagain, Giant Mascot) generally have lower Ni and PGEs contents and are smaller.

Several Ni-Cu-PGE occurrences in New Brunswick are associated with Silurian mafic intrusions and have economically interesting concentrations of cobalt. Maliseet North contains significant Co values (up to 0.12%) and is hosted by Goodwin Lake gabbro, which contains both mafic and ultramafic phases. The Wheal Louisiana deposit in southern New Brunswick occurs in quartz-carbonate veins in metasedimentary and mafic rocks and contains 0.06 wt.% cobalt. The Rogers Farm deposit in St. Stephen is hosted by the Moosehorn intrusion; according to different reports, Co content averages around 0.16 wt.%. Portage Brook in north-central New Brunswick is a relatively small Ni-Cu-PGE occurrence with 0.067 wt.% Co; it is also a Silurian mafic to ultramafic intrusion. Mount Webster in northern New Brunswick contains trace Co, Cu, and Ni hosted by a Siluro-Devonian mafic intrusion; average Co content is 0.11 wt.%. Cu-Co-Au mineralization at Ramsay Brook west-southwest of Bathurst is hosted in brecciated and carbonate altered sedimentary rocks adjacent to a mafic intrusion and contains up to 0.9 wt.%. Co. Several other Ni-Cu-PGE occurrences have lower Co contents, including Milltown Reservoir, Woodward Farm I, and Murchie farm in the St. Croix belt.

Hydrothermal rutile at Clarke Head, Minas fault zone (Nova Scotia, Canada) constrains the age of Windsor Group evaporites

Georgia Pe-Piper[1], David J.W. Piper[2], Justin Nagle[1], and Chris McFarlane[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <gpiper@smu.ca> ¶
2. Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada ¶
3. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada

At Clarke Head in the Minas Fault Zone, igneous megablocks include a syenite pegmatite intruding gabbro, and diorite with(?) lower Horton Group siltstone xenoliths. This study investigates the age and hydrothermal alteration of rutile in the syenite and the origin of the scapolite. It contributes to the current debates about the age of the lower Windsor Group and Ti mobility in the presence of halogens in subduction zones. Rutile was studied by SEM and dated by in situ U–Pb analysis. Syenite has magmatic K-feldspar, albite, quartz, rutile, and late stage analcime. Most feldspar is replaced by scapolite, which forms veins in gabbro and diorite. Millimetre-scale crystals of magmatic rutile in the syenite are rimmed by magmatic titanite and magnetite, and rutile also occurs interstitially. Hydrothermal alteration occurs preferentially along crystal margins and fractures as a layer-by-layer dissolution-reprecipitation process resulting in high Zr contents (~5000 ppm) in the rutile, enrichment in U, and depletion in high-field-strength elements. The magmatic emplacement age of the syenite is ~360 Ma (oldest dated rutile) and no younger than 353.9 ± 5.7 Ma (mean concordia age of interstitial rutile), synchronous with later regional A-type granite plutonism. Although this regional plutonism was Na- and halogen rich, with late-magmatic albitization and other Na metasomatism, only at Clarke Head is there extreme Na- and Cl-rich metasomatism,

indicated by scapolite and Cl-rich hastingsite. Deformation of halite in the Portapique fault, well south of the basin margin Kirkhill fault zone, supplied Na^+, Cl^-, and lesser F^- to the metasomatizing system. These fluids produced the widespread metasomatic Na-rich scapolite in the syenite and leached Ti and other HFSE, together with REE, from large fractured rutile crystals. The U–Pb system in the altered rutile was reset at 337.4 ± 3.5 Ma. Oxygen isotopes in the bulk rocks, and scapolite-analcime mixtures suggest an important component of magmatic fluids in the metasomatizing system. Biostratigraphy favours an age of ca. 347–343 Ma for the lower Windsor Group evaporites. The St. Peters gabbro, with a 339 ± 2 Ma age, has been correlated with a geochemically similar pre-Windsor gabbro in Toms Brook, suggesting a younger age for the Windsor evaporites. However, small mafic bodies along the Minas Fault Zone range from 369 to <310 Ma. We propose that our new date of 337 Ma for hydrothermal rutile at Clarke Head corresponds to the mid-Windsor hiatus following the deposition of thick halite in central Nova Scotia.

Intact microbial lipids as a tool to track active petroleum systems: a Scotian Margin case study on shallow marine sediments

Carl A. Peters[1], G. Todd Ventura[1], Jeremy Bentley[1], Casey Hubert[2], Julius S. Lipp[3], Adam MacDonald[4], Martin G. Fowler[5], Florence Schubotz[3], and Kai-uwe Hinrichs[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <todd.ventura@smu.ca> ¶
2. Energy Bioengineering and Geomicrobiology Group, 2500 University Dr NW, University of Calgary, Calgary, Alberta T2N 1N4, Canada ¶
3. Organic Geochemistry Group, Department of Geosciences, University of Bremen, Leobener Strasse, 28334 Bremen, Germany V ¶
4. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 3P7, Canada ¶
5. Applied Petroleum Technology Ltd., Calgary, Suite 400 119 - 14th Street NW, Calgary, Alberta T2N 1Z6, Canada

This study aims to develop novel indirect hydrocarbon indicators (IHIs) through the detection of intact polar lipids (IPLs) derived from hydrocarbon oxidizing bacteria and archaea. IPLs are considered diagnostic markers for living microbial cells and are ubiquitous as trace compounds in marine sediments. They consist of a core lipid chemically bonded to one or more polar headgroups, which makes them structurally distinct compounds. IPLs are also taxonomically diagnostic and therefore can be used to assess present and past environmental conditions. To test whether IPL fingerprinting techniques can be used as an IHI, surface and piston core sediments were collected during recent expeditions (CCGS *Hudson* 2015 and 2016; RV *Coriolis* 2017) from the gas- and condensate-prone Scotian Margin, off Nova Scotia. IPLs were extracted using a modified Bligh and Dyer protocol and analyzed with ultra-high-performance liquid chromatography-mass spectrometry (UHPLC-MS). Cored sites containing seep hydrocarbons yield lipid extracts that are significantly more variable and concentrated (ranging from ~300 to 800 µg/g sed.) relative to that of hydrocarbon-negative sites (~200–300 µg/g sed.). The same trend is reflected in the concentrations of IPLs. Archaeal IPLs reach 1000 ng/g sed. in hydrocarbon-positive sites, but only 160 ng/g sed. in ambient sediment samples. Thus far, we have been able to identify 10 different archaeal compound classes and 8 different bacterial IPL compound classes with a significant number of yet-unknown bacterial IPLs still being investigated. Glycosidic saturated and hydroxylated archaeal ether lipids (e.g., 1G-GDGTs, 2G-OH-GDGTs), likely produced by marine benthic archaea, and unsaturated dietherglycerols with phosphate-based headgroups (e.g., PE-DEGs, PME-DEGs) likely produced by sulphate-reducing bacteria, have been found in both hydrocarbon-positive and negative sites. Hydrocarbon-positive sites differ from ambient surface sediments by the presence of cardiolipins and an array of unknown bacterial IPLs. Cardiolipins have previously been found in sulphate-reducing bacteria. Given that they were only found in hydrocarbon-positive sites, this suggests these compounds are possibly sourced from hydrocarbon-oxidizing bacteria, as some sulphate-reducing bacteria also play a role in the oxidation of methane. Our presented lipid fingerprints may provide key information for the search of offshore petroleum in order to further reduce front-end exploration risks to oil and gas companies.

Age and source of bioturbated late Pleistocene muds on the continental slope: the use of portable X-ray fluorescence logging

David J.W. Piper[1], Harunur Rashid[2], Logan Robertson[3], Meng Tang[1], and Jenna Higgins[1]

1. Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada <david.piper@canada.ca> ¶
2. College of Marine Sciences, Shanghai Ocean University, Shanghai, China ¶
3. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

Much of the continental slope off eastern Canada comprises bioturbated muds with a stratigraphic record of sediment supply from ice streams crossing the shelf and variations in oceanic currents. Outstanding questions include: (a) Were times of rapid ice stream retreat and maximum sediment supply synchronous between different ice outlets? (b) What was the relative importance of fresh-water plume and contour current transport of sediment? (c) Were there major shifts in the location of oceanic currents over the last glacial cycle? Rapid down-core logging of selected elements at a 1 cm resolution using a track-mount X-ray fluorescence device (pXRF) has revolutionized our ability to address these questions. This is despite the fact that pXRF does not detect light elements, is strongly influenced by matrix effects including water content and core irregularities, and provides at best semi-quantitative data. Down-core variations in Ca/Ti ratio reveal detrital carbonate intervals derived from Lancaster Sound and Hudson Strait, the latter corresponding to Heinrich events. A core on the SE Baffin Slope has a full record of Hudson Strait supply but pXRF also shows a cryptic Baffin Bay detrital carbonate record, invisible to the naked eye, that is diachronous with respect to Heinrich events. The Heinrich detrital carbonate layers around Flemish Cap provide reliable stratigraphic markers that allow down-slope and lateral variations in the thickness of stratigraphic units to be interpreted. They suggest that carbonate deposition during Heinrich events was from a surface plume, but that interbedded red muds were transported by contour currents. In later Heinrich events, a "log jam" of tabular icebergs grounding on Sackville Spur may have reduced Labrador Current flow through Flemish Pass. The changing provenance of sediment in cores can be characterized by scatter plots of two dissimilar elements, including Ti, K, Zr, Ca, and Sr. Generally, K is higher in muds and Zr in silts and sands, so these elements can be used to monitor chemical variations due to changes in grain size. Such techniques demonstrate changes in sediment supply through time from Hudson Strait, Notre Dame Channel, and Halibut Channel, and also show that late Holocene carbonate in the Labrador Current in Flemish Pass is derived from Baffin Bay and not from slope erosion off Hudson Strait. This rapid, low-cost, non-destructive technique can guide subsequent sampling for more precise and expensive quantitative X-ray diffraction or bulk geochemistry.

Characterization of auriferous quartz veins of the Ptarmigan and Tom gold deposits, Yellowknife, Northwest Territories

Mark W. Richardson and David R. Lentz

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <m5b11@unb.ca>

The Yellowknife greenstone belt in the Northwest Territories, Canada hosts numerous orogenic gold deposits that formed in a range of structural and lithological settings during late Archean metamorphism. However, the ability to establish absolute ages for gold deposition has remained elusive. The Ptarmigan and Tom gold deposits comprise a series of *en echelon* vein-type gold deposits hosted by amphibolite-grade deformed turbiditic rocks of the Archean Burwash Formation of the Slave Structural Province. The deposits are located within a 4 km-wide metamorphic aureole of the Prosperous Granite to the east. The host rocks contain cordierite porphyroblasts and several pegmatite dykes. The proximity of the Ptarmigan mine to the Prosperous Granite intrusion and the numerous related pegmatite dykes presents a unique opportunity to evaluate what role magmatic fluids may have played in the formation of mesothermal gold deposits.

Groundwork assessment of structural controls on gold-bearing quartz veins of the Ptarmigan and Tom deposits was completed in the summer of 2018. Three generations of structures were identified: (D_1), a bedding-parallel, weakly spaced cleavage interpreted as S_1; (D_2), a dominant foliation with variable intensity that ranges from spaced cleavage in greywacke to a schistosity within slate horizons; and (D_3), a crenulation cleavage. In addition to the recognized structural generations, a sequence in the style of quartz veins was observed. Structural interpretation displays progressive deformation as follows: (a), bedding-parallel veins, ptygmatically folded and overprinted by porphyroblasts, and refolded by outcrop-scale asymmetric folding; (b), stratabound, *en echelon* veins folded by asymmetric F_2 folds; (c), Ptarmigan-style veins, sub-parallel to cleavage, locally cross-cutting bedding, locally boudinaged, asymmetrically folded, and crosscut by straight shear veins; (C^*), flat veins (extensional veins) that locally occur on both sides of the Ptarmigan and Tom veins; (D), cleavage-parallel straight shear veins.

The Ptarmigan vein exhibits pervasive muscovite and chlorite wall-rock alteration. Sulphide mineralization within the wall-rock is comprised of arsenopyrite, fine-grained pyrite, and pyrrhotite. Vein mineralization includes globular arsenopyrite (locally 5%), brown sphalerite (locally 5% in veinlets), pyrrhotite (locally 3%), chalcopyrite (locally 3%), tourmaline (locally 4%), galena (locally 3%), and rare muscovite. Additionally, millimetre-scale fractures are filled with dark green tabular epidote and massive globular arsenopyrite, brown sphalerite, pyrrhotite, and pyrite. Several polished thin sections have revealed the presence of hydrothermal apatite and monazite in gold-bearing quartz veins from the Ptarmigan mine. Next steps will include direct U–Pb dating using these gold-bearing veins.

The glacial and Holocene history of Notre Dame Trough, northeast Newfoundland shelf, Canada

Logan S. Robertson[1,2] and David J.W. Piper[1]

1. Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada <Logansidrobertson@gmail.com> ¶
2. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

This study was conducted at the Notre Dame Trough (NDT) on the northeast Newfoundland shelf. The purpose of the project is to help unravel the glacial history of the area, including the timing of a large slide block in the NDT, and to compare the late Quaternary sedimentary record in cores with other places on the Newfoundland margin. Air gun seismic and Olex bathymetry were used to determine that some features present in the NDT are glaciotectonic in origin, and likely formed during the Wisconsinan. A large slide block present in the NDT was analyzed using seismic survey data and down-core shear strength data, showing that the slide block likely post-dates the glaciotectonic deformation.

The physical properties of thirteen piston cores and chemical properties of five of the cores were analyzed to identify four main sediment units. Knudsen 3.5 kHz seismic data were used to determine the sedimentary context of the cores. Four new carbon-14 dates from these cores provide age control for changes in sediment supply and paleoceanographic events such as Heinrich events having a high supply of detrital carbonate.

The variation in sediment source in the study area indicates that the NDT was largely unaffected by the Labrador Current for some time before 14 ka. Correlations in the paleoceanographic records between the cores of this study and those of Flemish Pass and Cartwright Saddle show that Heinrich-0 (ca. 12 ka) can be correlated between NDT, Flemish Pass, and Cartwright Saddle. However, based on carbon-14 dates, Heinrich-1 is not marked by a detrital carbonate layer in Notre Dame Trough. A red mud bed correlated between several cores may represent a synchronous meltwater discharge event from ice in St. Anthony Basin. This study is the first to provide a reliable late glacial chronology for proglacial sediment on the northeastern Newfoundland shelf.

Geochemical prospecting in the Carboniferous Maritimes Basin of eastern Canada

Peter John Rogers

10902 Highway 215, South Maitland, Nova Scotia B0N 2HO, Canada <chavin_consulting@yahoo.ca>

Geochemical exploration in Canada is normally conducted in areas covered with thick sheets of glacial drift. Within the Maritimes Basin, traditional geochemical methods including those of soil, till, stream sediment -80 mesh, heavy minerals, lake sediments, and several vegetation media have been applied to locate many deposits outcropping at surface. Of those classical methods, vegetation is normally the most cost-effective sampling method to locate mineralization. However, where a significant bedrock cover masks buried mineralization, there is a distinct paucity of studies involving success in discovery. Several multi-media studies detail surface geochemical expression in the Maritimes Basin of Nova Scotia, including those at the Yava Pb and Jubilee Pb-Zn deposits; all show anomalous responses but to a varying degree of resolution depending on the sampling media applied. The Canfield Creek Cu-Ag deposit lies beneath 100 m of bedrock sedimentary rock and has no surface geochemical expression; it was found by wildcat drilling based on a geologist's hunch. In order to increase discovery rates in these covered situations, partial extraction soil technology is applied at several locations within the Maritimes Basin. This technology greatly enhances the resolution of the location of the Canfield Creek deposit not easily seen by other methods. Studies at the Jubilee Pb-Zn deposit at outcrop, along-strike, and under cover were able to locate the ore zone beneath 200 m of anhydrite. It is shown that buried deposits in the Maritimes Basin can be detected using partial extraction geochemistry, including but not limited to MMI, SGH, and Enzyme Leach, and that partial extraction geochemical methods are capable of detecting mineralization through at least 400 m of bedrock cover.

Micro-petrological analysis of Shergottite Meteorite 4468

Galena M. Roots and Richard A. Cox

Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <galena.roots@gmail.com>

This study investigates the chemical variations within mineral phases in the Martian meteorite sample North West Africa (NWA) 4468. Meteorites are of course the only samples of Martian rocks that can be studied directly. Their

geochemical and mineralogical compositions provide key evidence for magmatic processes occurring on Mars. Recent observations of volcanic areas on Mars, e.g., the Athabasca Valles, suggest that Mars is in fact still a volcanically active planet. Application of micro-petrology, i.e. processes represented and recorded on a mineral-scale, is the only effective way to study meteorites, which are exceedingly rare and found only as very small-volume samples. Meteorite NWA 4468 is an example of a Shergottite, a group of 150–220 Ma Martian meteorites, typically basaltic in composition, coarse-grained and enriched in incompatible elements. NWA 4468 is an olivine-phyric sample with large pyroxene oikocrysts, oxides, and plagioclase grains. The later have been shock-altered to maskelynite. Shergottites are generally thought to represent cumulates fractionated from high-volume melting of the lower, primitive, Martian mantle. Samples were examined using reflected light microscopy and back-scattering electron-imaging, followed by detailed X-ray mapping of both the large olivine and pyroxene crystals. The olivine crystals are generally not zoned in Fe and Mg, but do preserve phosphorus (P-) zoning. This occurs in about 20% of the olivine crystals and suggests early skeletal growth and subsequent ripening of the crystals, which in turn overprinted any Fe and Mg zoning that may have originally occurred. This type of P-zoning has been noted in terrestrial basaltic samples and can be used to make predictions about the growth history and cooling rates recorded. In this case, the olivine crystals formed early in the crystallization history but also at elevated temperatures. Pyroxene oikocrysts show distinct zoning from pigeonite to augite, i.e. from Ca-rich and Ca-poor sectors within individual grains. Zoning in Fe and Mg is also partially preserved in the pyroxene crystals. This can be used to determine the minimum recorded crystallization temperatures and relative cooling rates. The pyroxene crystals in this example likely formed later and at cooler temperatures than the olivine crystals. Analyses of oxides and plagioclase (maskelynite) have also been carried out to enable as wide a range of mineral thermobarometers as possible to be applied. Applied thermometry and barometry, combined with characterization of preserved micro-textural features in NWA4468, will provide further insight into the overall formation of large magmatic systems on Mars.

A tale of two tills in the McDougall Lake area, southwestern New Brunswick, Canada

Steven L.E. Rossiter[1], Bruce E. Broster[1], and Serge Allard[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <srossite@unb.ca> ¶

2. New Brunswick Department of Energy and Resource Development, Fredericton, New Brunswick E3C 2G6, Canada

The New Brunswick Geological Survey has collected basal till samples at 567 locations within the McDougall Lake area (NTS 21 G/07) as part of their provincial regional and follow-up till geochemistry programs. Laboratory analytical results have been released to the public, with minimal geochemical interpretation. During the most recent sampling effort, it became obvious that at many locations, most of the till's matrix is derived from distal, red sedimentary sources (up to 31 km north). The "red" till is in sharp contrast to the locally-derived, granite- or metasedimentary rock-rich till that is usually found nearby, or even at the same location.

Using field note descriptions as a guide, 23 red and 23 brown (granite-rich) till samples were selected for geochemical comparison. The 59-element Na_2O_2 Fusion ICP-MS data suggest that the red till population is relatively elevated in B, Ba, Co, Cr, Cu, Fe, Mg, Sb, Sc, Ti, and V, while the brown till population is relatively elevated in Bi, Ce, Hf, Nb, Pb, Sn, Ta, Th, Tl, Tm, U, W, Yb, and Zr. The brown till population also demonstrates large compositional variation for many incompatible elements, which is attributable to the diverse plutonic bedrock compositions of the Saint George batholith. The small compositional variation amongst the red till population suggests that the samples were derived from the same bedrock source. Given its broad spatial extent, the Shin Formation (Mabou Group) red beds would be a reasonable candidate for this source, although nearby Piskahegan Group red beds may have a similar chemical composition.

For the purpose of drift prospecting, it is advised that the red till samples be examined separately from locally-derived till. The results discussed here also enable the discrimination of a mixed till population, which could be included with either the red or brown till. Provided that till properties are quantified, multivariate statistical treatment is a good candidate for population discrimination. Given the ubiquity of red sedimentary rock in New Brunswick, this type of discrimination may be useful, and could form the basis for a more objective attribute-based till classification to complement genetic classification. Discrimination within the McDougall lake area is particularly easy given that the relatively firm, clay- and silt-rich red till contrasts sharply with locally derived sandy till.

Can the death of a cetacean in a November 1755 earthquake assist with downtown Boston geotechnical issues?

Alan Ruffman

Geomarine Associates Ltd. P.O. Box 41, Station M, Halifax, Nova Scotia B3J 2L4, Canada <aruffman@dal.ca>

Boston's downtown on the south side of the mouth of the Charles River began as the "Shawmut Peninsula" – a near-island connected to the mainland by the bar of "Boston Neck" in the mid-17th century as European settlers arrived to colonize the "New World" of America. Wharves were built, and extended, and infill was added between the wharves to create new land. The wharves were then extended to repeat the cycle and create more land. Within a century one could not easily find the original shoreline, as Boston had expanded in all directions to essentially double its area standing just above sea level of the day.

On Tuesday, November 18, 1755, at 04:30 a.m. local time, a sizeable earthquake was felt and roughly 1000–1500 brick chimneys fell to the ground in Boston. It was immediately recognized that the majority of the fallen chimneys were from houses built on the reclaimed land along the harbour's edge. Infilled land tends to have much more water incorporated in the sediment, which can amplify the vibrations of an earthquake and lead to greater shear, or "s" wave, damage.

The 1976 assessment of the risks of building a second Pilgrim nuclear power generating station at Plymouth on Cape Cod compiled the historic seismicity of New England from 1727 to 1927. It placed the epicentre of the 1755 earthquake in the offshore not far to the east of Cape Ann. Later work by geotechnical engineers considering liquefaction events during the 1755 event placed the epicentre onshore not far west of Boston. The currently accepted epicentre by John Ebel in 2006 places the 1755 epicentre about 39 km ENE of Cape Ann, with a magnitude of about 6.3.

All researchers appear to have dismissed, or totally ignored, a west-bound vessel's felt report some 70 "leagues" (387 km) offshore, well east of Cape Ann. The *Pegasus*, bound for Marblehead with a load of salt from Cadiz, encountered significant fish kill and three whales lying motionless on the sea surface and apparently dead. If the position of the *Pegasus* better reflects the true epicentre of the 1755 earthquake then its presently estimated magnitude must be increased somewhat and the building code requirements for downtown Boston and indeed for much of the eastern and coastal areas of the Massachusetts perhaps should be increased. A second nuclear reactor at the Pilgrim facility on Cape Cod has never been built. These issues hang on the question I put to myself last May. "Can an earthquake's large pressure ('p') wave concussive force seriously injure, or even kill a whale?"

Metamorphic mineral assemblages in fossils in the contact metamorphic rocks of the Portrush Sill, Northern Ireland

Cliff S.J. Shaw

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada, <cshaw@unb.ca>

One of the first examples of the occurrence of fossils in a metamorphic rock was originally described as *"shells in basalts"* in samples from Ramore Head in Portrush, Northern Ireland as early as 1799. The Ramore Head site has a special significance in the history of geology as it played a large role in settling the dispute between the Neptunists and Plutonists over the origin of basalt. An 1806 description of the fossiliferous "basalts" at Portrush by a noted Neptunist notes: *"A variety of basalt, found in abundance at Portrush, and the Skerrie Islands, is full of pectinites of belemnites, and, above all, of cornua ammonis: these are dispersed through the whole mass, equally abundant in the interior, and on the surface. This basalt vitrifies, and the marine substances, it contains, calcine, in the fire of a common salt-pan; of course, never could have sustained a volcanic heat"*. The plutonist camp responded with the conclusion: *"that the stones which contained the shells, or the impressions of the shells, were no part of the real basalts. They were all very compact, and had all more or less of a siliceous appearance, such as that of chert; they had nothing of a sparry or crystallized structure…"*

Despite their historical importance and a growing interest in fossil preservation in metamorphic rocks, the mineralogy and texture of the metafossils has never been described. The metafossils occur in hornfelsed Jurassic clay. The contact metamorphism is due to intrusion of a large basaltic sill complex. High temperature (>600 °C) metamorphism produced zoned mineral assemblages around the fossils due to reaction between the calcite and calcite /pyrite shells and the clay matrix. The metafossils comprise an inner wollastonite-rich core that also contains pyrrhotite and fayalite in the ammonites (zone 1), surrounded by iron-rich wollastonite, hedenbergite, titanite, and plagioclase (zone 2). The matrix in contact with the metafossil (zone 3) comprises magnesian hedenbergite, plagioclase, and potassium feldspar, and matrix distant from the fossils (zone 4) comprises augite, plagioclase, potassium feldspar, fayalite, and Fe-Ti oxides. The metamorphic reactions, in particular the reaction of calcite with silica-bearing fluids to form wollastonite and the transformation of pyrite to pyrrhotite, result in large volume changes that may have distorted the shape of the fossils. Nevertheless, original morphological features, particularly of the ammonites, can be detected.

The rapakivi-bearing Margaree pluton, Aspy terrane, Cape Breton Island, Nova Scotia, Canada: inherited geochemical signature in an extension-related intrusion

Gabriel Sombini Dos Santos[1], Sandra M. Barr[2] Chris E. White[3], and Deanne Van Rooyen[4]

1. Department of Earth and Environmental Science, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada <gabriel.santos@uwaterloo.ca> ¶
2. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada ¶
3. Nova Scotia Department of Energy and Mines, Nova Scotia B3J 2T9, Canada ¶
4. Department of Mathematics, Physics, and Geology, Cape Breton University, Sydney, Nova Scotia B1P 6L2, Canada

The Margaree pluton extends for approximately 40 km along the NNE-SSW axis of the Ganderian Aspy terrane of northern Cape Breton Island. Typically described in the literature as rapakivi-textured megacrystic syenogranite, detailed mapping has shown that the pluton can be subdivided into mappable units of (1) megacrystic syenogranite; (2) medium-grained, equigranular, biotite syenogranite; and (3) microgranite porphyry, all locally displaying rapakivi texture. The equigranular syenogranite intruded megacrystic syenogranite, and the porphyry intruded both granites. The units are locally mingled, consistent with similar U–Pb (zircon) ages of 363.0 ± 1.6 Ma from a megacrystic syenogranite sample, 364.8 ± 1.6 Ma from an equigranular syenogranite sample, and 365.5 ± 3.3 Ma from a microgranite porphyry sample. Although the pluton displays wide textural variation, chemical data from 50 samples collected throughout the pluton show similar trends. The Margaree pluton is peraluminous and ferroan, with an alkalic to calc-alkalic signature. The REE patterns for the three units that compose the pluton are virtually identical, with parallel trends characterized by enrichment in the LREE (La 20 to 100 times chondritic values), flat HREE, and moderate negative Eu anomalies. The observed variability in major element composition and textural features can be explained by the interaction of felsic and mafic magmas in the magma chamber, followed by fractionation of alkali feldspar, plagioclase, and quartz. The geochemical signature suggests that the pluton is an evolved I-type granite, a surprising signature given the ca. 365 Ma age and its location in an area presumed to be in an extensional regime since ca. 375 Ma. This apparent conundrum can be untangled by a combination of geochemistry and field relations. The Margaree pluton is highly enriched in heat-producing elements (HPE). Combined with the intrusion of mafic magmas in the Aspy terrane at the time, as evidenced by the textural features of the Margaree pluton and characteristics of coeval supracrustal units, the enrichment in HPE provides the engine for anatexis. The isotopic (Sm-Nd, Pb, Hf, and O systematics) signature of the Margaree pluton is consistent with melting of pre-existing igneous rocks from the continental crust. This magma produced by crustal recycling migrated to high crustal levels in the area where the Aspy Fault intersected the Western Highlands Shear Zone, as indicated by the *en-cornue* geometry of the pluton, with tails at the intersection point of both structures, during Late Devonian extension in the Aspy terrane.

Closure in compositional data analysis: is it always such a hazard?

Clifford R. Stanley

Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <cliff.stanley@acadiau.ca>

"Closure" is the mathematical constraint that component concentrations in a given system sum to 100%. Thanks to Felix Chayes, geoscientists have known for more than six decades that closure adds variation to compositional datasets and thus obscures variations caused by material transfer processes. In the late 1960s, Tom Pearce and others developed graphical, molar element ratio data analysis methods that avoid closure, thereby allowing recognition/quantification of material transfer processes. More recently, John Aitchison and others developed alternative log-ratio methods that avoid closure in the statistical realm. Unfortunately, the passion of these log-ratio enthusiasts has given many geoscientists the impression that log-ratio methods are the ONLY way of circumventing closure, and thus that these methods MUST be used in any form of compositional data analysis in order to reach valid conclusions. This presentation disproves these misconceptions, illustrating that not only can compositional data be evaluated properly using techniques other than log-ratios, but that many geochemical systems contain elements that are not impacted significantly by closure at all, and thus need not be evaluated by any closure-avoiding data evaluation procedures.

An equation derived from the definition of a concentration allows one to assess the relative magnitudes of closure- and material transfer-induced relative variation. Functional analysis of this equation reveals that closure does not mask material transfer when: (i) the system size doesn't change during material transfer, (ii) the concentration of components undergoing material transfer are small, and (iii) the relative amount of material transfer of a component is large relative to the change in system size. Thus, this equation confirms

what geoscientists have known intuitively since the dawn of geochemistry, that trace element concentrations generally do not suffer from closure, but major oxide concentrations commonly do, a feature that explains why miners have successfully extracted low concentration ores without the use of closure-avoiding data analysis methods for over a century.

To illustrate the above, two datasets are evaluated, one of feldspar compositions from a porphyry Cu deposit in Chile, and one of turbidite compositions from New Zealand. These evaluations demonstrate that the automatic use of closure-avoiding procedures in geochemical data analysis may be unnecessary, as some components, and even some geological systems, do not suffer from closure. Lastly, I illustrate strategies that allow the geoscientist to recognize, using conserved elements, which components of a system are affected by closure, and which are not, affording them the opportunity to take appropriate action to avoid closure only where necessary.

Beaufort Formation chronostratigraphy and Pliocene landscape evolution: new insights into the Pliocene offshore deposits, Canada

*Sydney A. Stashin[1], John C. Gosse[1], I. Rod Smith[2], and Adam Z. Csank[3]

1. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <sydney.stashin@dal.ca> ¶
2. Geological Survey of Canada, Calgary, Alberta T2L 2A7, Canada ¶
3. Department of Geography, University of Nevada, Reno, USA

Pliocene (2.6–5.3 Ma) global average surface temperatures were approximately 2 ∞C warmer than at present. However, at high latitudes, Pliocene mean annual temperatures were up to 19 ∞C warmer. The Beaufort Formation (BFm), currently extending along the western Canadian Arctic Archipelago, is a fluvial deposit that formed a contiguous coastal plain and westward thickening marine clastic wedge across the continental shelf and into the Canada Basin. Its eastern extent has not been established. Based on available biostratigraphy and geochronology, the BFm was deposited during the Late Miocene through Pliocene. Intervals of Pliocene continental-shelf progradation are also recorded offshore in the Iperk Sequence, a pervasive and thick package of fluvial and marine sediment in the Beaufort-Mackenzie, and Canada basins. The Iperk Sequence is considered to be Pliocene-Pleistocene, and parts of this sequence are thought to correlate with the onshore BFm. The combination of a large sediment volume (exceeding 3 km thick), the high sensitivity to climate change at this latitude, and exceptionally well-preserved sedimentary and fossil archives that capture the depositional and ecological environments, makes the BFm and Iperk Sequence among the best records for the study of landscape evolution during a large-scale climate change (such as the one currently ongoing).

Our research goals are to interpret and correlate the offshore stratigraphy and record of faulting to establish the history of sedimentation and progradation, the timing of faulting, the links with climate change, and the factors controlling the landscape response to climate change. Ultimately, we are attempting to test hypotheses regarding the maximum extent and thickness of the BFm and the tectonic or incision origin of the Northwest Passage.

Using recently acquired marine seismic imagery from ION Geophysical Technologies, we have for the first time (i) subdivided the Iperk Sequence in the offshore Banks Island region into its Pliocene-Pleistocene components, (ii) calculated sediment volumes, and (iii) located the Pliocene paleo-shorelines. Additionally, we are testing the hypothesis that the straits comprising the Northwest Passage were formed by Pleistocene fluvial and glacial incision, not faulting. Knowledge of how landscapes respond to large-scale climate deterioration such as the Pliocene-Pleistocene transition is critical for understanding first-order controls on ocean alkalinity and changes in sediment flux to terrestrial and marine basins. We discuss the implications of these data in relation to major transgressive sequences and landscape evolution during a period of significant climate change.

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

Matthew Stimson[1,2], Olivia A. King[1,2], R. Andrew MacRae[1], Randall F. Miller[2], Steve J. Hinds[3], and Adrian F. Park[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <mstimson29@gmail.com> ¶
2. Natural Science Department, New Brunswick Museum, Saint John, New Brunswick E2K 1E5, Canada ¶
3. New Brunswick Geological Surveys Branch, Fredericton, New Brunswick E3B 5H1, Canada

The evolution of the tetrapod crown groups, including the transition from aquatic environments to fully terrestrial environments, has remained enigmatic given the dearth of evidence during the Mississippian Period. Thus, it was hypothesized that these crown groups evolved during the so-called "Romer's Gap". Romer's Gap marks the start of a

critical divergent point in the history of life, as organisms transitioned from solely aquatic to terrestrial ecosystems. This expansion into dry environments sets the stage for the radiation of all terrestrial animal life on Earth, yet it is one of the least understood intervals of Earth's history. The exact timing for the radiation of tetrapods and other terrestrial biota into inland continental environments is not known due to a near lack of continental body fossils or ichnofossils from terrestrial deposits. New discoveries of body and trace fossils from sites in Scotland and Nova Scotia (Horton Bluff), represent rare exceptions that offer a glimpse into terrestrial ecologies during Romer's Gap; however, both sites display evidence for an open-water connection, suggesting a coastal paleogeographical position.

The half-graben, pull-apart Moncton Subbasin in southern New Brunswick accommodated up to 5 km of sediment during the Early Mississippian. The sediments deposited are interpreted to represent freshwater and intra-continental conditions (lacustrine, wetland, fluvial, alluvial settings). Within the Moncton Subbasin, a single stratigraphic horizon in the Hiram Brook Member of the Albert Formation exposed along Highway 1 south of Norton has yielded abundant tetrapod footprints. Preliminary assessment of these trackways suggests at least 4 ichnogenera are preserved in this formation (*Characichnos, Matthewichnus, Paleosauropus, Batrachichnus*). Footprints range in size from 1 cm to 3 cm, suggesting that tetrapods were smaller than those documented from time-equivalent sites in Nova Scotia, but are comparable in size to skeletal remains described from Scotland, including small microsaurs, temnospondyl amphibians, and stem amniotes that are candidates as trace makers. Additional putative disarticulated tetrapod bones (a limb and a mandibular jaw) have been found and warrant further study.

These footprints are interpreted to be preserved on the margins of small channels associated with dense fossil forests of *Lepidodendropsis* trees preserved in their ecological context. The large sample size of tetrapod footprints and association with previously studied invertebrate traces suggests that a community of tetrapods was present and part of a diverse ecosystem adapted to terrestrial and semi-aquatic continental environments in the Early Mississippian (Tourniasian) of New Brunswick.

Evolution of the Oxford sinkhole, Cumberland County, Nova Scotia, Canada

Amy Tizzard[1], Garth DeMont[1], Denise Brushett[1], and Jerry Borden[2]

1. Nova Scotia Department of Energy and Mines, Halifax, Nova Scotia B3J 2T9, Canada <amy.tizzard@novascotia.ca> ¶

2. Nova Scotia Department of Lands and Forestry, Oxford, Nova Scotia B0M 1P0, Canada

A small, 30 cm-wide opening in the ground was first observed by groundskeeping staff at the Lion's Parkland in Oxford, Nova Scotia, on July 28, 2018. Over the following weeks the sinkhole slowly grew in both depth and diameter until a sudden collapse on August 20 gave rise to a period of rapid development in which the sinkhole grew from a few metres in size to upwards of 40 metres in diameter and an unknown depth. Observations and measurements of propagation cracks encompassing the sinkhole demonstrate a progression to the northeast toward playground infrastructure and surrounding Salt Lake. Aerial surveillance of surrounding lakes and watercourses during the most active period of sinkhole development showed no unexpected turbidity, indicating a lack of mixing of sinkhole water with that in surrounding waterbodies. LiDAR imagery of the area shows numerous dry and ponded sinkhole activity in the vicinity of Salt Lake and area to the southwest. The underground extent of the collapsed cavern is presently unknown; however, the region is underlain by the Windsor Group, consisting of interstratified red beds, evaporites, and carbonate rocks that are prone to development of sinkholes. Gypsum and salt have been documented in the area, but no bedrock is visible at the sinkhole due to a thick deposit of sand. The sinkhole continues to slowly erode along its margins, although the rate of growth has significantly slowed. Ongoing monitoring and geophysical programs are planned to further investigate the sinkhole.

Application of portable X-ray fluorescence (pXRF) analyses to discriminate felsic units and hydrothermal alteration in the Murray Brook volcanogenic massive sulphide deposit, New Brunswick, Canada

Maiara Toniazzo Braga and David R Lentz

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <Mgirardi@unb.ca>

The Middle Ordovician Murray Brook volcanogenic massive sulphide deposit located in northeastern New Brunswick represents a significant base-metal resource in the Bathurst Mining Camp. The deposit occurs within the California Lake Group and is hosted by altered sedimentary rocks of the Charlotte Brook Member, in the lower part of the Mount Brittain Formation. Due to the complicated metamorphic and deformation history of the deposit, in addition to hydrothermal alteration, questions remain as to the origin of these rocks. To shed some light on this, the Olympus VANTA portable X-ray fluorescence (pXRF)

spectrometer was used to rapidly obtain trace element compositions of these rock units.

Four hundred twenty-seven samples from four drill cores that intersect the hanging wall, the massive sulphide body, and the footwall were described and analyzed. Each sample was measured four times at two different positions using the 50kV benchtop configuration with a total integration time of 720 seconds. Rigorous QA/QC was performed to calculate calibration correction factors using nine Certified Reference Materials and silica blanks during each analytical run. This will help to mitigate daily variance and equipment drift, and to obtain the correction factors for each element, supporting precision during statistical analysis. The relative standard deviation (RSD%) for most of the elements obtained shows that the pXRF data are very reliable.

To graphically discriminate rock types, the elements Al, Ti, Zr, Nb, Y, Cr, V, and Th were selected, since these elements are relatively immobile during hydrothermal alteration. In order to represent various alteration types, the indices known as AI (Ishikawa) and CCPI (chlorite-carbonate-pyrite) were modified to be used with the pXRF data in this study. Specifically, AI = 100(K/(K+Ca)) and CCPI = 100((Fe+Mn)/(Fe+Mn+Ca +K)). The alteration box plot (AI versus CCPI) shows that at least 80% of the samples fall in the "Most Altered" field (sericite-chlorite-pyrite), which coincides with observations in both hanging wall and footwall. The AI index displays the majority of relatively high values (60–90) in these altered rock units compared to the CCPI index (50–90). A late iron-carbonate alteration that overprints earlier alteration types was also detected. Plots of SiO_2 versus Al_2O_3 and SiO_2 versus TiO_2 suggest that sedimentary rocks with <60% SiO_2 have undergone hydrothermal alteration involving silica loss. Detailed field observations combined with this technology could offer quick and precise information to discriminate these strongly altered and deformed rocks.

A 100-year paleolimnological record of environmental change from Cecil Lake, northern British Columbia, Canada: application to the assessment of the habitat viability for migratory waterfowl

Garrett Velkjar[1], Ian Spooner[1], and Mark Mallory[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <131768v@acadiau.ca> ¶
2. Department of Biology, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada

Lake sediment archives are an established tool for examining environmental change over time. Cecil Lake is a productive shallow lake located in the Peace River region of northeastern British Columbia. It supports a variety of water birds, including a significant northern breeding population of eared grebes (*Podiceps nigricollis*). The Cecil Lake watershed primarily consisted of well-forested muskeg when the surrounding area was first homesteaded in 1928. As of 2018, ~80% of the landscape has been developed by the agricultural and energy sectors; consequently, Cecil Lake represents an opportunity to examine the effects of this development on a northern lake. The bulk geochemistry of the lake sediment archive at Cecil Lake was investigated to decouple natural and anthropogenic impacts over time. Water samples were collected for limnological assessment. Three sediment cores were collected in July 2018 using a NLA gravity corer. A 30 cm core was extruded at a 0.5 cm scale to determine stratigraphic variations in bulk geochemistry (metals, $\delta^{15}N$, $\delta^{15}C$, Total C, N). X-ray fluorescence analysis was used to determine metal concentrations at different depths in the core. Total lead data suggested that the duration of the recovered record was more than 100 years. A distinct zone of change, estimated to have occurred ~1920–1940, was characterized by increasing calcium, and manganese, as well as decreased titanium, potassium, and iron. This period was also characterized by increased %C, $\delta^{13}C$, and %N, and a steadily increasing trend in the $\delta^{15}N$ ratio. Strontium, zinc, and iron data showed increased variability from ~1940 onwards. Collectively, these data indicate three distinct signatures: (i) background conditions, (ii) a strong response to initial clearing and development, and (iii) increased environmental fluctuations associated with resultant water level variability and nutrient input changes. ^{210}Pb analysis of the core will provide temporal control allowing for the accurate correlation of historic events to the sediment archive. This record will be coupled with ecological data to better understand the vulnerability of similar lakes to environmental change.

Characterization of Cambrian sandstones on both sides of the modern Atlantic: implications for peri-Gondwanan terrane affinities in the Appalachian-Caledonide Orogen

John W.F Waldron[1], David I Schofield[2], D. Graham Pearson[1], S. Andrew Dufrane[1], Chiranjeeb Sarkar[1], Yan Luo[1], and Robert Dokken[1]

1. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada <john.waldron@ualberta.ca> ¶
2. British Geological Survey, The Lyell Centre, Research Avenue South, Edinburgh EH14 4AP, United Kingdom

The Appalachians of Atlantic Canada, and the Caledonides of Britain and Ireland, include terranes attributed to both Laurentian and Gondwanan sources,

separated along the Silurian Solway Line in Britain, and the Ordovician Red Indian Line in Canada. Gondwanan elements to the south and east have been variably assigned to the domains Ganderia, East and West Avalonia, and Megumia, based on their Cambrian sedimentary histories, their provenance, and their isotopic characteristics. A sample of Red Callavia Sandstone from uppermost Cambrian Stage 3 of the Midland Platform, attributed to East Avalonia, yields a U–Pb age spectrum dominated by Neoproterozoic and Paleoproterozoic sources, resembling those in the Welsh Basin, the Meguma Terrane of Nova Scotia, and northwestern Africa. Initial εHf values suggest that the Neoproterozoic zircon component was derived mainly from crustal sources <2 Ga and imply that the more evolved Paleoproterozoic grains were transported into the basin from an older source terrane, probably the Eburnean orogen of western Africa. A sample from Cambrian Stage 4 in the Bray Group of the Leinster-Lakesman terrane shows, in contrast, a distribution of both U–Pb ages and εHf values closely similar to those of the Gander terrane in Newfoundland and other terranes attributed to Ganderia, interpreted to be derived from the margin of Amazonia. East Avalonia is clearly distinct from Ganderia, but shows evidence for older crustal components not present in West Avalonia of Newfoundland. Comparison of these results with previous work suggests that Ganderia, Avalonia, and Megumia came from distinct locations on or close to the margin of Gondwana in the early Paleozoic, and that East and West Avalonia may have had different Neoproterozoic histories.

Progress report on bedrock mapping in the Munsungun Inlier, Maine, USA, in 2018: new field, geochemical, and geochronological constraints on its tectonic history

Chunzeng Wang[1], Stephen Pollock[2], Robert Marvinney[2], and David Putnam[1]

1. University of Maine at Presque Isle, Presque Isle, Maine 04769, USA <chunzeng.wang@maine.edu> ¶
2. Maine Geological Survey, Augusta, Maine 04333, USA

Bedrock mapping at 1:24 000-scale in the Munsungun Inlier of Maine has made significant progress towards understanding its geology and tectonic history. New field, geochemical, and geochronological data obtained in 2018 help to decipher the tectonic history of the Inlier. These new data confirm the existence of two separate volcanic belts formed at different times during the Ordovician – the Munsungun-Jack Mountain-Bald Mountain Volcanic belt in the east-southeast, and the Spider Lake-Mule Brook Mountain belt in the west-northwest.

The Munsungun-Jack Mountain-Bald Mountain Volcanic belt is underlain by the Munsungun Lake Formation and Round Mountain Formation. The Munsungan Lake Formation consists of cyclic layers of dominantly arc-type, calc-alkaline subaqueous basaltic (dominant), andesitic, and dacitic pyroclastic falls (dominant), ignimbrite flows (minor), and lava flows with large negative εNd values (-16.3 to -18). The Round Mountain Formation comprises cyclic layers of tholeiitic E-MORB-like (rifted arc) subaqueous basaltic pyroclastic falls, lava flows, and diabase sills/dikes with higher εNd values of 2.7-3.7 (one sample has -18.0). Two tuff samples from the belt yielded U–Pb concordia ages of 468.0 ± 2.0 Ma and 471.2 ± 4.2 Ma.

The Spider Lake-Mule Brook Mountain belt consists of subaqueous tholeiitic arc basalt/diabase and pyroclastic rocks with minor arc-type calc-alkaline rhyolite. Their εNd values are 3.5 to -4.8. Two tuff samples from the belt yielded U–Pb concordia ages of 454.4 ± 1.8 Ma and 456.6 ± 1.8 Ma. The respective ages suggest a minimum 14 m.y. gap between the two volcanic belts. Does it suggest arc-trench migration?

New data reveal the existence of several post-arc sedimentary formations. The Rowe Lake Formation has the youngest zircon grains, clustered at 447.0 ± 3.2 Ma, a Katian age supported by graptolite fossils. The Blind Brook Formation has detrital zircon grains clustered only at 445.2 ± 1.8 Ma, suggesting it was deposited in a restricted basin in middle Late Ordovician. The younger, post-arc sedimentary rocks were also mapped in several other locations, including one hosting the youngest zircon grains (clustered at 442.8 ± 3.2 Ma). The detrital zircon age spectra of all the samples point to a Laurentian provenance, suggesting that near the end of the Ordovician, the Munsungun arc was already accreted to the Laurentia margin and the restricted, post-arc successor basins began receiving sediments from Laurentia. The Chase Lake Formation was also recognized in the study area and its extent and lithology redefined; it is probably also post-arc and Late Ordovician.

Microstructural character of active fault zones, southwest Honshu, Japan

Joseph Clancy White

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <clancy@unb.ca>

Detailed examination of the microstructures of active faults in southwestern Honshu, Japan has been made at three types of occurrence: (1) surface exposures of the Rokko fault and adjacent damage zone of the Arima-Takasuki Tectonic Line (ATTL); (2) a trench excavated across the same fault; and (3) drill core acquired from the Nojima fault, source

of the 1995 Hanshin-Awaji earthquake. A primary objective was to characterize the mineralogical and textural nature of the ultra-fine-grained (typically less than 1 μm) component of the fault rocks. Laboratory techniques include optical petrography, SEM characterization, X-ray diffraction, micro-X-ray fluorescence, and transmission electron microscopy. The damage zone of the ATTL comprises a broad zone of crushed, comminuted, and pulverized granite/rhyolite containing cm-scale slip zones and highly comminuted injection veins. The fault and injection gouges have mixed mineralogy typical of the host material and form during several faulting events, as evidenced by overprinting. Damage zone material exhibits generally random textures whereas slip zones are macroscopically foliated, and compositionally layered, notwithstanding a fairly homogeneous protolith. The latter reflects fluid-rock interaction during both coseismic and interseismic periods. The slip zones are microstructurally heterogeneous at all scales, comprising not only cataclasites and phyllosilicate (clay)-rich gouge zones, but Fe/Mn pellets or clasts that are contained within gouge. The sub-structure of these growths can resemble crack-seal growths at 10–100 nm-scale that could reflect diffusion and growth over even shorter time periods. A central question related to earthquake recurrence along existing faults is the nature of the gouge. Notwithstanding the evidence for rapid comminution and particulate flow, fluidized particulate flow, fluidized injection, and fluid-rock reactions, there remain ambiguous aspects of gouge behaviour. In both near-surface exposures and drill core, "plastic" or "viscous" gouge zones comprise ultra-fine-grained clay-siliciclastic particles that would not necessarily respond in a simple frictional manner.

Mineralogy and U–Pb phosphate dating of the Los Angeles Martian diabase

Bennett J. Wilson, Chris R. McFarlane, and John G. Spray

Department of Earth Sciences, Planetary and Space Science Centre, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <bennett.wilson@unb.ca>

The Los Angeles Martian meteorite is a ~170 Ma shergottite consisting of two stones; Stone 1 at 453 g, and Stone 2 at 245 g. They consist primarily of pyroxene and maskelynitized plagioclase, together making up over 80 wt.% of each stone. About 2.5 wt.% of phosphates exists in both stones. Three analytical methods (Energy Dispersive Spectroscopy (EDS), Wavelength Dispersive Spectroscopy (WDS), and Raman Spectroscopy) have concluded that the phosphates are depleted in LREEs, and consist of two phases: dominantly high-Fe, low-Mg ferromerrilite (~1.5 wt.%) paired with minor Cl- and F- rich apatites (~1 wt.%). Ferromerrillite ($Ca_9NaFe(PO_4)_7$) has only recently (2006) been distinguished from merrillite ($Ca_9NaMg(PO_4)_7$), and manifests via replacement of Mg^{2+} by Fe^{2+}, which has been clearly identified in the results using EDS and WDS techniques in this study. The use of Raman Spectroscopy further distinguished ferromerrillite from whitlockite (often confused in the literature), as well as the Cl- and F-rich apatites from (OH)-apatite, both results indicating the absence of hydrous phases. Textural relations between the apatite and ferromerrillite suggest that they crystallized simultaneously and late in the igneous crystallization process. Utilizing the U–Pb system, the LA-ICP-MS yielded a refined phosphate age of 170 ± 16 Ma once outliers were rejected. Included in the dataset for this refined age were phosphates within and adjacent to shock-induced melt-pockets, showing that the U–Pb system within the phosphates was not reset to the shocked/lofting age of ~3 Ma. Using only the data points within, or neighboring the shock melt, a phosphate age of 147 ± 42 Ma was produced, suggesting that phosphates are robust geochronometers and can resist resetting.

The role of country rock assimilation on chromite crystallization in the Ring of Fire, James Bay lowlands, Ontario, Canada

Kate Woods[1], Erin Keltie[1], James Brenan[1], James Mungall[2], and Ryan Weston[3]

1. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <woodskate@dal.ca> ¶
2. Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada ¶
3. Noront Resources, Thunder Bay, Ontario, Canada

The Ring of Fire (RoF) intrusion in the James Bay lowlands, Ontario, is emplaced in the 2.7 Ga McFauld's Lake greenstone belt, and hosts the Black Thor, Big Daddy, Blackbird, and Black Label chromite deposits, together comprising ~192.7 million tonnes of measured and indicated chromite resources. Evidence suggests that magma contamination occurred during the emplacement of the RoF intrusion - a process that has been widely invoked for the formation of massive chromitite segregations. We have evaluated the role of contamination as a chromitite-forming mechanism in the RoF context by combining phase equilibrium experiments with trace element measurements on chromite, and modelling. Experiments involved equilibrating mixtures of synthetic komatiite and country rocks to the RoF intrusion (banded iron formation, Fe-rich metasedimentary rock and granodiorite) at 0.1 MPa and the FMQ buffer to measure phase equilibria, chromite solubility, and chromite composition. The most notable results are: (1) melt FeO content has the

strongest compositional influence on the chromium content of the melt at chromite saturation (CCCS); increasing melt FeO lowers the CCCS, although this effect is not large; (2) addition of contaminants shifts the olivine-chromite cotectic roughly parallel to the olivine-quartz join of the olivine-quartz-chromite ternary, but maintaining curvature concave to the olivine-quartz join; and (3) the Cr/Fe ratio decreases with temperature, and does not show any systematic changes with contaminant type. The presence of both cumulate chromite and ferromagnesian phases (olivine, orthopyroxene) suggests a chromitite-forming mechanism that increases the chromite/silicate ratio beyond normal cotectic proportions. Results from experiments suggests this is possible by the addition of a more siliceous component, or by cooling of any of the compositions investigated, but cannot solely account for rocks with chromite/olivine >1; other processes, such as crystal sorting, are required. We are now searching for additional evidence of contamination through LA-ICPMS analysis of individual chromite grains from various RoF chromitites, and employing available chromite-melt partition coefficients to establish the trace element characteristics of the chromite-forming magma. Results so far indicate that relative to average Munro Township komatiite (MTK), the compositions of chromite-forming magmas are similar to or enriched (up to 3-fold) in Hf, Ta, and Zr, and similar to or depleted (up to 2-fold) in Co, V, Ga, and Sc. Compared to mixtures of MTK and either BIF, Fe-rich metasedimentary rock or granodiorite, calculated chromite-forming magmas show more similarity to sediment-contaminated compositions, although the match is still imperfect.

Structural geology of West Beach Formation, Black River, New Brunswick, Canada

P.L. Edward Wu and Joseph C. White

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <edward.wu@unb.ca>

Rocks assigned to the Late Devonian-Early Carboniferous West Beach Formation, Lorneville Group, are exposed along the Bay of Fundy between the Neoproterozoic Millican Lake granite to the west and the Carboniferous Cumberland Group to the east. The studied units comprise basalt blocks embedded in foliated siltstone and sandstone, as well as more massive basalt. The objectives of this study are to establish the deformation geometry and history, including the dating of different tectonic events, and to test the utility of detailed photogrammetry and LiDAR in examining remote exposures. Herein we summarize the recent findings of the studies.

The intercalated sedimentary and basalt units are intensely deformed and exhibit multiple foliations. A minimum of three generations of folds are identified and they generally fall on a great circle distribution. The earliest compositional layering (S_c) dips gently to moderately southeast, as does the enveloping surface of folds. S_1 and S_1b are axial planar cleavages associated with near-recumbent folds; they are subsequently transposed by pervasively southeast-dipping S_2 and S_3. The observed transposition and cleavage orientations infers a southeast-to-northwest shearing and progressive deformation.

Fault orientations are similar to those of the foliations. Strike-slip faults and associated calcite-veined fractures are predominantly steeply dipping, and striking east-northeast—west-southwest to northeast-southwest. Slickenside fibres on fault surfaces preserved on strike-slip fault planes infer subsequent dip-slip motion. Basalts at Powers Point that are affected by steep northeast-southwest faults contain extensive hematite veins. Northeast-striking, gently to moderately dipping faults are interpreted from fracture patterns to be low-angle normal faults; however, given that the normal fault plane orientations are close to S_3, some of the normal faults could be re-activated thrust faults associated with earlier (S_3?) shearing. The detailed structural history will serve as a template for extracting absolute ages from the different events with the aim of extending such analyses to less well exposed areas.

An applied paleolimnological assessment of anthropogenic impact in a back-barrier lagoon: Pictou Landing, Nova Scotia, Canada*

Dylan Wyles[1], Ian Spooner[1], Baillie Holmes[2], Savanna Francis[3], and Selena Denny[3]

1. Acadia University, Department of Earth and Environmental Science, Wolfville, Nova Scotia B4P 1Y1, Canada <Dylan.wyles333@gmail.com> ¶
2. Dalhousie University, Centre for Water Resources Studies, Halifax, Nova Scotia B3H 4R2, Canada ¶
3. Pictou Landing First Nation, Band Office, Trenton, Nova Scotia B0K 1X0, Canada

An applied paleolimnological assessment of environmental impact was carried out on a back-barrier lagoon – Sitmu'k, also called Moodies Cove – that is recreationally and culturally important to the nearby community of Pictou Landing First Nation. Since the 1880s the region has experienced significant industrial impact; more recently, local residential development has taken place. There has been concern over water quality degradation at the site

over the past 50 years. In our study, the paleolimnological method was used to investigate environmental change in the lagoon. Issues identified include degraded water quality and the potential environmental legacy of local and regional industrial activity.

Sediment gravity cores were collected from 8 locations within Sitmu'k. A high resolution (0.5 cm interval) bulk geochemical analysis of one sediment core was conducted using X-ray fluorescence (XRF) to determine elemental concentrations; total Carbon (C), total Nitrogen (N), and stable isotope analyses ($\delta^{13}C$, $\delta^{15}N$) were also employed, as well as top-bottom analyses on cores throughout the basin. The data from Sitmu'k was then compared to paleolimnological data from nearby reference sites (Fergusons Cove, Chance Harbour Estuary, and Boat Harbour Estuary). C/N isotope data indicate that carbon input at Sitmu'k is primarily from marine sources, whereas XRF analyses indicate that metal concentrations (Pb, Cu, Zn) do not exceed marine interim sediment quality guidelines (ISQGs). All metal content data were at or below reference site averages. A limnological survey of the site in 2018 indicated a gradual and consistent increase over the summer in temperature (max 31.79 °C) and total coliforms, nitrate (>1.6mg/L) and total phosphorus (>0.59 mg/l) levels, placing the lagoon in a eutrophic to hypereutrophic state. Elevated $\delta^{15}N$ levels (compared to reference sites) in top-of-core samples throughout Sitmu'k indicate the potential influence of local septic system discharge. Air photo and satellite imagery indicate significant landward migration (>50 m) of the barrier beach (Lighthouse Beach) in the last 15 years. Sediment redistribution from the beach into Sitmu'k has resulted in shallowing and circulation constriction resulting in higher water temperatures, limited circulation, and elevated nutrient and coliform levels.

Collectively, the data suggest that a legacy of past industrial activity is not present at the site. Water quality degradation noted over the past 50 years can be attributed to both the rapid natural landward migration of the barrier-beach complex and the impact of increased local residential development, which may be significant and warrants further, longer-term investigation.

Winner of the AGS Rob Raeside Award for best undergraduate student poster

Fossil jellyfish from Carboniferous shales in the central USA

Graham A. Young[1] and James W. Hagadorn[2]

1. Manitoba Museum, Winnipeg, Manitoba R3B 0N2, Canada <gyoung@manitobamuseum.ca> ¶

2. Department of Earth Sciences, Denver Museum of Nature and Science, Denver, Colorado 80205, USA

Cnidarian medusae (jellyfish) have a very poor fossil record: only about a dozen well-documented deposits are known, and any new occurrence is significant. Fossil medusae occur from the Cambrian onward, and by the Carboniferous they were quite diverse. This study describes and considers the significance of a handful of remarkably preserved jellyfish from black shales of the North American midcontinent, USA. These are extremely rare fossils, with two of the three occurrences represented by a single specimen each. When considered together, they provide important information about cnidarian evolution, and about unusual taphonomic paths for the preservation of medusae. Two of the occurrences had never been previously documented; both of these fossils were in the collections of the Field Museum, Chicago. The third is a previously published slab at the Texas Memorial Museum, Austin.

One of the previously undocumented medusae is a chirodropid cubozoan (box jellyfish) from the Middle Pennsylvanian (Moscovian) Mecca Quarry Shale of Indiana. It is very similar to, and possibly conspecific with *Anthracomedusa turnbulli* Johnson and Richardson, a species already known from siderite concretions of the contemporaneous Mazon Creek Lagerstätte of Illinois. The other two occurrences, from the Upper Pennsylvanian (Kasimovian) Stark Shale, probably represent stem group Rhizostomeae. One is a slab including seven medusae from Iowa, which had been documented as *Prothysanostoma eleanorae* Ossian, whereas the other is a single medusan from Nebraska, which we refer to as *Prothysanostoma?* sp.

These fossils exhibit evidence of twisting, rupturing, and flexible deformation, while preserving delicate organs such as muscles, gonads, eyes, and tentacles. Although some tissues, like gypsum-rich rhopalia, are structures that were somewhat robust in life, others reflect preburial accentuation of tissue margins, such as tentacles that are mantled by silt and bells that were filled with quartz sand. Carbonaceous compression of soft tissue resulted from conditions where decay was delayed and scavenging inhibited, possibly through microbial activity and burial. Fossils from these deposits offer opportunities to understand how medusae change when they go through different taphonomic processes.

Anthracomedusa is remarkably similar in morphology to extant basal chirodropids, suggesting continuity of this body plan for at least 300 m.y. *Anthracomedusa* occurs in nearshore proximal-estuarine settings comparable to those of its modern counterparts, and *Prothysanostoma* and its modern allies are known from open-water settings. The preservation of jellyfish in Pennsylvanian black shales indicates that such facies may contribute significantly to the Late Paleozoic Lagerstätten record.