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Atlantic Geoscience Society

ABSTRACTS

48th Colloquium & Annual General Meeting 2022

Virtual

The organizers and all AGS members were saddened to learn of the sudden passing of our President, Dr. Anne Marie Ryan, on January 20th, 2022. She will be greatly missed as a vital member of the society for 40 years, especially her dedication and leadership in geoscience education. Hence, this year's Colloquium is dedicated to her memory.

Once again, due to the continued Pandemic circumstances, the 2022 Colloquium & Annual General Meeting was held using the virtual venue Zoom on February 11th and 12th. On behalf of the society, we thank Colloquium organizers David Lentz, Jim Walker, Rob Raeside, Deanne van Rooyen, Alan Cardenas, and Mike Parkhill, as well the numerous session chairs and judges, for facilitating an excellent meeting with about 185 registrants. AGS acknowledges support from the corporate sponsors and partners for the meeting: Nova Scotia Department of Natural Resources and Renewables (Geoscience and Mines Branch), New Brunswick Department Natural Resources and Energy Development (Geological Surveys Branch), Engineers and Geoscientists of New Brunswick, Galway Metals, and Terrane Geoscience Inc.

In the following pages, we are pleased to publish the abstracts of oral and poster presentations from the meeting on a variety of topics. Best undergraduate and graduate student presentations are recognized and indicated by an asterisk in the title. The meeting included five special sessions: (1) Regional geology in the northern Appalachians or development of the northern Appalachians: new data and new thoughts; (2) Current research in Carboniferous geology of the Maritimes; (3) Mineral resources and metallogeny of the northern Appalachians; (4) Trace elements in crystalline rocks: abundances, variation, and geochemical interpretation; (5) Advances in paleontology; (6) Resources, remediation, and environmental protection: surficial geochemistry and geology studies; (7) The 8Gs: a new paradigm in our geologic heritage; (8) Modern surface processes and sedimentary record: linking geomorphic processes through time and a general session on geoscience research developments.

The traditional Saturday evening banquet and social were replaced by a virtual Awards Banquet at which society awards were announced, as well as student prizes for best poster and oral presentation. The student award winners are noted at the end of the appropriate abstract.

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

THE EDITORS

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Impurities in uraninite: examples of crustal uranium cycling in the Nonacho Basin, Northwest Territories, Canada

Erin Adlakha and Kerstin Landry

Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <erin.adlakha@smu.ca>

Uraninite (UO_2) is the main ore of uranium and, like all minerals, pure UO_2 rarely occurs in nature. Other elements ("impurities") in major to trace abundances can substitute for U^{4+} and O^{2-} in uraninite); the charge and ionic radius of the impure elements control whether they can be incorporated in the structure of a mineral. For uraninite, these impurities are commonly Th^{4+}, Y^{3+}, REE^{3+}, Ca^{2+}, and Fe^{2+}. The abundances of these impurities in uraninite reflect the origin and environment of uraninite formation. However, the production of Pb^{4+}, a strong oxidizer, from the decay of U^{4+} complicates elemental substitution in uraninite. Tetravalent Pb oxidizes U^{4+}, producing Pb^{2+} and U^{6+}, when accumulated over time leads to the destabilization of the uraninite structure and alteration during later thermotectonic events and hydrothermal activity.

This presentation examines the impurities in different styles of U mineralization of the Paleoproterozoic Nonacho Basin of the Rae Craton, a lithotectonic segment of the Canadian Shield that hosts abundant and prolific uranium deposits (e.g., unconformity-type uranium, albitite-hosted uranium). Coupled with U–Pb geochronology, these data are used to comment on the cycling of uranium during the early assembly of Laurentia and processes responsible for its enrichment in the Rae Craton.

A diverse Late Carboniferous vertebrate and invertebrate ichnofaunal assemblage from Smith Point, Nova Scotia, Canada: implications for local stratigraphic mapping

Luke F. Allen[1], Matthew R. Stimson[2,3], John H. Calder[3,4], Tim J. Fedak[5], and Rowan E. Norrad[1]

1. Citadel High School, Halifax, Nova Scotia B3H 0A4, Canada <alf351678@gnspes.ca>; 2. Natural History Department, New Brunswick Museum, Saint John, New Brunswick E2K 1E5, Canada; 3. Department of Geology, Saint Mary's University, Halifax Nova Scotia B3H 3C3, Canada; 4. John Calder Earthworks, Halifax Central, Halifax, Nova Scotia B3J 2L4, Canada; 5. Nova Scotia Museum, Halifax, Nova Scotia B3H 3A6, Canada

The Maritimes Basin of Atlantic Canada is well known for its rich ichnological resources that span the Mississippian through earliest Permian periods. Upper Pennsylvanian strata along the Northumberland Strait of Nova Scotia have yielded large *Arthropleura* tracks at Cape John and Pugwash, as well as the first in-situ walchian conifer forest associated with a diverse tetrapod ichnofauna assemblage at Brule. Smith Point has previously yielded an articulated tetrapod skeleton (nicknamed "superstar") that is part of a concurrent project by another research group. *Arthropleura* tracks were first documented at Smith Point in the 1980s. They are the first occurrence of tetrapod tracks from that locality, associated with arthropod trackways, rare vertebrate remains, infaunal burrows, and macrofloral elements.

Exposed on the wave-cut platform, two primary sandstone horizons, interpreted as the tops of prograding channel bars, each preserve circa 25 and 40 individual *Arthropluera* trackways (*Diplichnites*). Although *Arthropleura* trackway-bearing strata are well known in Atlantic Canada, this outcrop is perhaps one of the most extensive exposures of *Arthropleura* derived *Diplichnites* tracks in the fossil record, based on trackway length and extent of the trackway surface. The adjacent cliff section exposes abundant fine-grained sandstone and mudstone interpreted as floodplain deposits. These strata commonly preserve small *Diplichnites*, infaunal meniscate backfilled burrows assigned to *Taenidium* and rare examples of *Kouphichnium*. Tetrapod tracks derive from red, flat-bedded sandstones in convex hyporelief, and convex epirelief impressions imprinted into the underlying red mudstone. The high-diversity tetrapod ichnoassemblage includes trackways that are interpreted to have been produced by pelycosaur-grade synapsids (*Dimetropus*), captorhinids (*Varanopus*), seymouriamorphs (*Amphisauropus*), temnospondyl amphibians (*Limnopus*, *Batrachichnus*), and parareptiles (*Dromopus*). Isolated bone fragments of unidentified tetrapods and xenacanthid shark teeth have also been recovered from intraformational mud chip conglomerate. This vertebrate and invertebrate ichnofaunal assemblage is inferred to have been preserved within an upland river system. Semi-articulated paleofloral elements include cordaitaleans, pecopterid tree ferns and walchian conifers which all point to a climate shift favouring drought-tolerant vegetation, consistent with the collapse of coal-forming peatland ecosystems late in the Carboniferous. Geological mapping has assigned strata at Smith Point to the Malagash Formation of the upper Cumberland Group (late Moscovian stage). However, the lithology, ichnofauna, and paleoflora all bear striking resemblance to the Brule fossil site as well as early Permian Euramerican localities, suggesting that the Smith Point strata be reassigned to the Pictou Group (late Gzhelian or younger).

Geophysical and geomorphological monitoring of coastal erosion of Bread and Cheese site, Bay Bulls town, Newfoundland, Canada

Marzieh Arshian and Alison Leitch

Department of Earth Sciences, Memorial University, St. John's, Newfoundland and Labrador A1B 3X5, Canada <marshian@mun.ca>

Coastal erosion can be a serious issue requiring accurate observation to evaluate vulnerable areas and determine the subsequent actions to address this problem. The Town of Bay Bulls, about 29 km south of St. John's, Newfoundland and Labrador, has coastal areas prone to erosion, and an important aim for the Town municipality is to reinforce these areas to avoid future road collapse. An inspection to describe an areas' geomorphological characteristics and a ground-penetrating radar (GPR) investigation were carried out along the Bay Bulls northern shoreline at the 'Bread and 'Cheese' site. To thoroughly assess an area's erosion potential, it is essential to evaluate the coastal geomorphology. Information about the geomorphological variations like wave characteristics, wind direction, fracture plane strike, slope, and beach elevation were acquired. Identifying if the beach is a steep reflective beach or flat dissipative one. can facilitate assessing the areas prone to erosion in shorelines. The shoreline at the Bread and Cheese site has steep cliffs subject to erosion by terrestrial and marine processes. The tilted bedrock is mainly light-grey sandstone, locally thinly bedded, greenish-grey to red sandstone, and siltstone. Regarding the cliff face and toe erosion, a noticeable downward dip is apparent in the cliff face due to soil creep or the slumping of the Quaternary cover including glacial diamicton. This occurrence would probably be considered a rotational slump, a common slumping type. The GPR survey was conducted along the road on a clifftop using 250 antennae, providing useful information about the underground structure. The GPR result at the Bread and Cheese area depicts the subsurface culverts, bedrock location, and highly fractured regions corresponding with the geomorphology observations.

A review of recent research relating to the Grande Anse Formation, Cumberland Basin, eastern Canada

Fadel Bahr and Dave Keighley

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

The Grande Anse Formation crops out in the Cumberland Basin north of the Minudie Anticline on the Maringouin Peninsula of southeastern New Brunswick, and in northernmost Nova Scotia. Previous biostratigraphic work indicated a temporal equivalence to some part of the Lower Pennsylvanian succession south of the Minudie Anticline in the Athol Syncline and exposed along Joggins Fossil Cliffs. Other work identified the Minudie Anticline to be a salt wall, the formation of which had a major influence on Lower Pennsylvanian sedimentation in the basin. Sedimentological studies identify similarities between facies of the Grande Anse and Ragged Reef formations south of Joggins. Both contain an abundance of red mudstone, of (semi-) humid climate, well-drained floodplain origin, interbedded with red and grey sandstone of braided, east flowing, fluvial origin. Geochemical investigation of coarse clastic deposits in the two units indicates no statistical difference in their elemental compositions. In contrast, underlying units along the Joggins coast (Little River, Joggins, and Springhill Mines formations) have visibly different facies, and many statistically significant differences in composition. The resulting working hypothesis is that salt tectonics produced oblique-to-the-north evacuation of Windsor Group (Mississippian) evaporites. This created the space that accommodated the thick succession of strata (Little River, Joggins, and Springhill Mines formations) in the developing Athol Syncline. Contemporaneously, to the north of the salt wall there was no net deposition, but uplift and folding of post-Windsor Group strata. As salt tectonism waned, any extrusive salt was then buried under strata of the Grande Anse and Ragged Reef formations. It remains unclear whether these latter two units formed contemporaneously and in disconformity to angular unconformity on older units (in which case the Ragged Reef Formation could be considered the junior synonym of the Grande Anse Formation), or whether deposition of the Ragged Reef Formation gradually onlapped both the salt wall and the folded strata further north. In the latter case, only the Spicers Cove Member of the Ragged Reef Formation might be directly equivalent, and reassignable, to the Grande Anse Formation. Petrographic studies of the Grande Anse Formation indicate that lithification was dominated by eodiagenetic processes. Several mineral phases are typical of shallow subsurface changes that would be expected in the (semi-) humid environment indicated by the sedimentology and geochemistry. However, other very distinct phases might be considered indicative of arid, evaporitic conditions; but for our understanding of the recently buried salt-wall that was likely influencing shallow groundwater chemistry.

Potential for post-glacial submarine landslides on Orphan Spur, offshore northeastern Newfoundland, Canada

Laura Broom, Vladimir Kostylev, Alexandre Normandeau, and Gordon Cameron

Geological Survey of Canada, Dartmouth, Nova Scotia B2Y 4A2, Canada <laura.broom@NRCan-RNCan.gc.ca>

Orphan Spur is a large sediment drift deposit located offshore northeastern Newfoundland. It is part of the Northeast Newfoundland Slope Closure which is closed to ground fishing to protect cold-water corals and sponges; however, it is also a region of potential hydrocarbon exploration. With competing interests involving the seabed, it is critical to assess the potential geohazards of this region. Previous studies based on limited hydroacoustic data have suggested that there are few post-glacial landslides in the area. Newly acquired hydroacoustic data including multibeam bathymetry and 3.5 kHz sub-bottom profiles reveal previously unidentified submarine landslides in the region. Some of the submarine landslides closer to the continental shelf appear relatively "fresh" in multibeam bathymetric data and the escarpments surrounding the failures appear sharp. No younger sediment cover has been resolved overlying these failures by the acoustic data. Piston and box cores were collected on the submarine landslide deposits in an attempt to constrain their timing. Preliminary results from radiocarbon dates suggest that some of the shallow submarine landslides were triggered during the Holocene. In addition, the headscarps of some of the largest failures appear to have been reactivated, probably locally, during post-glacial times. The submarine landslide hazard for Orphan Spur could therefore be underestimated and further examination into the timing of these deposits is underway.

Detection of buried rare metal mineralization in a glaciated landscape at Brazil Lake, southwestern Nova Scotia, Canada

Denise M. Brushett[1], M. Beth McClenaghan[2], and Roger C. Paulen[2]

1. Nova Scotia Geological Survey, Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada <denise.brushett@novascotia.ca>; 2. Geological Survey of Canada, Natural Resources Canada, Ottawa, Ontario K1A 0E8, Canada

The variable nature and thickness of glacial sediments affect the characteristics of mineralized dispersal trains in the Brazil Lake Li-Cs-Ta- (LCT) pegmatite district of southwestern Nova Scotia, an area currently being explored for its critical and rare-metal potential. The areal extent of the pegmatites at Brazil Lake are not well known because of their small size (less than 20 m wide), and extensive till cover that limits outcrop exposure. In southwestern Nova Scotia, glacial sediments blanket the region deposited over multiple glaciations throughout the Pleistocene. Thick sequences of glacial sediments coupled with multiple glacial flow trajectories have made bedrock mapping and exploration for buried mineralization in the region challenging.

A multi-year surficial mapping and till-sampling program was initiated by the Nova Scotia Geological Survey in 2019 employing till geochemistry and indicator minerals, aided by recently released LiDAR (Laser imaging, Detection, and Ranging) elevation data, and sediment thickness modelling. The goals of these activities are to: (1) better understand the effects of multiple glaciations on till provenance, depositional history, and net glacial dispersal in the region; (2) to assess the potential for additional rare- and base-metal mineralization; and (3) to document the geometry of glacial dispersion trains using till geochemistry and indicator minerals. The ultimate objective is to increase exploration success by providing advanced exploration models that can be applied to not only the Brazil Lake study area, but other regions of the province draped by thick Quaternary cover. This presentation will include an overview of these methods applied to surficial geological research in southwestern Nova Scotia, as well as preliminary results to date.

Multiple pyrite generations in mineralization of the Elmtree Gold Deposit, northeastern New Brunswick, Canada

Aaron L. Bustard[1,2], David R. Lentz[2], and James A. Walker[1]

1. Geological Surveys Branch, New Brunswick Department of Natural Resources and Energy Development, South Tetagouche, New Brunswick E2A 7B8, Canada <aaron.bustard@gnb.ca>; 2. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada

Northern New Brunswick hosts several shear zone-hosted gold occurrences associated with regional-scale faults and tectonism during the Salinic and Acadian orogens. Of these, the Elmtree deposit is the largest with a current resource estimate of 300 000 ounces of gold and subordinate polymetallic (Ag, Zn, Pb, and Sb) sulfide mineralization. The deposit straddles a locally sheared angular unconformity

separating an accretionary wedge complex (Elmtree Inlier) from unconformably overlying syn-orogenic sedimentary clastic and subordinate carbonate rocks of the Quinn Point Group.

Gold is hosted in three zones: the West Gabbro, South Gold, and Discovery zones. The West Gabbro Zone is the largest with mineralization occurring in a gabbro to anorthosite dyke/sill hosted by argillite of the Elmtree Formation, within the Belledune River Mélange. Mineralization at the South Gold Zone occurs within unconformably overlying Silurian conglomerate, calcareous siltstone/sandstone, and minor volcaniclastic rocks within approximately 40 m of the unconformity. The Discovery Zone is situated along the sheared unconformity and is host to both gold and the bulk of the later, cross-cutting, polymetallic mineralization.

Gold is primarily refractory in arsenopyrite precipitated during the sulfidation of iron-bearing phases including ilmenite, titanomagnetite, and Fe-silicates. Prismatic to acicular arsenopyrite occurs as the earliest ore phase sulfide and is later coeval with pyrrhotite in gabbro hosted mineralization (West Gabbro Zone) and pyrite in anorthositic gabbro, mafic dyke, and sedimentary rock hosted mineralization (West Gabbro, South Gold, and Discovery zones). Pyrite can be divided into at least four phases based on morphology: (1) a pre-ore phase; (2) early, spongy, euhedral cores that locally overgrow pre-ore pyrite; (3) inclusion-free overgrowths of earlier phases; and (4) inclusion-rich overgrowths or individual anhedral grains. Compositional variation occurs in pyrite precipitated over multiple stages in both backscatter electron imaging and micro-XRF compositional maps, where pyrite is enriched in arsenic relative to other phases. Pyrite is locally partially to completely desulfidized to pyrrhotite in portions of the deposit, and this desulfidation is sometimes associated with decorations of Ni-Sb alloys, gersdorffite, ullmannite, cobaltite, galena, chalcopyrite, and rare electrum. Electrum occurs as free grains; inclusions in arsenopyrite, pyrrhotite, and pyrite; and along grain boundaries.

Trace element mapping of pyrite using laser ablation inductively coupled plasma-mass spectrometry is ongoing to further characterize sulfide generations, and results will be integrated with geochronological and isotopic analyses to refine the petrogenesis of the Elmtree deposit and identify potential sources of mineralization.

Critical metals in the Cobequid Highlands, Nova Scotia, Canada: resolving the host rock, mineralogy, paragenesis, and controls of cobalt mineralization of the Bass River magnetite prospect

Aidan Buyers[1], Erin Adlakha[1], John Shurko[2], and Mark Graves[3]

1. Saint Mary's University Halifax, Nova Scotia B3H 3C3, Canada <aidan.buyers97@gmail.com>;
2. Spark Minerals Inc., Chester, Nova Scotia B0J 1J0, Canada;
3. Independent Consultant, Halifax, Nova Scotia, Canada

The Cobequid Highlands have a long and productive history as a region with a great endowment of mineral deposits hosting many commodities (e.g., Fe, Ba, Cu, Co, Ni, and Au). In the past 15 years, there has been a concerted effort to investigate Nova Scotia's IOCG (iron oxide copper gold) prospects along the Minas Fault Zone (MFZ), more recently focusing on critical metals like Co. The focus of this study is to use detailed petrography, micro-X-ray fluorescence (XRF) mapping, and scanning electron microscope (SEM) techniques on mineralized drill-core of the Bass River IOCG Prospect to determine the host rock, mineralogy, paragenesis, and mineralogical controls of critical metals.

Previous work done on the Bass River magnetite prospect include a regional gravity survey, a versatile time domain electromagnetic (VTEM) survey, an induced polarization (IP) survey, soil, till, and stream sediment sampling, prospecting, and mapping as well as several diamond drill programs. Most recent drilling by Spark Minerals in 2021 shows that the Bass River prospect is a magnetite breccia with clasts of feldspar-phyric to aphanitic mafic and felsic volcanic rocks, and massive to laminated, fine-grained, dark grey-black sedimentary rocks. The clasts in places show replacement by magnetite. The matrix is dominantly massive magnetite with fine- to coarse-grained, blebby to euhedral pyrite. The degree and coarseness of pyrite mineralization increases downhole. The matrix and clasts are crosscut by late carbonate veins, which are often vuggy close to the top of hole. Chalcopyrite stringers were also observed associated with vuggy carbonate. Representative mineralized samples are currently being analyzed using micro-XRF to map elemental distribution, including critical metals. Targeted samples will then be analyzed using classical petrographic techniques and SEM.

The acceptance and growth of the concept of geoheritage in Atlantic Canada and beyond

John Calder[1], Rob Fensome[2], Jason Loxton[3], Jeff Poole[4], and Matthew Stimson[5]

1. John Calder Earthworks, P.O. Box 43, Halifax Central, Halifax, Nova Scotia B3J 2L4, Canada <johncalder99@gmail.com>;
2. Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia B2Y 4A2, Canada;
3. Cape Breton University, Sydney, Nova Scotia B1P 6L2, Canada;
4. Nova Scotia Department of Natural Resources and Renewables,

Halifax, Nova Scotia B3J 2T9, Canada;
5. Natural History Department, New Brunswick Museum, Saint John New Brunswick E2K 1E5, Canada

The concept of geoheritage, born at the 1991 meeting of ProGeo in Digne, France, was captured eloquently in the *Declaration of the Rights of the Memory of the Earth*. Geoheritage has grown in the past decade from a concept whose worth was questioned and even derided by some established geoscientists to one fully embraced at the highest levels of the geoscientific community, including at the Geological Society, GSA, USGS, IUGS, IGCP, and even the IUCN, which is traditionally biologically and ecologically focused. The idea of geoheritage is very much rooted in inviting the public to consider the incredible story of our planet as recorded in the geologic record: in other words, to build an appreciation for geology and Earth history. It is public facing, and at its core is bringing to public attention, sites (geosites, geoheritage sites) where the Earth's history is well told. The construction of Geoheritage site lists will always be a source of contention but is fundamental to pointing the public (as well as geologists) to places where they can learn or simply marvel at the Earth's remarkable processes and history. Although perhaps unintentional, the list of sites featured on the Nova Scotia Geological Highway Map provided a starting point for Nova Scotia's Geoheritage Sites List, the first such list in Canada. Currently, international standards for recognition of global geosites are being developed under IGCP Project 731 and select geosites in Atlantic Canada will be considered as examples. Geosites are key to defining Global Geoparks, a growing designation now recognized at 169 regions in 45 countries, and a leading factor in geotourism.

In parallel to the concept of geoheritage is the concept of geodiversity, a concept and term consciously positioned to challenge non-geologists to consider how geology underpins Earth systems and gives rise to biodiversity. This year will see recognition of the first International Day of Geodiversity, endorsed by the United Nations. The first International Day for Geodiversity in October presents an opportunity for the Atlantic Geoscience Society to shine a spotlight on the rich geoheritage of Atlantic Canada and the concentration here of UNESCO World Heritage Sites and Global Geoparks, a legacy of our plate tectonic history and exceptional coastal exposures.

Using fluoride analysis in till to assist in identifying the bedrock potential for critical minerals in central Newfoundland, Canada

Heather Campbell[1], Steve Amor[2], Zsuzsanna Magyarosi[1], Chris Finch[1], and Rosauro Roldan[1]

1. Geological Survey of Newfoundland and Labrador, St. John's, Newfoundland and Labrador A1B 4J6, Canada <heathercampbell@gov.nl.ca>;
2. Geological Consultant, St. John's, Newfoundland and Labrador A1A 3C5, Canada

Fluoride analysis has successfully located previously unrecognized mineralization associated with Li-Cs-Ta (LCT) pegmatites in sandy, bouldery, variably eroded, and dispersed till overlying granites and metasedimentary rocks in the Snowshoe Pond region of the Meelpaeg Subzone in central Newfoundland. Fluoride, measured by Ion Selective Electrode (ISE), is a component of the analytical suite for till-geochemical samples in the province of Newfoundland and Labrador. In central Newfoundland, fluoride in till is thought to be derived from apatite that typically occurs in LCT pegmatites (up to 5%). Fluoride anomalies in till samples are more effective in defining the extent and locale of the underlying pegmatites than other geochemical indicators associated with mineralization (e.g., Cs, Li, Nb), as the fluorine-bearing apatites are; (1) relatively abundant in the source rocks, and (2) sufficiently resistant to reside in dispersed and eroded tills. Based on this study, the use of fluoride analysis in till is highly recommended in other areas with potential for rare element mineralization. More studies are being conducted to assess the potential of fluoride in till in exploring for other types of deposits, such as rare earth elements (REE) that are also typically associated with F-rich rocks.

Petrology, geochemistry, and geochronology of aplite dykes in the Cape Spencer area, southern New Brunswick, Canada

Alan Cardenas[1], David R. Lentz[1], Chris R.M. McFarlane[1], and Kathleen G. Thorne[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <alan.cardenas@unb.ca>;
2. Geological Surveys Branch, New Brunswick Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada

The Cape Spencer area is located 15 km southeast of Saint John, New Brunswick. Gold mineralization has been identified mainly in illitized (illite-carbonate ± quartz ± pyrite ± chlorite ± specularite), pyrite-rich rocks of the Millican Lake Granite and the Cape Spencer Formation, along thrust faults and folds, and in quartz ± carbonate veins with sulphides (pyrite ± chalcopyrite ± galena ± arsenopyrite). Other units of Carboniferous age present in the area are the Balls Lake and the Lancaster formations. A penetrative S1 cleavage is seen in all the lithologies, and a second, spaced crenulation cleavage can be observed in the finest sedimentary units. Previous $^{40}Ar/^{39}Ar$ geochronology (276.6 ± 0.9 and 283.7 ± 0.8 Ma) on illites defining these fabrics and related to the alteration event linked to gold deposition were considered "cooling ages" and constrained the timing of gold mineralization between those ages and the age of the youngest rocks affected by the illitic alteration (Lancaster Formation - Bashkirian).

Leucocratic non-foliated aplitic dykes are comprised of quartz, orthoclase, and plagioclase (An_{10-20}), and minor secondary epidote, specularite, and pyrite, intrude both the Millican Lake Granite and the Cape Spencer Formation. These bodies, varying mainly from 10–50 cm to several metres thick, occur both parallel and crosscutting the foliation in the host rocks, and exhibit a secondary earthy hematization that results in a pink colouration. Whole rock major- and trace-element lithogeochemistry together with U–Pb geochronology (zircon) were employed to evaluate the petrogenesis of these aplitic bodies to build on the understanding of the mineralizing system and the geological evolution of the region.

The aplitic dykes are metaluminous (A/CNK = 0.74–0.92) with SiO_2 content varying between 58.9 and 79.2 wt% and can be subdivided according to their Nb/Ta and Zr/Hf ratios into two groups. The first group has higher Nb/Ta (10.87–11.47) and Zr/Hf (43.8–44.6) ratios than the second group (Nb/Ta = 1.77–10, Zr/Hf = 22.1–30). Low Nb, Ta, Y, Yb, and Rb indicate an I-type affinity. The presence of microfracturing and textural setting (i.e., zircon sitting along grain boundaries vs. included in phenocryst phases), in addition to critical radiation damage threshold in zircon makes geochronological analysis complicated. Preliminary U–Pb zircon ages define two clusters around 275 and 350 Ma. The 350 Ma cluster is considered to be the crystallization age, whereas the 275 Ma cluster is related to hydrothermal alteration and complete resetting of the most heavily radiation-damaged grains.

Lithogeochemical and petrological constraints on the environment of deposition of the Nicola Group volcano-sedimentary rocks about the Copper Mountain alkalic Cu-Au porphyry deposit, Princeton, British Columbia, Canada

Nathan Carter[1], Cliff Stanley[1], and Peter Holbek[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <14282c@acadiau.ca>;

2. Copper Mountain Mining Corporation, Vancouver, British Columbia V6C 1G8, Canada

The upper Triassic Nicola Group is an economically important succession of volcano-sedimentary rocks that host the Copper Mountain alkalic Cu-Au porphyry deposit. All known mineralization at Copper Mountain appears to be associated with Lost Horse intrusive dykes and stocks of diorite to monzonite composition, and these intruded rocks of the Wolf Creek Formation within a 1000 by 4300 m NE-SW trending belt bounded on the south by the Copper Mountain Stock and on the north by the Smelter Lake and Voigt stocks. Discovery of additional copper resources in the camp will likely rely on a better understanding of the stratigraphy of the Wolf Creek Formation, and the environment it was deposited in. Consequently, mapping of Nicola Group rocks south and east of the Copper Mountain Stock and west of the Smelter Lake stock was undertaken, revealing the presence of flows, breccias, volcaniclastic sedimentary rocks, and dykes. One hundred and thirteen flow and volcaniclastic sedimentary rock samples were analyzed lithogeochemically and evaluated using molar element ratio analysis. Fifty-four of these samples were cut into thin sections for petrographic examination.

Wolf Creek Formation rocks from west of the Smelter Lake Stock appear to be less green and less altered than those elsewhere in the camp, containing measurably less chlorite and epidote, more calcite (in amygdales), and hosting exotic clasts of limestone. This suggests that these rocks were deposited in a subaerial environment. In contrast, Wolf Creek Formation rocks from south and east of the Copper Mountain Stock are demonstrably greener, more altered to chlorite and epidote, and interbedded with volcaniclastic siltstones and sandstones. They were likely deposited sub-aqueously.

Molar element ratio analysis indicates that Wolf Creek Formation rocks have a primary composition consistent with the presence of plagioclase, clinopyroxene, and biotite, a conclusion consistent with petrographic observations. In contrast, compositional variability was controlled only by plagioclase and clinopyroxene sorting. These rocks have also been variably altered to a likely low temperature assemblage of chlorite, epidote, albite, and calcite, and molar element ratio constraints suggest that this alteration was largely isochemical, with the exception of water and CO_2. Consequently, mapped rocks were likely subjected to only seafloor alteration, as they do not exhibit evidence of higher temperature potassic and albitic alteration and metasomatism associated with Cu mineralization elsewhere in the camp.

Trace element geochemistry of biotite from the Scrag Lake and New Ross plutons of the South Mountain Batholith, Nova Scotia, Canada: implications for magma differentiation

Kathleen Clark and James Brenan

Department of Earth and Environmental Science, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <kt747032@dal.ca>

The South Mountain Batholith (SMB) is a 7300 km^2, peraluminous, felsic intrusion that occurs in southwestern Nova Scotia and consists of 13 plutons that were emplaced in two different phases between ~385 and ~368 Ma. Previous research revealed that samples from phase 2 plutons show significant trace element variability in biotite compared to phase 1 plutons. Since phase 2 plutons tend to be more geochemically evolved, it is not clear if this difference arises due to sampling bias or is an intrinsic property of the second stage of batholith emplacement. Therefore, the goal of this work is to better characterize biotite compositions across a broad compositional range of representative phase 1 and phase 2 plutons. This work focuses on samples from the phase 1 Scrag Lake pluton (SGP) and the phase 2 New Ross pluton (NRP). An electron microprobe and laser ablation ICP-MS have been used to collect major and trace element data on biotite from a suite of 5 samples from each pluton covering a compositional range of ~68 to ~75 wt% SiO_2. In addition to spot analyses, major and trace element maps have been obtained from select biotite crystals to assess internal zonation. Although data for 34 trace elements were obtained, the current focus is on the critical metals Nb, Ta, Sn, and W. Preliminary results show continuous zoning in trace elements from core to rim in biotite grains in both pluton phases. The concentrations of Nb, Ta, Sn, and W all increase from core to rim, while the Nb/Ta ratio decreases from core to rim, which is expected with the crystallization of the assemblage biotite-quartz-plagioclase-k-feldspar. For similarly-sized grains and similar whole-rock wt% SiO_2, phase 1 samples show within grain variation from 10–100s mg/g, while variation within phase 2 biotites is 10–1000s mg/g. This indicates that the more extreme extent of trace element variation is an intrinsic property of stage 2 plutons. As both phase 1 and phase 2 samples show similar trace element concentrations in the cores of the biotite grains, the difference in variability is due to more extreme extents of crystallization, and not due to differences in starting compositions. This extreme crystallization could be due to the addition of a flux that lowers the solidus (B, Li). The data shows that Li concentrations are higher in phase 2 biotites, and B will be measured to investigate this potential explanation further.

The first description of vertebrate and invertebrate ichnofossils in the Stellarton Basin (Westphalian C), Nova Scotia, Canada*

Logan M. Cormier[1], Matthew R. Stimson[1,2], Olivia A. King[1,2], John H. Calder[1], Janey MacLean[3], Lorenzo Marchetti[4], Spencer G. Lucas[5], and R. Andrew McRae[1]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <logan.cormier@smu.ca>; 2. Steinhammer Paleontological Laboratories, Geology/ Paleontology section, Natural History Department, New Brunswick Museum, Saint John New Brunswick E2K 1E5, Canada; 3. 4621 Trafalgar Road, Hopewell, Nova Scotia B0K 1C0, Canada; 4. Museum für Naturkunde Berlin, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, Germany; 5. New Mexico Museum of Natural History, Albuquerque, New Mexico 87104, USA

Newly discovered tetrapod and invertebrate ichnofossils from the Pennsylvanian (Westphalian C) Stellarton Formation represent the first ichnofossil assemblage to be described in the Stellarton Basin of Nova Scotia. The Stellarton Basin is well known for its economic deposits of coal, yet apart from paleobotanical records and the exceptional discovery by Sir William Dawson of the tetrapod *Baphetes*, little paleontological work has been formally documented in the literature prior to this study. This is the first discovery of tetrapod traces from the Stellarton Formation. The tetrapod trackway-bearing Plymouth Member is exposed in an aggregate quarry near the town of Stellarton. The Plymouth Member is composed of fluvial sandstones and is interpreted to conformably overlie the lacustrine deposits of the Westville Member that crop out just east of the quarry along the East River of Pictou. The well-preserved, plantigrade tetrapod tracks within the Plymouth Member are identified as *Batrachichnus salamandroides* and *Matthewichnus* cf. *M. velox*, ichnotaxa that are often attributed to temnospondyl or microsaurian trackmakers. Of greater abundance and diversity is the invertebrate trace fossil assemblage of the Westville Member, which consists of *Cruziana* isp., *Monomorphichnus* isp., *Lockeia* isp. and various morphologies of *Rusophycus* tentatively assigned to various ichnospecies. They have been attributed to freshwater crustacean and molluscan tracemakers. In addition, a previously undescribed cubichnia morphotype shows morphologic features that may justify the erection of a possible new ichnogenus and is interpreted to have been produced by an isopod-like invertebrate. The marginal lacustrine depositional setting at this site encompasses a diverse invertebrate ichnoassemblage within the *Mermia*

Ichnofacies and a low diversity tetrapod ichnoassemblage of the *Batrachichnus* Ichnofacies.

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

Geothermal potential of New Brunswick, Canada: "Salt Chimneys"

Joseph de Luca and Dave Keighley

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

Geothermal energy provides a clean source of reliable electricity that may help provide energy security and reduce CO_2 emissions. The economical application of geothermal electricity requires sufficiently elevated subsurface thermal gradients to minimize costs associated with industrial development and production. Consequently, global focus for geothermal energy has traditionally been on areas with active tectonism and volcanism, where geothermal gradients easily meet conditions for cost-effective power stations. More recently, attention has been given to evaluating the potential for sedimentary basin geothermal production in strategic areas. While New Brunswick has not historically been such an area for inquiry, subsurface thermal-gradient contour maps have recently been updated for the southeastern half of the province. Updated maps show that New Brunswick has mostly low-potential geothermal gradients of around 20°C/km, but revealed areas of anomalously high gradients, relative to the provincial background, primarily associated with known subsurface Mississippian (Carboniferous) evaporites of the Gautreau Formation and the Windsor Group. Where geothermal gradients appear more prospective, exceeding 30°C/km, their values are being further assessed for their validity. The stratigraphy of 12 boreholes were divided into sections based on the dominant lithologies of lithostratigraphic units. Among the 12 boreholes, four terminate in the Windsor Group, one terminates below the Windsor Group, one cuts through a section of the Gautreau Formation but does not encounter the Windsor Group, and the remaining six have no direct contact with evaporitic bodies in the subsurface. Heat flow (q) was calculated using the equation

$$q = \frac{\Delta T \times k \times A}{L}$$

where ΔT = temperature difference between the top and bottom of a stratigraphic column or unit, A = cross-sectional area of a unit, and L = unit thickness. Thermal conductivity (k) of the units was experimentally determined in earlier work from rock samples of different lithologies, which had been taken from drill cores around the region. Preliminary calculations suggest that, in most cases where the Windsor Group is present, temperatures at the top of Windsor Group halite show the greatest positive separation from expected temperatures versus other contact points in the column. Elsewhere, this has been termed the "salt chimney effect" because of the inherently high thermal conductivity of halite, which when present in the subsurface brings higher temperatures closer to the surface.

Integrative geophysical analysis and characterization of prospective hydrocarbon seepage sites on the southwestern to central Scotian Slope, Canada

John Dooma[1], Natasha Morrison[2], Adam Macdonald[2], and G. T. Ventura[1]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <John.Mishael.Dooma@smu.ca>; 2. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 3P7, Canada

Nova Scotia has potential for undiscovered hydrocarbon reservoirs in the deep-water portion of the Scotian Margin. However, exploration in these environments involves major challenges and geological risks. As the presence, quality, size, and distribution of source and reservoir rocks are relatively still unknown, the cost of exploration and the risk multiplies. Therefore, new data are needed to de-risk offshore exploration to achieve the next generation of discoveries. This research project investigates the shallow depth (0 to 3000 m) of BP's 3-D Tangier seismic survey to better constrain the subsurface geology in regions where prospective hydrocarbon seep sites have been found. The 3-D Tangier seismic survey marks one of the most geologically complex regions of the slope and its shallow stratigraphy has not yet been fully understood. Seven key seismic horizons were interpreted and subsequent seismic attribute analysis using root-mean square (RMS) and coherence was completed, resulting in several depth structure and geophysical maps. Initial interpretation of these results indicates the region hosts a complex subsurface geology comprised of well-stratified sediments from draping and hemipelagic deposition incised by paleo-channels and mass transport complexes that are associated with localized slope failure. In some parts of the survey, these subsurface features are incised by deep submarine canyons. Direct hydrocarbon indicators (DHIs), which are anomalous amplitudes that mark potential sites of hydrocarbon migration and accumulation are identified in the seismic interpretation and further resolved with the RMS attribute extraction. Thus far, most identified DHIs lie within a shallow band

of ~2300 to ~2500 m below sea level. These DHIs are commonly located in sediments above salt diapir structures. The presence of shallow DHIs in the survey, combined with geochemical data from coring of potential seeps, suggests they are formed from migrating deeper fluids from either a reservoir or directly from a source interval. For future work, this project will investigate the deeper lithostratigraphic intervals below selected DHIs to locate a potential source and migration pathways of contributing fluids. The results of this study will then be further compared to the Play Fairway Analysis, high-resolution multi-beam bathymetric maps of prospective seeps within the seismic data block, as well as core geochemistry and genomic data to confirm and produce robust interpretation and results.

An experimental study of the effect of pressure on the formation of chromite deposits

Natashia Drage and James Brenan

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

Despite extensive research on the Bushveld Complex chromitites, the mechanism(s) that form such anomalous chromite segregations remains uncertain. Recent work applying the MELTS thermodynamic model proposed that reduction of pressure upon magma ascent shifts the silicate-in temperature to lower values, with the chromite-in temperature remaining unchanged, resulting in chromite-alone crystallization and formation of massive chromitites. Evaluation of this hypothesis is by laboratory phase equilibrium experiments conducted at 0.1 MPa, 0.5 GPa, and 1 GPa, employing two bulk compositions. Composition 1 (C1) corresponds to a widely accepted parental magma of Bushveld chromitites, termed B1. Composition 2 (C2) is the same used in the MELTS modelling study, which contrasts with C1 most significantly in Al_2O_3 (17.4 wt% vs 11.8 wt% in C1), MgO (6.7 wt% vs 11.9 wt% in C1), and Cr (680 µg/g vs 970 µg/g in C1) contents. Experiments were conducted at 0.1 MPa by equilibrating synthetic starting materials on Fe-Ir alloy wire loops over the temperature interval of 1170–1300°C in a vertical-tube, gas-mixing furnace for 12–48 hours, at FMQ and FMQ-0.4. Experiments at 0.5 GPa and 1 GPa were conducted with a piston-cylinder apparatus using Fe-Ir alloy capsules to buffer fO_2 at FMQ-0.4 at 1230°C and 1280°C for 4–12 hours. Results indicate that there is no significant change in Cr content of the melt at chromite saturation with pressure. For C1, the average Cr content of the melt over the pressure interval studied is 439 ± 22 µg/g at 1230°C and 799 ± 100 µg/g at 1280°C. The average Cr content for C2 is 417 ± 17 µg/g at 1230°C and 704 ± 48 µg/g at 1280°C. Results from C1, where pyroxene crystallizes at all pressures, show modal abundance and Cr content of pyroxene increasing with rising pressure. Using pressure and temperature trends for Cr content at chromite saturation and $D_{Cr(px/liq)}$ from experiments, chromite-in temperatures were modelled for different total Cr contents in the melt. Chromite-alone crystallization between 0.1–0.3 GPa occurs in C1 only for above average total Cr levels for this composition (>1100 µg/g). In C2, results predict a higher chromite-in temperature and therefore, larger interval of chromite-alone crystallization at low pressure compared to MELTS. For the same total Cr content as the initial MELTS model, the results show that chromite is dropped from the C2 assemblage above 0.5 GPa due to appearance of pyroxene, which differs from MELTS as Cr is not included in their pyroxene model.

Age, zircon chemistry, and petrogenesis of voluminous extension-related late Ediacaran silicic magmatism in the Coldbrook Group, southern New Brunswick, Canada

Alicia P. Escribano[1], Sandra M. Barr[2], and James L. Crowley[3]

1. Department of Earth Sciences, Memorial University, St. John's, Newfoundland and Labrador A1B 3X5, Canada <adpescribano@mun.ca?;
2. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada;
3. Boise State University, Boise, Idaho 83725-1535, USA

The Coldbrook Group is a unique suite of Late Ediacaran volcanic and epiclastic rocks that together with related plutons was emplaced in the Avalonian Caledonia terrane of southern New Brunswick. The suite is topped by the mainly rhyolitic Silver Hill Formation that has been recognized in five different areas of the Caledonia Highlands, each with distinct petrographic textures: Silver Hill, Coastal Fundy Park, Fundy Park, Vernon Mountain, and Blackall Lake. The coeval felsic Bonnell Brook pluton is represented by a medium- to coarse-grained granite and a fine-grained granitic dome. Whole-rock chemistry, zircon chemistry (LA-ICP-MS), and U–Pb dating (LA-ICP-MS and CA-TIMS) were used to study the relationship between the felsic volcanic and plutonic rocks and to constrain their age and tectonic setting. Transitional felsic I- to A-type chemical signatures in both volcanic and plutonic rocks suggest that magmatism occurred in an extensional within-plate setting, consistent with the tectonic regime at that time throughout Avalonia. Whole-rock chemistry shows that, although coeval, the medium- to coarse-grained granite was emplaced

at a deeper level and is not cogenetic with the fine-grained granite and rhyolite of the Silver Hill Formation. Rhyolite in the Silver Hill area yielded a weighted mean $^{206}Pb/^{238}U$ age of 551.65 ± 0.15 Ma, similar within error to the age of 551.71 ± 0.15 Ma for the fine-grained granite. Furthermore, zircon grains of the Silver Hill rhyolite and fine-grained granite have similar chemical compositions and morphology suggesting rhyolite and granite are comagmatic. However, the main belt of rhyolite in the Coastal Fundy and Fundy Park areas is younger at 549.18 ± 0.07 Ma, consistent with the older age of 551.19 ± 0.20 Ma obtained for an underlying lithic tuff unit. Stratigraphic relationships and petrography suggest that the rhyolite of the Coastal Fundy and Fundy Park areas formed in one event that commenced with pyroclastic flows and progressed to calmer eruptions, represented by rhyolitic lava flows. Younger dates of 540–520 Ma obtained from zircon grains in the same samples by LA-ICPMS indicate that the zircon experienced cryptic alteration and Pb loss and demonstrate the importance of combining LA-ICP-MS dating with CA-TIMS from the same zircon populations.

Ice dynamics and deglacial history of the northeast Newfoundland Ice Sheet

Sef C. Everest, John C. Gosse, Sophie L. Norris, and Arthur S. Dyke

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

The timing and dynamics of deglaciation of the Newfoundland Ice Sheet (NIS) represents a complex and poorly resolved portion of the North American Ice Sheet Complex. Establishing the flow dynamics of the NIS precisely is useful to minimize risk for mineral exploration through drift prospecting on the island, and is important to paleoclimatic, paleoceanographic, and glaciologic research owing to its proximity to the shelf-edge limit of the LIS and the interpreted occurrence of numerous ice streams juxtaposed with cold basal thermal regimes. High-quality surface exposure ages representing onshore ice margin retreat in Newfoundland are also needed for ongoing studies of subglacial erosion rates beneath warm-based and cold-based ice. Existing deglacial chronologies in northeastern Newfoundland are lacking input from onshore dates, and surface exposure dating methods are underutilized across the NIS. As a result, ice extent during the last glacial maximum is poorly constrained in Newfoundland and is the subject of ongoing debate. Marine evidence shows ice extending almost to the continental shelf-edge at the Last Glacial Maximum (LGM) but opposing models have argued for ice only reaching modern shorelines in Newfoundland, based on biological refugia evidence that certain uplands were ice-free. This study helps constrain ice sheet dynamics in central-eastern Newfoundland and contribute to the data gap in a critical region of Newfoundland. Ten new terrestrial cosmogenic nuclide ages were obtained spanning three strategic locations in northeastern Newfoundland. These data combined with previous published geomorphic maps, as well as new interpretations and synthesis provide an updated deglacial model for the region. The summary exposure age of the three sites selected for Be-10 dating are 13.3 ± 0.8 ka near New-Wes-Valley, NL; 12.7 ± 0.8 ka near Gander, NL; and 12.2 ± 1.0 ka near Glovertown, NL (errors are 1σ total external uncertainty). These ages are consistent with calibrated radiocarbon ages in the region. This record of deglaciation and new constraints demonstrate deglaciation at these sites was 1–2 ka later than in previous models, and this study will explore the potential effect of the Younger Dryas stadial on readvance or stagnation of the ice margin. Reconstructions of ice dynamics will also refine existing estimates of the location of ice divides in the northeast NIS.

Reaction rims on ilmenite macrocrysts from kimberlite as a proxy of kimberlite emplacement process

Lydia Fairhurst[1], Yana Fedortchouk[1], Ingrid Chinn[2], and Philippe Normandeau[3]

1. Department of Earth and Environmental Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <lydiafairhurst@dal.ca>;
2. DeBeers Group, Johannesburg, Gauteng, South Africa;
3. Northwest Territories Geological Survey, Northwest Territories, Canada

Kimberlites are mantle-derived magmas often emplaced in the upper crust as pipe-shaped structures. Large multi-phase bodies of class 1 consist of coherent kimberlite (CK) and different pyroclastic facies, including diatreme Kimberley-type pyroclastic kimberlite (KPK). The composition, crystallization conditions and emplacement processes of these kimberlites are poorly understood, especially the formation of KPK. CK facies include hypabyssal kimberlite (HK) and ambiguous partially fragmented CK. Ilmenite macrocrysts from some Orapa kimberlites show reaction rims developed due to a reaction with the kimberlite magma. The composition of these rims correlates with kimberlite facies and may provide information about their crystallization conditions. The goal of this study is to use the reaction products on ilmenite from different kimberlite facies in order to examine variation in crystallization temperature (T), oxygen fugacity (fO_2), and

silica activity (αSiO_2) during the emplacement of large kimberlite pipes. fO_2 is also important for assessment of diamond preservation in kimberlites as more oxidized conditions promote diamond resorption.

This study used thin sections from known depth intervals in drillholes from the AK15 and BK1 kimberlites from the Orapa kimberlite cluster (Botswana). The AK15 intrusion consists of a single phase of CK facies. The BK1 pipe consists of two CK facies (CK-A and CK-B) and one KPK facies. CK-B is a HK and CK-A shows areas of partial fragmentation. Secondary phases in ilmenite reaction rims were identified with SEM. The composition of perovskite, ilmenite, and magnetite was obtained from EMP analyses and used for T and fO_2 calculation. The ilmenite macrocrysts are unstable and develop magnetite-perovskite symplectite aggregate in the magmatic CK-B facies. Ilmenite macrocrysts are well-preserved in in CK-A and KPK and develop rims composed of magnetite and rutile in CK-A and highly variable mineralogy distinguished by the presence of titanite in KPK. In AK15, ilmenite macrocrysts have magnetite and perovskite rims. Perovskite crystallization conditions are estimated to vary from DNNO -5.74 to -1.30 and 560–700°C based on the ferric iron content in perovskite. Magnetite crystallization conditions are estimated to vary between ΔNNO -1.6 to 0.5 and 850–1200°C based on Fe-Ti exchange in magnetite and ilmenite. fO_2 estimates vary between facies with magmatic CK-B showing the narrowest range and a slight oxidation towards the surface, and KPK showing the largest range and no correlation with depth. In KPK, an increase in αSiO_2 is evidenced through the development of titanite ($CaTiSiO_5$) while perovskite ($CaTiO_3$) becomes unstable.

3D modelling of the Key Anacon Titan deposit near Bathurst, New Brunswick, Canada using ELF-EM data and open-source inversion software

Alex Furlan

Department of Earth Sciences, Brock University, St Catharines, Ontario L2S 3A1, Canada <afurlan@brocku.ca>

The Key Anacon Titan deposit is a Bathurst-type volcanogenic massive sulfide (VMS) hosted in the same stratigraphic horizon as the well-known Brunswick No. 12 mine. The current mineral resource reported by AGP Mining Consultants Inc. indicates 0.3 million tonnes of material with ~4.4% Zn, ~1.6% Pb, ~0.7% Cu, and ~39 g/t Ag. Exploration and development of the Key Anacon deposit were stunted by falling zinc prices in the 1950s and 1960s and since then, only two major exploration programs have occurred. While Osisko waits for the deposit to become economically viable (zinc was recently listed as a critical mineral by the USGS), it provides a great location to test new exploration methods. In 2012, the Extremely Low Frequency (ELF) EM survey system was developed as a ground-based version of Z-axis Tipper Electromagnetics (ZTEM). By measuring in the 1–1440 Hz frequency range, the ELF-EM system can see ~2 km into the ground depending on subsurface conductivity. This system makes use of a transfer function which relate the horizontal and vertical magnetic field components to subsurface conductivity changes. The resulting data are known as tippers (T_{zx} and T_{zy}), dimensionless ratios which get their name by 'tipping' the magnetic field vector away from horizontal in response to 3D conductivity variations. In 2019, an ELF survey was collected over the Key Anacon Titan deposit to test the systems ability to resolve conductivity changes in the subsurface. The data collected agreed with previous findings but at the time of the survey, 3D modelling ELF-EM data was an arduous task. Recent developments in SimPEG (Simulation and Parameter Estimation in Geophysics), an open-source Python package, provides tools for users to create their own inversion workflow. This package was used to write a new 3D ELF inversion script that could run on modern hardware without the need to license any software. The Key Anacon ELF survey was a perfect test candidate due to its small footprint allowing it to be run quickly and repeatedly with tweaks in parameters. The inversion models produced by ELF tipper data are conformable to 3D geological wireframe models independently derived from other geophysical surveys as well as borehole logs. With this recent improvement to 3D modelling, the ELF-EM system shows great potential to be a reconnaissance tool for deep conductive structures in both greenfield and brownfield exploration projects.

Composition of mafic minerals from intrusive rocks near the Teahan Mine, Caledonia Highlands, southern New Brunswick, Canada: implications for mineralization and conditions of magma solidification

Ayalew Gebru

New Brunswick Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada <Ayalew.gebru@gnb.ca>

Using Electron Probe Microanalysis, the composition of biotite was determined for the Teahan area granitoids (Pollett River Granodiorite and Rat Tail Brook Granodiorite) along with amphibole and chlorite compositions of the nearby Pollett River Gabbro/Gabbroic Diorite, Caledonia Road Diorite/Gabbroic Diorite, Kent Hills Granodiorite, Forty Five River Granodiorite, Teahan Mine Granodiorite,

and a "younger" sheared gabbro. On the Al^{iv} vs Mg/(Mg + Fe) and Fe/(Fe + Mg) compositional fields, the biotite grains both from the Pollett River and Rat Tail Brook granodiorites plot within the biotite field, near the biotite-phlogopite field boundary close to the Annite–Phlogopite binary. Relatively high TiO_2, MnO, MgO, CaO, K_2O, BaO, F, and Cl, and low Na_2O, Al_2O_3, and H_2O contents distinguish the biotite of the Pollett River Granodiorite from that of the Rat Tail Brook Granodiorite. The X_{phl} versus $\log(X_F/X_{Cl})$ compositions of biotite from these granitoids indicate an I-type magmatic composition, whereas on the $\log(X_F/X_{OH})$ versus $\log(X_{Mg}/X_{Fe})$ discrimination diagram, the biotite compositions indicated a weakly contaminated I-type granitoid source composition. The Mg versus Al binary plot (apfu) demonstrates the peraluminous affinity of the Rat Tail Brook Granodiorite, and the calc-alkaline nature of the Pollett River Granodiorite. The FeO_t–MgO–Al_2O_3 composition of biotite from the Pollett River Granodiorite also supports the calc-alkaline nature of the source magma, whereas the source for the Rat Tail Brook Granodiorite plots close to the calc-alkaline-peraluminous granite boundary.

The IV (F/Cl) versus IV(F) data distribution of biotite from the granitoids is transitional between the porphyry copper and W-(Cu-Au-Bi) magmatic systems. They have higher IV(F) values relative to porphyry Mo and Sn-W-Be mineralizing systems. From additional petrological information (i.e., ore element ratios such as Mo/Cu, Rb/Sr, Cu/Mo, Cu/Sn), the Pollett River Granodiorite is the most favourable for potential porphyry copper and W-(Cu-Au) skarn mineralization, provided there is a favorable host lithology in the latter case.

The temperature of biotite crystallization was determined using the Ti-in-biotite thermometry; the Pollett River Granodiorite yielded a temperature of 600–720°C, whereas the Rat Tail Brook Granodiorite yielded 500°C with the latter temperature possibly being a result of re-equilibration. The apfu composition of amphiboles from the Pollett River gabbroic diorite correspond to titanian and ferrian tschermakitic hornblende, ferrian-tschermakite, ferri-titanian-tschermakitic hornblende, and magnesio-hornblende composition. Pressures of equilibration of the titanian, ferrian tschermakite and the titanian and ferrian tschermakitic hornblende group of minerals range from 4.8 to 6.5 kb, from the mean of various barometric determinations. Magnesio-hornblende equilibrated from 2.4 to 3.1 kb. Amphiboles from the Caledonia Road gabbroic diorite are ferri-magnesio-hornblende to ferrian-magnesio-hornblende in composition and equilibrated at pressures around 2 kb.

The chlorite in the Kent Hills Granodiorite is of brunsvigite composition, whereas the Pollett River Diorite/Gabbroic Diorite and the Caledonia Road gabbroic diorite have pycnochlorite compositions. The Forty Five River Granodiorite, the Teahan Mine Granodiorite and a highly sheared gabbroic diorite intruding the Teahan Formation west of the Kent Hills contain chlorite of ripidolite composition.

Using pXRF to differentiate igneous rocks in the Bermuda volcanic basement

Wednesday Gillespie, Emma Stainsforth, Alex Hancock, and Lexie Arnott

Department of Earth and Environmental Science, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <Wednesday.Gillespie@dal.ca>

The island of Bermuda is unique because its geology is inconsistent with established theories on the formation of volcanic seamounts. Research into the formation of the Bermuda rise began in the early 20th century with the emergence of the theory of plate tectonics. The 1972 Deep Drill core is 802 m with almost all of it intersecting the igneous basement. Since then, little has been done to geochemically analyze the samples, which were visually classified on site as containing alternating ultramafic intrusions and mafic lavas. In this study, a portable X-ray fluorescence (pXRF) spectrometer was used to geochemically analyze samples from the drill core. The samples showed that there is a significant variation in the SiO_2 content between sheets and lavas, with intrusions having a mean of 41.8% and lavas having a mean of 52.0%. Based on the project results, using pXRF to measure the SiO_2, TiO_2, and P_2O_5 found in rock samples of the Bermuda rise is a valid technique for efficiently differentiating between intrusions and lavas in the field. However, further analysis is needed to quantify this. Traditional X-ray fluorescence analysis should be conducted to confirm the major element geochemistry.

An evaluation of magmatic processes responsible for tungsten enrichment in the Canadian Tungsten Belt: evidence in melt inclusions of granitoids associated with the Cantung and Mactung W-Cu deposits

Gabriel Gomez Garcia[1], A. Wagner[1], E. Adlakha[1], J.J. Hanley[1], P. Lecumberri-Sanchez[2], K.L. Rasmussen[3], and H. Falck[4]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <Gabriel.Gomez.Garcia@smu.ca>; 2. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada; 3. Department of Earth, Ocean and Atmospheric Sciences, *University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada; 4. Northwest Territories Geological Survey, Yellowknife, Northwest Territories X1A 2L9, Canada*

The world-class Cantung and Mactung W-Cu-Au skarn deposits are hosted in limestone of the Selwyn Basin, where it is intruded by a series of Cretaceous-aged granitoids known as the Tungsten plutonic suite. Tungsten and the associated metals (e.g., Au, Cu, Mo, Sn) in W skarn settings are thought to be provided and transported by exsolved magmatic-hydrothermal fluids from the granitoids. Several mechanisms for W enrichment in fertile magmas have been proposed, all of which focus on the incompatible element (IE) behaviour of W during protracted fractional crystallization due to (i) mid-crustal depths of magma staging and emplacement, and/or (ii) high dissolved volatile content, and/or (iii) reduced oxidation conditions that prevented fractionation of W in phases such as magnetite.

This study aims to determine the major and trace element concentrations of apatite-hosted silicate melt inclusions (SMI) from the Mine Stock and associated aplite dykes at the Cantung deposit, as well as the Cirque Lake and Rockslide Mountain Stocks and leucocratic dykes at the Mactung deposit. The major element composition of homogenized SMI will be gathered via electron probe microanalysis (EPMA) to classify the tectonic environment of the magmas. The trace element abundances of homogenized and non-homogenized SMI will be acquired via laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to determine the W and other important ore elements concentrations of the melts during different stages of fractional crystallization. The data will also be used to model the behaviour of the trace elements during fractional crystallization by using the petrography results and mineral-melt partition coefficients of the minerals in the rock samples in batch crystallization calculations.

Preliminary data show a wide range in compositions from intermediate to felsic reflecting the trapping of melts at different stages of fractional crystallization. The transition from syn- to post-collisional may also reflect the entrapment at different stages. Tungsten content in the most evolved melts is up to three orders in magnitude higher than the average crustal values as well as the whole rock. The inclusions with the lower IE represent melts trapped during the earliest stages of fractional crystallization. Positive correlations between Zr/Hf and Nb/Ta indicate the preferred fractionation of Nb and Zr in biotite and zircon, respectively. The negative correlation between Nb/Ta and Ta indicate the incompatible behaviour of Ta during biotite crystallization. When compared to the concentrations of Ta and other IE, W shows enrichment during fractional crystallization reflecting its incompatible behaviour with crystallizing phases.

Sulfur isotope and trace element systematics of pyrite and marcasite associated with epithermal gold mineralization in the northeastern Cobequid Highlands, Nova Scotia, Canada

Jacob Hanley[1], Kevin Neyedley[1,2], Ryan Sharpe[3], Mostafa Fayek[3], and Brandon Boucher[4]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <jacob.hanley@smu.ca>; 2. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada; 3. Department of Earth Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada; 4. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada

The chemistry and S isotope composition of pyrite and marcasite from silicified and sulphidized, variably Au-As-Sb-Hg-enriched and barren, Late Devonian to Early Carboniferous bimodal volcanic rocks in the Nuttby and Warwick Mountain areas were investigated by in-situ microanalytical methods (SIMS, LA-ICPMS, EPMA). The aim of the ongoing study is to determine if S isotopic and trace element systematics of Fe sulfide minerals can be used to recognize zones of hydrothermal fluid flow tied to epithermal mineralization, differentiating those from pyritic zones related to other geological processes, unrelated to Au mineralization.

Petrography (optical, SEM) coupled with LA-ICP-MS trace element mapping (14 areas) and $\delta^{34}S$ analysis by SIMS (n = 190 spots) identified 4 stages of pyrite/marcasite. The earliest (type 1 pyrite) comprises ^{34}S-depleted ($\delta^{34}S_{VCDT}$ = -6.4 to -5.4 ‰), metal-poor (based on SEM-EDS) pyrite within sedimentary enclaves enclosed within felsic volcanic rocks. Incorporation of this pyrite into the volcanic rocks did not contribute metals but may have been an important S contaminant. Following this stage, two stages of epithermal pyrite are recognized: Early marcasite and pyrite (type 2), forming the cores of pyrite grains show enrichment in Co-Ni-Cu-Ag-Hg-Cd-Bi-Sb (±Au, As); these cores have $\delta^{34}S_{VCDT}$ from -2.0 to 6.0 ‰ with 90 % of values between -1.5 and 2.0 ‰. Later pyrite (type 3; occurring as rims and oscillatory zones overgrowing type 2) shows enrichment in As-Sb-Mo-Cu-Se (±Au, Ag, Co); the dominant Au-enrichment stage in all pyrites examined occurs in type 3 rims. Type 3 pyrite has $\delta^{34}S_{VCDT}$ values from -6.8 to 2.0 ‰ with 90 % of values between -3 and 1 ‰. Core to rim transitions from type 2 to 3 pyrite generally show a shift to lower $\delta^{34}S_{VCDT}$ values, likely reflecting isotope fractionation during transient fluid boiling. Finally, a late pyrite generation (type 4) shows minor enrichment in Hg-Sb-Ag-Mo and occurs as overgrowths on type 3 pyrite; these overgrowths yield very high $\delta^{34}S_{VCDT}$

values (17.9–23.8 ‰) interpreted to reflect incursion of a fluid containing S derived from the reduction of seawater sulphate at the cessation of epithermal mineralization.

Although there were likely multiple sources of S, overall, the study of pyrite/marcasite indicates that the most important stage of Au enrichment is late in the paragenesis and is most closely correlated to As-Sb-Mo-Cu-Se-Ag enrichment. Some of these metals, including Au, may have been remobilized from earlier pyrite. Incursion of cooler, marine-derived fluids and transient boiling were likely triggers for late Au deposition.

Relationship between gold mineralization in the Annidale and Clarence Stream areas of southern New Brunswick, Canada

Hassan Heidarian[1], David R. Lentz[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 Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada

Tectonically, the various types of hydrothermal gold deposits form progressively through the evolution of subduction-related processes along convergent margins. The orogenic and intrusion-related gold deposits in the Annidale and Clarence Stream areas are interpreted to be different in terms of geological environment, tectonic setting, ore formation system, and timing of mineralization. Since these areas are parallel to each other and formed close to the margin of the subducted zone of Avalonia under Ganderia, gold-forming processes in these two different regions may still have formed in a common geodynamic environment.

The Annidale Belt, along with the Miramichi and St. Croix belts, were accreted onto the New River terrane on the trailing edge of Ganderia during the Early Ordovician closure of the Penobscot back-arc basin. Orogenic gold was formed during the Penobscot orogeny in the Annidale and New River belts. Ordovician orogenic gold was preserved in the Annidale area as no later major magmatic activities occurred in these belts. It is probable that similar orogenic gold mineralization was formed in the southwestern part of the New River Belt (Clarence Stream area) at the same time as in the northeastern part of this belt. The New River Belt was covered by sedimentary sequences of the Ordovician St. Croix and Silurian Mascarene belts in southwestern New Brunswick. Partial melting of the lower Avalonian lithosphere during subduction close to the convergent margin between the Avalonia and Ganderia zones caused extensive magmatic activity, generating the multi-phase Saint George Batholith; this protracted magmatic activity (during the Neoacadian orogeny) digested (assimilated and/or sequestered) parts of the New River and Mascarene belts during emplacement of several phases of the Saint George Batholith. In the Clarence Stream area, the emplacement of the Early Devonian Magaguadavic Granite was followed by thermal events, such as contact metamorphism and fluid circulation. The advanced hydrothermal activities related to emplacement of the Magaguadavic Granite recycled and may have remobilized pre-existing auriferous systems, including orogenic lode gold deposits. These activities ultimately led to the precipitation of gold as several intrusion-related deposits in the shear zones related to the Sawyer Brook Fault. The combination of several factors, including pre-existing orogenic gold deposits, advanced hydrothermal activities related to the Magaguadavic Granite, and the presence of local brittle-ductile shear zones, were crucial and explain the greater concentration of gold in intrusion-related deposits in the Clarence Stream area relative to the orogenic gold deposits in the Annidale area.

Paragenesis of mineralized South Mountain Batholith granitoid rocks at the Castle Frederick prospect, Upper Falmouth, Nova Scotia, Canada

Luke Hilchie[1] and Fergus Tweedale[2]

1. Earthbound Eyes Consulting, East Lawrencetown, Nova Scotia B2Z 1V1, Canada <EarthboundEyes@gmail.com>;
2. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

The Castle Frederick prospect is a Pb-Zn play hosted in the granitoid rocks of the Late Devonian (~380–365 Ma) South Mountain Batholith (SMB), within the Meguma terrane, near Upper Falmouth, Nova Scotia. The geochemical anomalies of economic interest (Pb, Zn) and reported mineralogy (sphalerite, galena, pyrite, barite, calcite) bear resemblance to Pennsylvanian (~320–300 Ma), low-temperature epigenetic ores within mineralized sedimentary carbonates of the Windsor Group, a major proportion of the infill of the Maritimes Basin. The base of the Maritimes Basin (i.e., the Devonian–Carboniferous unconformity) is exposed near the prospect, where Horton Group clastic rocks overlie the eroded SMB, and the world-class Walton barite-Pb-Zn-Cu-Ag deposit lies ~30–40 km northeast. The purpose of this research was to test whether mineralization at Castle Frederick is an expression of the same hydrothermal system that produced Maritimes Basin-associated Pennsylvanian

hydrothermal deposits. The work focused on petrographic characterization of several samples selected from drill core, and isotopic microanalytical characterization of minerals associated with the late hydrothermal paragenesis to either date the mineralization or establish an isotopic affinity with the overlying Pennsylvanian hydrothermal deposits. Three parageneses: magmatic crystallization products, hydrothermal "autometamorphic" alteration associated with magmatism, and late hydrothermal mineralization were identified. Magmatic mineralogy is typical of the SMB (cordierite-bearing two-mica monzogranite/granodiorite with accessories of apatite zircon, monazite, TiO_2), as is the autometamorphic suite (alkali feldspar exsolutions, myrmekite intergrowths, sericite after plagioclase, chlorite [with brookite] after biotite, and rare molybdenite). The late hydrothermal suite differs, featuring veins of pyrite (with anatase), calcite, and barite with fine SMB rock fragments, and grain-boundary network replacements/overgrowths (phengite rims on chlorite, calcite-anatase after chlorite-brookite) and disseminations (pyrite, anatase, chalcopyrite, galena, sphalerite) commonly associated previously biotite-rich domains. Pending laser ablation inductively coupled plasma mass spectrometry studies will attempt to date hydrothermal anatase and brookite, and/or examine changes in radiogenic Pb isotope ratios in sheet silicates across the parageneses and in late sulphides to probe connections to the regional Pennsylvanian hydrothermal system associated with the Maritimes Basin.

The Visean to Serpukhovian Millstream Subbasin within the Midland to Lower Millstream areas: implications for Carboniferous regional tectonics of southern New Brunswick, Canada

Steven Hinds[1], Matthew Stimson[2,3], Olivia King[2,3], Duncan McLean[4], and Adrian Park[1]

1. New Brunswick Department of Natural Resources and Energy Development, Geological Surveys Branch, Fredericton, New Brunswick E3B 5H1, Canada <steven.hinds@gnb.ca>;
2. Department of Natural History, New Brunswick Museum, Saint John, New Brunswick E2K 1E5, Canada;
3. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada;
4. MB Stratigraphy Ltd., Sheffield, S9 5EA, UK.

Recent integration of seismic profiles, palynology, industry reports, boreholes, and field interpretation has confirmed the existence of the Millstream Subbasin, an approximately 80 km^2 pull-apart basin within the Midland area of southern New Brunswick. From the late Tournaisian (?) to Visean–Serpukhovian, the Millstream Subbasin was deposited as a pull-apart basin resulting from differential rates of strike-slip movement along the Belleisle Fault to the north, and the Kennebecasis Fault to the south, which were both intermittently active as dextral strike-slip systems during this time range. The age justification is from palynology samples collected from boreholes and outcrops within the basin. The Millstream Subbasin is bounded by a minor system of normal faults; the Lower Millstream–Parleeville faults to the north and the Dickie Mountain–Peekaboo faults to the south. An initial episode of fault activity caused the opening of the basin by movement on the Lower Millstream and Dickie Mountain faults, which allowed for deposition of a thick, basal red bed clastic sequence of probable Late Tournaisian (?) age, and the subsequent deposition of Visean limestone and evaporite facies. After a period of quiescence, renewed transtension initiated movement on the Parleeville and Peekaboo normal faults, resulting in the deposition of a red clastic sequence above the evaporites and the down-dropping of the central part of the basin until fault movement waned during the early Serpukhovian. Activation of the late normal faults is most likely due to the differential rotation of the Midland area between the Belleisle and Kennebecasis faults, and/or the transfer of dextral movement from the Belleisle Fault to the Kennebecasis Fault. Limited field mapping to the east in the Smiths Creek area suggests the current understanding of the dextral displacement kinematics of the Kennebecasis Fault during the Visean–Serpukhovian needs revision, however additional field studies and palynology will be required to improve the confidence level of these initial observations.

Modelling the pressure-temperature-time evolution of in situ shock veins from the Manicouagan impact structure

Randy G. Hopkins and John G. Spray

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

The Manicouagan impact structure is one of three terrestrial craters in which in situ shock veins have been identified. Shock veins are thin (<2 mm) shock-induced frictional-melt bodies that form syn-shock during the early compression stage of impact crater formation. Their formation has been attributed to pressure excursions within the target rock leading to the presence of high-pressure polymorphs within shock vein matrices, with less regard for the effect that temperature may play in these transitions.

This work utilizes numerical computing software (via MathWorks MATLAB), which has been developed to understand the relationship between shock wave passage in geological targets (i.e., heterogeneous media) and the formation of shock veins (and associated high pressure/temperature polymorphs) within the target rock. This approach takes into consideration the pressure due to the passage of the shock front, subsequent rarefaction unloading pressures, and associated heating and cooling rates. The model is applied to calculate pressure-temperature-time conditions for hollandite-structured plagioclase and stishovite-bearing shock veins within the central uplift of the Manicouagan impact structure of Quebec.

Modelling reveals that: (1) at the time of shock vein formation (1.5 s following the initial contact of the projectile), the shock front pressure was 10.5 GPa and the width of the shock wave was 7.9 km; and (2) the melt within the shock veins initially reached ~2200°C, which corresponds to the melting temperature of the target rock at 10.5 GPa. These conditions are sufficient for hollandite and stishovite formation. Thus, pressure excursions beyond the peak shock pressure of the shock wave are not required for the shock veins to enter the appropriate stability fields. This work suggests that high pressure phases within the shock vein system are not the result of pressure excursions but rather are facilitated by localized high temperatures realized by the shock vein system.

A new exhibit at the Quartermain Earth Science Centre: bridging geology with biology celebrating paleontology and ornithology of Atlantic Canada. Honouring the work of paleontologist Dr. Ronald Pickerill

Grace Jackson, Ethan Mcdonald, and Ann C. Timmermans

Quartermain Earth Science Centre, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <quartermain@unb.ca>

A new interactive exhibit bridging the disciplines of biology and earth science is near completion at the Quartermain Earth Science Centre (QESC), located at the University of New Brunswick. Phase I of the project is dedicated to paleontologist Dr. Ronald Pickerill in recognition of his important contribution to the field of ichnology. Three robust collapsible cabinets contain six dioramas, representing the six periods of the Paleozoic Era and are QESC's first transportable exhibit. Each diorama features colourful landscapes with paleontological and ichnological fossils from targeted locations around Atlantic Canada. The exhibit includes informative legends for the various invertebrate, vertebrate, and plant fossils, plexiglass-covered drawers with additional specimens, and four introductory panels. Each cabinet can be easily disassembled into five pieces for transport. Transitioning to the Mesozoic Era, Phase II of the project focuses on several theropod dinosaurs from the Triassic to Cretaceous periods. A series of interactive displays including floor mounted trackways have been established along a high-traffic route between the Forestry and Geology Building, through the Science Concourse, culminating at the Biology Greenhouse. Informative display panels covering example fossil discoveries as well as phylogenetic and macroevolutionary studies are presented alongside the trackways. Seven evolutionary jumps are represented along the journey, from the theropod's earliest ancestor (*Herrerasaurus* sp.), to the earliest recognizable bird (*Archaeopteryx* sp.), to the more recent giant flightless bird of the Cenozoic Era (*Gastornis* sp.). The exhibit ends with Phase III, inside the entrance lobby to Loring Bailey Hall. Presented in the form of a wall-size phylogeny graphic opposite of a large diorama case of taxidermized avian, visitors can examine the diversity, detail, and delicate beauty of Neornithes (modern birds), from New Brunswick and around the world. This exhibit has been designed so that students, educators, and visiting groups can engage with and learn about many fields of science, including ichnology, taphonomy, invertebrate and vertebrate paleontology, paleoenvironmental geology, phylogeny, biophysics, biomechanical engineering, and ornithology. This project is made financially possible through gracious funding by the Canadian Geological Foundation, the Quartermain Earth Science Centre, and the department of Biology at the University of New Brunswick. Presenters will share the highlights of the exhibit and the applications to education.

Nova Scotia basalt as a soil additive for CO_2 capture and fertilizing crops

Christopher D. Jauer

Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada <chris.jauer@NRCan-RNCan.gc.ca>

Recent work on Enhanced Rock Weathering (ERW) shows that pulverized basalt spread over croplands is not only an effective crop fertilizer but also a stand-alone CO_2 sink. Airborne carbon dioxide mineralizes upon contact with the various minerals in pulverized basalt. Compared to subsurface CO_2 injection, this method of capture is inexpensive and simple to regulate and has the added benefit that the resulting basalt fertilizer runoff can ultimately contribute to the amelioration of ocean acidification.

Nova Scotia has an abundance of basalt deposits, both exposed and buried. The chemical storage of carbon dioxide in basalt is reasonably established, however the use of these deposits as fertilizer for agriculture is not widely known. The North Mountain Basalt from Nova Scotia also hosts zeolites that act as a cation intensive agent that when added to soil makes an excellent supplement for enhanced plant growth.

It has been estimated that the volume of North Mountain Basalt accessible onshore is over 2300 km^3, spread over some 9400 km^2. Given the relative potential ease of extracting and transporting this rock, much of which is exposed along the southern coast of the Bay of Fundy, it could represent a new "green industry" working to apply ERW methods using agriculture on a regional scale to help meet Canadian CO_2 emission limits. Mapping the North Mountain Basalt and similar basalt formations in the Maritime Provinces with respect to their suitability for ERW development is a necessary first step, which can be achieved with archival data sets. An initial laboratory proof-of-concept test for ERW in a laboratory setting could be arranged with the Centre for Sustainable Soil Management, Department of Plant, Food, and Environmental Sciences at Dalhousie University. This step would add credibility in a Canadian context toward the application of this new method of carbon sequestration.

The work described here is being carried out under the Carbon Capture Utilization and Storage section within the Marine Geoscience for Marine Spatial Planning program of the Geological Survey of Canada.

A targeting tool for gold mineralization in the Williams Brook epithermal system northern New Brunswick, Canada: insights from compositional geochemical balances

Farzaneh Mami Khalifani[1], David R. Lentz[1], Mohammad Parsa[1], and James A. Walker[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <farzaneh.mamikhalifani@unb.ca>;
2. New Brunswick Department of Natural Resources and Energy Development, South Tetagouche, New Brunswick E2A 7B8, Canada

The Williams Brook property, located in the northwestern part of the Chaleur Bay Synclinorium of northern New Brunswick, hosts gold mineralization within Silurian–Devonian, bimodal volcano-sedimentary rocks of the Wapske Formation (Tobique Group). The Tobique Group is bounded to the north and west by the Rocky Brook–Millstream Fault, and to the south and to the east where it lies unconformably on the Miramichi Inlier. The fault-controlled mineralization at Williams Brook is a low-sulfidation epithermal style system, hosted by quartz veins cross cutting flow-layered K-feldspar porphyritic rhyolite. Preliminary studies indicate that dextral movement along the Rocky–Brook–Millstream fault system during Early Devonian Acadian orogenesis exerts substantial control over gold mineralization at Williams Brook. Despite the similarities in the processes that trigger ore-metal deposition among various systems variation in local geological settings render differences in grade, shape, geochemical, and geophysical features of individual deposits. Consequently, a solid understanding of individual mineral deposits in a specific area is critical to future exploration success. Although pathfinders have been applied to constrain gold deposits geochemically, it is challenging to identify a unique suite of pathfinder elements for use as a vectoring tool exclusively for gold exploration. This study seeks to (i) address the question as to which elements can be regarded as pathfinders at the Williams Brook deposit and (ii) define a geochemical targeting tool for similar style mineralization. Geochemical samples (n = 1153) collected from trenches and outcrops underwent multi-element analysis. Grab samples collected from quartz veins were commonly anomalous in Au (128, 44.4, 38.8, 21, 15.95, 7.38, 6.63, 5.55, 2.94, and 1.14 ppm). In addition, the rhyolite, which contained a network of quartz veinlets to stockwork, contained several significant gold results. These were subjected to compositional data analysis (CODA) techniques, namely CODA-based principal component analysis, compositional balance analysis, and element association analysis. The compositional data includes information about relative magnitudes. Analyzing the covariance structures of the log ratios can inquire about the relationship between compositional variables. These techniques help reveal the interconnection between various element associations at the Williams Brook property as either uni- or multi-element geochemical signatures. Subsequent mapping of these signatures using CODA-based geochemical tools and measuring their spatial association with gold mineralization was conducted. The results of this study can help assist further exploration and finding promising area in the Williams Brook area. The methodology adopted herein can be applied to other gold deposits/occurrences, especially epithermal systems, for unraveling the interrelationship between different elements and gold mineralization.

Palynology of the Albert Formation of New Brunswick, Canada

Olivia King[1, 2], R. Andrew MacRae[2], Matthew Stimson[1, 2], Steven Hinds[3], Adrian Park[3], and Duncan McLean[4]

1. Department of Natural History, New Brunswick Museum, Saint John, New Brunswick E2K 1E5, Canada <olivia,king@smu.ca>;

2. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada;
3. New Brunswick Geological Survey, New Brunswick Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada;
4. MB Stratigraphy Ltd., Sheffield, S9 5EA, UK.

A palynological (plant spores) biostratigraphic study of the Tournaisian (Early Carboniferous) aged sites between the townships of Bloomfield and Norton, New Brunswick is being conducted. Newly collected and historical samples are being used to study the subdivisions within the *Vallatisporites vallatus* zone: *Claytonispora distincta* (formerly *Dibolisporites distinctus*) and *Speleaotriletes cabotii* subzones (informally NB Spore Zone 2 and 3).

The Tournaisian and Visean stages of the Mississippian Period are considered part of 'Romer's Gap', an interval of time when tetrapods diversified and made the transition from aquatic into terrestrial environments. Three fossil locations are known to yield fossil evidence of tetrapods from Romer's Gap: Scotland; Horton Bluff, Nova Scotia; and the newly discovered tetrapod tracks preserved in sites around Norton, New Brunswick. Interest in the relative age of these fossil-bearing strata arose due to the discovery of these important tetrapod ichnofossils as they could represent some of the earliest evidence of terrestrial tetrapods within this hiatus. Refining the age of the fossil bearing strata is important to better understand how the recently discovered sites near Norton compare to the broader evolutionary story of vertebrate life on land. A lack of marine biota, datable macrofossils or radiometrically-dateable volcanic rocks leaves palynology as the sole tool to assess the relative timing of the New Brunswick stratigraphy.

The historical palynological framework (biozonations) applied to the Tournaisian in the region is based on sites along the Horton Bluff shoreline and surrounding area in Nova Scotia (including Blue Beach). This biozonation framework has been widely accepted and applied across Atlantic Canada. Upon further inspection of the original literature and sampled sites, questions have been raised about the *Claytonispora distincta* (formerly *Dibolisporites distinctus*) and *Speleaotriletes cabotii* biozones at the Blue Beach tetrapod locality. Once fully unravelled, this new information may affect how to determine the relative age of similar sites in Atlantic Canada. Better understanding of this original palynological framework will allow for better correlation of sites within Romer's Gap, both locally and globally.

Survey of porewater geochemistry within deep marine hydrocarbon seep sediments of the Scotian Slope, Nova Scotia, Canada*

Nikita Lakhanpal[1], Venus Baghalabadi[1], Natasha Morrison[2], Adam MacDonald[2], and G. Todd Ventura[1]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H3C3, Canada <nikita.nikita@smu.ca>;
2. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 3J9, Canada

The ocean floor surface sediments of the Scotian Slope, Nova Scotia are host to a complex network of microbially mediated reactions that knit together the carbon, sulfur, and nitrogen biogeochemical cycles. Limited diffusion between the upper water column and ocean floor muds pore space, coupled with competitive microbial ecological niche partitioning, leads to the formation of biogeochemically controlled redox gradients. The energetics of such gradients are further governed by microbial heterotrophy with the deposition of detrital organic matter that is primarily sourced from terrestrial runoff and upper water column productivity. However, these microbial biogeochemical zones will likely change if surface sediments are impregnated by hydrocarbon seepage that migrates up from deeper within the basin. Extracting the porewaters anions, such as sulfate, carbonate, nitrate, nitrite, from frozen marine sediment cores located in prospective hydrocarbon seep sites is proposed to reconstruct biogeochemical stratification depth profiles that can provide additional evidence for active seepage events. These profiles define microbial metabolic processes within the sediment subsurface. To test this hypothesis, a total of 28 samples across 7 sediment cores were collected, separated, centrifugated, and analyzed using ion chromatography. Systematic stratigraphic trend of anions was observed in the sampled cores. For example, carbonate porewater concentrations increase with sediment burial depth. Sulfate concentrations, however, systematically decrease with depth. Additionally, seep locations will be examined as this study progresses. When complete, it is expected that the results will help constrain the depth and extent to which biogeochemical cycles change within the Scotian Slope surface sediments.

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

Seeking seeps with geophysics in the Blow Me Down Massif, western Newfoundland, Canada

Alison Leitch

Department of Earth Sciences, Memorial University of Newfoundland, St John's, Newfoundland and Labrador A1B 3X5, Canada <aleitch@mun.ca>

The Bay of Islands Ophiolite (BIOC) in western Newfoundland consists of four massifs, blocks of oceanic lithosphere that were obducted onto the margin of Laurentia during the Taconic orogeny (~ 470 Ma). Chemical reactions between meteoric waters and peridotite result in the serpentinization of the rock and highly reducing spring water. Also produced are hydrogen and methane which may support extreme life, which in turn is of interest to biogeochemists and astrobiologists. The small springs, or more often seeps, are difficult to detect, and they are usually found by ground searches for associated travertine deposits. However, the reactions involve strong electrical potentials and result in the production of magnetite, therefore they may be detected by geophysical surveys. Previous studies in Winterhouse Canyon, within the ultramafic Tablelands Massif, were successful in correlating known seeps with strong magnetic and self-potential (electrical) anomalies and identifying a further potential occurrence. In the summer of 2021, magnetic and self-potential surveys were carried out along a section of a canyon within the more southerly Blow Me Down Massif. In this location, electrical and magnetic anomalies of similar magnitude to the Tablelands sites were observed, though their relationship to observed seeps was more enigmatic, possibly due to more complex geological structure.

Reconciling adakite geochemical systematics: a review

David R Lentz and Fazilat Yousefi

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

Since 1978, adakitic volcanic and subvolcanic rocks have been recognized from the Island of Adak in the Andreanof Islands (Aleutians chain); they have enrichment in LILE, LREE, with high La/Yb, but also high Sr/Y and are low in HREE, Y (<18 ppm), and Yb (<1.8 ppm). Since the 1990s, adakites have been recognized worldwide, with similar geochemical characteristics, from recent to Archean TTGD magmatic suites. Based on GEOROC data, the geochemical composition of adakite rocks are divided into two types; high-SiO_2 adakites (HSA; SiO_2>60 wt%) and low-SiO_2adakites (LSA; SiO_2<60 wt%), although they should be redefined to be high-SiO_2 adakites (HSA; SiO_2>63 wt%), with low-SiO_2 adakites (LSA; SiO_2 57–63 wt%) and basaltic andesite adakites (BAA; SiO_2 52–57 wt%), which are similar to high Mg adakites (MgO>3 wt%). These rocks are subalkalic on the TAS diagram, and the boundary between sodic (Na), sodic-potassic (Na-K), and potassic (K) should follow the lower and upper boundary of the calc-alkaline series. The ASI is typical of metaluminous compositions and I-type suites (<1.1). The FeOt/MgO is <4, but typically ranges between 1.0 and 2.5 depending on redox and fractionation. The MnO is low (<0.15 wt%) with low FeOt/MnO ranging between 20–120, again reflecting higher redox. TiO_2 ranges from 0.15 to 1.15 wt%, V is 25 to 250 ppm, and the Ti/V <100, typical of transitional to calc-alkaline compositions reflecting higher redox. As many major elements are mobile in altered rocks, like porphyry environments, Zr/Ti is used as proxy for SiO_2 with a direct correlation. Immobile high field strength element and immobile element ratio diagrams are very useful; the Zr/Ti vs Nb/Y diagram that is a popular compositional discriminant has issues with anomalously low Y, i.e., the Nb/Y is over 0.7, even though these are all subalkaline rocks. The Nb + Y are like volcanic arc rocks (I-type) (<<50 ppm) and does not vary systematically with Zr/Ti. The Th abundance of suites varies with Zr/Ti, with multiple trends reflecting fractionation, and possibly magma mixing or contamination by subducting sediments or continental crust. The La/Yb (>2.6), Zr/Y (>2.8), Th/Y (>2.0), Th/Yb (>0.35), Zr/Nb (>5), and Th/Nb (>0.2) are all consistent with transitional to calc-alkaline signatures. Other than higher redox due to subduction metasomatism, the discrimination of various melt sources, like oceanic slab (very low Th), supra-subduction zone mantle (low Th), and crust (via AFC) (higher Th) relative to fractionation can only be discriminated by certain LILE like Th and Nb.

The impact of submarine canyons and channels on primary productivity dynamics in the Lower St. Lawrence Estuary, eastern Canada

Audrey Limoges[1], Jean-Carlos Montero-Serrano[2], Alexandre Normandeau[3], David Didier[4], Daniel Bourgault[2], Camille Deslauriers[5], Michel Gosselin[2], Patrick Lajeunesse[6], Catherine Lalande[7], Kateri Lemmens[5], Urs Neumeier[2], André Rochon[2], Owen Sherwood[8], Guillaume St-Onge[2], Pascal Bernatchez[4], Danny Rondeau[9], Khouloud Baccara[2], Camille Bernier[8], Florian Jacques[2], Tina Laphengphratheng[5], and Hannah Sharpe[1]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <alimoges@unb.ca>; 2. Institut des Sciences de la mer de Rimouski, Université du Québec à Rimouski, Rimouski, Québec G5L 2Z9, Canada; 3. Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia B2Y 4A2, Canada; 4. Département de Biology, Chimie and Géographie, Université du Québec à Rimouski, Rimouski, Québec G5L 3A1, Canada; 5. Département des lettres et humanités Université du Québec à Rimouski, Rimouski, Québec G5L 3A1, Canada; 6. Département de Géographie, Université Laval, Québec, Québec G1V 0A6, Canada; 7. Amundsen Science, Université Laval, Québec, Québec G1V 0A6, Canada; 8. Department of Earth and Environmental Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada; 9. Département d'Éthique et Philosophie Pratique, Université du Québec à Rimouski, Rimouski, Québec G5L 3A1, Canada

The complex topography surrounding submarine canyons influences local hydrodynamics. For example, canyon-induced upwelling can supply nutrients to the surface waters and stimulate biological productivity. Canyons may also represent hazard hotspots by acting as preferential pathways for turbidity currents traveling down to deeper marine basins. The glacial history of the Lower St. Lawrence Estuary (LSLE), Quebec, created a deep and steep estuary that now hosts several submarine canyon and channel systems. While these canyons may provide numerous ecosystem services, it is hypothesized that they may also be pathways for the dispersion of toxic algae, notably the dinoflagellate *Alexandrium catenella* for which sedimentary seedbeds are documented regionally.

This highly multidisciplinary project aims to assess the impact of hydrodynamic processes occurring in submarine canyons located off Pointe-des-Monts on primary production in the LSLE. Coastal sediment budgets around Pointe-des-Monts were monitored and current profilers were deployed along with sediment traps inside and outside the Pointe-des-Monts canyon system. Coastal and nearshore imagery shows that sediments are stored on the shelf, in small, ponded basins. During intense storms, increased wave heights sometimes lead to shelf-sediment resuspension and trigger turbidity currents. Other hydrodynamic processes including internal tides and internal waves also remobilize near-bed sediment and cause vertical mixing. Chlorophyll-a data from the sediment traps suggest that these processes impact primary production, as unpredictable phenological patterns of pelagic primary production are recorded in the canyon compared to background LSLE conditions. Finally, this research animates literary creations that will be combined into a logbook for the large public.

Save paper, save time? Digital answer entry during in-person geology labs (a pilot study)

Jason Loxton and Lilian Navarro

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

The shift to online learning in Nova Scotia during the 2020–2021 academic year forced faculty to digitize activities that would traditionally be done using paper and pen. This included geology labs, which needed to be completed using a digital interface, even where physical specimens were provided by mail. While adopted by necessity, digital data entry offered several significant advantages over paper and pen: (1) many questions can be set for automated grading, allowing for real time feedback to support student learning; (2) automated marking of fact-based questions frees up instructor time, allowing them to concentrate on more intellectually taxing activities; (3) digital entry eliminates the risk of misplaced labs; and (4) digital entry significantly reduces the paper required (a positive environmental step). The transition back to in-person learning provided an opportunity to test whether these benefits could be retained by having students enter answers using a digital device, while working in a laboratory setting with physical specimens. The results of a pilot study of digital answer entry, conducted in an introductory Engineering Geology lab over the 2021 fall semester at Cape Breton University (n = 30) are reported. This pilot demonstrated the feasibility of utilizing digital entry, using the tools offered by the Moodle learning management system; general acceptance of a digital interface (69% preferred digital entry or were neutral); and—somewhat surprisingly—student tolerance for smart phone-only data entry. However, it also highlighted limitations, including periodic technical glitches, high initial instructor effort (during lab buildout), and difficulty accommodating short answer questions.

The Signal Hill Group, Newfoundland, Canada: a record of pre-vegetated fluvio-deltaic response to progressive Neoproterozoic deformation during the Avalonian orogeny

David G. Lowe[1], Santiago Serno Ortiz[1], Andrea Mills[2], Benjamin F. Stanley[1], and Grace Khatrine[1]

1. Department of Earth Sciences, Memorial University, St. John's, Newfoundland and Labrador A1B 3X7, Canada <dlowe@mun.ca>;

2. Geological Survey of Newfoundland and Labrador, St. John's, Newfoundland and Labrador A1B 4J6, Canada

The Signal Hill Group consists of the youngest Neoproterozoic strata in the Newfoundland Avalon Zone. It records sedimentation coeval with the ca. 560–555 Ma Avalonian orogeny, defined by local deformation of west Avalonia, including metamorphism, faulting, and folding coinciding with the shutdown of arc magmatism and initiation of local extensional magmatism. The regional tectonic significance of this orogeny is equivocal, attributed to either oceanic trench subduction or terrane collision. Nevertheless, the Signal Hill Group provides a record of clastic progradation during the Avalonian orogeny, details of which can resolve the near-surface effects and kinematics of the Avalonian orogeny and provide an excellent example of the response of pre-vegetated fluvio-deltaic systems to progressive deformation. The Signal Hill Group conformably overlies fine-grained shelf and pro-deltaic strata of the St. John's Group, forming a north-south oriented folded succession exposed along the eastern edge of the Avalon Peninsula. At the base of Signal Hill, the Gibbet Hill Formation and overlying Quidi Vidi Formation record southward progradation of a sandy delta front environment dominated by mouth bars and distributary channel networks. Preliminary structural and stratigraphic evidence suggests blind faulting, folding, unconformity development, and basin reconfiguration between these units, supported by locally intense soft-sediment deformation along their contact. Conformably overlying the Quidi Vidi Formation are gravelly braided fluvial deposits of the Cuckhold Formation, recording amalgamation of alluvial channel belts with overall coarsening-up to pebble-cobble conglomerate followed by fining-up to pebbly sandstone.

In the northern (proximal) Signal Hill basin, subsequent folding of the Signal Hill Group coincided with erosion that locally removed the Cuckhold Formation, with subsequent onlap of gravelly braded fluvial growth strata of the Flatrock Cove Formation. Here, progressive fault propagation then resulted in a change from braided channel belt to alluvial fan floodplain conditions. Conversely, in the southern (distal) part of the Signal Hill basin, the Cuckhold Formation is conformably overlain by the Blackhead Formation, recording anomalous overbank mudstone preservation under conditions of high sediment accommodation. It is not understood if or how these post-Cuckhold proximal and distal events were related; however, it is possible that renewed thrust propagation and orogenic loading led to proximal deformation and growth stratification (Flatrock Cove Formation), with coinciding reciprocal foredeep subsidence and preservation of overbank strata farther south (Blackhead Formation). Ongoing facies, stratigraphic, provenance, and geochronology investigations will test this hypothesis and resolve details of pre-vegetated fluvio-deltaic sedimentation and its response to orogenesis in the Signal Hill Group.

New insights about Ganderian accretion to Laurentia and post-accretion tectonism from the southern end of the Miramichi inlier, east-central Maine, USA

Allan Ludman

School of Earth and Environmental Sciences, Queens College (CUNY), Flushing New York 11367, USA <allan.ludman@qc.cuny.edu>

The Miramichi inlier is the largest Ganderian Cambrian–Ordovician belt in New Brunswick, extending 250 km from Chaleur Bay to the Maine border. It is also the northwesternmost Ganderian belt in New Brunswick, and tectonic models for its middle Ordovician accretion to Laurentia have been based almost entirely on decades of intense studies from Bathurst to the Eel River area. Results of recent mapping and volcanic geochemical and geochronologic studies of the ~100 km long continuation of the inlier in Maine support some aspects of the tectonic model but require rethinking of others.

As in New Brunswick, a continental arc is suggested by a siliciclastic substrate beneath a calc-alkaline basalt-andesite-rhyolite suite and confirmed by trace element discrimination diagrams. Ages of the Maine (469 Ma) and most likely correlative Meductic Group volcanic rocks in New Brunswick (480 Ma) suggest active subduction related volcanism over at least 11 million years. Stratigraphic and lithologic differences in the volcanic suites along the length of the inlier probably result from eruptions at multiple volcanic centres.

Volcanic rocks in the Munsungun–Winterville and Weeksboro–Lunksoos Lake inliers in northeastern Maine provide information as much as 150 km (present distance) closer to the leading edge of Ganderia than those in the Miramichi. Current work, the first in those areas in the plate tectonic era, reports ages that indicate eruptions coeval with those in the Miramichi inlier in Maine and New Brunswick (Meductic Group). This is not consistent with models positing progressive northwest migration of volcanism in a single arc and suggests that a multiple arc model is more likely.

The Miramichi inlier is separated by faults from adjacent cover rocks – in Maine the Fredericton trough to the southeast and Central Maine/Aroostook–Matapedia basin (CMAM) to the northwest. Map relationships suggest a complex, multi-phase history for the northwestern boundary, beginning with large-scale pre-Acadian thrusting of CMAM strata onto and in some places over their Miramichi source.

Those strata are preserved in a small klippe near the New Brunswick border, and the southwestern segment of the inlier in Maine appears to be a window through the thrust sheet.

The Miramichi inlier terminates abruptly in east-central Maine at the intersection of its northwest and southeast boundary faults. Southwest of the termination, similar Fredericton and CMAM strata are juxtaposed, but their similarity obscures the continuation of the fault that separates them.

Geogenic sources of arsenic in well water related to granites from southwestern Nova Scotia, Canada

Bryan J. Maciag and James M. Brenan

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

Arsenic toxicity in drinking water sourced from groundwater is a global concern. Elevated arsenic in Nova Scotia well water is typically drawn from aquifers with metamorphic or granitic bedrock. In southwestern Nova Scotia, the granitic bedrock is divided into two geochemical and petrological affinities, central (South Mountain and Musquodoboit batholiths) and southern (Port Mouton, Shelburne, and Barrington Pass plutons). Arsenic concentrations in 84% of well water samples taken from the central batholiths are greater than the highest concentrations observed in the southern plutons. Since well water arsenic content does not scale with the whole-rock arsenic concentrations, it is thought the origin of this discrepancy is mineralogical. This study examines the arsenic content of the major and accessory phases of central and southern granites, as well as evaluates the susceptibility of these phases to weathering by calculating the saturation index (SI) of each mineral in the local well water. Analysis by laser ablation ICP-MS was performed on over 292 grains from 8 samples from the central granites (with an additional 472 analysis of primarily apatite and biotite from another 45 samples from a separate study) and 79 grains from 4 samples of the Port Mouton Pluton which represents the southern granites.

The major rock-forming silicates contain over 50% of the arsenic in all Nova Scotia granites. In the central granites, monazite, pyrite, and cordierite, along with its alteration products, contain 5–9%, 5–8% and, 9–27% of the total arsenic budget, respectively. Additionally, ferric hydroxide and hydrous oxide (FOH) oxidation products of pyrite may contain 0.5–6% of the arsenic budget. Mineral saturation index and Eh-pH calculations show that both monazite and the rock-forming silicates are stable in the local groundwater, whereas pyrite and cordierite are unstable and therefore release arsenic upon dissolution. In the southern granitic bodies, pyrite is the only significant source of arsenic other than the rock-forming silicates. This pyrite is largely pristine rather than oxidized, in contrast to the central plutons. The absence of FOH replacement of pyrite suggests that pyrite does not contribute significant arsenic to the local well water. Thus, the difference in well water arsenic concentration between the southern and central granites is attributed to (1) the absence of cordierite in the southern plutons and (2) different degrees of pyrite oxidation. The lower degree of pyrite oxidation in the southern granites suggests that the sulphides have not reacted with groundwater, likely due to lower rock permeability.

The paleobiogeographic distribution of graptolites in the earliest Silurian following the Late Ordovician mass extinction event

Bailey Malay

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

The Late Ordovician Mass Extinction Event (LOME) was the world's first major mass extinction of the Phanerozoic, which killed an estimated 80 percent of global species. The immediate aftermath of the LOME is well documented in the earliest Silurian, as it was a time of anoxia that readily fossilized deep marine organisms. One group of organisms that were incredibly helpful in documenting the aftereffects of the LOME are the graptolites. Globally well preserved in black shales during the Rhuddanian (the earliest Silurian), these zooplankton were geographically widespread and make excellent biostratigraphic index taxa. Samples taken from the Road River Group in the Peel River area of the Yukon Territory, along with samples taken from Cape Phillips South on Cornwallis Island, part of the Canadian Arctic Islands, have been identified and documented. These taxa belong to the earliest Silurian, specifically the *Akidograptus ascensus – Parakidograptus acuminatus* Biozone, a biozone that is globally correlative as there are a significant number of graptolitic black shales of this age preserved. A quantitative global paleobiogeographic analysis has been undertaken using data from this study, together with global data available from critically reassessed published and unpublished studies. These results will help determine the changes in paleobiogeography of the graptolites following the LOME in the earliest Silurian. Cluster analyses, specifically using the Unweighted Pair Group Method algorithm and non-metric multidimensional scaling (NMDS), were implemented to analyze the data. Together

these analyses show that graptolites underwent little change in paleobiogeographic distribution between the *ascensus* to *acuminatus* biozones. The assemblages of South China and northern Canada cluster together, as both were on the outer edge of the Panthalassic Ocean in the northern paleotropics. The assemblages from peri-Gondwanan Europe cluster closely with those of Scotland, England, Wales, and Baltica, as these were all located in the closing Iapetus Ocean in the southern subtropics to middle-paleolatitudes. Comparison with published paleoceanographic studies suggest that ocean circulation kept these two clusters mostly separate. Faunas of northern Africa were found to be separate from all other assemblages, likely due to their location in Gondwanan deep epicontinental basins.

Automated sinkhole delineation using LiDAR in the Cumberland Basin, Nova Scotia, Canada

Mitch Maracle[1], Morgan Snyder[1], and Peter Opra[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <159979m@acadiau.ca>;
2. 34 Agincourt Crescent, Dartmouth, Nova Scotia B2V 1J1, Canada

The Maritimes Basin is composed of multiple intra-basin depocentres each with variable structural and depositional regimes related to halokinesis. The Cumberland Basin, in northwestern Nova Scotia, is one such depocentre oriented parallel to the east-west striking Cobequid–Chedabucto fault system. Stratigraphy in the Cumberland Basin is dominantly terrestrial; however, does include marine rocks of the Visean Windsor Group. Evaporites of the Windsor Group, including halite, anhydrite, and gypsum, accumulated in marine supersaline water bodies during a period of transtensional rifting. Windsor Group evaporites in the Cumberland Basin are abundant; however, because evaporites are highly soluble, very few outcrops are exposed. Karstification of evaporitic rocks can produce solution collapse structures (i.e., sinkholes). Recognition of solution collapse structures on aerial photography is difficult in Nova Scotia due to overburden and vegetation. LiDAR (Light Detection and Ranging) is an active remote sensing system that can model the ground surface with the ability of penetrating the overlying vegetation, allowing for the clear observation of structural geomorphological features, including sinkholes. A model to automatically identify and delineate sinkholes in the Cumberland Basin is here created using ArcGIS software to transform provincial LiDAR data into raster datasets, on which the analysis is conducted. ModelBuilder is an application in ArcGIS that allows geoprocessing tools to be tied together. The model allows an automated workflow that extracts a bare earth model from the input LiDAR data and employs a sink-filling method to locate solution collapse structures systematically and accurately. Map Algebra, and the application of filters, such as low pass and high pass, are the methods investigated to remove insignificant and artefact features. Constructing the geoprocessing model in ModelBuilder results in an intuitive tool that is sharable with other ArcGIS users. To test the model's effectiveness on solution collapse structures in the Cumberland Basin, an area of interest along the Phillip and Pugwash rivers was chosen. The area of interest is a zone with sinkholes atop or adjacent to mapped diapirs. The model identified both known and unknown structures within the study areas, indicating preliminary success in the model's delineation methods, especially when compared to manual visual identification and interpretation. This new model will be used for subsequent studies in sinkhole detection in Nova Scotia as morphometrical variables are further constrained. Identifying the locations of surface collapse structures gives greater insight to both the halokinetic history of the Cumberland Basin and potential risks associated with future sinkhole development.

Influence of tectonically controlled topography on deep-water sedimentation

Vittorio Maselli[1], Aaron Micallef[2,3], Alexandre Normandeau[4], Davide Oppo[5], David Iacopini[6], Andrew Green[7], and Zhiyuan Ge[8]

1. Department of Earth and Environmental Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <vittorio.maselli@dal.ca>;
2. Marine Geology and Seafloor Surveying, Department of Geosciences, University of Malta, Msida, 1805, Malta;
3. Helmholtz Centre for Ocean Research, GEOMAR, 24148 Kiel, Germany;
4. Geological Survey of Canada, Natural Resources Canada, Dartmouth, Nova Scotia B2Y 4A2, Canada;
5. School of Geosciences, University of Louisiana at Lafayette, Lafayette, Louisiana 70504, USA;
6. DiSTAR, Università di Napoli Federico 11 II, 80138 Naples, Italy;
7. Geological Sciences, University of KwaZulu-Natal, Durban, 4041, South Africa;
8. College of Geosciences, China University of Petroleum, Beijing, 94305, China

Increasing availability of high-resolution bathymetric and seismic data along the slope of continental margins has allowed a step change in understanding processes

and products of turbidity currents. Yet, many questions regarding how such flows interact with tectonic-driven deformation of the seafloor are outstanding. Using 3D seismic reflection data from the Levant Basin (Eastern Mediterranean Sea), the spatial and temporal evolution of bedforms on a deep-water fan cut by an active normal fault was investigated. The goal is to understand how a dynamic knickpoint controls sediment deposition from superficial to transcritical turbidity currents, and how allogenic signals, such as tectonic processes, are preserved in the sedimentary record. Seismic data show that in the footwall the fan comprises cyclic steps and antidunes along its axial and external portions, respectively, which is interpreted to result from the spatial variation in flow velocity due to the loss of confinement at the canyon mouth. Conversely, in the hanging wall, the seafloor is nearly featureless at seismic scale. Numerical modelling of turbidity currents shows that the fault triggers a hydraulic jump that suppresses flow velocity downstream, thus explaining the lack of visible bedforms basinward. This study shows that the topography generated by active normal faulting controls the downslope evolution of turbidity currents and the associated bedforms, and that seafloor geomorphology can be used to evince syn-tectonic deposition.

A novel approach to generating in situ Lu-Hf garnet isochrons using micro-XRF mapping, LA ICP-MS mapping, and MS/MS-ICP-MS

Christopher R.M. McFarlane

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

Garnet is widely used for Lu–Hf isochron (beta-decay) geochronology because of its strong affinity for HREE and comparatively low initial Hf. The first increments of garnet growth during metamorphism of metasedimentary rocks tend to sequester Y and HREE at the expense of accessory minerals like xenotime ((Y, HREE) PO_4). This typically produces Lu-enriched garnet cores with concentrations sometimes >100 ppm. The corresponding ^{176}Lu/^{177}Hf values for core domains can range up to 100 thereby exerting considerable leverage on the age and error produced using isochron methods. Conventional bulk dissolution approaches typically produce Lu/Hf <1.0. Finding and targeting these Lu-rich domains for in situ Lu–Hf garnet geochronology is the focus of this study. Assessing the impact of other mineral inclusions (e.g., zircon, ilmenite, apatite) is also possible using this approach. The dataset also demonstrates the ability to eliminate ^{176}Yb interference from ^{176}Hf using NH_3 reaction gas to mass-shift Hf isotopes.

The first step in this process is to produce high-resolution (20 μm/pixel) micro-XRF maps for several 100 μm thick polished thin sections of garnet-rich target rocks. Doing so reveals which garnets expose near-central sections as defined by elevated zoning in Mn and Y. Conventional LA ICP-MS is then used to rapidly map (10 μm/pixel) the core regions of target grains to reveal Lu distribution and assess inclusion suites. The LA ICP-MS maps are added as overlays in the laser software to guide the position of spots for LA MS/MS-ICP-MS using a crater size of >100 μm if possible. The MS/MS-ICP-MS setup includes inclusion monitors ^{90}Zr, ^{49}Ti, ^{31}P, and ^{89}Y to assess the impact on Lu–Hf isochrons of inadvertent ablation of zircon, FeTi-oxides, and phosphates. Two previously dated rocks, a 2650 Ma paragneiss and a 400 Ma metapelitic schist, establish the veracity of the technique and define target precision required to achieve 1% (2σ) error on final isochron ages. By anchoring at an initial ^{176}Hf/^{177}Hf of 0.282 ± 0.004, precise isochrons are obtained for 2–3% (2σ) error on ^{176}Lu/^{177}Hf and 1% error ^{176}Hf/^{177}Hf. A similar approach is applicable to other beta-decay chronometers such as Rb/Sr and K/Ca in micas.

Petrology, age, and tectonic setting of mafic-intermediate intrusions in the northeastern Meguma terrane, Nova Scotia, Canada*

Shae J. Nickerson[1], Sandra M. Barr[1], Donnelly B. Archibald[2], and Chris E. White[3]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <shaenickerson@acadiau.ca>;
2. Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia B2G 2W5, Canada;
3. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada

Small plutons of mafic to intermediate composition are locally associated with the abundant Devonian granitic plutons that intruded the Goldenville and Halifax groups in the eastern Meguma terrane of mainland Nova Scotia. In addition, a swarm of mafic-intermediate dykes, here termed the Eastern Shore dykes, occur in the coastal part of that area. The purpose of this study is to investigate the age, petrology, and tectonic implications of these mafic-intermediate plutons and mafic dykes. Understanding the petrogenesis of these mafic-intermediate rocks provides sights into their genetic relationship with granitic magmatism, the origin and tectonic significance of the coeval granitic plutons, and a better understanding of the tectonic evolution of the Meguma terrane. The mafic-intermediate plutons in the Forest Hills and Cranberry

Lake areas are of tonalite to quartz diorite composition and occur close to the Cobequid–Chedabucto Fault System that separates the Meguma terrane from Avalonia. They range from undeformed to proto-mylonitic, contain abundant metasedimentary xenoliths, and show magma mingling textures with their adjacent granitic plutons. The Melrose dioritic dyke intruded the Cranberry Lake pluton because it contains granodiorite xenoliths from that pluton. Farther west, mafic-intermediate plutons (Porcupine Lake, Bog Island Lake, Mink Lake, and Ten Mile Lake) form part of the Trafalgar Plutonic Suite. They range in composition from tonalite to gabbronorite, contain mafic enclaves, and metasedimentary xenoliths, and are mostly undeformed. The Eastern Shore dykes range in width from ~10 cm to ~15 m and consist of lamprophyre (variety spessartite) based on their dominant mineralogy of plagioclase and amphibole with K-feldspar in the groundmass. They are subdivided into two groups based on the presence or absence of xenoliths and on geochemical data. Group one dykes lack xenoliths and show convex rare-earth-element (REE) patterns. Group two dykes contain xenoliths, have higher Sr and Zr, and show more sinuous REE patterns. Chemical compositions of the mafic-intermediate rocks from the Forest Hills, Cranberry Lake, Melrose, and Trafalgar areas range in SiO_2 from ~50 to ~70 wt%. They display light REE-enriched patterns with both negative and positive Eu anomalies, and have high Al_2O_3 and low Cr and Sr. In contrast, the Eastern Shore mafic-intermediate dykes have lower SiO_2 (~50 to 57 wt%) and higher MgO, Cr, and Ni. Zircon U–Pb dating and isotopic data will better constrain the ages and assist in evaluating crustal and mantle components in these rocks.

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

A new approach for investigating thermal and fluid evolution in critical mineral deposits of southern Nova Scotia via paired in situ Rb/Sr and Ar/Ar geochronology of micas

Adam Nissen[1], Dawn Kellett[1,2], and Jacob Hanley[1]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <Adam.Nissen@smu.ca>;
2. Geological Survey of Canada, Atlantic, Natural Resources Canada,Dartmouth, Nova Scotia B2Y 4A2, Canada.

Paleozoic granite-hosted ore systems in southern Nova Scotia have complex thermal and fluid histories, including a post-magmatic, major regional tectonothermal event that disturbed geochronometers at ca. 315 Ma. As such, reconstructing the timing of mineralization and alteration events in these systems is challenging, particularly when using standard bulk mineral separate analysis. The spatial resolution made available by evolving in situ methods for geochronology can reveal multiple age domains in targets with multiphase thermal histories. The challenge presented by the complexities in these ore systems presents the opportunity to compare two modern in situ methods for mica geochronology. This project will compare in situ $^{40}Ar/^{39}Ar$ mapping of micas with newly developed in situ Rb/Sr age mapping of the same grains to characterize the mica geochronology of two mineralized systems, the Brazil Lake lithium-cesium-tantalum pegmatite, Yarmouth County, Nova Scotia, and the East Kemptville tin greisen complex, Yarmouth County, Nova Scotia. The proposed work will include full chemical and textural characterization of the minerals to be dated, and initial dating results. Geochronology data will be reconciled with fluid inclusion systematics to resolve the nature of mineralizing or post-mineralization fluids. Major contributions from the ongoing work will: (1) provide insight into the use of in situ Rb/Sr geochronology, an emerging method that makes use of state-of-the-art tandem mass spectrometers separated by a reaction cell; (2) inform critical mineral exploration and mining in the Canadian Appalachians; and (3) produce a framework for interpreting mica geochronology in systems with complex thermal histories.

An Early Carboniferous strike-slip duplex in the Belleisle Fault zone, southwestern New Brunswick, Canada, (or 'The secrets of Deadmans Harbour')

Adrian F. Park[1], Steven J. Hinds[1], and Susan C. Johnson[2]

1. Geological Surveys Branch, Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada <Adrian.Park@gnb.ca>;
2. Geological Surveys Branch, Department of Natural Resources and Energy Development, Sussex, New Brunswick E4E 7H7, Canada

The Belleisle Fault (Lubec Fault in southeast Maine) is one of several large strike-slip faults in the Appalachians of Maritime Canada. For much of its length, the Belleisle Fault is a relatively simple structure marked by mylonite-bearing high strain zones and brittle structures, such as between the Pocologan River and Loch Alva in southwest New Brunswick, and southwest from Eastport in Maine. Between the Pocologan River and the west end of Campobello Island, the Belleisle Fault zone consists of major splays defining a strike-slip duplex. Within the duplex occur fault-bounded 'horses' of units seen to the northwest in the New River terrane, namely: (1) The early Ediacaran (ca. 625 Ma) Blacks Harbour granite and its thermal aureole, (2) The late Ediacaran to earliest Cambrian Belleisle Bay Group of volcanic and sedimentary rocks and related granites, (3) The Cambrian Saint John Group, including the mafic volcanic Waites Lane Formation, (4) The late Ordovician–Silurian Mascarene Group and, 5. The late Devonian Perry Formation. The early Silurian Kingston terrane forms the southeast margin of the duplex (as well as the southeast side of the Belleisle Fault in general), and its rocks are not found within the duplex. Older units within the duplex generally display more deformation, and within the structure there are extensive zones of tectonic mélange. Primary relationships, such as the intrusion of Blacks Harbour granite into its aureole and the non-conformity of Perry Formation on the Blacks Harbour granite are preserved, but most contacts are tectonic, and some fault-bound enclaves are merely metres long and less than a metre thick. The duplex is overstepped by a Carboniferous sequence forming the Cripps Stream and Russels Point formations (Beaver Harbour Group). Good miospore assemblages acquired from the Perry Formation (middle Famennian, youngest unit in the duplex) and Russels Point Formation (lower Visean, oldest overstepping unit) constrain a major period of strike-slip displacement along the Belleisle Fault to the Tournaisian interval.

Exploiting the potential of legacy data with artificial intelligence for renovating VMS mineral prospectivity models of the renowned Brunswick Belt, Canada

Mohammad Parsa[1], David Lentz[1], and James Walker[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <m.parsa@unb.ca>;
2. New Brunswick Department of Natural Resources and Energy Development, South Tetagouche, New Brunswick E2A 7B8, Canada

The renowned Brunswick belt (BB) that hosts the Brunswick Horizon (BH), the stratigraphic sequence constituting the upper contacts of the Nepisiguit Falls Formation (NFF) with the overlying Flat Landing Brook Formation (FLBF), is associated with several well-known massive sulphide deposits and some mineral occurrences. These include the supergiant Brunswick No. 12, the Brunswick No. 6, Key Anacon, and Austin Brook deposits. Historically, this belt has been subjected to various geophysical, geochemical, and geological surveys by governments and private companies, making it a data-rich zone. However, these data have never been exploited to their full potential, and to the best of the authors' knowledge, there is no publicly available renovated mineral prospectivity model for this belt or the Bathurst Mining Camp as a whole. This study seeks to bridge this knowledge gap by adopting AI-based techniques for developing renovated predictive models of volcanic-hosted massive sulphide mineralization for this well-endowed belt, that will then serve to build better models for the Bathurst Mining Camp.

Aiming to achieve the above goal, two sets of exploration targeting criteria, namely the one used for deposits hosted by the NFF and the other used for deposits hosted by the FLBF, were adopted to distill the legacy geoscientific data available into predictor models using state-of-the-art machine-learning techniques. In the context of this study, major differences considered in these sets are: (i) whereas the presence of iron-rich chemically derived sedimentary rocks, known as iron formations (BH), is intrinsic to the deposits hosted by the NFF, the deposits hosted by the FLBF predominantly lack this feature; and (ii) in contrast to the deposits hosted by the FLBF, the deposits hosted by the NFF show lateral chemical zonation. The legacy data employed in this study are the results of aeromagnetic, airborne electromagnetic, airborne radiometric, till geochemical, and bedrock mapping surveys. Based on the exploration targeting criteria defined, these data were reprocessed and re-analyzed to highlight the subtle patterns linked to these data that might represent mineralized horizons.

This study started by recognizing that the process of developing a probability map pointing to the location of possible mineralized zones can be deemed a type of regression analysis. Employing the recently developed regularized regression techniques were based on this premise, namely Ridge and Lasso. The results of this study were further compared to the previously developed BB and BH prospectivity models. Given a set of spatial/statistical methods commonly used to compare prospectivity models, the models developed in this study are more robust than those developed earlier. A further step in this study is a risk-return analysis applied to predictive models to prioritize prime exploration targets based on their uncertainty. This procedure estimates the stochastic uncertainty of predictor models and links the estimated values to selecting low-risk, confident exploration targets. The outcome of this preliminary reanalysis is an exploration targeting model that effectively reduces the search space for exploration in the BB and can be used by decision makers and exploration campaigns.

Late Devonian deformation and exhumation in the northern Appalachian orogen: a syntaxial origin?*

Nicolas Piette-Lauzière[1], Kyle P. Larson[1], Dawn A. Kellett[2], Lyal B. Harris[3], Nathan R. Cleven[4], and Neil Rogers[5]

1. Earth and Environmental Sciences, IKBSAS, University of British Columbia Okanagan, Kelowna, British Columbia V1V 1V7, Canada <nicolas.piette-lauziere@alumni.ubc.ca>; 2. Geological Survey of Canada (Atlantic), Natural Resources Canada, Dartmouth, Nova Scotia B2Y 4A2, Canada; 3. Institut National de la Recherche Scientifique, Centre Eau Terre Environnement, Québec, Québec G1K 9A9, Canada; 4. Geological Survey of Canada, Vancouver, British Columbia V6B 5J3, Canada; 5. Geological Survey of Canada – Central, Natural Resources Canada, Ottawa, Ontario K1A 0G1, Canada

The pre-accretionary shape of the eastern Laurentian margin with promontories and re-entrants, in conjunction with the obliquity of the collision of the various crustal fragments, primarily control the timing, kinematics, and intensity of deformation related to accretionary events in the northern Appalachian orogen. When considering the progressive accretion of oceanic arcs and microcontinents to the composite Laurentian margin, it is often difficult to determine which tectonic setting controlled the deformation or reactivation of shear zones not located in the immediate vicinity of the active suture. This problem is best represented by the lack of tectonic interpretation for the regional deformation occurring during the Late Devonian oblique collision of Meguma leading to the Neoacadian orogeny.

Modern collisional settings provide a conceptual framework to investigate the Late Devonian to Mississippian deformation inboard of the Neoacadian suture. In active mountain belts, accreted promontories can form syntaxes characterized by rapid crustal deformation, high elevation, and fast erosional exhumation with abundant sedimentation. Compiled new and published shear zone kinematic interpretations, deformation ages, and regional $^{40}Ar/^{39}Ar$ cooling ages was compared and integrated with structural interpretation of aeromagnetic and gravimetric depth slices covering the northern Appalachians.

Results indicate that between the Late Devonian and Mississippian, regionally extensive NE-SW and ENE-WSW oriented shear zones such as the Cobequid–Chedabucto suture, the Hermitage Bay–Dover shear zone, the Norumbega fault zone, the Pocologan–Kennebecasis shear zone, and the Catamaran fault were formed or reactivated with a dextral strike-slip shear sense consistent with a large-scale C-C' system. Depth slices of aeromagnetic and gravity geophysical data indicate that several of these structures are listric, and thus formed a lateral succession of transpressive and transtensive segments crosscut by antithetic sinistral shear zones. At the apex of the collision between Meguma terrane and the composite Laurentian margin of New England, $^{40}Ar/^{39}Ar$ cooling age transects highlight large regions of focused Neoacadian cooling and exhumation. These regions spatially correlate with an area of contemporaneous high paleoelevation flanked by the opening of the Maritimes and Catskills basins. A regional structure with a component of Neoacadian southeast-side up motion, tentatively named the Honey Hollow fault, forms the back-thrust that accommodated this uplift, while the Norumbega fault zone (northern New England) and the Clinton Newbury fault (southern New England) appear to have accommodated the frontal uplift. Such a setting is potentially similar to transpressive syntaxes such the present-day oblique collision of the Yakutat terrane to North America.

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

Resolution of the hydrocarbon molecular matrix by comprehensive two-dimensional gas chromatography as evidence of hydrocarbon sources of the Scotian Margin, offshore Nova Scotia, Canada

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Elish Redshaw[1], Anirban Chowdhury[1], Jeremy N. Bentley[1], Adam MacDonlad[2], Natasha Morrison[2], and G. Todd Ventura[1]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3N 3C3, Canada <elish.redshaw@smu.ca>; 2. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 3J9, Canada.

Shallow deep marine surface sediments often contain hydrocarbons that do not have a well-constrained point of origin. Over the course of three cruises (2015, 2016, and 2018) subsurface sediment samples of piston and gravity cores were collected over prospective hydrocarbon seep sites. These cores have been classified based on petroleum geochemistry as being either positive or negative for containing hydrocarbon that have migrated up from deeper within the Scotian Basin. The extractable hydrocarbon matrix of the shallow sediments may represent a mix of organic matter having different origins. This study will examine the hydrocarbon matrix of 8 sediment cores (n = 37). Hydrocarbon extraction involved isolation of organic matter (OM) from the sediment by means of sonication and separation of apolar and polar fractions in organic solvents. Comprehensive two-dimensional gas chromatography, coupled with high-resolution mass spectral data, will be used to resolve these hydrocarbon matrices. The produced two-dimensional chromatograms will be used to map down core variations in the absolute abundance of compounds in the hydrocarbon matrix. A background hydrocarbon fingerprint will be formulated from an average chromatographic trace that will further be subtracted from individual sample chromatograms.

The resulting mean difference chromatograms will be used to identify downcore matrix attenuation and evaluate point sources from the multimolecular composition in the sediment strata. Bulk extract data, including total lipid extracts, apolar, and polar fractions, along with sediment TOC and their associated multi-molecular difference chromatograms will further the support downcore mapping. Through this methodology, the project aims to provide evidence for sources of hydrocarbon production by differentiating native and migrated hydrocarbons.

Geoscience through the lens of heritage: virtual geoheritage education at Stonehammer UNESCO Global Geopark, New Brunswick, Canada

Catrina Russell

Stonehammer UNESCO Global Geopark, Saint John, New Brunswick E2L 4Z6, Canada <catrina@stonehammergeopark.com>

Geoscience education in New Brunswick is often hindered by a lack of process and understanding on the part of school boards and a lack of training and comfort level on the part of many teachers assigned to instruct on it. In New Brunswick, the curriculum calls for geoscience topics to be discussed in Grades 4 and 7. Stonehammer has long delivered hands-on programming geared specifically at these grades, as well as workshops for teachers instructing at these levels. As the Global Pandemic has put a hiatus on in class programming, Stonehammer has gone virtual, developing new strategies to build upon these initial offerings using a more holistic approach. Exploring multidisciplinary topics throughout the geopark that link to curricula across all grade levels has proven extremely engaging for students. This content acts as a gateway, leading to opportunities to delve deeper into and foster greater understanding of more specific geoscience topics. The subject of geoheritage has long fascinated this author, and recent initiatives to better acknowledge and celebrate indigenous cultures throughout the region have inspired the creation of a virtual program that ties together themes of indigenous culture and custom with the region's geological history. This session will outline best practices within Stonehammer Geopark to deliver geoscience and geoheritage content to all ages.

Seasonal and spatial changes in vertical export and deposition of productivity tracers in a submarine canyon system of the Lower St. Lawrence Estuary, eastern Canada

Hannah Sharpe[1], Audrey Limoges[1], Michel Gosselin[2], Catherine Lalande[3], Jean-Carlos Montero-Serrano[2], and Owen Sherwood[4]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <hsharpe@unb.ca>; 2. Institut des sciences de la mer de Rimouski, Université du Québec à Rimouski, Rimouski, Québec G5L 3A1, Canada; 3. Amundsen Science, Université Laval, Québec, Québec G1V 0A6, Canada; 4. Department of Earth and Environmental Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada

The coastal shelf of Pointe-des-Monts (PDM), located on the northern shore of the Lower St. Lawrence Estuary (LSLE), is characterized by active submarine canyons. Despite the presence of regional biological hotspots, there is a lack comprehensive understanding of the relationship between canyon processes and surface primary production (i.e., conversion of inorganic material into energy-bearing organic material). This study documents seasonal and spatial variations in primary production based on the analysis of 29 surface sediment samples and 72 sequential sediment trap samples over the span of an annual cycle, from within and outside the canyon system. A particular focus is placed on potentially harmful taxa, including the toxic dinoflagellate *Alexandrium catenella*, which has been associated with regional mass mortality events in the past.
Preliminary analyses show that the surface sediments contain well-preserved organic-walled dinoflagellate cysts with an average concentration of 54 000 cysts dry g^{-1} inside the PDM canyons and 99,000 cysts dry g^{-1} outside the canyons. A clear pattern of increasing dinoflagellate cyst concentrations with distance from the shore is observed. Surface sediments have nitrogen isotopic ($\delta^{15}N$) and carbon isotopic ($\delta^{13}C$) values ranging between 5.1 and 6.3‰, and -23.2 and -25.6‰, respectively. Indeed, nearshore samples contain more terrestrially derived organic carbon with an increasing proportion of marine organic carbon with distance from the shore. Total particulate matter (TPM) fluxes in the sediment trap samples were significantly greater at PDM (maximum 7.9 g m^{-2} d^{-1}) than outside the canyons (maximum 1.1 g m^{-2} d^{-1}). Chloropigment fluxes (maximum 1.6 mg m^{-2} d^{-1}) indicate a typical seasonal production cycle over the course of one year outside the canyons, while this pattern is not observed at PDM. During the spring bloom, chloropigment and TPM fluxes are coupled outside the canyons and decoupled at PDM. Subsequent enumeration of phytoplankton cells (dinoflagellates and diatoms), along with compound specific carbon isotope analyses, will provide information about variations in the taxonomic composition and sinking fluxes of primary producers. This project will help to identify the relative importance of key forcing mechanisms for the preconditioning of harmful algal blooms, thereby improving coastal management strategies in the LSLE and directly influencing public health, marine life, and the economy.

Application of ore deposit models for critical mineral assessments: examples from Maine, USA

John F. Slack[1,2]

1. U.S. Geological Survey (Emeritus), National Center, MS 954, Reston, Virginia 20192, USA <jfslack@usgs.gov>; 2. Department of Earth Sciences, Memorial University of Newfoundland,St. John's, Newfoundland and Labrador A1B 3X5, Canada

Evaluation of undiscovered resources of critical minerals and metals is greatly enhanced by the use of current ore-deposit models. Such models are crucial for the understanding of geological settings in which various deposits may occur, and how the presence of even small deposits and prospects can be highly prospective, when their settings are compared to those of major deposits elsewhere. Analysis of the potential in Maine is divided into two groups of deposits based on metal signature and geological setting. One group consists of known deposits (sediment-hosted Mn, volcanogenic massive sulphide, porphyry Cu-Mo, mafic- and ultramafic-hosted Ni-Cu[-Co-PGE], pegmatitic Li-Cs-Ta) that are in most cases relatively large, well-documented, and explored extensively. The second and much larger group of commodities comprises small deposits, prospects, and occurrences that are minimally explored or unexplored.

The qualitative assessment used here relies on three key criteria: (1) the presence of known deposits, prospects, or mineral occurrences; (2) geological settings that are favorable for containing certain deposit types based on descriptive and genetic ore-deposit models; and (3) geochemical anomalies in rocks or stream sediments, including panned concentrates. Geophysical data may be relevant in some cases. Among the 20 deposit types considered, a high resource potential is assigned to only three: (1) sediment-hosted Mn, within and near the large (~327 Mt @ 9.0 wt% Mn) Silurian deposits in northeastern Maine that constitute the largest resource of this metal known in the US; (2) mafic- and ultramafic-hosted Ni-Cu(-Co-PGE), represented chiefly by deposits within the Moxie mafic-ultramafic pluton of Devonian age in central Maine; and (3) pegmatitic Li-Cs-Ta, the largest being the Plumbago Mountain Li deposit (~10 Mt @ 4.68 wt% Li_2O_3) hosted by Permian(?) pegmatite in western Maine. In the Silurian sediment-hosted Mn-Fe deposits higher grades may occur in euxinic facies of the host black shales thus minimizing the Fe present in the deposits and in weathered Mn-rich oxide zones, such as exist in the giant orebodies of Groote Eylandt in Australia and Moanda in Gabon, respectively. The Moxie pluton is considered especially prospective because its elongate shape suggests formation in a magma conduit, like the dyke-sill complexes that host world-class Ni-Cu(-Co-PGE) deposits such as Noril'sk in Russia and Voisey's Bay in Labrador. Potential for pegmatitic Li deposits in Maine can be assessed by integrating relevant occurrences of spodumene and other Li-rich minerals with favorable geology including evidence of post-Acadian anatectic felsic magmatism.

Petrology and tectonic setting of the Park Spur pluton, central Cape Breton Highlands, Nova Scotia, Canada

Amanda M. Smith[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 <160000s@Acadiau.ca>; 2. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada

The Park Spur pluton (PSP) is located in the central Cape Breton Highlands, near the eastern margin of the Aspy terrane and its tectonic contact with the adjacent Bras d'Or terrane. The PSP has not previously been the focus of a petrological study, and hence this study was undertaken to determine the petrological characteristics of the pluton, including its potential for critical element mineralization, and to compare the pluton to the Black Brook Granitic Suite (BBGS) to the northeast and the Bothan Brook–West Branch North River granite (BB–WBNRG) to the south. Based on previously published U–Pb zircon ages, all three plutons have similar middle-to late Devonian ages of about 373 Ma, but their relationship to one another and tectonic setting are not well understood.

Thirty-seven samples were collected for petrographic study and a subset of twenty were submitted for whole-rock chemical analysis, including critical elements. As a result of field work and petrographic study, the extent of the pluton has been modified compared to published maps, and the pluton has been subdivided into three units. Most widespread is medium-grained muscovite-biotite monzogranite, intruded in places by pegmatite and aplite dykes. The northwestern tip of the pluton consists of finer-grained garnet-bearing muscovite monzogranite. An area of protomylonitic granite occurs along the southwestern margin of the of the PSP, near its contact with metamorphic rocks of probable Ordovician–Silurian age. Deformed granitic dykes occur in metamorphic units adjacent to the southeastern margin of the pluton. Both the dykes and deformed pluton margin are characterized by large K-feldspar grains with anastomosing texture of the surrounding quartz and plagioclase grains.

Most samples from the PSP contain 70–73% SiO_2 but the fine-grained muscovite monzogranite is more evolved, with 74–75% SiO_2. Variations in major element oxides with SiO_2 suggest that petrological variations were caused by fractional crystallization, an interpretation supported by negative Eu anomalies indicative of plagioclase removal. The rocks are enriched in light rare-earth elements up to 300 times chondritic values with flat heavy REE, although anomalous trends in some samples suggest involvement of accessory phases such as garnet and zircon. Comparison to the BBGS and BB–WBNRG shows that all three plutons are peraluminous with trace element compositions consistent with those of volcanic-arc to syn-collisional granites formed in association with slab breakoff. However, the BB–WBNRG lacks muscovite and shows chemical differences such as higher SiO_2, K_2O, Th, and Nb compared to both PSP and BBGS.

Bay St. George subbasin, Newfoundland, Canada: deformation of evaporites and wet sediment in a tectonically active basin

Morgan E. Snyder[1], John W.F. Waldron[1,2], and Paul Durling[3]

1. Department of Earth and Environmental Science, Acadia University, Wolfville Nova Scotia B4P 2R6, Canada <mesnyder@ualberta.ca>; 2. Department of Earth and Atmospheric Sciences, Edmonton, Alberta T6G 2E3, Canada; 3. Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia B2Y 4A2, Canada

The Bay St. George subbasin of SW Newfoundland, part of the larger late Paleozoic Maritimes basin, formed under the influence of strike-slip faulting and the movement of evaporites. New stratigraphic correlations between Newfoundland and other late Paleozoic subbasins illustrate the effects of both basement and salt movement. Coastal outcrops show complex combinations of synsedimentary, salt-related, and tectonic structures.

Map relationships and dramatic thickness contrasts in the Tournaisian Anguille Group indicate that a large, concealed, northeast–striking normal growth fault (here termed the Ship Cove fault) controlled sedimentation. An exposed structure, the Snakes Bight fault, originated as a hanging wall splay. Structures formed during, or soon after deposition in the Anguille Group include soft-sediment folds, boudins, clastic dykes, and millimetre-scale diapiric bulb structures formed by overpressuring and liquidization of sediment. These suggest that the subbasin was tectonically active throughout deposition of the Anguille Group, and that tectonic disturbance of sediment continued into the Visean, when the overlying Codroy Group was deposited. The Codroy Group originally contained thick salt units, interbedded with clastic and carbonate sediment. Former evaporite units are represented in outcrop by mudstone breccias, the residues of salt solution. Complex outcrop relationships indicate salt welds and suggest that units of the upper Codroy and overlying Barachois groups represent fills of minibasins that subsided into thick evaporites. Early expulsion of evaporites can explain otherwise enigmatic contrasts between laterally equivalent units.

Field relationships suggest tectonic inversion deposition related to E-W dextral strike-slip motion that affected the entire Maritimes basin in the Serpukhovian, producing reverse-sense offsets and contractional folds. Many of the structures in the Bay St. George subbasin, previously interpreted as post-depositional and purely tectonic, were formed by deformation of unlithified sediment and ductile evaporites during basin development and subsequent shortening.

Six years at Boat Harbour, Pictou County, Nova Scotia, Canada: a review of research on the spatiotemporal distribution of contaminants in pulp mill stabilization basin sediments

Ian Spooner[1], Kirklyn Davidson[2], Ballie Holmes[3], Dewey Dunnington[4], Tony Walker[5], and Craig Lake[3]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <ian.spooner@acadiau.ca>; 2. SGC Industries, Saint John, New Brunswick E2M 5Y5, Canada; 3. Centre for Water Resources Studies, Department of Civil and Resource Engineering, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada; 4. Voltron Data, San Francisco, California 94041, USA; 5. School for Resource and Environmental Studies, Kenneth C. Rowe Management Building, Halifax, Nova Scotia B3H 4R2, Canada

Boat Harbour is a sediment stabilization basin located in Pictou County, Nova Scotia that has been impacted by industrial effluents discharged by a bleached kraft pulp mill (1967 to 2019) and a chlor-alkali plant (1971 to 1992). The former estuary now contains >577,000 m^3 of unconsolidated sediment, impacted by inorganic and organic contaminants, including metal[loid]s and polychlorinated dibenzofurans (PCDD/Fs).

In the past 6 years over 100 gravity, percussion and piston core samples have been taken to determine contaminant spatiotemporal distribution of As, Cu, Pb, and Zn sediment concentrations which consistently exceeded guidelines for aquatic sediments. Results demonstrate that there is no distinct spatial trend in metal concentrations though effluent is introduced from a point source. High and variable concentrations of Cu and Zn in the contaminated sediment likely represent a combination of cation capture by the highly organic sediment and influence of the effluent from the pulp mill on lakebed sediment chemistry. Elevated Pb in the contaminated sediment is the result of atmospheric deposition from combustion of fossil fuels and bioaccumulation in the effluent feedstock. Temporal trends reflect changes in effluent treatment procedures as well as composition of effluent solids. Comparison of geochemistry of effluent influenced sediment and pre-effluent substrate sediment at Boat Harbour to freshwater and marine reference was required to understand the degree to which geogenic and anthropogenic sources of metal(loids) have influenced effluent chemistry. This research demonstrates that undisturbed, time transgressive samples from both impacted sites and reference sites combined with non-destructive, rapid, small sample analytical techniques such as X-ray fluorescence, provide an accurate assessment of sediment metal contaminant distribution, data required to guide remediation and environmental effects monitoring and compliance.

Petrology and lithogeochemistry of the Wildcat Brook Mo-W deposit, Charlotte County, New Brunswick, Canada

Cliff Stanley[1], Jacob Hanley[2], Abdul Asfour[2], and Patrick Crouse[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4N 2R6, Canada <cliff.stanley@acadiau.ca>;
2. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

The Wildcat Brook Mo-W deposit is located approximately 9 km east of the former Mt. Pleasant Sn-W-Mo mine in Charlotte County, New Brunswick. It is hosted by a leucocratic, quartz-feldspar porphyritic-to-aplitic, peraluminous, EW-striking, moderately north-dipping dyke. This intrudes turbiditic metasedimentary wackes and argillites of the Digdeguash Formation of the Fredericton Trough immediately north of the Magaguadavic granite of the St. George batholith. High-grade Mo mineralization up to +4% over one metre consists of molybdenite blebs up to 4 mm in diameter disseminated in small miarolitic cavities within albite- and muscovite-altered dyke, and medium-grade Mo mineralization at the margins or cores of 2–5 cm wide quartz veins cutting altered or unaltered dyke and adjacent metasedimentary rocks. Wackes adjacent to the dyke also contain up to 2 cm diameter rare white orbs of radially arrayed acicular crystals of powellite ($CaWO_4$) replacing the matrix and clastic grains. At present, the dyke has been intersected by 17 diamond drill cores spanning approximately 250 m along strike and dip. Dyke thickness ranges from 17 to 42 metres (averaging 27 m thick), and the dyke contains a sample length-weighted average grade of 0.27% Mo, and sample length-weighted average grade-meter product of 5.76% Mo × m, calculated from 325 samples, 25 of which have assigned grades of 0.4001% Mo, as their upper detection limit concentrations (>4000 ppm) have yet to be updated via re-assay.

Two styles of hydrothermal alteration occur in the dyke: albite-minor epidote, and muscovite-quartz. Molar element ratio analysis of 110 drill core samples, constrained by petrography, reveal that the addition of Na and loss of K accompanied albite alteration: Microcline + Na^+ => Albite + K^+ (-8 vol.%), and 4 Anorthite + 4 Quartz + 2 Water + 2 Na^+=>2 Clinozoisite + 2 Albite + 2 H^+ (+26 vol.%), and inverse material transfers, plus Ca loss, accompanied muscovite plus quartz alteration: 3 Albite + K^+ + 2 H^+ =>Muscovite + 6 Quartz + 3 Na^+ (-7 vol.%), and Clinozoisite + K^+ + 3 H^+=> Muscovite + Water + 2 Ca^{+2} (-0 vol.%). These alteration styles principally affect the dyke, but several greisenized hydrothermal compartments up to several metres width, bounded by quartz veins and containing coarse muscovite and minor Mo mineralization, occur above the dyke in drill core. Isolated high-grade wolframite-bearing quartz veins 4–8 cm thick also occur sporadically above the felsic dyke.

Discovery of Visean to early Serpukhovian (Mississippian) aged tetrapod burrows from Midland and Lepreau Falls, New Brunswick, Canada: an ichnological, palynological and seismic investigation of the Millstream Subbasin

Matthew Stimson[1,2], Steven Hinds[3], Olivia King[1,2], Duncan McLean[4], Lynn Dafoe[5], R. Andrew MacRae[2], and Adrian Park[3]

1. Department of Natural History, New Brunswick Museum, Saint John, New Brunswick E2K 1E5, Canada <mstimson29@gmail.com>;
2. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada;
3. New Brunswick Geological Survey, New Brunswick Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada;
4. MB Stratigraphy Ltd., Sheffield, S9 5EA, UK;
5. Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia B2Y 4A2, Canada

During the spring of 2018, residents Gary, David, and Rick Leblanc, found a near-horizontal burrow fossil within red sandstone along a ditch outcrop at Midland, New Brunswick. These red sandstones, minor conglomerates, and mudrocks are considered part of the undivided Mabou Group, which is Visean to Serpukhovian in age. This fossil burrow is about 50 cm long, has a maximum width of 10 cm, and is tentatively assigned to the ichnogenus *Katarrhedrites*, which is commonly ascribed to tetrapod burrowing activities. Other features of the burrow include an entry chamber, a complex tunnel structure with preserved digging scratches along the sides, and a terminal living chamber. A second, 50 cm scale, subhorizontal burrow structure was found within unnamed red beds of the "Mabou Group" at Lepreau Falls in 2020. This feature has no ichnological designation at present and is interpreted as a tetrapod burrow. In general, tetrapod burrows are extremely rare in the fossil record during the Carboniferous Period, limiting the knowledge of tetrapod dwellings (domichnia) during this interval. The only known occurrence of a Mississippian fossil tetrapod burrow occurs in the Mauch Chunk Formation (Chesterian or Arnsbergian), near Pottsville, eastern Pennsylvania, USA. The Mauch Chunk burrow appears to be near vertical, has no ichnological taxonomic assignment, and is approximately five times the size and diameter of the New Brunswick burrows. The age of the Mauch Chunk Formation was determined through paleobotany. Both palynology and macrofossil analyses from outcrop and boreholes were used at the Midland and Lepreau Falls fossil sites to determine their relative age. Using seismic and recent field mapping in Midland, shallow cross-sections were created that allowed the successful correlation of the fossil burrow locality to outcrops and adjacent boreholes over 20 kilometres northeast from the fossil burrow site along the axis of the Millstream Subbasin. The age of the Midland burrow (*Katarrhedrites*) can be constrained to Arnsbergian and younger; approximately time-equivalent to the Mauch Chunk Formation burrow. The tetrapod burrow from Lepreau Falls is assigned a Visean age and is older than the Mauch Chunk burrow. The presence of Visean burrows in the Maritimes Basin has ethological and paleoecological implications for the timing of fossorial tetrapods. The detailed stratigraphic work, palynology analysis, and geological mapping from boreholes and seismic profiles confirms the existence of the Millstream Subbasin, which was only inferred in previous literature.

Extent and timing of deformation and metamorphism associated with the Eastern Highlands shear zone, central Cape Breton Highlands, Nova Scotia, Canada*

Evelyne Sunatori[1], Deanne van Rooyen[2], Sandra M. Barr[1], and Chris E. White[3]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada <evelynesunatori@acadiau.ca>;
2. Department of Mathematics, Physics, and Geology, Cape Breton University, Sydney, Nova Scotia B1P 6L2, Canada;
3. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada

The Aspy and Bras d'Or terranes in northern Cape Breton Island are both interpreted as part of Ganderia in the northern Appalachian orogen but contrasts in rock types, ages, and magmatic, metamorphic, and tectonic history make their original relationship difficult to interpret. The two terranes were juxtaposed along the Eastern Highlands shear zone (EHSZ). In its northern part, the EHSZ strikes northeast and previous structural studies documented evidence for three deformational events between 424 Ma and 375 Ma and Bras d'Or-over-Aspy terrane sense of motion. The purpose of this study is to determine the extent and timing of deformation and metamorphism in the rocks within and adjacent to the EHSZ father south in the central Cape Breton Highlands where its location and history are less well constrained. Four main units occur in the study area: the Ordovician to Silurian Calumruadh Brook Formation (CBF) and Middle River metamorphic suite (MRMS) in the Aspy terrane, and the Neoproterozoic McMillan Flowage Formation (MFF) and Kathy Road dioritic suite (KRDS) in the Bras d'Or terrane. In the NE part of the study area (CBF in contact with MFF) the deformation is strongly partitioned into the CBF, and most foliations dip steeply to the NW. Lineations are variable so sense of motion is cryptic, but C-S fabrics suggest that the main shear plane is roughly E-W, with a moderate dip to the N. In the central part of the study area the KRDS is variably deformed, and deformation is most intense along its western margin where rocks are strongly lineated and foliated (L>S) for about 1.5 km into the diorite. The foliations dip moderately to the NW and lineations plunge moderately to the NW, suggesting that the main shear direction is top-to-the-SE (Aspy over Bras d'Or). In the south foliations in the MRMS and CBF dip very steeply to the W and kinematic indicators and mineral lineations suggest the main shear plane is oriented roughly N-S and the major S-directed motion was dextral in a transpressional setting. The metamorphic minerals in the rocks affected by the movement on the EHSZ are limited to chlorite (overprinting pre-existing amphibolite-facies metamorphism in the MRMS and upper greenschist facies metamorphism in the CBF), indicating that the activity on the shear zone in this area represents lower greenschist conditions and suggesting that rocks currently at the surface were buried <7 km when the shear zone was last active.

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

The application of melt inclusions to evaluate magma ore metal fertility, oxidation state, sulfur saturation, and volatile contents in the South Mountain Batholith, Nova Scotia, Canada

Anna Terekhova[1], Jacob Hanley[1], and Kevin Neyedley[1,2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <anna.terekhova@smu.ca>; 2. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada

The South Mountain Batholith (SMB), the largest granitoid body in the Appalachian orogen, outcrops over a large portion of central and western Nova Scotia. The SMB has been the target of sporadic mineral exploration since the late 1800s and mining in the 1980s (e.g., Sn greisen deposit at the East Kemptville Mine) while extensive research has yielded a comprehensive geochemical classification of the granitoids, with the distinction made between Phase 1 and Phase 2 plutons. However, there are no comparative studies that focus on the metal and volatile "fertility" of magmas associated with the formation of dominantly barren Stage 1 and commonly mineralized Stage 2 plutons in the SMB. Additionally, there have been no studies of melt inclusions in those intrusive rocks. This study will aim to quantify and compare the metal and volatile content, and oxygen fugacity of magmatic liquids from Stage 1 and Stage 2 plutons in the SMB. This will be done by analyzing aliquots of the former magmatic liquids directly from preserved silicate and sulfide melt inclusions (trapped samples of crystallized melt) hosted in zircon and combining high spatial resolution microanalytical methods (laser ablation-inductively coupled plasma mass spectrometry, scanning electron microscopy, Raman spectroscopy, electron microprobe analysis, and cathodoluminescence) with detailed zircon and inclusion petrography. Through the analysis of melt inclusions in zircon, and evaluation of associated physicochemical conditions, comparison of melt inclusion parameters within and between Stage 1 and 2 plutons will aim to identify differences in magmatic parameters that may have led to the differential metal associations and tenors of these plutons. The project will also aim to establish the temporal variations in melt and volatile composition, and associated entrapment conditions, as well as develop exploration indicators and mass balance constraints for the mineralized systems within Stage 2 plutons. The planned integration of coupled zircon-melt inclusion analysis to define the above parameters is innovative and will lead to quantitative, predictive criteria for differentiating barren or sub-economic from well-endowed plutonic suites.

Physical Geography 110: a new course for New Brunswick high school learners

Ann C. Timmermans[1] and Ryan Jones[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <ann.timmermans@unb.ca>; 2. New Brunswick Department of Education and Early Childhood Development, Fredericton, New Brunswick E3B 5H1, Canada

A new Physical Geography 110 high school course for New Brunswick learners is nearing completion. This endeavor has been co-led by the Department of Earth Sciences at UNB and seeks to replace the current course published in the middle 1990s. New curriculum writing supports the International Geoscience Syllabus and is consistent with the Earth Science Literacy initiative outlined by the National Science Foundation. The curriculum embeds the New Brunswick Global Competencies and United Nation's Sustainable Development Goals. Aspirational ideas for the enactment of this course include aspects of human knowledge, culture, and equity. For the final summative assessment, educators will be encouraged to engage learners in a comprehensive field project instead of a traditional paper-based exam. The new positioning of the Physical Geography 110 course will provide a science credit for graduation and the acquisition of science skills, and appeal to a broader range of learners and interests. Presenters will share aspects of the curriculum writing journey, gather feedback, and facilitate general Science Education discussion.

Dissolution features on diamonds from hypabyssal kimberlite facies and the effect of melt composition on diamond resorption

Rosa Toutah and Yana Fedortchouk

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

Diamonds can preserve features from their time deep in the Earth's mantle and their ascent from the mantle to the Earth's surface in hot kimberlite magma due to their high stability. The record of dissolution textures on diamond surfaces opens a window into the history of the diamonds journey through the kimberlite. Composition of kimberlitic fluid affects dissolution textures on diamonds from volcaniclastic kimberlite facies. The focus of this study is to identify different resorption styles of diamonds from hypabyssal kimberlite facies and use experiments in

volatile-undersaturated melt to determine the effect of melt composition on diamond resorption features. The study uses 1300 diamonds from 16 kimberlites from the Ekati Mine, selected hypabyssal dykes, and sills. This data obtained for class 3 kimberlites will be compared to the existing data on diamonds from class 1 kimberlites. SEM, AFM, and microscope imaging will be utilized for analysis of surface features. Secondary dissolution corrosion sculpture (CS) features seen on tetrahexahedra (THH) diamond faces will act as a proxy for kimberlite melt composition to allow for the identification of kimberlitic conditions in class 1 and 3 hypabyssal kimberlites. Experiments in a Piston-cylinder apparatus will quantify the effect of melt composition and temperature/pressure variation on the diamond dissolution features. The experiments are conducted between 1000–1200°C in silicate, carbonate, and silicate-carbonate melts at 1 GPa in "dry" or H_2O-undersaturated conditions. Experiments done in exact temperature pressure conditions with either silicate or carbonate melts have shown drastic differences in resorption styles and features. Diamonds in silicate rich melts under 1 GPa of pressure at 1100°C demonstrate strong resorption on the {111} and {012} faces whereas the same experiment in a carbonate melt demonstrates strong graphitization and little resorption. The established relationship between dissolution features on diamonds and composition of kimberlitic melt will allow a long-standing question to be addressed; if different kimberlite classes are formed by a uniform kimberlite melt due to difference in the country rock characteristics or due to compositional differences in kimberlite melt. In addition, use of surface features on microdiamonds from hypabyssal kimberlite facies for early identification of kimberlite class will help better planning for drilling programs and diamond grade assessment. This allows for saving on drilling costs and improves the modelling of kimberlite emplacement.

Geophysical exploration at Castle Frederick prospect, Upper Falmouth, Hants County, Nova Scotia, Canada

Fergus Tweedale[1] and Charles Banks[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <fergus.tweedale.gmail.com>; 2. 70 Country Club Lane, Falmouth Nova Scotia, B0P 1L0

A road-accessible aggregate quarry situated on crown land, 4.5 km west of Windsor Junction, exposes mineralization and is the designated geographic centre of Castle Frederick (CF) prospect. The east-facing quarry headwall strikes N-S, is 130 m in length and up to 3.5 m in height. Centimetre-scale sulphide (pyrite-galena-sphalerite)-barite veins of unknown lateral extent are hosted in megacrystic biotite-rich granitic phases of the South Mountain Batholith (SMB). The veins are spatially associated with brecciation and fault gouge, clearly not magmatic and considered hydrothermal in origin. Observations of drill core extracted from beneath the quarry confirm the sporadic occurrence of sulphide veining and carbonate veinlets to at least 125 metres depth. Presently, relative age of sulphides and carbonates is indeterminate. The CF quarry is situated <1 km from an unexposed late Devonian-Carboniferous contact, suggesting an unconformity cuts through the property. Proximal location of CF prospect to Walton Mine (barite-galena-sphalerite-chalcopyrite-silver) and the Millet Brook uranium showing further suggest prospective potential in Hants County. Sporadic drilling throughout the county and local magnetic anomalies identified in small-scale aeromagnetic surveys support this claim. An exploration tool suited specifically to areas around Windsor, Falmouth, and Windsor Junction would help clarify questions about potential mineralization, and the objective of this work is to determine if ground-based magnetic surveying is an appropriate exploration tool. Magnetometer data (nanotesla units) collected during repeat walking transects along a bisecting quarry road is interpreted to reveal a measurable magnetic-field-intensity anomaly associated with sulphide veining. Graphical representation of this data provides a visual reference for the interpretation of other field data collected in an unexplored 2 km^2 forested area. Except for a few metasedimentary rocks, boulders and outcrop in the study area are granitic. A second quarry, intersected by a transect path, exposes SW dipping mudstones and medium- to coarse-grained sandstones, confirming the presence (but not the location) of an unconformable contact. Conspicuous hematite veining cutting at least one sedimentary horizon suggests late Devonian–Pennsylvanian hydrothermal fluid circulation was not spatially restricted to the SMB.

The energy transition - our winter of discontent

Grant D. Wach

Basin and Reservoir Lab, Department of Earth and Environmental Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada <grant.wach@dal.ca>

Access to energy has been recognized by The United Nations Economic Commission for Europe (UNECE) as "critical for assuring quality of life", and at present 80 per cent of the energy usage in the UNECE region is fossil-fuel based. Many countries are reliant on non-renewable sources for their energy security and economic well-being, yet there is a growing global urgency to transition to a more sustainable energy future with increased dependence

on renewable energy sources, improved energy efficiency, and reduced global carbon emissions but at present this is being disrupted by severe spikes in energy prices, delivery networks, and the supply of both fossil and renewable energy systems.

Canada also has carbon reduction targets that the energy transition must help achieve. In Atlantic Canada, the provinces are in a unique position to become a green energy powerhouse, with reduced dependence on fossil fuels and to help lead Canada, and the World, in the transition to clean energy. An area tentatively called the Energy Corridor, straddling the New Brunswick and Nova Scotia boundary, has all the components for green energy success, including regular wind patterns in the nearby Gulf of St. Lawrence, salt deposits suitable for energy storage, and a central location with power links to the northeastern U.S.A.

Research into the Scotian and Sydney basins for carbon capture and storage (CCS) for emission reduction, renewable energy sources such as biomass, geothermal, tidal, hydrogen, and wind energy, and the energy storage potential in salt caverns will be discussed with other issues contributing to the overall energy situation in Atlantic Canada. This lecture will present an overview of the 'greening' of the Atlantic Canada provinces, review the vision for the energy future, and highlight opportunities to improve energy sustainability in the region. With energy costs spiking around the world, and a "winter of discontent" upon us, the Energy Transition is very important for Atlantic Canada and the World.

Stirring the Maritimes Basin: more than a pinch of salt

John W.F. Waldron[1,3], Alison Thomas[2], and Morgan E. Snyder[3]

1. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada <john.waldron@ualberta.ca>;
2. Department of Mathematics, Physics, and Geology, Cape Breton University, Sydney, Nova Scotia B1P 6L2, Canada;
3. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada

The Maritimes Basin of Atlantic Canada is a large and deep sedimentary basin underlying large parts of Atlantic Canada. The basin fill is predominantly late Paleozoic (Devonian–Permian) non-marine clastic sedimentary rocks, but the Visean Windsor Group, and the correlative Codroy Group of Newfoundland, contain substantial evaporites, including gypsum and anhydrite, halite, and potash. Laterally correlative limestone-evaporite-shale cycles have been traced throughout the middle and upper parts of the Windsor Group.

The role of Windsor evaporites in the tectonics of the Maritimes Basin has long been recognized. In addition to diapiric features generated by primarily vertical tectonics, there are extensive low-angle deformation surfaces characterized by anomalous breaks in the basin-wide stratigraphic succession. These breaks were originally interpreted as thrust faults, but later investigations, noting substantial omission of stratigraphy, led to their re-interpretation as a single low-angle detachment - the Ainslie Detachment. The availability of industry seismic reflection data allows these structures to be again reinterpreted as salt welds, in the light of recent advances in evaporite tectonics on passive continental margins.

For example, the famous Joggins Pennsylvanian succession was rapidly deposited in accommodation space created by salt expulsion, showing that Windsor Group salt remained in place until the Pennsylvanian before rapidly moving into diapiric salt walls. In contrast, in the eastern Cumberland subbasin, evaporite expulsion was already controlling sedimentation during Mississippian deposition of the Windsor and Mabou groups. Field relations in other parts of the Maritimes Basin suggest that this history of early evaporite expulsion is more usual.

These observations suggest an interpretation in which movement of the thick lower Windsor evaporites began within a few million years of their deposition. Feedback between halokinesis and sedimentation occurred from middle Visean onward. Multiple minibasins were simultaneously flooded by eustatic sea-level rises, related to glacial cycles on Gondwana, accounting for the laterally correlative limestones. Differences in the overlying stratigraphic successions are best explained, therefore, by deposition above a changing configuration of moving evaporite bodies that culminated in complete expulsion of salt beneath some minibasins.

The tops of evaporite diapirs have probably remained near the surface, producing areas of subsidence and karst development, throughout much of Nova Scotia's subsequent history. The distribution of near-surface evaporites continues to be marked by widespread development of sinkholes at the present day.

What drove the Acadian orogeny?

John W.F. Waldron[1,2]

1. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada <john.waldron@ualberta.ca>;
2. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada

Most orogenic events in the northern Appalachians and the Caledonides have relatively clear tectonic drivers. The Taconian–Grampian orogeny (latest Cambrian to Ordovician) represents a collision of the hyperextended Laurentian margin with a SE-dipping subduction zone. Salinian deformation (mainly Silurian) recorded accretion of Ganderian fragments at the now-active Laurentian margin, culminating in the Scandian collision of Baltica (already connected to East Avalonia along the 'Tornquist line'). Late Paleozoic Alleghanian deformation resulted from the arrival of Gondwana.

The Silurian (~423 Ma) to Devonian (~385 Ma) Acadian orogeny is more difficult to interpret. It is widely attributed to collision of Avalonia with Laurentia, following NW-dipping subduction recorded by the coastal igneous belt (Maine, New Brunswick, Cape Breton Island, and southern Newfoundland). Nonetheless the major nappes in the Acadian orogen in southern New England are rooted to the SE. The Acadian orogeny has been interpreted to involve major transpression, but authors have been divided as to whether that transpression was dextral or sinistral. Further complicating the issue is the 'Neoacadian' orogeny, a term used to describe shortening both in the Meguma terrane (~400 Ma), and much later (370–355 Ma) in New England, coincident with early extension in the Maritimes Basin in Atlantic Canada.

Transpression provides a potential solution to the enigma. In Scotland, a major tectonic mismatch occurs across the Great Glen Fault. To the NW, major Silurian Scandian deformation affected the Northern Highlands, where Grampian deformation was insignificant. In contrast the Grampian Highlands, to the SE, underwent major Ordovician Grampian tectonism, but were little deformed in the Silurian. British geologists have suggested up to 1000 km of sinistral slip, bringing these disparate terranes together in the Late Silurian to Early Devonian. Acadian sinistral transpression is widely reported through southern Britain, though overprinted by dextral shear in the Carboniferous.

Because of the shape of the Laurentian margin, sinistral deformation of this magnitude would have led to transpression in the Appalachians, consistent with sinistral Acadian shear zones in Newfoundland (Gander terrane), Cape Breton Island, northern Maine, and southern New England. This convergence may have brought West Avalonia into oblique collision with the NW-dipping subduction zone that fueled the coastal igneous belt. Collapse of the Mascarene backarc led to the vergence change responsible for the southern New England nappe pile. A change to dextral motion in the Middle Devonian overprinted Acadian structures, leading to Neoacadian transpression in New England but transtension in Atlantic Canada.

Introducing a new addition to the Atlantic Geoscience Society's geological highway map series: *'Journey through time: places of geological significance in New Brunswick and Prince Edward Island'*

Jim Walker[1], Erin Keith[2], Jolane Sorge[2], and Kathleen Thorne[2]

1. New Brunswick Department of Natural Resources and Energy Development,South Tetagouche, New Brunswick E2A 7B8, Canada <jim.walker@gnb.ca>; 2. New Brunswick Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada

The Atlantic Geoscience Society (AGS) undertakes a wide range of communication and educational activities and projects, one of which is the publication of geological highway maps. One of the newest (soon to be released) maps in this series, entitled: *'Journey through time: places of geological significance in in New Brunswick and Prince Edward Island'* is an updated version of the 'Geological Highway Map of New Brunswick and Prince Edward Island' (AGS Special Publication Number 2) that was published in 1985. Since that time, substantial advances have been made in the understanding of New Brunswick's geology; primarily due to work carried out by the province's Geological Survey but also with significant contributions from researchers at local universities and colleagues with the Geologic Survey of Canada. It is for this reason that the decision was made to release this new map.

The new map will be a digital product measuring 68.5 x 99 cm (27″ by 39″) from which hard copies can be printed. The front side of the map presents New Brunswick's geology at the Group level with a shaded relief background and includes an up to date (somewhat simplified) provincial road network, and major water courses. The map highlights points of geological interest (84 in New Brunswick and 7 in Prince Edward Island) that are accompanied by short descriptions of their geological attributes. These sites were selected on the basis of geologic interest, geographical distribution, ease of access and safety. The reverse side of the map is divided into 16 sections providing more detailed information on a variety of topics including the geological-tectonic history of the region, specific metallic and industrial minerals and petroleum resources, the geology of New Brunswick's parks (e.g., Mount Carleton Provincial, Fundy National, Stonehammer Geopark, and Hopewell), the paleontological riches, glacial geology, and coastal zone issues pertaining to climate change. Many of the points of interest or back panel sites are described in greater detail in the 'Geology of New Brunswick and Prince Edward Island' field guide published by Hickman Hild and Barr in 2020, and are identified as such for those searching for more in-depth descriptions.

The map is intended to provide the neophyte a rudimentary understanding of the complex bedrock and glacial geology and how that geology relates to landforms and mineral endowment. It is anticipated that this map will be popular with the public, used in schools and university earth science classes, and will increase the profile of geoscience in New Brunswick, Prince Edward Island, and beyond. It will also serve as the base for a proposed extended digital version (downloadable app) of New Brunswick's geological points on interest.

Progress report on northern Maine geology: new data and thoughts on the extent and geologic history of the Munsungun–Winterville Belt

Chunzeng Wang

University of Maine at Presque Isle, Presque Isle, Maine 04769, USA <chunzeng.wang@maine.edu>

The Munsungun–Winterville Belt (MWB) is a major Ordovician lithotectonic belt developed on the leading edge of the ensialic Ganderia in northern Maine. Recent mapping reveals a much wider extent of the belt, and the belt includes 11 inliers of various sizes. In addition to the Munsungun, Winterville, Portage Lake, Haystack Mountain, and York Ridge inliers, the belt also contains several much smaller ones, including the small inliers in the headwater of the East Branch Penobscot River and Aroostook River. The MWB is believed to connect the Caucomgomoc inlier, Chesuncook "dome", and Lobster Mountain "anticlinorium" in the SW, as part of the Bronson Hill–Popelogan arc. The MWB and the overlying cover strata occur as a widespread imbricated stack of multiple NE-striking reverse-thrust faults that resulted from a prolonged faulting history starting from the earliest phase of Salinic orogeny to the Neoacadian–Alleghanian orogenies. Several small inliers even occur entirely as fault blocks. The MWB is composed predominantly of several NE-striking petrographically and geochemically distinct volcanic units that were formed in different tectonic settings. Most of them exhibit calc-alkaline or tholeiitic arc signatures, with the remaining lesser ones having tholeiitic non-arc affinity. Zircon U–Pb ages of the calc-alkaline and tholeiitic arc volcanic rocks show a generally NW-younging trend across the MWB, from 471 Ma to 451 Ma, probably indicative of northwestward trench-arc migration, likely associated with a prolonged SE-dipping, retreating subduction system between Laurentia and Ganderia. The tholeiitic non-arc volcanic rocks were produced in extensional setting (back-arc or intra-arc rifts) and probably associated with the NW-directed Brunswick Subduction System from Late Ordovician to Early Silurian. Detrital zircon age spectra and sedimentary features of several minor Upper Ordovician syn-tectonic forearc formations deposited along the MWB indicate a Laurentian provenance, suggesting that, immediately after the accretion of the Munsungun–Winterville arc to the Laurentia margin during closure of the Iapetus Ocean during the Late Ordovician, the rapid exhumation facilitated the deposition of the detritus derived from the accreted Laurentia over the MWB. Subsequent Salinic and Acadian orogeneses significantly reshaped the MWB as indicated by the widespread unconformities of the foreland Silurian formations and Devonian Seboomook Group and the large-scale reverse/thrust faults. The large post-Acadian, plant fossil-rich molasse basins (aged Emsian) discovered recently marked the end of the Acadian orogeny, but a NE-striking, SE-directed reverse/thrust fault system significantly displaced the basins, indicating a remarkable Neoacadian–Alleghanian faulting event in the northern Maine Appalachians.

Late-Triassic epithermal polymetallic Sb-Au (-Pb-Zn-Co-Ag) veins, Meguma terrane, Canadian Appalachian orogen: a new critical metal deposit type in Nova Scotia

Naomi Welt[1], Joshua Jackman[1], Erin Adlakha[1], Jacob Hanley[1], Mitchell Kerr[1], Robert Creaser[2], and Geoffrey Baldwin[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada <naomi.welt@smu.ca>; 2. University of Alberta, Department of Earth and Atmospheric Sciences, Edmonton, Alberta T6G 2R3, Canada; 3. Nova Scotia Department of Natural Resources and Renewables, Halifax, Nova Scotia B3J 2T9, Canada

A multi-analytical approach has been applied to the characterization of a little-known polymetallic (As-Sb-Zn-Pb-Fe-Cu-Co-Au-Ag) vein-hosted occurrence in the Digby area of southwestern Nova Scotia, called the Lansdowne occurrence. This occurrence has been selected as a case-study to further understand critical metal endowment of the Meguma terrane, the outward-most terrane of the Canadian Appalachians. Detailed petrography along with mineral chemistry, and Re–Os geochronology of arsenopyrite in mineralized zones constrain two distinct periods of mineralization: the early stage (composed of arsenopyrite), which formed at ~365 Ma, and the more dominant late stage (composed of early sphalerite, chalcopyrite, and pyrrhotite, followed by later arsenopyrite, galena, and Sb-Pb sulfosalts boulangerite and jamesonite), which formed at ~214 Ma. These two mineralizing stages coincide temporally with major tectono-magmatic events affecting the Meguma

terrane: (i) the waning stages of the Neoacadian orogeny and emplacement of the South Mountain Batholith (early stage), and (ii) rifting of the Bay of Fundy, due to the opening of the Atlantic Ocean from the breakup of Pangea (late stage). Results of Al-in-chlorite thermometry associated with early sphalerite of the late stage indicates chlorite formation at 350 to 390°C. Fluid inclusion petrography, microthermometry, and Raman spectroscopic analyses indicate two mingling fluids during the Sb-Pb sulfosalt stage: a variable salinity (6.16 – 27.35 wt% eq. NaCl) aqueous brine and a methane dominated fluid. Isochore calculations suggest epithermal conditions for Sb-Pb mineralization (approximately 165°C and 15 bars). High and positive S isotope values of sulfides ($\delta^{34}S$ = 14.7‰ to 25.1‰) suggest a sulfate source for S. An increase in $\delta^{34}S$ values from early to late stage arsenopyrite (15.30‰ to 23.95‰) suggests recycling and re-precipitation of early-stage sulfides (up to 30%) to form the late-stage sulfides. Base metals are likely sourced from surrounding country rock (mafic sills and host metasedimentary rocks) because of their alteration to calcite-chlorite, but sources of As and Sb remain unknown. Comparisons can be drawn between the Lansdowne occurrence to other Au deposits in the Meguma terrane (e.g., West Gore deposit), as well as other epithermal Sb-Au vein-type occurrences worldwide, such as those of the Variscan orogen in western Europe (e.g., the Berga Antiform of eastern Germany or the Biards Sb-Au-bearing shear zone in central France). The results of this project support exploration of this newly classified deposit type for critical metals in Nova Scotia.

A new edition of Atlantic Geoscience Society's Geological Highway Map of Nova Scotia

Chris E. White[1], Angie Barras[1], Sandra M. Barr[2], Jeff Poole[1], and Robert Raeside[2]

1. Nova Scotia Department of Natural Resources and Renewables, 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

The Atlantic Geoscience Society (AGS) undertakes a wide range of communication and educational activities and projects, one of which is the publication of the Geological Highway Map of Nova Scotia. Three editions of this map have been published previously, in 1980, 1990 (repackaged version in 1994), and 2005 (reprinted in 2014). The maps show the road systems of Nova Scotia and, using colours, the types of bedrock that occur at the surface throughout the province. The map is intended to encourage people to observe and help them to understand the origins of the varied geological features visible from their vehicles as they travel through Nova Scotia or visit coastal sections and viewpoints. The understanding of the bedrock geology has improved since 2005 because of new bedrock mapping by government and university geoscientists combined with other studies, especially geochronology. Hence it is timely to produce a fourth edition of the map that includes not only updated geological interpretations but also the current road network, which has changed since 2005. Like the 2005 edition, the product will be a digital map from which hard copies will be printed on a sheet size of 27″ by 39″; in addition, the option of producing a software application to be accessible on digital devices is being explored. The layout of the map is similar to the 3rd, with one side showing the geological map at the same scale as the third edition. The associated Table of Formations uses the 2021 International Chronostratigraphic Chart as the time scale. Also included is information on how to use the map, a symbols key, representative block diagrams, and a list of geological sites of interest. The reverse side provides more detailed maps and descriptions of particular areas that are well known and accessible, including Joggins, the Cabot Trail, the Parrsboro–Five Islands area, Scots Bay–Burntcoat Head, Yarmouth–Cape St. Marys, Arisaig, Halifax, and Louisbourg. The descriptions emphasize rock types, minerals, fossils, structural features, landforms, and glacial history. It is anticipated that the 2022 edition of the Geological Highway Map of Nova Scotia will continue to be used in schools and university earth science classes as part of the course material, an integral part of the annual EdGeo Workshops, and a product sought by residents and visitors to the province.

Characteristics of metamorphic textures of the Loch Eil Group of the Moine Highlands

Julie Woods and Richard Cox

Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada. <jl569631@dal.ca>

Recent studies on the Moine Supergroup suggests that ages over a large extent have been poorly constrained, and lack of research conducted is a result of structural complexity and mineralogical monotony. The purpose of this research is to fill in said gaps in knowledge and data, with the following research question: how many metamorphic events are being recorded in the rocks of the southern Moine Highlands. It is hypothesized that there are 2 events at 800 Ma, caused by different phases of the Knoydartian event, 1 event at 450 Ma, caused by the Caledonian event, and possible contact metamorphism at 425 Ma, caused by the Strontian granitic intrusions. The methodology being implemented consists of microscope analysis to broadly identify mineral assemblages and metamorphic textures in the samples, followed by major element analysis conducted on an electron microprobe, which is then proceeded by X-ray mapping of garnet grains present in the samples, U-Th-Pb analysis of monazite grains to help establish a range of ages, and geothermobarometric modelling to establish temperature and pressure conditions of the samples. For this research, garnet geothermobarometers such as GASP, GMBP, and garnet-biotite-plagioclase-quartz will be used, and the data being inputted into the models will be extracted from major element analysis. The mineral assemblages present in the four samples used in this study show varying percentages of quartz, feldspars, and micas, with garnet and monazite having abundance in one sample. Primary metamorphic textures present are symplectite, undulatory extinction, and schistosity. Current limitations are due to; overprinting, which affects age precision; distinguishing between older and younger fabrics; deciphering between competing P-T paths; and a lack of aluminosilicates in the samples.

Biogeochemical cycling within the Grand Lake Meadows floodplain. New Brunswick, Canada

Regan Worden and Allison Enright

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

Grand Lake Meadows is Atlantic Canada's largest freshwater wetland, providing flood storage for the lower Saint John River basin. Each spring, the spring freshet submerges the 5000ha floodplain with high stand floodwater that transports essential particulate and dissolved nutrients to the wetland. These nutrients supply the sediment-hosted microbial community with organic carbon and other reduced ions which are energy sources for chemotrophic metabolic processes. The microbial consortium performs a variety of critical biogeochemical tasks, such as fixing N, C, and S that are used by higher trophic level organisms. In this way, microbial processes underpin the distribution of elements and energy for the entire ecosystem. Thus, the annual flooding cycle and associated transportation of nutrients are important energy sources to the floodplain. As New Brunswick experiences more frequent and severe flooding due to climate change, the timing and volume of the spring freshet becomes increasingly unpredictable. In high-water level years, such as 2018, floodwater reaching industrialized areas could negatively influence the chemical characteristics of the incoming water.

By creating a multivariate geochemical dataset of the Grand Lake Meadows floodplain, the aim is to determine a healthy geochemical baseline against which the geochemical and ecological impacts of future extreme floods can be measured. Providing a healthy baseline reference of this wetland aids as a protective strategy to quantify the effects of flooding on the wetland and critical biogeochemical cycling occurring. The study focuses on the microbially-mediated redox chemical reactions that fix critical nutrients (i.e., N, C, S) into the biosphere, over the duration of a flood pulse to determine modes of biogeochemical cycling within Grand Lake Meadows. By providing this knowledge, a baseline assessment will make it possible for investigators to mitigate negative impacts of flooding and climate change on freshwater wetlands in New Brunswick.

Petrogenesis and geochemistry of the Late Devonian Eagle Lake Granite and its association with Cu-Au-Mo mineralization in southwestern New Brunswick, Canada

Fazilat Yousefi[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 <fazilat.yousefi@unb.ca>;
2. Geological Surveys Branch, Department of Natural Resources and Energy Development, Fredericton, New Brunswick E3B 5H1, Canada

The Late Devonian Eagle Lake Granite is an elongate 1.2 km-long hypabyssal stock located in southwestern New Brunswick just south of the Belleisle Fault. Copper, Mo, and Au mineralization is associated with this pluton and related dykes (15 cm to <1 m in width) that intruded Silurian meta-basic units of the Kingston Group. The granite comprises phenocrysts and microcrystalline groundmass of quartz, K-feldspar, and plagioclase (exhibiting oscillatory zoning), with minor biotite (primary, re-equilibrated, and secondary), magnetite, titanite, and apatite. The groundmass of these variably porphyritic rocks is medium-grained hypidiomorphic granular with an average grain size of two millimetres, whereas the fine-grained variety averages 0.05 mm in size. A zircon U–Pb age of 363.2 ± 4.2 Ma was determined for this granite using laser ablation methods. Based on the SiO_2 content, the Eagle Lake Granite can be further subdivided into three groups: (a) 69–70% SiO_2; (b) 71–73% SiO_2; and (c) 75–76% SiO_2 with group (a) consisting of porphyritic varieties restricted to the external parts of the stock; these three phases are peraluminous magnesian I-type granite (A/CNK = 1.0–1.3). In these rocks the ratio of Fe_2O_3/FeO is about 1.11 and Mg/(Fe + Mg) is 0.09–0.60. Based on the $Na_2O + K_2O$-CaO versus SiO_2 diagram, they plot in the range of calc-alkaline and alkali-calcic field. Electron microprobe analyses of biotite crystals indicates the calc-alkaline nature of the Eagle Lake rocks.

The Eagle Lake rocks are enriched in large ion lithophile elements (LILE), depleted in high field strength elements (HFSE) with positive anomalies of K, Rb, and negative anomalies in Ti and Nb. The Zr content of the Eagle Lake samples ranges from 15 to 170 ppm and Nb contents range from 7.2 to 9.2 ppm. The Zr/Ti, Zr/Y, and Nb/Y ratios are consistent with calc-alkalic granites. The mineralogical, petrographic, and geochemical characteristics of the three phases are consistent with volcanic arc granites; these are consistent with the NB-2 granites in the region that are associated with Cu-Mo mineralization. Their magnesian bulk composition and magnetite-titanite assemblage with Mg-biotite are consistent with a higher oxidation potential, although local ilmenite with sulfides supports local reduction, possibly via assimilation. The similarity in age and composition to the DMd1 phase of the Mount Douglas Granite suggests a related late tectonic origin. These Late Devonian intrusions have an elongated shape, somewhat parallel to the regional faults, suggesting that faulting played a role in their high-level emplacement.

Feldspar, biotite, and magnetite phenocrysts with groundmass compositions from the Benjamin River South Porphyry Cu-Mo-Au deposits, northeastern New Brunswick, Canada: analysis of primary, re-equilibrated, and hydrothermal forms

Fazilat Yousefi[1], David R. Lentz[1], and James Walker[2]

1. Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada <fazilat.yousefi@unb.ca>;
2. Geological Surveys Branch, Department of Natural Resources and Energy Development, South Tetagouche, New Brunswick E2A 7B8, Canada

The Early Devonian (400 Ma) Blue Mountain Granodiorite Suite (BMGS) underlies an area of approximately 80 km^2 in the Benjamin River South area of northeastern New Brunswick. Porphyry-related copper and molybdenum deposits occur in the northeastern part of BMGS; these hypabyssal intrusive rocks range in composition from tonalitic to granodioritic. These rocks contain phenocryst to phenoclasts of subhedral hornblende (2%), subhedral biotite (8–12%), euhedral and subhedral prismatic plagioclase (42–47%), and anhedral magnetite (≤ 0.5%) in a fine- to medium-grained granular groundmass consisting of anhedral quartz (25–27%) and subhedral alkali feldspar (6–11%). Partial chloritization of some biotite is evident. These intrusions have an adakitic affinity.

In addition to the lithogeochemical data, biotite chemistry supports a calc-alkaline orogenic affinity. Furthermore, a range of Fe-biotite compositions, that fall mostly in the re-equilibrated biotite field on the FeO^{tot} + MnO - (10*TiO_2) - MgO discrimination diagram, confirms that both phenocryst and groundmass biotite formed over a protracted period in an evolving magmatic-hydrothermal system. These data indicate primary or modified primary igneous biotite compositions as well as hydrothermally generated compositions. Plagioclase in the BMGS is mostly anorthite, which is indicative of Ca-metasomatism. Quartz is released and anorthitic feldspar is formed in solid solution in plagioclase: $2(K,Na)AlSi_3O_8 + Ca^{2+} \rightarrow CaAl_2Si_2O_8 + 4SiO_2 + 2K(Na)^+$

The composition of iron and titanium oxide minerals is between magnetite and ilmenite. Magnetite is a common accessory phenocryst and is stable over a wide range of conditions in igneous rocks and in a diversity of ore deposit types. An initially oxidized I-type magma can generate features of ilmenite-series (reduced) intrusions if the magma is subsequently emplaced into rocks with low redox potential. The presence of pyrrhotite in some samples is an indicator of increasing fH_2S with decreasing T of the hydrothermal fluid. The formation of ilmenite exsolutions is controlled by the oxidation of ulvospinel at temperatures above the magnetite-ulvospinel solvus: ($6Fe_2TiO_4 + O_2 \rightarrow 2Fe_3O_4 + 6FeTiO_3$). In the BMGS, hydrothermal alteration is widespread and commonly zoned on the deposit scale, as well as around individual veins and fractures. Porphyry deposits commonly exhibit an inner potassic zone characterized by K-feldspar and/or biotite, thence outward into a zone of phyllic alteration (quartz, pyrite, and phengite), and finally an outer most zone propylitic alteration (epidote, chlorite, and carbonate); sulphides and biotite form along micro-fractures, with the chalcopyrite-pyrite mineralization (up to 5%, with molybdenite), occurring as disseminations in potassically altered upper part of the cupolas and is consistent with the mineralization and alteration of the potassic zone of many porphyry systems.