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Atlantic Geoscience Society

ABSTRACTS

41st Colloquium & Annual General Meeting 2015

SACKVILLE, NEW BRUNSWICK

The 2015 Colloquium & Annual General Meeting was held at Mount Allison University, New Brunswick, on January 30 and 31, 2015. On behalf of the society, we thank Colloquium organizers Melissa Grey, Tim Fedak, Rob Raeside, and Elisabeth Kosters, as well as the numerous student volunteers, for facilitating an excellent meeting. We also wish to acknowledge support from the corporate sponsors: Joggins Fossil Cliffs; Acadia University; Corridor Resources Inc.; Potash Corporation; Geoscientists of Nova Scotia; Fundy Geological Museum; and Mount Allison University.

In the following pages, we are pleased to publish the abstracts of oral and poster presentations from the meeting, which included the following special sessions: (1) Palaeontology in Atlantic Canada, a session in recognition of the work of Laing Ferguson; (2) Geoscience Education and Outreach: Past Successes and New Initiatives; (3) Hypabyssal Magmatic Hydrothermal Processes and Associated Mineralization; and (4) Current Research in the Atlantic Provinces.

In addition, the AGS Travelling Speaker Series took place January 29 with a talk entitled "Arsenic in Groundwater" by Cliff Stanley. Also included with the conference was a Geoheritage Workshop to explore issues and applications of Nova Scotia's Geoheritage List in promoting awareness of Earth Science both on the ground and through GIS and other apps, community economic development possibilities, and specific events for the upcoming year.

THE EDITORS

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In situ spectroscopic studies of the Mo-H-O system to 500°C and 150 MPa

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Fluid inclusion evidence suggests that aqueous fluids of intermediate density play an important role in the transport of molybdenum in ore-forming hydrothermal systems associated with hypabyssal intrusions. In order to better understand the solubility and speciation of Mo in such supercritical fluids, a method has been developed to directly investigate the Mo-H-O system at elevated pressures and temperatures using complementary X-ray and vibrational spectroscopic techniques. In this communication we describe a novel procedure for in situ solubility measurements of minerals, and present new data on the solubility of molybdenite and on the local structure of Mo aqua ions in aqueous fluids of intermediate density at temperatures and pressures up to 500°C and 150 MPa, respectively.

Seismic strain and the state of stress in the crust of the Himalaya*

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The Himalayan orogen is characterized by a series of north-dipping thrust faults and shear zones formed as a result of the ongoing convergence of the Indian and Eurasian tectonic plates. The Main Frontal Thrust (MFT) and the Main Boundary Thrust (MBT) span the entire length of the orogen and merge at depth into the Main Himalayan Thrust (MHT) – the basal detachment of the Himalaya. The majority of seismicity is concentrated along a belt located approximately 100 km from the mountain front. Most of the available focal mechanisms yield solutions compatible with thrusting along a ramp of the MHT. In a section of the eastern Himalaya the seismic belt is interrupted and there have been no major seismic events in written record. Since the geodetic convergence rates in the eastern Himalaya are higher than in the west, and the lithology does not change significantly, the lack of seismicity in this area is puzzling. This study uses records of crustal seismicity to determine and quantify changes in seismic strain along strike of the orogen.

The Himalaya was separated into five geographic regions and fault-slip inversion was performed on the related seismic data. Fault plane solutions show a prominent thrust fault regime in the seismic belt of the western to central Himalaya and a normal fault regime directly to the north. From west to east, the normal faults indicate NW-SE to W-E extension which is interpreted as the result of faulting along the south Tibetan grabens. In contrast, a strike-slip fault regime is dominant both in the eastern Himalaya (east of 87°E) and to the south of the Himalaya in the Shillong Plateau. The latter is the only elevated area outboard the Himalaya and is one of the most seismically active areas covered in this study. Along the entire Himalayan arc the orientation of the kinematic axes and of the principle stresses changes progressively with the curvature of the orogen. However, from west to east we observe a sudden change in the relative size of the principles stresses.

Understanding how the geometry of seismic strain changes throughout the Himalaya is necessary in order to properly assess where stresses might be accumulating, as infrastructure in northeastern India would not withstand a large-magnitude earthquake.

Winner of the AGS Rupert MacNeill Award for best undergraduate student oral presentation

Using biotite composition of the Devonian Mount Elizabeth Intrusive Complex, New Brunswick, as a proxy for magma fertility and differentiation in W-Mo-Au-Sb mineralized magmatic hydrothermal systems

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The Early Devonian (418 ± 1 Ma, monazite U-Pb) Mount Elizabeth intrusive complex, New Brunswick, Canada, is a multiphase metaluminous to weakly peraluminous, high K calc-alkaline body that shows within-plate affinity. The complex consists of apparently contemporaneous igneous suites including a mafic suite, an eastern peraluminous granite suite, and a western alkali granite suite. The eastern part comprises a compositionally and texturally homogeneous biotite granite, whereas the western part is mostly heterogeneous and contains five different units. The most abundant unit of the western suite is a medium- to coarse-grained alkaline equigranular granite. This complex is poorly exposed so that most of the available interpretations, including inferred contact relationships, are based on geophysical data. It should be added that no mineral occurrences have been reported so far from this complex.

Fresh biotite from this intrusion was analysed from core to rim by electron microprobe, and laser ablation-ICP-MS at the University of New Brunswick to test whether biotite preserves a record of magma evolution in terms of major- and trace-element and halogen compositional variations. Subhedral to elongate biotite phenocrysts are less than

700 µm long and reddish brown in colour indicative of a reduced I-type source. A calc-alkaline affinity is also suggested by biotite major element classification schemes. Biotite is locally altered to chlorite along cleavage planes, and typically contains iron oxides, monazite, ilmenite, apatite, xenotime, and zircon as mineral inclusions.

Results of electron microprobe and laser-ablation ICP-MS studies indicate that biotite grains are homogeneous in major elements; however, they show variation in trace elements from core to rim. The biotite grains investigated have the highest Sn, W, Sb, and Mo concentrations recorded thus far among Devonian granitoid intrusions of New Brunswick (130, 40, 1, and 3 ppm, respectively). There is no systematic correlation between major elements including Fe_{Tot}, or Fe_{Tot}/Ti and any of these trace elements. To further study trace-element distribution, a biotite from each of the phases was mapped with laser-ablation ICP-MS revealing patchy Ba, Rb, and Cs zoning. These patterns are interpreted to be a result of localized hydrothermal alteration and intracrystalline volume diffusion in these biotite grains. The intracrystalline distribution of Sn, W, Mo and Sb is homogeneous. Furthermore, halogen contents analysed by EPMA indicate that hydroxyl is the dominant component of hydroxyl site followed by fluorine. It also showed that these biotites formed from strongly contaminated and reduced I-type granite. As a result, high concentration of Sn in biotite is interpreted to be caused by crustal contamination, and low-temperature hydrothermal processes (sub-solidus) rather than being magmatic in origin.

Determining the heterogeneity of reference materials

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A new method is proposed to determine the heterogeneity of a reference material to separate the analytical and inter-lab errors from the standard deviation. Reference materials are used by geoscientists to assess the quality of a geochemical analysis. Certified Reference Materials are reference materials for which an accepted concentration and standard deviation have been determined by independent labs. Ideally, geoscientists can use Certified Reference Materials to determine laboratory error, and apply it to geological samples with a similar concentration and matrix. However, the accepted standard deviation is a function of Certified Reference Material heterogeneity, lab error, and inter-lab error. Inter-lab error is caused by variations in procedure between the laboratories that determined the certified values. Furthermore, the accepted standard deviation only applies to the sample mass for which the element was certified. Procedures using a larger sample mass will have less variance and procedures using a smaller mass will have more variance. It is possible to algebraically separate the analytical and inter-lab errors from the standard deviation by analyzing both small and large samples. This approach uses the product of the sample mass and the variance to express sample heterogeneity which can be applied to any sample mass.

A geological compilation map of Cape Breton Island, Nova Scotia, Canada

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Cape Breton Island is well known for its scenic vistas, economic resources (e.g., coal, gypsum, sulphide deposits), and diverse geology. All three are related to its long and complex geological history, including the oldest and youngest geological units in Nova Scotia. This history, akin to that of Newfoundland and New Brunswick, makes the island an important target for economic resource exploration; however, such work is hampered by the lack of a consistent set of detailed geological maps. This project is aimed at producing such maps at a scale of 1:50 000 covering the entire island and incorporating all bedrock geological units. The maps will be supported by a database including outcrops locations, structural information, samples, geochemical, and magnetic susceptibility data.

The data are being compiled in an ArcGIS database, and the maps will include topographic contours, outcrops, and structural data draped on a shaded relief image. The data for Carboniferous units have been compiled mainly from previously published geological maps and databases of the Nova Scotia Department of Natural Resources and the Geological Survey of Canada. For pre-Carboniferous units, the data are derived in large part from digitation of decades of 1:10 000-scale field data in theses and reports by Barr and her students and colleagues at Acadia and Dalhousie universities. It is anticipated that the maps will be available by the end of 2015, although work on the database will be a longer term project.

Video as a tool in geoscience education

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In today's world, making a video is a spontaneous, daily activity for some. These vid clips (as they are commonly called) most often serve to entertain. To produce a video for education purposes is another matter, requiring detailed planning, varied expertise, and professional equipment. The Atlantic Geoscience Society (AGS) Video Committee has a long history and good reputation in the production of educational videos. This experience and knowledge is an excellent foundation on which to develop video clips (3–5 minute) for an outreach education audience. A number of other, reputable geological societies and surveys around the world have created video and audio products for their online audiences, and AGS needs to join this trend. The British Geological Survey, the Geological Society of London, the United States Geological Survey, and the New Zealand Geological Survey can boast of excellent traditional video clips as well as "artsy" clips that present a range of topics from geological history of their country, to trendy climate change and coastal erosion, to building stones of historical sites. Some groups also produce podcasts (audio only) that AGS could develop to enhance its geological-site publications. Atlantic Canada has untold geological stories waiting to be posted to the online world in this new format. To establish such a presence, AGS can choose to produce video clips of the sites highlighted in its "Nova Scotia Rocks" brochure or the field guides for the 20 years of Nova Scotia EdGEO Workshops and numerous Elderhostel programs. A quick mark could be made by posting a selection of stand-alone segments of AGS's professionally-produced videos (e.g., "Halifax Harbour: A Geologic Journey"). Establishing an AGS channel on You Tube, in addition to posting the clips and podcasts on the AGS website, would disseminate the works to a wider audience. Whatever the path, the AGS Video Committee has some busy and exciting days ahead.

Tracking rapid landscape change in Gros Morne National Park with time-lapse photography

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Parks and other protected areas can provide baselines for environmental monitoring, where the condition of landscapes and ecosystems away from direct human interference can be tracked in response to regional or global stresses, including climate change. However, despite efforts to maintain them in some static, pre-human "natural" state, parks, like landscapes everywhere, are subject to numerous non-human drivers of rapid change, involving physical, chemical and ecological processes. Within Gros Morne National Park in western Newfoundland, a personal project involving repeated (time-lapse) photography is helping to assess the current physical stability of certain coastal and inland sites. The result is a photographic record up to a century long, of slope failure by sagging, slumping, and rock falls, the development of stone rings and patterned ground, the formation of travertine deposits at sites of on-going serpentinization, the movement of rocks along intertidal platforms, changes to marine estuaries and to alluvial rivers and fans, and trends in late-lying snow beds along mountain tops. Other sites, where changes might have been expected, show little or none. The information derived from such studies can contribute to assessments of ecological integrity and general environmental "health". In Gros Morne, and for the towns and villages within and adjacent to the Park, this can assist in the management of public safety (landslides, rock falls, large-scale sags and coastal slumps), ecological integrity reporting, the protection of special sites (e.g., the C/O boundary stratotype at Green Point), and visitor interpretation programs. Involving local residents and school kids in similar projects can help to give them a clearer sense of the abiotic components of landscapes and the nature of contemporary geological change.

The diversity of life in braided river systems during the Late Triassic at Burntcoat Head, Nova Scotia, Canada

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Braided-fluvial deposits of the Late Triassic Wolfville Formation at Burntcoat Head have yielded important vertebrate bone material. The present study integrates fluvial sedimentology with the fossil record to gain a more complete understanding of the paleoenvironment and paleoecology. The Wolfville Formation was deposited within the extensional Fundy Basin during the break up of Pangaea. The 30 m studied section comprises channel bodies up to 6 m thick stacked to form three channel-belt complexes with planar bases, up to 13.5 m thick. The channel deposits comprise thin lags of mud-clast conglomerates, coarse- to fine-grained sandstones, interpreted as bedload deposits of bars and channel fills, and floodplain deposits that include pedogenically modified clay rich fine sandstones and claystones with carbonate nodules. Architectural elements include laminated sand sheets, lateral and downstream accretion macroforms, and sandy bedforms, with plane-bedded sandstones and large dunes prominent. Paleoflow was near parallel to the cliff line with an average direction of 057°.

Reworked partial skeletons and bone and teeth fragments reveal a substantial diversity of vertebrates. Collections at the Nova Scotia Museum of Natural History yielded over 60 specimens from the area, some specific to the studied interval. Bone fragments of tetrapods range from a few mm to over 20 cm in length and were found as clasts within mud-clast conglomerates and fine- to medium-grained sandstone. Recent discoveries from the site include the partial skeleton of an archosauromorph reptile, *Teraterpeton hrynewichorum*, and procolophonid reptiles including *Acadiella psalidodon*, *Haligonia bolodon*, and *Scoloparia glyphanodon*. Trace fossils transitional between Taenidium and Planolites are locally abundant within channel sandstones and floodplain fine sandstones and claystones. Plant fossils were not observed, but possible vegetation-induced sedimentary structures were documented.

The fluvial deposits formed near the paleoequator in a semi-arid climate with seasonal rainfall and high discharge, as indicated by thick plane-bedded sandstones, the abundance of scoured surfaces, and carbonate paleosols. Known localities of bone material are linked to the base of channel fills and in-channel dunes, and the matrix of other fragments suggests a similar setting. Burrows indicate that invertebrates were active in channels during periods of abandonment and in floodplain deposits, and a cryptic record suggests the presence of vegetation. The variety of taxa indicates that life flourished along these Triassic braided channels.

Coastal buried valleys: an unappreciated resource and potential hazard risk

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During glaciation, ice sheets occupied all of Atlantic Canada and parts of New England, significantly altering the landscape and changing drainage patterns. Pre-existing valleys were enlarged, new channels eroded and many valleys infilled with glacial sediments, some buried under ground moraine during glacier advance and others buried during glacier retreat. Deglaciation in many coastal areas was accompanied by frontal retreat of decaying glacier masses as isostatically depressed areas experienced marine transgression from rising sea level. New drainage patterns were developed where pre-glacial valleys remained buried or not fully exhumed by proglacial or Holocene-age fluvial down-cutting.

In some areas buried valleys exist as isolated remnants or conduits connected to lakes that can be used as potable groundwater aquifers (e.g., Sussex and Plaster Rock in New Brunswick). However, in coastal areas buried valleys often extend off-shore and can enable rapid infiltration and up-river migration of saline water as fresh water is extracted from aquifers farther inland. Examination of drill records in New Brunswick indicates that saline waters are found along some valleys at locations over 100 km from existing shorelines. This is demonstrated where the buried or existing estuarine valleys extend to depths greater than -60 m or -40 m, such as the Saint John River at locations 70 km and 90 km, respectively, upstream of the Bay of Fundy.

The occurrence of buried valleys and potential salinization of their resource aquifers remains a little studied hazard risk that has not be given the recognition and scientific attention that is required for the adequate protection of a sustainable resource.

Why we need to embrace the concept of geoheritage

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The concept of geoheritage may seem redundant or unnecessary to practicing geoscientists who do not engage either with the public or with politicians who are steered by public opinion, but at the peril of the sustained funding of geoscience. Gone are the days where geoscience is handed a blank cheque by funding agencies, or is given license by an unquestioning public. The concept of geoheritage was given form in Digne, France, in 1991, in the eloquent Déclaration Internationale des Droits de la Mémoire de la Terre (Declaration of the Rights of the Memory of the Earth). Early on, the concept was embraced primarily in Europe, where it fueled the explosion of European Geoparks. In recent years, the movement has been formally recognized by a dedicated journal Geoheritage, and specialist working groups of the IUCN and IUGS. Across Canada, the systematic documentation of each Province and Territory's geoheritage sites is gaining momentum. The purpose of a geoheritage list is to build public awareness of their geologic heritage and its influence on a region's cultural history. Geoheritage provides the best vehicle for public engagement, to help people better value geology and the role of geoscience in our lives. Specifically, a systematic geoheritage strategy has potential: (i) to be the best vehicle to make something tangible that is to most people intangible - the principles of geology; (ii) to open the doors of our scholastic towers to our fellow citizens, for their use in community-based economic development initiatives, including an essential role in identifying candidate Global Geoparks; and (iii) to reconnect a largely disconnected society with the Earth on which we depend. The realization of these goals is not just a 'feel good' exercise, but is vital to two great issues facing humanity: (i) access and limits of mineral and energy resources, by increasing public awareness of the connections between our cultural heritage and geology; and (ii) better understanding of current and future global change by consulting the geologic record. A systematic, site-based approach to Geoheritage recognition, now in place for Nova Scotia, lays the foundation for realizing these goals that lie at the heart of geoscience practice.

A potential marine paleo-earthquake record from Pond Inlet, Nunavut, Canada

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The area offshore Baffin Island is one of the most seismically active regions in Canada with an earthquake hazard similar to coastal British Columbia. One of the largest measured passive margin earthquakes (M 7.3) occurred off northeast Baffin Island in 1933 and many measurable earthquakes happen each year in that vicinity. A primary issue for assessing earthquake hazard in the region is estimating the recurrence of large earthquakes. Instrumented records only go back to the early 1900s and large earthquakes, such as the 1933 event, may have a recurrence of 100s to 1000s of years. In this study, the marine geological record was used in an attempt to improve the estimation of regional earthquake recurrence.

Pond Inlet forms part of the waterway that separates northern Baffin Island from Bylot Island. Multibeam bathymetry from the inlet, collected as part of ArcticNet activities, shows that the seabed consists of exposed bedrock and deep sediment-filled basins. The basin sediments provide a record of late glacial and post glacial processes. In some cases, the bathymetry data reveal faults and fractures in the bedrock that coincide with lineaments and escarpments on the basin floors. In 2013, a piston core was collected in 1035 m water depth from the floor of one of the basins near the base of an interpreted fault escarpment. The purpose of the core was to test the hypothesis that the sedimentary succession at the foot of the escarpment would provide a record of movement along the fault through the deposition of debrites and turbidites. The core recovered 8 m of brown mud. There was no obvious indication of the 1933 event in the core, however eight potential 'earthquake events' are interpreted; two debrites and six lamina sets comprising muddy turbidites. At this time, only one radiocarbon result is available for the core indicating a sedimentation rate of 69 cm/kyr in the upper part of the core. Two additional radiocarbon results from a nearby core taken in the same basin suggest sedimentation rates of 73-160 cm/kyr. Therefore, the core likely represents a record of the last 5 to 10 thousand years. Based on these results, sediment failure occurs along the escarpment every 600–1200 years. Although other failure trigger mechanisms are not discounted at this time, this rate potentially provides insight into the recurrence of regionally significant earthquakes in northern Baffin Bay.

A preliminary multi-element pXRF analysis of alteration and mineralization in the various felsic rocks of the polymetallic North Zone deposit area, Mount Pleasant, New Brunswick, Canada

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The Mount Pleasant deposits, located in southwestern New Brunswick, are part of a late Devonian sub-volcanic eruptive complex that intrudes into the western margin of the associated caldera; granitic intrusions are the McDougall Brook and Mount Pleasant granite suites. Mount Pleasant is divided into two zones, the North Zone dominantly Sn-Cu-Zn-In with local W-Mo and the Fire Tower Zone W-Mo-Bi deposits, with a Zn-In lode-breccia zone. A multielement pXRF study (X5000) of the surface samples (34) from the North Zone was conducted. The Ti, Th, Nb, Zr, Y, and related Ti ratios, i.e., Th/Ti, helped identify three groups of variably altered felsic host rocks; these elements are typically interpreted as immobile, although that has not been ascertained here yet. Based on correlations with Inverno's work from 2006 and mapping in the region, they are the Little Mount Pleasant Formation (LMP) (tuff) (21), McDougall Brook porphyry/granite (MBG) (volcanic to subvolcanic) (11), and possibly Granite I or II (2) that is associated with each of the deposit systems. Further analysis of the dataset using mobile elements (pXRF data) is utilized to describe the alteration and associated mineralization and characterize it with respect to the three units identified (spatial analysis). Chlorite and sericite are associated with alteration of all units, but chloritization and sulphidation dominates at higher degrees of alteration. The high acidic conditions along with the high activity of Fe stabilized chlorite are related to sericitic alteration. Sericitization begins with the destruction of feldspars in the host rock to form sericite and biotite seems to be slightly chloritized, although it is hard to observe depending on the degree of overprinting by younger alteration assemblages. Chloritization in the rocks locally seems to be accompanied with quartz and (or) fluorite. The dominant ore minerals associated with chloritization are Fe-rich sphalerite and arsenopyrite. The amounts of Fe present reflect pyrite, magnetite, and (or) chlorite abundance, whereas chloritization gives high amounts of Fe, Mn, and Mg in the rocks. Because chloritization and sulphidation dominates and higher degrees of alteration, Fe increases and K decreases; therefore Fe/K increases from weakly

to intensely altered and mineralized rocks. Fe correlates poorly with K (r' = -0.05), but shows that Granite I-II is probably less affected by sericitization than LMP and MBG. A plot of Fe/K vs. Ca (r' = 0.26) indicates fluorite alteration in greisen and chlorite zones. Fe/K vs. S shows a positive correlation (r' = 0.42) related to sulphidization associated with chlorite. W correlates with Fe/K (r' = 0.48), Bi correlates with Fe/K (r' = 0.37), Sn correlates with Fe/K (r' = 0.49), Mo correlates with Fe/K (0.35), and Cu correlates with Fe/K (r' = 0.30).

Applied forensic igneous petrogenesis: locating the source quarry for the "Black Granite" Titanic headstones in Halifax, Nova Scotia, Canada

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In Halifax, Nova Scotia, 149 victims of the 1912 sinking of the Titanic lie beneath petrologically identical "black granite" headstones. Those headstones, supplied by the White Star Line, arrived in Halifax in late 1912, but no known historical document reveals their source. They consist of a medium- to coarse-grained olivine-bearing gabbro, with cumulus phases consisting of randomly oriented euhedral plagioclase laths (An_{50-70}), corroded olivine (~Fo_{63}), and titano-magnetite (7.5 wt.% TiO_2) with Ti-hornblende and biotite reaction rims, and intercumulus material consisting of titanaugite (~$Wo_{43}En_{42}Fs_{15}$) with reaction rims of titaniferous hornblende, both of which are variably uralitized. Three types of evidence (*quantitative* – radiometric age of ca. 422 Ma, zircon U/Th ratios, olivine FeO/(FeO+MgO) ratios, clinopyroxene trace-element compositions, whole-rock chemical compositions; *qualitative* – mineral assemblage, modal proportions, textural parameters, style and degree of alteration; and *circumstantial* – regional reputation, quarrying history, local logistics, regional transportation, McGrattan "paperweight") connect the Titanic headstones to the St. George Batholith in SW New Brunswick. Precise matching of any dimension stone to its source quarry is problematic, because that stone no longer resides in the quarry. Given this constraint, one of three possible conditions must obtain: (i) if the correct quarry is homogeneous on a scale larger than the quarry, all the physical, chemical, and temporal parameters of the quarry walls and floor will perfectly match those of the headstones; (ii) if the correct quarry is monotonically heterogeneous on a scale larger than the quarry, the physical and chemical parameters of the walls and floor of the quarry will bracket those of the headstones, and the ages will match precisely; or (iii) if the correct quarry is erratically heterogeneous, the physical and chemical parameters in the walls and floor of the quarry may not bracket some, or even all, of these parameters in the headstones, but the ages will still match precisely. In the case of the Titanic headstones, most quantitative parameters in the quarry fall under condition (ii) above, but some parameters (Sr, Zr, Hf, Ga, middle REEs) fall under condition (iii). No individual line of evidence, on its own, is sufficient to identify the source quarry, but the combination of the cumulative weight of all the quantitative, qualitative, and circumstantial evidence plus a process of elimination suggests that the Charles Hanson Quarry near Bocabec, SW New Brunswick, is the source for the gabbroic Titanic headstones in Halifax. More information is available at: earthsciences.dal.ca/www/titanicgranite

Trace fossils as indicators of fully marine and restricted marine settings in conventional core, offshore Labrador, Canada

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Offshore Labrador, the Labrador Sea formed during Cretaceous rifting and Paleogene seafloor spreading. The 26 wells drilled in this area are located on the shelf in the Hopedale and southern Saglek basins and intersected Lower Cretaceous through Cenozoic sediments. In this study, sedimentary conventional core intervals of Cretaceous to early Eocene age from 13 wells were analyzed in terms of lithology, sedimentary structures, degree of bioturbation, trace fossil suites and presence of fossil material, which is extremely rare. Trace fossils combined with the sedimentology allowed for interpretation of depositional settings in the Bjarni (Barremian-Cenomanian in age), Markland (Santonian-Maastrichtian in age), and Gudrid (Paleocene-early Eocene in age) formations. In the Bjarni Formation of the northern Hopedale Basin, dark grey shales are characterized by a low abundance and low diversity, highly stressed expression of the *Cruziana* ichnofacies comprised of: *Phycosiphon*, *Helminthopsis*, *Chondrites* and *Schaubcylindrichnus*. The trace fossil suite and sedimentological characteristics suggest deposition within a restricted bay setting with limited oxygenation. Heterolithic sandstones and shales encountered across the Labrador margin are also characterized by trace fossil suites with a low diversity and low abundance of forms representing a stressed *Cruziana* ichnofacies primarily including: *Helminthopsis*, *Chondrites*, *Planolites*, *Rhizocorallium*, *Palaeophycus*, *Asterosoma*, *Phycosiphon*, *Thalassinoides*, and *Skolithos*.

These sandier facies are cross-bedded with unbioturbated mudstone intervals and coal fragments suggesting delta front to prodelta settings under river-dominated and wave-influenced conditions. The Markland Formation in both the Hopedale and Saglek basins is characterized by fully marine trace fossil suites of the *Cruziana* ichnofacies (*Helminthopsis*, *Chondrites*, *Phycosiphon*, *Planolites*, *Rhizocorallium*, *Asterosoma*, *Thalassinoides*, *Schaubcylindrichnus*, and *Skolithos*) reflecting intense bioturbation in inner to outer shelf settings. Conversely, the Freydis Member of the Markland Formation (cored in the southern Saglek Basin) is sandstone-dominated with rare trace fossils suggestive of a stressed Cruziana Ichnofacies reflecting river-dominated deltaic deposition. The Gudrid Formation in the southern Saglek Basin is characterized by heterolithic facies with trace fossil suites consistent with weakly-stressed expressions of the *Cruziana* ichnofacies. In one core, cross-bedded sandstones with intensive bioturbation by *Helminthopsis*, *Macaronichnus*, and *Spirophyton* trace-makers represent a wave/storm-dominated delta front succession. In another core, wave-rippled sandy mudstones are predominated by *Phycosiphon* and *Helminthopsis* trace-makers in a prodeltaic setting. In some core intervals, localized trace fossil occurrences provide the only evidence of shallow marine deposition in what is otherwise considered to be non-marine in origin, and in other cases, trace fossils aid in delimiting more specific marine depositional settings or paleoenvironmental conditions.

A pebble identification guide for Nova Scotia, Canada

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Nova Scotia's extensive shoreline creates abundant opportunities for studying various aspects of geology. High-energy beaches collect thick deposits of pebble- and cobble-sized material from a variety of sources, resulting in diverse and unique assemblages. Following the lead of pebble guides created in other provinces, an initial pebble identification guide was created in 2012. The goal of this guide is to provide a means of identifying, appreciating and understanding the origin of pebbles found on Nova Scotia beaches. There has been ongoing discussion within the AGS Education Committee to produce a second, refined version of the pebble guide for wider distribution. The audience for this guide would be elementary to high school students and the general public. Over the past few years, the guide has been primarily used as supplementary material for EdGEO courses. For this past year's EdGEO course (at the Atlantic Science Teachers Conference) on beaches, the guide was used for a playground pebble identification activity. The pebble guide highlights the three rock types (igneous, metamorphic and sedimentary) and has a range of photographs and simple illustrations. Other interesting finds such as veins, chert, small-scale folds, and man-made objects are also included. The vision for this guide is to be available in paper (ideally free) in a format similar to that of the highly successful Nova Scotia ROCKS brochure, in addition to an online version combined with simple activities.

Exploring the effect of chloride from de-icing salts on heavy metal concentrations in urban soils: a case study in Halifax, Nova Scotia, Canada

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Established in 1749, Halifax has long been home to various factories and extensive military installations, and experienced the largest ever non-nuclear explosion. Still an active port city, Halifax soils variably reflect aspects of this and its geological past. A pilot study by the 2013/2014 Environmental Geoscience class at Dalhousie University determined heavy metal concentrations in residential soils of the Halifax Peninsula. At each of over 30 residences, three samples were obtained: house dripline, roadside, and an ambient sample from an open location on the property. The samples were dried, sieved to <1 mm and analyzed using X-Ray Fluorescence (XRF) for Pb, As, Cr, Cu, Zn, Ba, V, Cd, Co, Se, Mo, and Sn. In many cases, dripline values of some metals were greater than ambient values, which in turn were higher than roadside values.

One possible explanation for the lower roadside metal values is mobilization of metals by chloride from de-icing salts. Sodium chloride (NaCl) is particularly effective for anti-icing and de-icing in Halifax due to the moderate climate. The objective of this study is to explore the process of chloride leaching and its impact on metal mobility using soils from the Halifax Peninsula. Soil samples were collected to a depth of 10 cm and sieved to <2 mm. For each sample, leaching experiments were done with controls of 0%, 3.5%, and 23% NaCl solutions to represent pure water, saline water, and brine, respectively. For each experiment, an 85 g (approximately 1 cm thickness) soil subsample was placed in a Buchner funnel with filter paper, and compacted slightly. Subsequently, 565 mL of solution was poured through, to represent the annual average precipitation in Halifax scaled down by a factor of 10. For the 3.5% and 23% controls, 200 mL of the saline solutions were added, followed by 465 mL of distilled water. This is to account for the fact that salt loading occurs mostly from December to March, with approximately 36% of the total annual precipitation occurring in the winter months.

Pre- and post-leaching heavy metal concentrations will be analyzed using XRF to determine if metal concentrations have decreased as a function of salinity. Metals of focus will be those with existing guidelines set by the Canadian Council of Ministers of the Environment. No results have been obtained to date; however, gradual darkening of the leachate from the 0% to 23% controls may suggest greater leaching with higher salinity.

Testing a grain size-based approach to TCN isochron burial dating

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We hypothesize that a significant sediment flux to the Andean piedmont occurred at the Pliocene-Pleistocene transition (ca. 2.6 Ma) based on thermochronology results from Antinao et al. (in prep) and tenuous terrestrial cosmogenic nuclide (TCN) burial dating by Veloza (2.6 + 0.75/ - 0.65 Ma, unpublished). However, it is difficult to date Cenozoic-aged sediments that are older than the limit of radiocarbon and OSL (Optically Stimulated Luminescence) dating, in the absence of volcanic ashes, or a high-resolution biostratigraphy. A recently developed $^{26}Al/^{10}Be$ isochron burial dating approach uses samples with differing TCN concentrations collected from depth profiles in buried sediment. However, the use of this isochron burial dating method is dependent on finding a buried paleosol, or any surface that was exposed for a significant period of time and then subsequently buried. In regions of high relief, which are prone to landslides, there may be an alternative for sediments lacking paleosols. We evaluate here a new method of $^{26}Al/^{10}Be$ isochron burial dating based on previously observed relationship between fluvial sediment grain size and TCN concentration. There may be a sufficient range in TCN concentration across the different grain sizes (150 to 2000 μm) that an isochron curve can be precisely defined.

Fine sand to granular gravel fractions were extracted from a single 3 kg sediment sample previously collected 100 m below an incised river terrace in the Eastern Cordillera of the Colombian Andes (4.979 N, 72.825 W, 686 m elevation above sea level). The site is ideal for this study because it is still tectonically active, has high sedimentation rates (therefore low TCN concentrations to test the method's limit) and high relief. Pure quartz from six different grain size fractions was extracted, cleaned, dissolved, and converted to Al_2O_3 AMS targets at the Dalhousie Geochronology Center. $^{27}Al/^{26}Al$ results from AMS (Accelerator Mass Spectrometer) at Lawrence Livermore National Lab reveal a linear relationship in ^{26}Al concentration (ranging from 2.79 to 4.19 X 103 atoms/g) with grain size, as well as sufficient scatter (beyond the 20% 1-sigma precision of the AMS measurements) to define an isochron and test the new dating method. Pending 10Be concentrations will be higher (longer half-life) and more precise, so we are optimistic that this new approach will provide a useful option for dating deeply buried sediment that lack paleosols and other exposure surfaces. This should allow us to test the hypothesis of a significant Andean sediment flux increase at the climate transition.

Laboratory modelling of magma mingling*

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Magma mingling is the process in which two separate magmas interact in a dynamic environment to cause some stirring with each other, but distinct boundaries are preserved between them. This differs from the process of magma mixing, where the resulting magma is a homogeneous rock with intermediate composition. The dynamics of magma mingling and mixing depend primarily on density and viscosity contrasts, rheology and the geometry and vigour in which one magma intrudes into another.

A series of laboratory based experiments were conducted to study the effect of magma mingling when a viscous felsic magma chamber is intruded by a localised injection of denser, intermediate to mafic magmas. A motivation of this study was to understand the dynamics of formation of a particular outcrop of the Holyrood Intrusive Suite in Eastern Newfoundland. Here, a coastal exposure shows metre-scale rounded blobs of a medium-grained intermediate rock within a medium to coarse-grained felsic host. The experiments were conducted in transparent decimetre scale tanks, and experimental materials were chosen to have density and viscosity contrasts analogous to those of magmas of differing compositions. Density contrasts were controlled by the use of aqueous salt solutions (such as $NaNO_3$) having varying weight percentages, while viscosity contrasts were controlled by varying concentrations of oxyalkene polymers (PEG 600 wax) or cellulose ethers (MethocelTM and NatrosolTM). The effect of crystals in magmas was replicated by the use of small plastic and/or glass beads having a diameter between 0.09–0.35 mm. The experimental tank was filled with the host analogue magma, and denser analogue magma, dyed blue for visual contrast, was introduced by pump from below, by syringe from above, or more commonly by emplacing a blob-like aliquot from above.

Depending on the physical properties of the two materials, many different behaviours of the injected material were observed, including slow drips, turbulent plumes and crater-forming impacts on the bottom of the tank. The best match to the Holyrood Granite outcrop was obtained when the introduced 'blob' contained 25–50% beads (analogue crystals) and was only slightly denser than a high-viscosity host. This resulted in blobs which maintained their shape as they slowly sank without mixing with the surrounding fluid. This result is consistent with recent models of the Holyrood Granite outcrop blobs based on petrographic observations.

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

Silurian crinoids from northern New Brunswick, eastern Canada

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Silurian crinoids are well documented from Iowa and Ohio, through New York, into Ontario and Anticosti Island (Québec) Canada, and across to the British Isles and Ireland. One of the remaining gaps in the database is the Silurian strata around the coast of Chaleurs Bay in the Gaspé (southern mainland Québec) and northern New Brunswick, where crinoid material has often been noted, but rarely identified. Recent investigations have described *Scyphocrinites* sp. from west of Campbellton, New Brunswick, and a new morphospecies of *Lanxocolumnus* (col.) from west of Belledune, New Brunswick. *Scyphocrinites* is a genus that is an international marker for the Silurian-Devonian transition. *Lanxocolumnus* represents an older heteromorphic crinoid column from the upper Llandovery (Telychian) and is related to the English Telychian morphospecies *Cyclocyclicus* (col.) *geoffnewalli*. The articular facets are sunken and nodals(?) have a unique feature, a circular pseudolumen into which a small internodal, lacking an epifacet, may fit. This is a further example of a crinoid taxon that migrated from Laurentia to Avalonia as the Iapetus Ocean closed.

A 10 000 year record of environmental change at Long Lake, Cumberland Marshes Region, Nova Scotia-New Brunswick border region, Canada*

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Long Lake, Nova Scotia is a small, shallow lake located 12 km inland from the head of the Bay of Fundy within the Amherst Marsh, which is part of a large coastal wetland system (Cumberland Basin marshes - CBM) in the New Brunswick – Nova Scotia border region. The Border Marshes are located along the Atlantic migratory flyway and are particularly important for waterfowl and marsh bird production providing both migration and breeding habitat. Though ecosystem integrity has been studied extensively, there are no records of the physical and chemical evolution of lakes in the CBM. In this study we use the paleolimnological method at Long Lake to construct a 10 000 year record of both natural and anthropogenically influenced change.

The paleolimnological records were derived from percussion and gravity cores and indicate that Long Lake was a productive, fresh water lake from at least 10 500 cal. BP, long before most lakes in the CBM were established. Increases in various metals including Pb, As and Hg in the core at about 5000 cal. BP are likely the consequence of regional fires, and indicate that a significant reservoir of these metals exists in the natural environment. The fire events are broadly coincident with a period of widespread drying from 8000 to 4000 cal. BP. Wetter conditions and a raised water table have persisted at the site since 4000 cal. BP. Though tidal range had increased by this time, $\delta^{13}C$ data indicate that long term marine incursions did not occur at the Long Lake site. The gravity core data indicate that physical and biological character of Long Lake has been fundamentally altered in the last 300 years by anthropogenic activity. Evidence of water level lowering and forced sediment aggradation (tiding) in the 1800s was found, consistent with historical records. Increases in metals near the top of the core are likely associated with fossil fuel combustion and naturally occurring lead mobilized by sediment re-suspension and mixing associated with boat traffic. Collectively these data indicate that Long Lake may be one of the oldest lakes in the Cumberland Basin marshes and has been fundamentally altered by anthropogenic activity in the last 300 years. The sediments in Long Lake may also represent a source for the bioaccumulation of specific metals.

Winner of the AGS Graham Williams Award for best graduate student poster

Tectonic evolution of the Sackville sub-basin, New Brunswick: problems and possibilities

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The Sackville sub-basin of New Brunswick lies within the Maritimes Basin in Atlantic Canada. It is a structurally complex basin bounded by: the Caledonia Uplift to the west; the Hastings Uplift, the Harvey-Hopewell and Wood Creek faults to the south; and the Westmorland Uplift and Dorchester fault to the north, which separate it from the Moncton sub-basin. Orogen-scale dextral motion and strike-slip boundaries define movement of the region during the Carboniferous. Major movement in the Sackville sub-basin occurred along the Dorchester and Harvey-Hopewell Faults. Throughout the Carboniferous, the Sackville sub-basin experienced periods of subsidence, inversion, and extension. Carboniferous sedimentary rocks within the sub-basin include Albert Formation (Horton Group) oil- and gas-bearing shales, Round Hill Formation (Sussex Group) conglomerates, Upperton Formation (Windsor Group) evaporites, Maringouin Formation (Mabou Group) red mudstones, Hopewell Cape Formation (Mabou Group) coarse conglomerates, and Boss Point Formation (Cumberland Group) sandstones.

Industry seismic profiles show an allochthonous thrust wedge of unknown origin dominating the geology in the subsurface. This thrust wedge appears to be inserted southeastward into Windsor Group evaporites low in the section. The wedge could represent subsurface equivalents of the nearby Caledonia Uplift, or of the adjacent Moncton sub-basin. Clues to the nature of the wedge are provided by rock chip well samples and surface correlation.

The upper surface of the wedge is probably correlative with the Harvey-Hopewell Fault adjacent to the Caledonia uplift. However, it is unclear where the trace of the Harvey-Hopewell fault continues eastward after it passes into the Shepody Bay; it may connect with the Dorchester fault through the Memramcook Estuary, connect with the Wood Creek fault across the Bay of Fundy, or die out underneath the Sackville Syncline. Regardless, the wedge indicates an important and often overlooked episode of shortening late in the history of the Sackville sub-basin.

Visual skills in geoscience education: drawing, a museum perspective

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The ability to observe and document physical and spatial relationships are fundamental skills of a professional geologist. We "learn to see" like a geologist, as we do any other occupation. The ability to document through drawing is considered essential for success across most disciplines of science, technology, engineering and mathematics.

Improving spatial skills is an appropriate goal for university and museum education programs. There is convincing evidence that visual skills training can have positive and lasting effects on learners at all ages. These trends are likely to continue within the digital age. Visual elements in digital media are rapidly changing concepts of literacy and also modifying opportunities for learners to draw and document what is seen.

Insights are shared from drawing sessions offered to several groups over the past five-years, to explore linkages between observation and drawing skills. Prior sessions have included medical students (Anatomy Drawing Club), geology and biology undergraduate students (Natural History Drawing), youth science camp participants (WISE Atlantic), as well as adult and youth museum visitors (Fundy Natural History Drawing). An overview of new programs will be reviewed, including the use of in-gallery and outdoor activities, as well as new online projects with 3D-digital models.

The Atlantic Geoscience Society and the Photographic Guild of Nova Scotia - a collaboration 14 years strong

Robert A. Fensome and William C. Macmillan

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Following the production of the Atlantic Geoscience Society (AGS) book, *The Last Billion Years* and considering the significant input into that project of several members of the Photographic Guild of Nova Scotia (PGNS), there was enthusiasm in 2000 for a continuing collaboration between the two societies. Proponents agreed that this should take the form of an annual competition within PGNS sponsored by AGS, as well as an annual field trip. The inaugural competition was held in 2000 and the winner claimed "The Atlantic Geoscience Society Award". The rules for the competition stipulated that the subject matter could include "rocks, sediments, geological processes …, minerals and fossils, as well as landscapes." In contrast to some other PGNS competitions, the rules encouraged human interest, such as people for scale, quarries and building

stones. The judging takes place at a regular PGNS meeting: as per convention, there are three judges, at least one of whom is a member of AGS. By 2003 it was clear that most entries were of images of the geology of the southwestern USA, a favourite hunting ground for PGNS members. It was decided therefore to institute a second award, *The Last Billion Years Award* (LBY), which was first competed for in 2004. If the overall winning image is a depiction of the geology of Atlantic Canada, it claims both awards; if not, then the best image claims the AGS Award and the best Atlantic image wins the LBY award. The competition is now in its 15th year. In addition to the completion, an annual field trip for the PGNS has been run under the aegis of AGS. The first trip was focussed on the Halifax area, and one was to Kejimkujik Seaside; but otherwise most have focussed on the diverse and colourful rocks around the Minas Basin. The trips generally attract between 10 and 30 people, with some participants more interested in the geological story and others distracted from the science by the attractive surroundings. The benefit of the interaction for the photographers is that they have an incentive to chase images from a somewhat unusual angle (for them); and the benefit for AGS is that submitted images are available for use in its educational projects or products such as *The Last Billion Years*.

Adventures in Mesozoic-Cenozoic event stratigraphy, northern and offshore eastern Canada

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In a series of projects and with various collaborators over the past two decades, we have been using event stratigraphy to more rigorously determine the temporal framework of Mesozoic and Cenozoic strata in northern and offshore eastern Canada. Events may be any one-time contemporaneous regional to global marker, for example a distinctive regional stratum, seismic marker or log pick, or a global geochemical signal. However, we use mainly events related to ranges of fossil species, such as extinctions, primarily of dinoflagellate cysts (dinocysts). Several of our collaborative studies also incorporate data from microfossil groups such nannofossils and foraminifera: the more disciplines involved, usually the more refined will be the stratigraphic framework developed. The first study of the series involved Late Cretaceous–Cenozoic strata of the Scotian Margin and incorporated events based primarily on dinocysts and nannofossils, but also on spores and pollen (miospores) and foraminifera. This study was a key element of a much larger project on the Scotian Basin — the biostratigraphy component of the OETRA Play Fairway Analysis study funded by the Nova Scotia Government. This study involved new commercial analyses, as well as historical data from GSC Atlantic and incorporated data from several groups of microfossils. Throughout the progress of these studies, we were also pursuing a collaboration with the Denmark and Greenland Survey (GEUS) in developing an event stratigraphy for the Labrador Sea-Davis Strait-Baffin Bay region (the Labrador-Baffin Seaway). This study has involved the palynological analyses of 17 wells on the Canadian and Greenland margins, although using only palynological data. A gap in data caused by the lack of industry wells on the Canadian margin of Baffin Bay is being filled by ongoing studies of the palynological assemblages of shallow core holes on the Baffin Shelf and of onshore sections on Bylot Island. We are now in the initial stages of applying this approach to Mesozoic-Cenozoic strata in the Sverdrup Basin. There exist many biostratigraphic studies of these strata, but they tend to be piecemeal and zonation based. Bringing all the data together, plus the generation of new data for this purpose, will provide a significant advance in the understanding of the geological history of the Canadian Arctic, and will involve events based on multiple fossil groups, as well as on geochronology and geochemistry.

Four Billion Years, four hundred weeks and four hundred people (give or take): the story of a popular book on the geology of Canada

Robert A. Fensome and Graham L. Williams

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In 2003, based on several factors, including success of a previous book, *The Last Billion Years*, on the geology of the Maritimes, we proposed the idea of a popular book on the geology of Canada. The early planning stages involved a special session at the GAC/MAC conference in Halifax in 2005, shortly after which we consolidated an editorial board of seven geologists and a group of experts across the country to pull together regional and topical stories that we could ultimately weave together into a single narrative. Concurrent with the writing of regional and topical drafts, we proactively sought photographs to illustrate the story, funding for the book, and a publisher to produce it. It became compelling too that we needed also to have a French edition. By 2008, the project had been officially adopted by the Canadian Committee of the International Year of Planet Earth (2009). Through fundraising efforts by this Committee and the generosity of the Canadian Geological Foundation, Nexen and other supporters, we accumulated sufficient funds to develop an English edition (*Four Billion Years and Counting*), a French edition (*Quatre Milliards d'Années*), and a bilingual website. By then too we had developed working agreements with two publishers, Nimbus for the English edition and Éditions MultiMondes for the French, with the Canadian Federation of Earth

Sciences co-publishing both. One setback was that by 2010 the manuscript was getting too large, so we had to reduce the text by about 40 percent, a surgery that was painful and caused delays but was ultimately beneficial. The book was now taking its final shape, with the text divided into three parts: Foundations (outlining geological fundamentals from a Canadian perspective); Evolution of Canada (unravelling the history of Canada's land mass); and Wealth and Health (exploring the ways in which geology impacts our daily lives). The English edition was published in late September 2014 and the French in November 2014: the accompanying website is expected to go live in early 2015. Both editions are large format books, the English with soft cover and the French with hard. The books are packed with colour photographs, accessible graphics and lively artwork. Reactions from readers so far indicate that we are satisfying our target audience of interested non-specialists; and sales are progressing such that we will probably have to reprint the English edition in 2015.

Earth science education – shake it up!

Martha E. Grantham

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Few teachers have a background in science, let alone geology. So when topics about earth science are to be covered in the classroom, teachers often look for help to bring it to life. Geoscientists can translate the complex language of 'geologese' into the appropriate level for their audience, whether students or the public. It is well known that many in today's society, especially youth, are disconnected from the natural world and where things come from. You can improve the earth science literacy of students and educators. Explore some hands-on, brains-on activities, demonstrations and experiments that will engage students in earth science topics, and suggestions about how to get the most out of your classroom visit. We will also cover the use of specimens, props, and the technology students love, and the value of taking it outdoors. You'll discover approaches and techniques that will work with different learning styles, whether in the classroom, board room, or around the dinner table. Be prepared for some geology fun-damentals!

Preserving collections

Robert G. Grantham

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The natural sciences of biology and the earth sciences are based upon collections. Specimens provide the structure upon which all future studies are based. The scientific description of the first of its kind whether it be a fossil, mineral or biological specimen, provide the basis upon which all subsequent discoveries and descriptions are founded. Museums and universities have provided safe and secure places to store and make available these natural and intellectual treasures. In these decades of restrictive museum funding, severe cutbacks, and the tendency to create virtual representations, collections are threatened with their very existence, let alone collection expansion. This is a matter of international concern.

This presentation presents experiences with and insights into, earth science collections gathered over a 45 year career in industry, academia, museums, Foundations and the private sector.

A popular guide to the geology of publically accessible scenic sites in Nova Scotia, Canada

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Nova Scotia is well known for its scenic vistas and diverse geology; the link between those two facts is well known to geologists but much less so to the general public. Our goal in this project was to create a practical and engaging field guide for the bedrock geology of Nova Scotia, modeled closely on an existing field guide, the *Geology of Newfoundland: Touring Through Time at 48 Scenic Sites* authored by Hild and published by Boulder Publications. Its design — based on available research into reader needs and behaviours — was developed specifically to demystify the process of finding and understanding interesting rocks, while also providing substantive content for the well-educated, curious traveller. We visited numerous outcrops to evaluate their geotourism potential, wove the selected sites into a compelling narrative, and gathered all the details readers would need to feel confident, motivated, and knowledgeable on their geological outings.

Adult learners absorb information best when presented in a meaningful context, and for that reason units are sequenced to tell the story of Nova Scotia's geologic past. A series of 4- or 6-page units describe how to find, explore, and understand 48 sites of geologic interest in Nova Scotia. The sites were selected for their scenic beauty, access, safety, geological significance, and to a lesser extent, geographic distribution. The sites are grouped into 3 sections: Foundations, Meguma, and Pangaea. The Foundations section features 16 main sites that tell the story of the ancestry and assembly of Laurentian and Gondwanan terranes. The Meguma section focuses on 15 sites illustrating turbidite sedimentation, deformation, and metamorphism. The remaining 17 sites in the Pangaea

section cover the Carboniferous–Permian assembly of Pangaea and subsequent break-up and opening of the Atlantic Ocean.

The book uses language that is accessible and lively but not "dumbed down." Front and back matter provide basic information, context, and vocabulary: succinct but accessible explanations of geologic time, rock types, plate tectonics, and the history of the Appalachian mountains/Pangaea, as well as a glossary. Other features that facilitate easy use include detailed, foolproof travel directions, a separate Trip Planner cross-referencing the province's tourism regions, a place-name index, and a colour-coded, visual "thumb index" along the book edge. Physical properties are appropriate to the book's function as a field guide, and include a sturdy waterproof cover, robust, flexible binding, and generous use of colour.

Pennsylvanian fluvial channels influenced by vegetation in the Joggins Formation, Nova Scotia, Canada

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Riparian vegetation profoundly influences modern fluvial channels, depending on plant life-history strategies, tolerance to disturbance, and habitat drainage. Direct evidence for these dynamic relationships is usually cryptic in ancient deposits. We report evidence for interactions between rivers and in situ vegetation in the Lower Pennsylvanian Joggins Formation based on architectural analysis of channel bodies associated with exposed upright trees. Although this site selection imposes some bias, the case studies encompass fixed, meandering, and distributary channels originally up to 6 m deep, from poorly and well drained settings across a coastal to alluvial plain. Plant groups include lycopsids that preferred stable wetland settings, disturbance-tolerant calamitaleans, and slow-growing long-lived cordaitaleans.

Our observations suggest that vegetation was effective in stabilizing banks and bars and promoting aggradation. Lycopsids and calamitalean groves colonized the channel bed during periods of reduced flow, and mounds around upright trunks indicate that they nucleated bars after flow resumed. Bank-attached bars with lateral accretion sets contain upright trees, which may have stabilized inclined sediment surfaces, and trees between small distributary channels may have formed vegetated islands. In several cases, lycopsids rooted below the channel base project up into the channel fill and are enclosed in sediment mounds, implying that they survived avulsion and formed obstacles in active channels.

On channel cutbanks, upright lycopsids are tilted towards the channel, and early-formed rhizoconcretions are associated with deep cordaitalean root systems in the tops of channel fills. Both features imply that vegetation contributed to sediment stabilization. The predominance of in situ over transported plant remains suggests that these low flow-strength rivers had limited ability to erode and entrain large woody debris, especially for small channels with strengthened banks.

We infer that patterns of interaction between rivers and vegetation broadly resembled those of today. By the Early Pennsylvanian, rivers had moved from a geomorphic and biogeomorphic mode of operation into a fully ecological mode with prominent feedback loops between vegetation and fluvial processes. Vegetation is commonly poorly preserved in fluvial systems but should be incorporated into facies models for Pennsylvanian and younger formations, possibly also for some Devonian and Mississippian formations.

Multistage corona formation in Algonquin metagabbro: unravelling the metamorphic history of Grenvillian lower crust

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The petrology, chemistry, and time of intrusion of alkaline mafic bodies in the southwest Grenville Province have been used to differentiate between autochthonous and allochthonous domains in this region. In the allochthons, the characteristic mafic suite is a group of coronitic metagabbros, the Algonquin metagabbros, which intruded at approximately 1170 Ma. Metamorphism at ca. 1060 Ma produced spectacular coronitic textures between igneous olivine and plagioclase and between igneous Fe-Ti oxides and plagioclase. This study examines in detail one metagabbro body exposed as a continuous 150 m wide outcrop in a road-cut near Emsdale, Ontario. Corona structures in this body preserve the products of multiple stages of metamorphism. Three stages of corona formation have been identified, dividing samples into three types differentiated by their mineral assemblages and textures. In Type 1 samples, which have the best preserved igneous texture, pseudomorphs after primary olivine are separated from plagioclase by coronas of orthopyroxene ± clinopyroxene, amphibole ± biotite, garnet + amphibole ± clinopyroxene ± orthopyroxene ± plagioclase symplectite. Coronas surrounding Fe-Ti oxides include amphibole + biotite and garnet + amphibole ± clinopyroxene ± orthopyroxene ± plagioclase. With increasing retrogression in Type 2 samples, relict igneous plagioclase and clinopyroxene are progressively recrystallized, mafic

phases are progressively replaced by amphibole, and a sodic plagioclase moat appears between amphibole and garnet. Highly retrogressed Type 3 samples retain little to no igneous texture, with coronas largely obscured by late amphibole and plagioclase. Petrographic and electron microprobe analyses are currently underway to determine the metamorphic reactions and P-T conditions recorded in the corona products at each stage. Preliminary P-T estimates for corona assemblages in Type 1 samples, assumed to represent peak metamorphism, are ~900°C and ~13 kb, and Type 2 and Type 3 estimates are in progress. Placing constraints on the P-T conditions for the three types will reveal a P-T path of metamorphism for the metagabbro body and shed light on its metamorphic history.

Magmatic-hydrothermal ore-forming systems: products of resurgent boiling, fluid focusing, and changing PTX conditions

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High-level magmatic-hydrothermal ore systems cover a large range in terms of the progenitor magma, tectonic setting, and metal endowment (e.g., Cu, Mo, Sn, W, Au, rare metals). However, all these ore systems share a common feature, this being they are the end product of ore metal precipitation from fluids generated due to volatile saturation of evolving melts through the processes of first and second, or resurgent boiling. This latter stage of magma evolution is critical to ore-deposit formation since it is the vehicle by which metals are transferred from a metal-rich melt to a fluid under conditions of favourable elemental partitioning (i.e., $KD^{fluid/melt} > 1$). The preservation of both melt and fluid inclusions in, for example, miarolitic cavities provides direct evidence of this process and confirmation of fluid-metal enrichment. The subsequent focusing of this metal-rich fluid into sites undergoing transient changes in PTX leads to metal precipitation; a variety of mechanisms are possible, such as fluid:rock interaction (e.g., greisens, skarns) or fluid mixing or unmixing. In this presentation, a range of textures (e.g., miaroles, stockscheiders, USTs, breccias) preserved in samples from a variety of ore settings are used to illustrate these important ore-forming processes, commencing with melt saturation and fluid exsolution, which can be either passive or catastrophic depending on the ΔP, through fluid focusing and ore formation. In order to illustrate these processes in further detail, two case studies are used: (1) the 380 Ma East Kemptville greisen-hosted Sn-Cu-Zn-Ag deposit which is related to the extreme fractionation of a F-rich and volatile charged felsic magma that, due to second boiling, generated a metal-rich mineralizing fluid. This fluid was subsequently focused along the faulted contact between topaz leucogranite and sediment where greisen formation controlled cassiterite precipitation; and (2) the Cretaceous Mongolian topaz ongonites that which are spatially associated with rare-metal mineralization. These topaz-two feldspar dike rocks record preservation of primary igneous textures and have been considered by some as pristine examples of metal- and F-rich felsic melts. However, detailed mineralogical and isotopic studies indicate these rocks record a pervasive metasomatic event due to reaction at high temperature (ca. 400°C) with fluids of both magmatic and meteoric origin. The latter observations suggest some rare-metal enrichment in evolved felsic rocks, such as the ongonites, is secondary rather than primary magmatic, as considered by many, which has implications for genetic models for these systems.

Boundary|Time|Surface: art and geology meet in Gros Morne National Park, Newfoundland and Labrador, Canada

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Environmental Art works range in scope from major permanent interventions in the landscape to less intrusive, ephemeral site-specific installations constructed from local materials. Despite this range of intervention, these works share a tradition of art-making in which the artwork responds directly to its environs. Andy Goldsworthy and Richard Long, for example, favour methods that combine sculpture and performance in the creation of non-permanent interventions in the landscape, and both rely upon photographs, text, or video as the only lasting record of the works' existence.

Similarly, Earth Scientists are responsible for interventions in the landscape, both physical and conceptual. In Earth science, the systems of the geologic timescale - Cambrian, Ordovician, etc. - were established by 19th century geological pioneers, who believed them to represent natural chapters in Earth history. Since the mid-20th century, stratigraphers have resolved ambiguities in the original definitions by defining stratotypes: sections of continuously deposited strata where a single horizon is chosen as a boundary. One such international stratotype, marking the Cambrian-Ordovician boundary, is defined at Green Point in Gros Morne National Park, Newfoundland.

Boundary|Time|Surface was an ephemeral sculptural installation constructed in June 2014. This artwork was a fence of 52 vertical driftwood poles, 2–3 m tall, positioned precisely along the boundary stratotype horizon at Green Point. It extended across a 150 m wave-cut platform from sea cliffs to the low-water mark, separating Ordovician from Cambrian strata. The installation was hand-built (with volunteer assistance) on June 22, on the falling tide, and was dismantled by wave action and the incoming flood tide. The cycle of construction and destruction was documented in video and with time-lapse still photography.

This project provided viewers an opportunity to contemplate the brevity of human experience relative to time's passage, and the fragile, arbitrary nature of human-defined boundaries of all types. Exhibitions of the installation documentation are envisaged, which will provide opportunities for direct interaction with still and video images of the work, both as aesthetic objects and as sources of information regarding the geological and human history of the site.

Mesh- and surface-based geophysical inversion of IOCG deposits

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Geophysical inversion is a data processing technique that calculates models of the Earth's subsurface physical properties (e.g., density and magnetic susceptibility) from geophysical survey data (e.g., gravity and magnetic measurements). Inversion provides the means to integrate geophysical measurements, petrophysical data and other geological information. Standard mesh-based inversion strategies discretize the Earth region of interest into a mesh of space-filling cells, for example a 3D rectilinear mesh comprising prisms. The relevant physical properties are assumed to be uniform within each cell but possibly different from one cell to the next, creating pixelated models. The inversion attempts to determine a distribution of the relevant physical properties that could have given rise to the measured survey data. The numerical data-fitting problem is highly non-unique, meaning there are an infinite number of models that could fit the survey data to an acceptable degree. Common practice is to create a tractable inverse problem by accepting only smoothly varying distributions, a so-called "minimum-structure" approach.

Models recovered through a minimum-structure mesh-based inversion approach are often at odds with existing geological knowledge of the subsurface. Geologists' interpretations about the Earth typically involve distinct rock units with contacts (interfaces) between them, each unit having essentially homogeneous physical properties. While there are mesh-based inversion methods that can produce models closer to that character, we are also developing a fundamentally new and different type of inversion that works directly with a 3D geological Earth model comprising wireframe contact surfaces of tessellated triangles. This parameterization is sufficiently flexible to allow the representation of arbitrarily complicated subsurface structures. The inversion moves the contact surfaces as required to fit the data, while honouring any a priori geological knowledge.

We are applying both our mesh- and surface-based inversion approaches to investigate Iron Oxide Copper Gold (IOCG) type deposits in South Australia. Preliminary results using gravity and magnetic survey data have produced subsurface models consistent with current understanding of the deposits.

Petrogenetic controls on gold mineralization within the Amber Zone at Cantung W mine, Northwest Territories, Canada

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The Cantung W-Cu-Au skarn is located within the Canadian Cordillera in the Northwest Territories approximately 400 km northeast of Whitehorse, Yukon Territory. It is related to an intrusive system that is part of Middle Cretaceous felsic plutonic suites that were emplaced into Neoproterozoic rifted margin and Paleozoic passive margin rocks bordering Laurentia. The deposit consists of a contact metasomatic hydrothermal system associated with a peraluminous biotite monzogranite that intruded into Lower Cambrian marble sequences, producing a zoned array of anhydrous and hydrous reduced skarns. There are several orebodies in the deposit, including the E-zone, the Pit, and the Amber Zone. The spatial and temporal relationship between the different zones is unclear.

Previous studies which investigated the gold mineralization in the E-Zone found no native gold or electrum. Spearman's Rank correlation coefficients (r') were calculated using whole-rock lithogeochemistry of samples from the E-Zone ore body (n = 48); a strong correlation between Au and Bi (0.76), Ag (0.70), Fe (0.64), and Cu (0.64) was identified. LA ICP-MS analyses of native Bi showed it did not contain anomalous gold concentrations. Bi- and Ag-tellurides and sulfosalts were found to be associated with the native bismuth; LA ICP-MS raster analyses detected highly elevated gold concentrations (800–1000 ppm) at the boundaries between alloy and sulfosalt minerals, which corresponded with high Ag peaks. The correlation between gold and bismuth suggests that low temperature bismuth melts played some role in the enrichment of gold in this system.

Samples taken from the Amber Zone also contained elevated gold concentrations (1 sample >10 g/t and 7 samples > 1g/t). Petrography of polished thin sections from these samples was conducted to characterize the ore and gangue minerals from these high grade samples and mineral paragenesis determined. No native gold or electrum was observed in these samples either. The textures exhibited by native bismuth in these samples suggest they formed as low-temperature melts. These low-temperature melts mainly formed native bismuth; however Bi-Te-Se, and As-bearing phases also exsolved from these melts. Characterization of these Bi-bearing phases was conducted using SEM-BSE imaging and SEM-EDS analyses. The FEG-SEM was used to obtain more quantitative analyses on the small (<2–3 μm) Bi-Te-Se- and As-bearing phases. The objective is to use in situ LA ICP-MS analyses to determine the phases that host gold in the Amber Zone. Understanding the elemental associations at the mineralogical level will ideally provide vectors towards higher gold grades within this complexly zoned polymetallic skarn system.

The role of thermal constraints in extreme fractionation of felsic magmatic systems: examination of critical controls to protore and (or) ore formation

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Extreme fractionation is evident in many magmatic systems including evolved felsic magmatic systems. Although considerable focus in the literature has been on volatile complexing (alone) in explaining metal enrichment in magmatic systems, only a few researchers conduct experiments and highlight field studies presenting primary magmatic processes as responsible for generation ore-forming systems in various granitoid magmas. The behavior of incompatible elements during partial melting and (or) fractional crystallization is well known, although the effects of the duration of a magmatic system from a thermal perspective is very rarely considered. It is postulated that the efficiency of crystal-melt partitioning and crystal-melt separation is very much a function of the duration of a cooling system. Using thermal modeling techniques, various magma injection scenarios were examined, in particular mafic magmas cogenetically emplaced with felsic magmas, to illustrate the range in cooling times for fractionating magmatic systems. The thermal energy modeling was done using the program HEAT by Ken Wohletz (Kware). This program is versatile and enables input of variable thermal gradients, and emplacement of different timing of intrusions into any package of rocks. It is easily shown that the duration of crystallization of felsic magmatic bodies can be easily extended by >> 10 times, such that crystallization from a typical granitoid solidus temperature of 700°C to << 600°C could be over 1 million years, which could overcome the viscosity issues with crystal fractionation at very low temperatures. If correct, any system can now be geochronologically constrained by dating each phase of a magmatic system, and associated ores formed, i.e., the importance of thermal models can be tested in ore systems. The specific purpose of which is to determine the lengths of times that specific magmatic systems were above their liquidi through to their lowermost solidus and in terms of extreme fractionation to very evolved magmatic systems like Li-Cs-Ta (LCT-type), Nb-Y-F (NYF-type), Sn, Mo, U, and LREE apogranitic to granitic pegmatite systems to extremely low T's consistent with each of their solidi, i.e., well below 600°C. Partitioning of elements between crystal and melt thus approaches ideal distribution coefficients for incompatible elements. As well efficient crystal – melt separation (Rayleigh fractionation and partial melting) in increasingly viscous magmas has time to separate and migrate promoting fractionation and concentration of fluxing volatiles in those derivative melts. Furthermore, prediction of economic potential of a particular felsic magmatic system is possible by appropriate thermal modeling of these magmatic systems.

Sediment disturbance due to storm wave action on a steep, mixed sand and gravel beach on the Bay of Fundy, Canada

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Little work has been conducted on mixed sand and gravel (MSG) beaches compared to their single sediment type counterparts, although they are a common occurrence on Canada's shoreline. Our study site, Black Rock Beach, is a planar steep MSG beach with a 1:7 slope. The site is situated on the northern side of the Minas Passage, in the Bay of Fundy. The purpose of this study is to contribute new understanding of MSG beach dynamics. More specifically we aim to examine how waves and currents affect the beach profile and the depth of sediment reworking during storms. Understanding the interaction between sediment and incoming waves at this site is important due to the potential for power generation in the Minas Passage. Because power will be brought to shore via cables buried in the beach, the depth of burial must exceed the maximum depth disturbance.

An array of equally-spaced depth of disturbance rods with free-sliding washers were deployed normal to the shoreline up the beach face. The array records the maximum depth of sediment activation and relative changes in bed elevation. Pressure and temperature data were logged by two submersible dual-channel loggers. Weather data were collected from a weather station 200 m north of the study area. Post-tropical-storm Arthur was the only wave-generating event to have significant effects on the beach during our study from July 4 to September 5, 2014. The storm, with winds up to 100 km·h^{-1}, produced significant wave heights of about 1 m. The maximum DOD was 42.5 cm ± 0.2 cm near the high-water line, values decreasing down the shoreface to about 9.8 cm ± 0.2 cm near the low-water line. An increase in relative beach elevation was recorded, with values of about 18.6 cm ± 0.2 cm closer to high-water and about 1.1 cm ± 0.2 cm closer to low-water. Calmer conditions persisted through the rest of the study, resulting in much lower DOD values, 5 cm or less, and following a similar trend of decreasing values down the shoreface.

Using pancakes and Plexiglas® to teach geology

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Although geoscience education researchers actively pioneer effective teaching strategies and technologies, which are disseminated through formal scientific journals, most teaching advances are still made through trial and error by frontline educators. These practical methods and insights are often shared only with immediate colleagues, if at all, and are frequently lost upon retirement. This presentation shares two demonstrations that the author devised while teaching introductory geology labs at Cape Breton University (non-majors, primarily Arts and Engineering students). The first technique uses actual pancakes to teach stratigraphic principles, and the second utilizes dry erase markers and a large Plexiglas® sheet to show the relationship between how structures are represented on geological maps via map symbols and what those structures look like in three dimensions. In a follow up survey, students strongly agreed that these two methods helped them understand and retain the concepts. These techniques are readily transferable to secondary and lower grade levels. These two examples are shared with the hopes that other educators will find them useful and to encourage AGS attendees to share their own hard-earned teaching tricks.

An examination of fractionation on a planetary scale: examples from meteorites

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Carbonaceous chondrites are a type of meteorite that are thought to be the most primitive and undifferentiated material in our solar system, and therefore can provide a better understanding of the early history and evolution of our solar system. Geologists have extensively studied the carbonaceous chondrite Allende CV3 since its observed fall in 1969, providing a foundation of geochemical and petrologic data. Chondrites are defined by small spherical aggregates of minerals called chondrules. Many questions about the formation of chondrites and chondrules remain unanswered, and the genetic relationship between meteorites and other bodies such as planets are only speculated. Planets such as the moon are achondrites, formed by partial melting and are considered to be differentiated material. This research will attempt to show a relationship between chondrules in Allende CV3 meteorite to that of lunar samples and komatiite samples from Earth using distribution coefficients and phase distributions. Chondrules within Allende are treated as individual rocks, which can be grouped based on mineral constituents. Phase distribution maps are created using the electron microprobe and determine bulk composition of 8 different chondrules in Allende. The spectra of major elements in chondrules are overlapped to give a visual representation of phase distribution. Distribution coefficients or more simply the ratio of element concentration in a single mineral to the concentration of the element in the whole rock will be calculated using weight percent of specific elements in olivine, pyroxene and plagioclase in the meteorite, Lunar and Earth samples. Distribution coefficients for major, minor, and trace elements will show trends in fractionation providing an evolution of material from primitive chondrites to earth-like material. Chondrules from Allende will be analyzed and compared to known petrologic types on earth, to better understand chondrule formation and processes. A genetic relationship between chondrites and achondrites could be formed using distribution coefficients. Comparing the geochemistry of chondrules in Allende to that of known rock types on Earth and the moon could provide insight into the early history of our solar system and the formation of chondrules and chondrites.

The Altan Nar carbonate-base metal gold-silver deposit, southwestern Mongolia

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The Altan Nar deposit was discovered by Erdene in 2011 as part of a regional, grassroots mineral exploration program over southwest Mongolia. Since that time, Erdene has completed nearly 10 000 m of diamond drilling and 3 000 m of trenching and has established Altan Nar as a significant new Au-Ag-Pb-Zn mineralized system. The geology of Altan Nar is dominated by a series of andesite volcanic flows with several stages of late granitoid dykes (generally <30 m wide) and andesite dykes (generally <10m wide), some of which intersect mineralized zones. Altan Nar extends over a 5.6 by 1.5 km mineralized corridor that is defined by a widespread Pb and Zn soil anomaly and is host to 18 target zones with near-surface Au-Ag-As-Pb-Zn geochemical anomalies. Mineralized zones are often associated with zones of phyllic alteration (i.e., quartz-sericite/muscovite-pyrite), up to 100 m wide. Drilling to date has identified several high-grade zones within broad zones of mineralization, including a five metre wide, near-surface intersection, that returned assay values averaging 17.7 grams per tonne Au, 69 grams per tonne Ag, and 4.6 % combined Pb-Zn. Au and Ag mineralization is mostly present in quartz breccia zones with characteristic multiple stages of brecciation, silicification and quartz veins. Quartz veins typically have comb, colloform and crustiform textures, although some late veins have chalcedonic quartz. Both low and high arsenic gold mineralization has been identified at Altan Nar. Preliminary work indicates that the low-As mineralization is widespread with high-As mineralization generally restricted to narrow zones thought to be related to late stage mineralization. Mineralogical investigations of As-rich samples indicate a complex ore and gangue mineralogy including gangue minerals quartz, mica, calcite, rhodochrosite and several Mn-bearing carbonate, oxide and silicate phases along with ore minerals including arsenopyrite, galena, sphalerite, chalcopyrite, pyrite, pyrrhotite, and tetrahedrite. Gold is mostly invisible, however, very small gold grains (0.001–0.004 mm) were observed in a few thin sections. Altan Nar is interpreted as a carbonate-base metal-gold deposit, a style of epithermal deposits that are the major gold producers in the southwest Pacific Rim region and includes the very large Porgera deposit (24 million ounces Au) of Papua New Guinea.

Peritidal cycles and paleoecology of the early Carboniferous Windsor Group, Nova Scotia, Canada

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Evaporites and carbonates from Subzone B of the middle Viséan Windsor Group (ca. 340 Ma), Maritimes Basin, define brining-upward peritidal cycles that accumulated during a marine transgression. The exceptional preservation of evaporitic and fossiliferous facies provides a unique opportunity to investigate the formation of saline giants, which lack precise modern analogues. Saline giants are economically significant and hold important clues to understanding Earth's climate evolution.

Stacked, decameter-scale peritidal cycles are composed of up to nine lithofacies that record progressive shallowing and increasing salinity. Cycles are defined by flooding surfaces overlain by fossiliferous or evaporite-rich lime mudstone that grades upward into massive anhydrite. This anhydrite is in turn overlain by massive halite or laminated siltstone that changes gradually into oolitic grainstone, microbialite, nodular anhydrite or red beds. The tops of peritidal cycles are marked by either the basal flooding surface of the next cycle or a karst diastem.

Each aggradational succession is interpreted to reflect progradation of sabkha deposits over subtidal facies. The mosaic of lithofacies composing cycles is interpreted to record the effects of sub-basin geometry and evaporation, which controlled the degree of connectivity with the open ocean and water mass chemistry. Cycles from sub-basins with good connectivity to the open ocean lack massive halite and contain a high diversity assemblage of normal marine organisms that includes crinoids, brachiopods, bryozoans, and ostracods. Sub-basins with restricted circulation are characterized by cycles containing ubiquitous massive halite and a depauperate fauna indicating profound salinity stress.

The variability in facies composition between sub-basins demonstrates the heterogeneous character of some saline giants. Thus, depositional models that evoke evaporation to produce a single, large, stratified water mass from which evaporites precipitate are overly simplistic. Understanding the complex nature of the Windsor Group has provided new information about the effects of climate, tectonics, and oceanography on the development of large evaporitic depositional systems.

Evolutionary trends of the Carboniferous ostracod *Velatomorpha altilis*, Joggins Fossil Cliffs, UNESCO World Heritage Site

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The ostracod *Velatomorpha altilis* thrived in brackish coastal environments of the Carboniferous. Especially well preserved examples occur in strata exposed at the Joggins Fossil Cliffs World Heritage Site, providing an opportunity to investigate the link between evolutionary mode and temporal changes in depositional environment.

The relationship between the evolutionary mode of *V. altilis* and its environment is especially important since few other studies have examined evolutionary mode of organism living in marginal environments.

V. altilis was analyzed for evolutionary mode by measuring the length, height, width, area, and perimeter of valves from 332 specimens from 5 stratigraphic levels in the Boss Point and overlying Joggins formations. After quantitative model-based analyses, an unbiased random walk was supported as the evolutionary mode when ostracods from all 5 stratigraphic levels were included. Stasis was the suggested evolutionary mode only when ostracods from each formation were considered separately. This is consistent with other work on the evolutionary mode of *V. altilis* in the Joggins Formation.

Stasis is expected in fluctuating, stressed environments, such as the brackish coastal paleoenvironments of the Boss Point and Joggins formations. This is because organisms that inhabit those environments are usually tolerant to changing conditions. It is possible that between the formations an environmental threshold was reached that triggered rapid change in shell size. This represents a classic example of punctuated equilibrium wherein long periods of stasis are punctuated by geologically short periods of drastic morphological change.

Hydrothermal alteration of porphyry dykes related to Cu-Ag porphyry and skarn mineralization in the McKenzie Gulch area, northern New Brunswick, Canada

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The McKenzie Gulch Cu–Ag skarn mineralization occurs in four zones: the Woden Brook occurrence (0.5% Cu over 6.0 m) to the northeast, the McKenzie Gulch occurrence (1.11% Cu and 10.63g/t Ag over 0.50 m) and the Legacy skarn deposit (0.87% Cu in 1 500 000t and 10.29 g/t Ag) in the middle, and the Burntland Brook occurrence (0.40% Cu over 10.2 m) to the southwest. These occurrences are localized between two northeast-trending, dextral strike-slip fault systems, the McKenzie Gulch Fault to the west and the Rocky Gulch Fault to the east. All four zones are hosted by carbonate-bearing sedimentary rocks of the Upper Ordovician through Lower Silurian Matapédia Group and spatially associated with northeast-trending Middle to Late Devonian intermediate to felsic dyke swarms.

Geochemical data indicate that the dykes are granodioritic to tonalitic in composition and have an I-type, volcanic-arc signature. Overall these data indicate a trend towards increasing SiO_2 and Zr with decreasing TiO_2, Al_2O_3, MgO, Sc, and V from the plagioclase-hornblende porphyry through to the quartz-plagioclase porphyry, and is consistent with evolution by fractional crystallization of plagioclase, hornblende, magnetite, and titanite. However, parallel fractionation arrays for Y, Zr, and Nb in the two suites indicate that the quartz-plagioclase porphyry fractionated from a related, but slightly different source than the hornblende-plagioclase porphyry.

Petrographic examination coupled with XRD analysis indicates that primary mineral composition (i.e., plagioclase, K-feldspar, biotite, hornblende), both phenocrysts and groundmass, have been partially or completely replaced by hydrothermal alteration assemblages dominated by calcite-sericite-illite, with subordinate chlorite and kaolinite. Minor pyrite occurs as disseminations and fracture filling. Trace amounts of hematite exist in veins and replacing pyrite. Molar element ratio analyses indicate alteration styles consistent with petrographic and XRD analyses.

As a result, these hydrothermal alteration assemblages can be summarized into: (a) phyllic alteration that varies from weak to strong, and can be differentiated into two subgroups: (i) quartz-sericite-pyrite assemblage that is characterized by the complete replacement of plagioclase-K-feldspar-biotite phenocrysts and groundmass; (ii) weak sericite-pyrite ± illite assemblage that is characterized by the presence of weakly to unaltered plagioclase; (b) weak propylitic alteration, but moderate to strong along contacts with skarn, and along joint-like fractures and hydrofractures. This alteration style is characterized by partial to complete replacement of plagioclase-hornblende-biotite by chlorite-illite-calcite ± epidote. Thus, variations and distributions of these alteration assemblages reflect several important variables including degree of alteration, and nature and composition of protolith.

Carboniferous volcanic rocks in the Picadilly Mine, Sussex, New Brunswick, Canada

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Recent mining activities in the PCS Picadilly potash mine, southeastern New Brunswick revealed the existence of disrupted, finely laminated buff- to reddish-brown layers hosted near the top of the basal anhydrite unit (Upperton Formation) of the lower Carboniferous evaporite sequence (Windsor Group) in southern NB. The layers are characterized by millimeter-scale euhedral semi-translucent crystals set in a fine-grained matrix locally interrupted by fragmental textures defined by lenticular and more deeply coloured reddish clasts up to 2 cm in length. These layers are distinctively different from other finely-laminated grey- and grey-brown siliciclastic horizons in the deposit.

Petrographically, the fine-grained matrix can be seen to be composed of large (1–2 cm) mattes of optically continuous carbonate and anhydrite and exhibits a foam-like texture defined by 50–200 μm flattened ellipsoidal features that resemble variably squashed 'bubbles' and cuspate bubble fragments. These fragmental textures are reminiscent of ash-fall tuffs whereas more coherent masses of intact bubbles resemble perlitic fractures in glassy volcanic flows. Scanning electron microscopy revealed individual ellipsoidal domains to comprise an outer rind of a K-Al-Mg silicate mineral whereas the inner domains are either carbonate or halite. The matrix also contains exotic REE-minerals such as chevkinite. Euhedral fluorite and zircon crystals were also locally identified in the matrix. The larger euhedral minerals visible in hand sample were identified as quartz and altered sanidine. Cathodoluminesence imaging of fresh quartz grains revealed faint oscillatory zoning, again reminiscent of igneous phenocrysts. The U-Pb age of zircon in the sample was measured using in-situ LA-ICP-MS. A total of 5 zircon grains in 3 samples yielded a range of Pb^*/Pb^c and generated a semi-total Pb/U isochron with a lower intercept of 335 ± 8 Ma. The Pb^c-corrected data are near-concordant with a spread of $^{206}Pb/^{238}U$ ages ranging from 349 Ma to 333 Ma and a weighted mean age of 338 ± 9 Ma.

These results point to the origin of these rocks as tuffs, with U-Pb zircon ages that overlap within error the episode of peralkaline felsic volcanism documented in the Cumberland Hills rhyolite, east of Grand Lake, New Brunswick. Whereas the phenocryst assemblage and volcanic eruption ages are well preserved, the silicate matrix has been almost completely replaced by a mixture of carbonate and halite while preserving the intricate details of volcanic glass shards and perlitic fractures. The nature and physical conditions attending this replacement process are still under study.

A paleoenvironmental and paleogeographic reconstruction of the Terminal Archaic - Woodland Boswell site, Kingston, Nova Scotia, Canada

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The Boswell archaeological site is located near Kingston, Nova Scotia, on farmland next to the Annapolis River. Despite being the area of earliest European occupation in Canada, very little is known about Pre-Contact occupation along the Annapolis River drainage system. This has long puzzled local archaeologists, as the Annapolis River is an obvious travel route to the interior, and a large (2130 km^2) watershed rich in plant and animal resources. However, in 2009 artifacts were found at the location which has subsequently revealed a complex history of site development. Excavations at the site have uncovered potsherds, lithics and ecofacts which collectively indicate Terminal Archaic to Late Woodland occupation. Ecofacts from the site suggest that beaver hunting and fishing took place, along with the collection of various edible berries and nuts. Although the site was likely intermittently occupied from the Terminal Archaic to the Late Woodland (ca. 3800–1000 BP), the environmental and ecological conditions which made this location appealing for native occupants are unknown.

High resolution paleoenvironmental data from wetland and lake records in southwestern Nova Scotia indicate that at about 3000 BP forest composition changed rapidly as cooler and moister conditions developed. At this time hemlock became a more significant component of the forest cover in the region. From 3000 BP till 1000 BP, cool and moist conditions were punctuated by occasional droughts. The Boswell site is located on one of the few reaches of the Annapolis River that experienced little lateral migration in the last 3000 years, a condition which facilitated site preservation. The river terrace at the excavation site was formed by 3000 BP in response to both an increase in river discharge and a prominent bedrock sill which aided sediment aggradation. A prominent depression in the sill about 20 m upriver from the site has created one of the few large, deep (>3m) pools along the stable reach of the river and may have been a harvesting site for migrating fish species including shad, alewife, brook trout and smelt all of which were thought to be important resources.

Collectively, forest composition, which aided in bank stability, increased river flow which facilitated fish occupation and migration, bank stability and the presence of a harvesting site nearby may have made this site desirable for continued seasonal use over a long period of time. Recent erosion at the site appears related to development both upstream and downstream from the Boswell site.

Magmatic evolution of the Late Devonian Mount Douglas leucogranites, southwestern New Brunswick, Canada: an example of extreme fractional crystallization

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The Late Devonian Mount Douglas intrusive suite (MD, ~600 km^2) of southwestern New Brunswick, Canada, eastern part of the Saint George Batholith, is a suite of peraluminous leucogranites extended from Red Rock Lake to Mount Douglas. Extreme fractional crystallization associated with formation of this suite is the most important factor affecting the magmatic evolution, producing three compositionally and chronologically different intrusive units, Dmd1, Dmd2, and Dmd3. Petrochemical data show that the subunits of the Mount Douglas Granite have within-plate geochemical character with evidence of hybrid I- and S-type affinity. Very low K/Rb (average 102.7), Nb/Ta (≤6.8), and Zr/Hf (≤37.45) ratios in Dmd3 compared to Dmd1 possibly reflect significant involvement of extreme low T crystal fractionation in the last-stages of magmatic differentiation; The continuous variation trends for many major and trace elements (e.g., Zr vs. TiO_2, Zr/Hf vs. K/Rb, F vs. K/Rb, and Pb vs. Ba) suggest that probably Dmd2 and Dmd3 were generated by extensive fractionation of the parental Dmd1 magma. Also, normalized to the least-evolved sample of the MG granites (Dmd1), the Dmd3 unit is the most enriched in Rb, Th, U, Ce, Ta, Pb, Nd, Sm, Dy, Y, Yb, and Lu, and depletion of Cs, Ba, Sr, P, Zr, Eu, and Ti content, reflects their production of the same parental magma by crystal fractionation from Dmd1 to Dmd3. A flat "birdwing shape" REE patterns with the most pronounced negative Eu anomalies and the lowest (La/Yb)N (ranging from 1.7–7.4) ratios of Dmd3 show the highly evolved attributes of Dmd3. Calculation of zircon saturation temperatures supports an interpretation of crystal fractionation from Dmd1 to Dmd3. Estimated average temperatures using the bulk rock Zr composition for Dmd1, Dmd2, and Dmd3 range 747–826°C, 733–817°C, and 729–816°C, respectively. All above data suggest that they might have a single genetic group with different fractionation originated from a homogenous parental magma, in which this fractionation increases from the early unit (Dmd1) to the latest unit (Dmd3); significant mineral occurrences, such as Sn, W, and Mo, seem to be mostly associated with the latest and most highly differentiated Dmd3 intrusive phases.

Salt water intrusion within a Carboniferous sandstone aquifer at Richibucto, New Brunswick, as revealed by hydrogeophysical and petrophysical investigations

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Hydrogeophysical surveys have been carried out in the vicinity of Richibucto, New Brunswick, as part of a project to assess the risk that salt water intrusion along the Northumberland Strait could increase over time as a consequence of climate change and rising sea level. The surveys involved electrical resistivity imaging (ERI) measurements along several lines extending inland from the coast in conjunction with geophysical logging of two new and several pre-existing boreholes. The investigation indicates that the elevated salinities that have intermittently affected Richibucto's municipal wellfield are likely a consequence of salt water upcoming beneath pumping wells. Evidence of a salt water wedge extending approximately 200 m inland was also observed beneath one ERI line acquired in a particularly low lying area adjacent to Richibucto Harbour. The results illustrate that ERI surveying can be an effective tool in identifying the extent and modes of salt water intrusion in Carboniferous sandstone aquifers that supply water to many coastal communities along the Northumberland Strait coast. Data interpretation is, however, complicated by the presence of relatively thin, discontinuous layers of electrically conductive shale.

With core recovered from boreholes, a relationship was established in the laboratory between the bulk conductivity of rock samples and their pore fluid conductivity. With this relationship, along with a relationship of chloride concentration to water conductivity acquired from water sampling, it was possible to estimate in-situ pore water salinity from borehole resistivity measurements.

Reconciling mutually incompatible models for the tectonostratigraphic zonation of the Variscan orogen in western Europe

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The Late Paleozoic Variscan orogen in Europe is widely acknowledged to be the result of convergence and collision between Laurussia and Gondwana during closure of the Rheic Ocean. The orogen is classically divided into a number of tectonostratigraphic zones that have a distinctive curvature (Ibero-Armorican Arc, IAA) and record different aspects of the Late Cambrian-Early Ordovician opening of the Rheic Ocean and the migration of terranes from the Gondwanan margin towards Laurussia, as well as the tectonothermal events that accompanied the closure of that ocean and the development of the IAA. Although there is a general consensus that the curvature originated at some stage during the development of the Variscan orogen two models have emerged to explain the distribution of tectonostratigraphic zones:

(1) a consequence of indentation tectonics due to collision with Laurussia by a (Ibero-Aquitanian) promontory of Gondwana during the Devonian; (2) development of the Cantabrian orocline at ca. 295 Ma at the inner core of the IAA, an interpretation supported by a wealth of paleomagnetic, structural and geochronological data. These models have been viewed to be mutually incompatible because the former requires curvature along the Gondwanan margin prior to its ca. 400 Ma collision with Laurussia, whereas

the latter requires that the tectonostratigraphic zones were linear prior to bending at ca. 295 Ma.

Recent sedimentological and structural data have rekindled the hypothesis that the Cantabrian Orocline is connected to a second orocline to the south (Central Iberian Orocline), highlighting the possibility that inner (Gondwanan) and outer (Laurussian) zones of the Ibero-Armorican arc may be structurally discordant with respect to each other, implying that the geographic limits of orocline formation are presently unclear.

The two models can be simply reconciled if the geography of Gondwana's leading edge was irregular, but the tectono-stratigraphic zones remained approximately linear within the inner zones of the putative Ibero-Aquitanian indenter and deformation associated with initial collision was largely accommodated by sinistral (SW Iberia) and dextral (Armorican Massif) motion along shear zones on either side of the promontory).

Geochemical characterization of fine-grained Carboniferous strata of the Maritimes Basin Complex of New Brunswick, Canada

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The Carboniferous Maritimes Basin Complex of New Brunswick is divided into six lithostratigraphic groups; the Horton, Sussex, Windsor, Mabou, Cumberland, and Pictou groups. Unfortunately, it is often difficult to distinguish units from each other; including some of economic importance such as the Horton Group. These difficulties include: restricted outcrop exposures, lithologically similar fine-grained strata in many units, a near complete absence of radiometrically datable materials, and reworking of rare microfossils throughout the succession. In other stratigraphic successions with similar complications, chemostratigraphic approaches have been used to help differentiate units. As for the Carboniferous of New Brunswick, little such geochemical data currently exists to aid in the differentiation of these units. Accordingly, 139 samples in total have been collected from fine-grained strata in outcrop and borehole representing each of the Carboniferous groups throughout the province. For each sample, and additionally for reference standards, 55 elements were analyzed by Inductively-coupled-plasma and mass spectrometry (ICP-MS).

Broadly, the samples from each unit are geochemically all quite similar. However, several trends have been visually identified from preliminary analyses of the data that currently are being assessed through statistical analyses. For example, when ratios of Al_2O_3:TiO_2 are compared, the lower three groups (the Horton, Sussex, and Windsor) of the succession show strongly positive correlations and goodness of fit to the regression line (with R2 values of 0.669, 0.5794, and 0.8536 respectively), whereas the groups higher in the succession (the Mabou, Cumberland, and Pictou groups) have an R2 value of no higher than 0.15. When comparing plots of Na_2O/K_2O against Zr/Cr, the Windsor and Cumberland groups display relatively strong negative correlations and goodness of fit to the regression line (R2 values of 0.501 and 0.273 respectively), the Horton Group shows a weak positive correlation and goodness of fit (R2 value of 0.104), while the rest show R2 values of less than 0.090.

By further comparing the geochemical data collected from the finer-grained rocks of the Carboniferous Maritimes Basin, certain potential anomalies or trends seen throughout the groups of the succession may become apparent which can aid in a chemostratigraphic characterization of the Carboniferous of New Brunswick.

Stratigraphic constraints on Cambrian stratigraphy, Mira and Bras d'Or terranes, Cape Breton Island, Nova Scotia, Canada

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Cambrian sedimentary rocks of Cape Breton Island, Nova Scotia, contain generally well preserved acritarchs recovered from the majority of the sampled levels. The data provide considerable additional age constraints to the largely siliciclastic successions from which earlier age constraints are sparse. Because the majority of acritarchs likely were cysts of planktic organisms they do not provide new insights into ongoing arguments on the paleogeographical configuration (and number) of terranes present within the Cape Breton Island. On the other hand, the recovery here of characteristic acritarchs that are also found in Baltica, and other regions enables fossil-based correlation for much of the succession, and a better control of the age correlation between different parts of Cape Breton Island. In fact, Cape Breton Island provides an exceptionally complete succession of Cambrian acritarch zones.

In the Avalonian Mira terrane, a low diversity assemblage with leiosphaerids, *Granomarginata*, and small ornamented acritarchs (*Asteridium*) have been recovered from the MacCodrum Formation north of Mira River. Although not age-diagnostic, this association and the absence of taxa indicating a younger age are consistent with an early Early Cambrian age. A late, but not latest,

Early Cambrian association including *Globosphaeridium cerinum* and *Skiagia ornata* was recovered from the Canoe Brook Formation west of the Mira River. East of Mira River acritarchs are found in the Trout Brook Formation and are particularly well-preserved and diverse in the MacLean Brook and MacNeil Formations, including various species of *Cristallinium*, *Stelliferidium*, *Timofeevia*, and *Vulcanisphaera*. Our samples cast doubt on the existence of an Ordovician unit (McAdams Brook Formation) in the Coxheath Hills, which was erected based on an earlier report of Ordovician acritarchs. The recovered acritarchs rather suggest that these strata belong to the MacMullin Formation as was originally suggested.

In the Indian Brook area (part of the Ganderian Bras d'Or terrane) acritarchs were recovered from the Middle Cambrian Eskasoni, Dugald, and MacMullin formations in the south, and from the otherwise fossil-poor MacMullin Formation in the north. Our results support earlier evidence that the MacMullin Formation is largely contemporaneous with the MacLean Brook Formation, but indicate that the Dugald-MacMullin Formation transition is somewhat younger than previously interpreted, and potentially contains a hiatus.

In-situ Gamma-Ray Spectrometry: a tool to examine the degree of fractionation of pegmatites in the Prosperous Suite, Northwest Territories, Canad

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Exotic minerals, such as beryl, spodumene, and schorl, have been identified in LCT pegmatites located in the granitic plutons of the Prosperous Suite and surrounding supracrustal rocks of the Slave Province within a 40 × 50 kilometre zone north and northeast of Great Slave Lake. The presence of these minerals is typical of rare-element pegmatites that represent extreme fractionation. A gamma-ray spectrometer (GRS) was used in this preliminary study to measure the pegmatites, granites, and supracrustal rocks for K, equivalent U (eU), and equivalent Th (eTh). Uranium and Th are typically incompatible in fractionating magmatic systems and are used to evaluate general fractionation, which will constrain the search for their rare-element potential. This data, coupled with field observations, is used to examine the degree of fractionation seen in the pegmatites locally and regionally.

Sampling of pegmatites around four of the 14 Prosperous Suite plutons (Prestige, Prosperous, Sparrow/Hidden) was completed this past summer. A total of 225 pegmatite and 71 granite surface GRS measurements were taken at this time, ranging up to 236 ppm eU and 56 ppm eTh for pegmatites and up to 35 ppm eU and 45 ppm eTh for granites. The measurements were made using a handheld RS-125 Spectrometer equipped with a 2 × 2 NaI crystal detector with an integration time of 120 seconds. The measurements were taken along transects across zones of unweathered pegmatites and of surrounding unweathered rock.

In general, the pegmatites intruding the supracrustal rocks are more fractionated than those intruding the plutons of the Prosperous Suite. The transects across the zones of the pegmatites show an increase of eU and eTh when moving from wall zone to intermediate zone, and a decrease in the eU/eTh in the core. The metasedimentary sequence surrounding the Prestige pluton has multiple pegmatites with large beryl crystals (up to 10 cm in diameter). These pegmatites have abnormally high eU/eTh ratios. The pegmatites hosted in the pluton have low eU and eTh contents. These observations lead to the interpretation that the pegmatites intruding the metasedimentary sequence are more fractionated than those intruding the Prestige pluton. Pegmatites surrounding the Prosperous pluton have a low average eU/eTh ratio, suggesting a lower degree of fractionation; however, an outlier zone was identified at the Riber pegmatite. The pegmatites intruding both the plutons and supracrustal rocks in the Sparrow/ Hidden area have the highest average eU and eU/eTh measurements, which coincides with an elevated content of beryl and spodumene in these pegmatites.

Southwestern end of the St. Martins–Stewart Mountain high-strain zone: Big Salmon River–St. Martins area, southern New Brunswick, Canada

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The St. Martins-Stewart Mountain high-strain zone divides the Avalonian Caledonia Highlands, into a southeastern segment, where predominantly volcanic rocks of the upper Coldbrook Group overlie volcanic and sedimentary rocks of the older Broad River Group (both Ediacaran) and plutonic rocks of the Point Wolfe River suite (and related plutons); and a northwestern segment comprised of lower and upper Coldbrook Group volcanic and sedimentary rocks intruded by the contemporaneous

Bonnell Brook and related plutons. The high-strain zone reaches the southern coast of New Brunswick between Little Salmon River and St. Martins with a series of southerly splays. Associated with the Ediacaran units in this area are enclaves of Cambrian Saint John Group, and a volcanic unit (Fairfield rhyolite) with a poorly constrained Devonian age.

Construction of the Fundy Coast Parkway has created extensive new outcrop in this problematic area, and detailed mapping and structural analysis show that tectonic enclaves of Saint John Group are intercalated with Coldbrook Group rhyolite and mafic rocks and minor sedimentary rocks. Both the Ratcliffe Brook and Glen Falls formations are present, and above them, in ascending order: (1) grey-green siltstone, sandstone and shale, with minor purplish-grey mudstone; and (2) grey to black mudstone and siltstone. These last two units may correlate with the Hanford Brook and Silver Falls formations, respectively. One problematic unit contains rhyolite intercalated with grey-green siltstone-shale and red-brown siltstone-sandstone. The contact is deformed but not completely transposed. The age of the rhyolite is unknown and dating will permit assignment either to the Cambrian Saint John Group or the Ediacaran Coldbrook Group.

New radiometric dating has resolved one problem: the age of the Fairfield rhyolite – now shown to be ca. 620 Ma and most probably a wedge of Broad River Group between splays of the main shear zone. Another new radiometric age from a faulted block of mafic volcanic rocks along the coast, previously considered to be Coldbrook Group (Hosford Brook Formation) or Broad River Group (Hayward Brook Formation), or Devonian-Carboniferous Lorneville Group, at ca. 695 Ma is more problematic with no obvious correlatives in the area.

All the rocks through this area previously assigned to the "Seeley Beach Formation" of the Coldbrook Group, with the exception of the one problematic unit, are units of the Cambrian Saint John Group. The original relationship with Neoproterozoic rocks was an unconformity. Geometry of the tectonic enclaves is complex, but suggests partial entrainment into a right-lateral strike-slip duplex.

No tin deposits in Chile? Focus on one exception: the Belén -Tignamar district, Arica

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The Central Andes are rich in metal deposits associated with magmatism arising from subduction of oceanic lithosphere under South America. Bolivia, southern Peru and northwestern Argentina are rich in tin deposits associated with Paleozoic to Pliocene igneous rocks; yet coeval magmatic centres in immediately adjacent Chile rarely contain tin. One anomaly is the polymetallic Capitana deposit, Belén-Tignamar district, in the high Andes of Arica (18°35'S; 69°30'W). A unique specimen collected by M. Zentilli in the abandoned mine in 1963 is being used as a focus to review the question of why tin is so rare in Chile. Reportedly, a Capitana vein contained 7% Sb, 0.1% Ag, 5% Cu, 2.5% Pb, 11.8% Bi, and 4.7% Sn.

There have been many different hypotheses concerning the contrast between tin-rich Bolivia and tin-deprived Chile. Workers suggested that granitophile tin originated in anomalously tin-rich crust, or was remobilized from pre-existing tin concentrations. Differences in elevation and depth of erosion were considered to play a role. In the 1970s a popular hypothesis proposed that during subduction, tin was selectively distilled from subducted lithosphere, deeper and farther (east) than copper. More recently, experimental studies and chemical modeling have shown that when magmas evolve with low oxygen fugacity, such as when interacting with reducing carbon in the crust, Sn^{2+} behaves as incompatible element and becomes enriched in hydrothermal fluids, whereas in oxidized magmas Sn^{4+} gets incorporated in rock-forming minerals, and is thus dispersed. If the reduced stannous fluids encounter oxidizing conditions, tin is precipitated as cassiterite (SnO_2); in the presence of S, As, and Sb, for example in epithermal Capitana, tin goes into sulphosalts.

The mineralogy and geochemistry of the ore specimen have been studied using reflected light microscopy, XRD, electron microprobe and bulk chemical analysis. The specimen has quartz, pyrite, sphalerite, (covellite), tetrahedrite-tennantite ($Cu_{12}Sb_4S_{13}$-$Cu_{12}As_4S_{13}$) and other sulphosalts. Chemically it contains 6.1% Cu, 0.5% Zn, 10% Pb, 4.8% Bi, 0.7% Ag, 0.05% Sn (predominantly in sphalerite), 3.5% Sb, 3.1% As, and is enriched in Hg (46 ppm) and U (57 ppm; Th/U = 0.01).

The geological map may hold the clue to the existence of this unique tin deposit in Chile. Capitana is hosted by Mesozoic to Cenozoic volcanic rocks, and associated with a Tertiary porphyritic intrusive. A most unusual fact is that within the Belén-Tignamar district there are outcrops of an isolated, fault bounded inlier of the Belén Schist, a Proterozoic-Paleozoic gneissic complex of metamorphosed igneous and sedimentary rocks similar to those known from the crystalline basement of the Bolivian tin province.

Petrographic and chemical characteristics of mafic dykes and sills in the Antigonish Highlands, Nova Scotia, Canada

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The Antigonish Highlands of northern mainland Nova Scotia have a long and complex tectonic history involving at least three major episodes of magmatism during the Late Neoproterozoic, Ordovician, and Devonian-Carboniferous. Mafic dykes and sills are abundant throughout the Antigonish Highlands, presumably related to one or more of these magmatic episodes. Dykes/sills have been observed at almost 200 locations, most in units older than the Silurian Arisaig Group. In Neoproterozoic stratified units, many of the sills were originally thought to have been flows. Wide variations in petrographic, magnetic, and chemical characteristics suggest multiple episodes of dyke/sill emplacement. Based on the petrography of 67 samples, two main types of sills and dykes are recognized: clinopyroxene-bearing and plagioclase porphyritic. The clinopyroxene-bearing group is subdivided into intergranular, coarse-grained, and secondary amphibole-bearing. Whole-rock chemical analysis of 33 of these dykes/sills shows that the majority are mafic (<52% SiO_2) but a few are intermediate with up to 55% SiO_2. Loss on ignition is typically high (ca. 5–10%) consistent with extensive alteration in the rocks, including saussuritization of plagioclase and replacement of pyroxene by chlorite. Both major and trace elements show wide variation, likely also linked at least in part to alteration, and correlations between chemical characteristics and petrographic characteristics are not apparent in the existing data set, even when augmented by chemical data obtained using a portable XRF instrument. However, the dykes/sills appear to fall into two distinct chemical groups based on tectonic setting discrimination diagrams using mainly immobile elements: volcanic-arc and within-plate. Samples in the volcanic-arc group are subalkalic and show chemical characteristics similar to those of the Neoproterozoic volcanic and plutonic units of the Antigonish Highlands, generally interpreted to have formed in a subduction zone. The within-plate samples are subalkalic transitional to alkalic and show chemical similarities to the Ordovician within-plate Ordovician plutonic and volcanic units of the Antigonish Highlands. However, a number of subalkalic samples are ambiguous in their classification and/or plot in units too young for them to be Neoproterozoic. None of the samples examined in thin section seem unaltered enough or have petrographic features to suggest that they are related to the Devonian-Carboniferous magmatic events.

A cabinet of curiosities: treasure hunting in the collections of the Nova Scotia Museum and the importance of community engagement

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Provincial museums safeguard a wealth of cultural heritage. This cultural heritage includes specimens with incredible scientific and historical significance of interest at the regional, national, and global scale. Fostering this interest in members of the community is of the utmost importance as donations of specimens serve as important sources for artefacts. One such donation led to the acquisition of a portion of the collection of the Nova Scotia Museum's first director and curator: Reverend David Honeyman.

When a gentleman purchased a small, glass-fronted cabinet filled with shells, shark teeth, and other curiosities at an estate sale in the 1970s, he hoped that it would encourage an interest in natural history in his children. Decades later in 2011, he rediscovered this lost treasure trove. Approaching the Nova Scotia Museum, this gentleman wondered if his cabinet was of interest to Nova Scotia's cultural heritage. Little did he know that this little cabinet and its dozens of handmade cardboard trays full of fossilized clams, snails, coral, and teeth represented a portion of the collection used by Reverend David Honeyman when writing his book *Giants and Pigmies: Earth's Order of Formation and Life and the Harmony of the Two Records.*

Among the material in this cabinet are several specimens that Honeyman collected or discussed during, or incorporated into displays at, the International Exhibitions of London (1862) and Dublin (1865) as well as the Universal Exposition in Paris (1867) and the Philadelphia Centennial International Exhibition (1876). These specimens include Megalodon teeth, giant sea snails, irregular sea urchins, and dozens of nummulitid foraminifera.

The acquisition of this collection offers several avenues for study beyond that of the evolutionary and geological history of the specimens. These specimens, and the pages of Giants and Pigmies corresponding to them, provide an opportunity to better understand specimen collection and fieldwork in the latter half of the 19th century, as well as the context for important international meetings from the 1860s–1880s. Likewise, this material can help improve our understanding of Honeyman himself, and of the origins of the Nova Scotia Museum. Finally, collections such as these help to encourage community engagement and enthusiasm about provincial natural history, further stimulating interest in provincial museum collections and, perhaps, encouraging further donations.

Long-term joint monitoring of self-potential and temperature with active thermometry for seepage surveillance at the Mactaquac Dam, New Brunswick, Canada

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A seepage monitoring study has been underway at the Mactaquac hydroelectric generating station as of April 2013 involving the joint monitoring of temperature and self-potential (SP) near the interface of an embankment dam and concrete diversion sluice way structure.

Two 50 m long boreholes were drilled in the concrete, parallel to the interface and ~0.5 m from the adjacent embankment core. Focused coverage of the interface was provided by fibre optic distributed temperature sensing (DTS) cables, heating cables, and 32 SP electrodes installed in the boreholes. In addition to the borehole instrumentation a 20 × 54 m surface electrode grid consisting of 30 SP electrodes were installed on the downstream slope of the embankment close to the concrete structure. SP and DTS signals are recorded continuously at sample rates of 1 min and 30 min respectively in the ongoing experiment.

The SP response recorded by the surface electrodes has been analyzed over a 20 month period, and reveals to be a complex superposition of electrical potentials likely influenced by dam seepage, temperature, rainfall, telluric currents, head pond flow, freezing, and electrochemical reactions. Qualitatively, the SP responses during each freshet event and the annual seasonal cycle shows some reproducibility from year to year.

The upstream heating cables were activated for a 27 day period in July of 2014. The corresponding temperature response during heating and cooling was recorded in an attempt to identify areas preferentially affected by advective heat transfer. The temperature response from active heating agreed well with the known position of the water table and preliminary results from numerical modelling, and revealed an anomalous area in the saturated zone. However the irregular failure of one of the heating cables during the heating period necessitates that the experiment should be repeated.

Further work will require analysis and modelling of the long term seasonal variations of temperature, and forward modelling of the electrokinetic response due to bulk seepage, head pond currents, and preferential seepage pathways.

Ethics in geoscience: our integrity is at stake

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Ethics in geology is one of the most important aspects of geoscience today. It lies directly at the convergence of Earth sciences and society. In 2013, we distributed an online survey to a variety of geoscience-related organizations across Canada. Our intent was to: (1) determine the current state and understanding of geoethical considerations across the geoscience community; and (2) determine whether there was a need to more formally incorporate geoethics education into our undergraduate programs. Over 120 respondents with different levels of training, fields of expertise, and experience contributed anonymous responses to questions related to the following aspects of potential geoethical considerations: (i) scientific integrity; (ii) social responsibility; (iii) aboriginal issues; (iv) corporate ethics; and (v) fieldwork. The majority of respondents agreed that most categories identified were important considerations. A second section on the survey asked respondents to identify from a list given, suspect behaviours they had observed in the working geoscience environment. Over 60% of respondents indicated they had observed biased representation of information and failure to give credit to the author or originator of an idea; over 40% of respondents also indicated they had observed abuse of power by a supervisor, degradation of persons for reasons of gender, minority/race, or sexual orientation, potential conflict of interest, and private land access without permission.

A third section sought to determine how and where geoscientists learned about geoethics, and whether they believed their undergraduate education prepared them to make the ethical decisions they faced in their workplace. Discussions with peers and independent reading were the dominant means for learning about geoethical considerations, and less than 35% of respondents indicated that their undergraduate program prepared them for ethical decision-making in geoscience. These findings collectively speak to an urgent need to address geoethical issues in our undergraduate programs. We are currently in the process of developing materials for wider distribution and welcome ideas and suggestions as we develop these geoethical principles materials.

A soil geochemical survey of Fredericton, New Brunswick, Canada

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A total of 101 locations were sampled as part of a soil geochemical survey of the downtown urban centre of Fredericton, New Brunswick. The city obtains ~95% of its potable water supply from an aquifer mostly confined by a discontinuous clay-silt aquitard underlying the urban centre. The aquitard contains "windows", which could allow contaminates into the aquifer; hence, the focus of this study.

The area, which has been the provincial capital since 1785, occupies a broad floodplain located between the Saint John River and higher bedrock terrain to the west. Two samples were obtained at most sites, an 'A' sample collected at a depth of approximately 10 cm and, where possible, a 'B' sample collected at a depth of approximately 30 cm. Till samples were collected from areas of higher elevation where the terrain has been less disturbed by natural or anthropogenic activity. Samples <63 μm (230 mesh) were analyzed by Instrumental Neutron Activation Analysis (INAA) or Inductively Coupled Plasma Analysis (ICP) in order to determine elemental concentration for 50 elements. Five elements, As, Cr, Ni, Pb, and Zn, were found to exceed the Canadian Council of Ministers of the Environment (CCME) soil content guidelines for 'A' samples collected in the downtown area. For example, of this sample group 100% of the samples exceeded CCME guidelines for Cr soil concentrations, by 1.7 times the recommended limit of 64 ppm, and approximately 89% of this sample group exceeded the CCME guideline limit of 12 ppm for As soil content by 2.6 times. Concentrations of 34% of the sampled population for Pb were also found to be 2 times greater than CCME recommended soil content of 140 ppm. One particular downtown location demonstrates anomalous concentrations of all five elements and the history of anthropologic activities at that site are presently being investigated.

Topography and elemental mobility are interpreted to represent a major factor in the dispersion of the elements. The till 'B' samples displayed higher elemental concentrations than the 'A' samples; likely due to weathering and element mobility. Samples from the downtown area were collected from re-worked fluvial floodplain sediments that demonstrated much higher elemental concentrations in the 'A' samples in comparison to the underlying 'B' samples. The higher concentrations of some metals in the near-surface soils are interpreted to be caused by long-term anthropological activity in the urban centre.

Sedimentology and taphonomy of the plant-bearing beds of the Colwell Creek Pond site in the Early Permian Clear Fork Group of north-central Texas, USA*

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The Clear Fork Group is a 400 m thick, fluvio-continental unit that was deposited on the Eastern Shelf of the Midland Basin. Colwell Creek Pond is a fossiliferous site within the informal middle unit which provides a rare opportunity to evaluate the environments in which plants grew and the taphonomic conditions responsible for the well-preserved plant leaves.

Two partially preserved channel bodies are present. Storey 1 is a 5 m deep channel cut with a width: thickness ratio of 13:1. A thin basal channel deposit (50 cm) of pebbly conglomerate, ripple cross-laminated and planar-stratified sandstone rests erosionally on red massive siltstones interpreted as paleosols; the sandstone contains diplichnitid trackways. Above is a 2 m thick laminated claystone with varicoloured laminae, loop bedding and microfaults. Each lamina ranges from 0.3 cm to 2 cm in thickness and is normally graded from coarse silt to clay with non-erosive, parallel-planar bedding surfaces. XRD and TOC analysis indicates the presence of chlorite, illite and other detrital grains but no carbonate or evaporite minerals, with negligible organic carbon. The storey is capped by 2.9 m of massive claystone with root traces and abundant slickensides below the erosive base of Storey 2, a sheet-like channel body with stacked fining-upward cycles.

The Storey 1 channel was abruptly abandoned shortly after incision. Sediments were delivered by slow-moving density underflows that laid down graded laminae. The upward change to rooted claystone indicates shallowing due to sedimentation and, perhaps, declining water levels. Similar well laminated abandonment fills are common in the Clear Fork Group but rare in fluvial units elsewhere, and imply a lack of bioturbating organisms.

Plant fragments are preserved in the laminated claystone, and probably settled from suspension after transport by the density underflows. Well-preserved fronds of the conifer *Walchia piniformis*, the cycadophyte *Taeniopteris* spp. and the peltasperm *Auritifolia waggoneri* were probably derived from the adjacent riparian zone. They were preserved as 3D goethite petrifactions which suggest that early mineralization, probably promoted by microorganisms, arrested decay and aided preservation.

The abundance of exceptionally preserved plants might suggest a well vegetated landscape and relatively humid setting, as supported also by the detrital nature of the laminae. However, within the Clear Fork Group, the lack of upright trees, the scarcity of logs, and the presence of laminated, non-bioturbated fines suggest a relatively arid setting. Early biomineralization and exceptional preservation of fronds may have imposed a taphonomic bias on the assemblage.

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

Petrology and age of the “Chéticamp pluton”, western Cape Breton Highlands, Nova Scotia, Canada

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The Chéticamp pluton is a large mainly granodioritic to granitic pluton defined and mapped in the 1980s in the western Aspy terrane of Cape Breton Island, Nova Scotia. The poorly constrained late Neoproterozoic age previously reported for the pluton, as well as its mainly faulted contacts, have made it difficult to understand its relationship to its host rocks and the significance of its location in the otherwise mainly Ordovician-Silurian Aspy terrane. Mapping during the summer of 2014 and follow-up petrological work have resulted in subdivision of the pluton into seven map units, although relative ages remain uncertain. The Grand Falaise granodiorite is the largest, and occurs in two separate areas in the central and northern parts of the pluton. It is medium- to coarse-grained and locally megacrystic with large crystals of K-feldspar; the main ferromagnesian mineral is biotite. The Grand Falaise granodiorite is in faulted contact with the Pembroke Lake monzogranite, muscovite-bearing, medium- to coarse-grained, and locally megacrystic with K-feldspar megacrysts. The Chéticamp River tonalite forms two separate areas in the northern part of the pluton. It is equigranular and fine- to medium-grained, and contains both biotite and ferroan-pargasitic hornblende. Dioritic rocks occur in two small areas, one in the upper part of Fisset Brook where is appears to have intruded part of the Jumping Brook Metamorphic Suite, and the other in the southern part of the pluton around Lavis Brook south of the Pembroke Lake monzogranite. In both areas the rocks are mainly equigranular to porphyritic quartz diorite, grading locally into granodiorite and quartz monzodiorite. The McLean Brook granodiorite, previously interpreted to be of Devonian age, occurs in the southernmost part of the pluton. It is subporphyritic, and shows a distinctive texture of subhedral plagioclase laths and interstitial potassium feldspar. A small area of fine-grained equigranular syenogranite occurs at French Mountain where it clearly intruded the northern body of the Chéticamp River tonalite. Geochemical data from all units have SiO_2 between about 50% and 76%, with typical fractionations trends well developed in the Grand Falaise and Pembroke Lake granodioritic and monzogranitic units, but less so among the other units. However, all are calc-alkalic and likely formed in a converging plate setting. Preliminary results of U-Pb dating of zircon (still in progress) indicate that the units of the “Chéticamp pluton” have a wide range of ages, including ca. 566 Ma (Grand Falaise granodiorite), ca. 500 Ma (Chéticamp River tonalite), and ca. 440 Ma (Lavis Brook quartz diorite and McLean Brook granodiorite).

Tetrapods from the Tournaisian of Nova Scotia, Canada and northern Britain: new evidence of tetrapod diversity in the Early Carboniferous

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Tetrapod trackways have been known from the Tournaisian Horton Bluff Formation at Blue Beach, Nova Scotia, for more than 170 years. An extensive new collection of tracks and trackways from several localities in the Horton is now the oldest known diverse tetrapod ichnofauna, with 5 footprint morphotypes, including a smaller *Batrachichnus*-type, suggesting a 0.2 m or smaller trackmaker. Tetrapod body fossils were first found there in the 1960s, but only over the past 15 years has the extraordinary richness of the locality been realized. Regular walking of the beach has revealed a wealth of new material in the talus from the eroding cliffs. Many isolated tetrapod limb and girdle bones have been collected, but diagnosable skull and axial elements are rare. At least four taxa have been identified so far, including one with an *Acanthostega*-like femur and another with a *Tulerpeton*-like femur. This may be evidence that Devonian-grade tetrapods continued into the Early Carboniferous. All the diagnostic tetrapod remains are from larger animals, in the range 0.5–1.5 m long. This contrasts with the tetrapods discovered recently from nearly coeval deposits of the Ballagan Formation in the Tweed Basin of northern Britain where, alongside large individuals, much smaller adult forms c 30 cm long are present. These would match the sizes of some of the small tracks from Blue Beach. The associated vertebrate fauna at Blue Beach includes rhizodonts, elasmobranchs, large and small actinopterygians, and several acanthodian groups (scarce gyracanthids, rare climatiids, and abundant acanthodidids). Lungfish are very rare. This differs from that of the Tweed Basin fauna where gyracanthids are common, lungfish are diverse, actinopterygians are small

and elasmobranchs are almost entirely absent. These differences probably reflect contrasting geological settings. The Horton Bluff Formation is interpreted as accumulating in marginal marine conditions, and many of the vertebrate bearing horizons appear to be storm deposits. The Ballagan Formation in the Tweed Basin is interpreted as deposition on extensive low-relief vegetated coastal-alluvial plains. There is evidence that both were in close proximity to upland areas. Vertebrate fossils have occasionally been collected from other localities in the Horton Bluff Formation in the Minas Basin. Experience in the Tweed Basin suggests that this augurs well for the prospect of future Tournaisian discoveries in Nova Scotia and other parts of the world.

The top predator of Joggins and its tracker Donald Reid

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The Carboniferous section exposed at the Joggins Fossil Cliffs World Heritage Site is famed for its record of Pennsylvanian tetrapods and their footprints. The tetrapod body fossil record is dominated by small tetrapods due to their taphonomic bias of being entombed within fossil tree hollows. The corresponding record of larger tetrapods at this locality is scarce. A clue to the existence of large tetrapod footprints at Joggins was first recognized by Sir William Dawson, who collected a partial print later assigned by George Frederick Matthews in 1905 to *Baropezia abscissa*. In the late Twentieth Century, a much richer record emerged primarily due to discoveries by Don Reid that included numerous specimens of the largest tetrapod footprints yet discovered at Joggins. The footprints have been documented from within a 1500 m thick interval that spans the upper Boss Point Formation and overlying Little River and Joggins formations, all of the Cumberland Group. The age of this stratal interval falls within the Bashkirian stage of the Lower Pennsylvanian. Ascribing the footprints to existing ichnotaxa has been problematic, in part due to the antiquity of descriptions, synonomy of large tetrapod footprints of this time period, and a restricted number of type specimens. Candidate ichnotaxa from the published literature include the ichnogenera *Baropezia*, *Pseudobradypus*, *Schmidtopus*, *Parabaropus*, and *Megapezia*. The newly recognized footprints conform best to the concept of *Baropezia* but not to a known ichnospecies. The footprints average 10 cm in width, with stubby toe prints that invariably show extramorphological variation created by extraction of deeply impressed feet with resulting toe drags. As is usually the case, there is no 'Cinderella with its foot in the slipper'; an incomplete skeletal record of a crocodile-sized tetrapod comprising a jaw and pelvic girdle, assigned at least in part to the amphibian *Baphetes*, is the leading candidate for trackmaker. It is fitting that footprints of the top predator and largest tetrapod at Joggins eventually be named in honour of Mr. Reid, 'Keeper of the Cliffs', who has excelled in his ability to recognize the fossil footprint record of Joggins, and whose collection contributed to the inscription of Joggins on UNESCO's list of World Heritage.

An evaluation of alteration assemblages and fluid-inclusion chemistry in granitoid samples from the South Mountain Batholith, Nova Scotia, Canada: a tool for deciphering barren and mineralized zones

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The Devonian South Mountain Batholith (SMB) of Nova Scotia is a large (~7300 km^2), contiguous granitoid intrusion that consists of 13 coalesced plutons of granodiorite to leucomonzogranite composition which host a variety of mineralized zones (e.g., Sn-Zn-Cu-Ag, Mo, Mn-Fe-P, U, and Cu-Ag). Given the hydrothermal nature of this mineralization, it is expected that the mineralizing fluids might manifest itself both petrographically, as alteration assemblages, and by the chemistry of secondary fluid inclusions in the granites on a scale equal to or larger than the mineralized centres. This study assesses the potential of using such information to decipher barren and mineralized areas. The novel research protocol includes: (1) detailed petrography of hundreds of archived samples that focuses on: (i) abundance and type of perthite, (ii) degree of chloritization of biotite, (iii) abundance of sericite, (iv) degree of saussuritization of plagioclase, (v) abundance of white mica, and (vi) abundance of secondary fluid inclusions in quartz; and (2) the chemistry of quartz-hosted fluid inclusions, based on SEM/EDS mound analysis from a sample suite representative of the entire batholith. The petrographic data and fluid chemistry was used to map the extent of alteration across the batholith, which indicates that fluid:rock interaction was batholith-wide and that its interaction generated Na-K-Ca-Cl-F rich fluids in addition to primary enrichment of Fe, Zn, and Cu. Specifically, two distinct fluid types are present, one Na-K-Cl and the other Na-Ca-Cl-F; this enrichment of F in one of the fluid populations is the first recognition of this phenomenon in granitic bodies on such a large scale. The occurrence of this F-rich fluid across the SMB, including its most primitive rocks (i.e., granodiorites), suggests its generation is part of the natural evolution of the system and consistent with the

presence of topaz in both the most evolved phases and as an integral part mineralized greisens.

Cross-hole electrical resistivity imaging to study water and nitrate infiltration processes at Harrington Research Farm, Prince Edward Island, Canad

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Nitrate is a necessary nutrient for plants, originating from both natural and anthropogenic sources, such as mineralization of organic matter and agricultural fertilizers. However, high concentrations of nitrate in water can negatively affect aquatic ecosystems and human health. 3D Electrical Resistivity Imaging (ERI) is one of the techniques being used at AAFC's Harrington Research Farm near Charlottetown, Prince Edward Island, to investigate the subsurface transport of nitrate including (i) the time taken to percolate to the water table, (ii) the partitioning between (slow) matrix and (fast) fracture flow, and (iii) the generation of perched water table overlying low permeability layers that may give rise to lateral flow and discharge to surface water at certain times of year. The infiltration of water and electrical conductive tracer can cause changes in subsurface resistivity distribution. Thus, 3D imaging and monitoring of resistivity may be used to infer water/tracer pathways and the downward velocity of water. Since nitrate is highly soluble, its movement may be similarly monitored, although its progress may be delayed by chemical reactions along the way.

To monitor groundwater movement with 3D ERI through the ~17 m thick vadose zone, without sacrificing resolution at depth, a cross-hole measurement geometry is used. There are 24 electrodes, spaced 0.68 m apart in each of three boreholes located at the vertices of an equilateral triangle with 9 m sides. An additional 8 "trench electrodes" are buried at 0.5m depth along each side of the triangle. Soil moisture, temperature and electrical conductivity are being monitored using 11 Decagon 5TE sensors in each borehole. Borehole casings have been removed and all electrodes and sensors buried below surface so they can remain in place during farming operations. Each ERI survey involves the acquisition of a sequence of apparent resistivity measurements with different kinds of dipole-dipole configurations. Initial surveys, acquired between early September and late December, 2014 reveal a model consisting of five sub-horizontal layers, in general agreement with the expected geology of overburden overlying interbedded fluvial sandstone and shale layers. Two of these layers are more electrically conductive and are thought to represent shale-rich units which are expected to impede water infiltration and could give rise to perched water table conditions. Future work will involve the production of time-lapse images to monitor natural water infiltration and the application of a conductive tracer to enhance our ability to image ground water pathways and variations in the speed of infiltration.

Results from the first topo-bathymetric lidar surveys of the Chiroptera II sensor reveals near-shore structures to improve geological mapping

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The Applied Geomatics Research Group (AGRG) within the Nova Scotia Community College (NSCC) acquired a new shallow water airborne topo-bathymetric lidar sensor and flew the first missions in September 2014. The survey areas consisted of several embayments along the Northumberland Strait. Many of the areas sheltered bays that host or offer the potential to host shellfish aquaculture farms. The low flow rates associated with the inner bays promote high volumes of sediment cover and bedrock features are rarely exposed. However, the area near Cape John, Nova Scotia, where Carboniferous sandstone of the Cumberland Basin are exposed provides insights into the potential of this sensor to be used to enhance and extend structural information on geological maps. Traditional topographic lidar reveals a smooth terrestrial landscape with limited outcrop as a result of the deposition of glacial till. The bedrock is exposed along cliffs at the coast where limited bedding and structural measurements can be taken. The penetration of the green laser is limited by water clarity, which in this region is influenced by wind-induced waves which can re-suspend fine-grained sediment derived from the glacial till and increase the turbidity of the water. The first attempt to survey Cape John was aborted on September 25 because of high water turbidity levels and poor bathymetric lidar returns. However, after a day of reduced winds the area was surveyed on September 26 with penetration to 6 m water depth. The fact lidar is an active remote sensing system allows surveys to be conducted at night when the winds typical die down and thus further promote settling of the fine sediment and improved water clarity. The results of the survey reveal several previously uncharted features on the seabed including reefs. Other than near-shore areas covered by sand bars, the offshore currents have scoured the exposed bedrock geology on the seabed revealing subtle

topographic differences representing the different bedding planes and fault structures. Details of the strike of the beds offshore reveal new details on the folding and faulting in this area and these new data can be used to update the existing geological map, NSDNR Map ME 1990-014.

Continental rifts: lithospheric weakness and strength contrasts as triggers for necking instabilities

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Continental rifts are the first stage in the formation of rifted margins. Since continents are far from homogeneous after multiple cycles of collision, strike-slip motion and rifting, heterogeneities can influence the location and geometry of rifting. We use 2D finite element models containing embedded finite weak zones in the crust and/or mantle as well as a vertical lithospheric boundary across which the rheology changes to represent these heterogeneities. The resulting strength contrast at the lithospheric boundary changes the growth rate of necking instabilities on either side of it.

Necking is a mechanism that depends on the distribution of viscous and plastic layers in the lithosphere; stiff layers deform plastically and rapidly grow necking instabilities, whereas pliable, viscous, layers slowly grow necking instabilities. Additionally, the growth rate of necking instabilities is amplified by the background strain rate (the strain rate in the absence of any weak zones), which implies faster necking in parts of the lithosphere where background strain rates are highest. Considering these competing mechanisms, we recognize two controls on the location of rifting: Control 1, the stiff/pliable nature of the lithospheric layers, and; Control 2, the distribution of the background strain rate in the lithosphere.

In a laterally homogeneous lithosphere, the background strain rate is uniform along each layer and Control 1 will dominate, preferentially initializing necking in stiff layers. However, juxtaposed lithospheres with different strengths will lead to an asymmetrical strain with a higher background strain rate in the weaker lithosphere. In this case, faster necking can occur in pliable layers under a higher strain rate, even if inherited weak zones are present in stiff layers that are under a lower strain rate; Control 2 wins. Our results show that deformation localizes away from the lithospheric boundary in the lithosphere under the higher strain rate. Our model results imply Control 2 wins whenever the background strain rate contrast is larger than 1.0×10^{-16} s^{-1}. That Control 2 wins has implications for the preservation of cratons, which are cold and strong, and probably stiff. Even though they contain inherited weak heterogeneities, they are protected by Control 2, provided they are surrounded by weakling lithospheres such as younger orogens. We will also present a case where a combination of Control 1 and 2 produces a highly asymmetric margin, which we compare with the Gabon-Camamu conjugate margins in the South Atlantic.

It's a Laing story: the life and times of an icon

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One of the most momentous events in the geological lore of Nova Scotia during the last fifty years has been the recognition of the Fossil Cliffs of Joggins as a UNESCO World Heritage Site. A major contributor to this achievement was Laing Ferguson, whose role as an innovative thinker in geology is being recognized by the dedication of a special session at the 2015 Colloquium of the Atlantic Geoscience Society (AGS). The groundwork for Laing's career was laid at Edinburgh University, where he graduated with a B.Sc., honours geology in 1958, and a Ph.D. in paleontology in 1960. Following graduation, Laing and his wife, Joyce, moved to Edmonton, Alberta, in 1960, before settling in Sackville in 1962, where he became an associate professor of geology at Mount Allison University. In his early years at Mount Allison, Laing became intrigued by the Joggins section and especially its plant fossils. A dramatic find during his exploration of Joggins was the trail of the giant *Arthropleura*, an arthropod that could be up to two metres long. Laing included an illustration of this monster in his popular geology book, *The Fossil Cliffs of Joggins*. The book was a milestone for several reasons, but mainly because it could be read by anyone with an interest in geology. This passion for outreach coincided with his role as chief instigator in the production of the Atlantic Geoscience Society's *Geological Highway Map of New Brunswick and Prince Edward Island*, published in 1985. Laing served on AGS Council for many years, being President in 1982. He was the first recipient of its Distinguished Service Award in 1989, given in recognition of his outstanding contributions to the Society. This award was subsequently renamed the Laing Ferguson Distinguished Service Award given in recognition of his outstanding contributions to the Society. The Lifetime Membership Award was inaugurated in 1999 by AGS, especially to honour Laing. To date, there are only two other recipients. Outside geology, Laing has led an exemplary life, being President of Amnesty International Canada from 1976 to 1978. For many years he was at the forefront of efforts to free political prisoners and in the fight against repressive regimes. Laing was a great geological teacher and researcher, who was also a gifted humanitarian. The world needs more people of his ilk.

Wetzeliella and its allies — the "hole" story: a new look at the Paleogene dinoflagellate subfamily Wetzelielloideae

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Dinoflagellate cysts are found as organic-walled microfossils in Mesozoic-Cenozoic strata. They have distinctive and variable morphology and evolved rapidly; hence they have become invaluable for providing biostratigraphic control in shelfal marine sediments. Many living dinoflagellates have a distinctive cellulosic "armour" of plates, the pattern of which tends to be reflected in various ways on the resistant organic walls of fossilizable cysts. For example, the excystment aperture (archeopyle) of cysts tends to consistently occur within a genus or species at the site of one or more specific reflected plates. Members of the Paleogene (now extinct) subfamily Wetzelielloideae have a stable reflected tabulation pattern distinguished by a four-sided (quadra) rather than a six-sided (hexa) mid-dorsal 2a plate. Aside from tabulation, wetzelielloideans show great morphological variability, especially in ornamentation and horn development, but also in wall structure. This variation shows no clear trends through time, but has dominated criteria for the definitions of genera and species, leading to frustrations in attempts to use wetzelielloideans as stratigraphic index fossils. Diversity in shape, wall structure and ornamentation has also distracted attention from the morphological variation of the archeopyle, which, although always formed through loss of the 2a plate only, shows variations that we consider critical in unravelling the group's phylogeny, and hence stratigraphic utility. Important factors are the shape and relative dimensions of the archeopyle and whether the operculum is attached or detached. These parameters allow us to define five archeopyle types: equiepeliform, hyperepeliform, hypersoleiform, latiepeliform and soleiform. Based primarily on archeopyle type and secondarily on wall and morphology and ornamentation, we recognise six genera with an equiepeliform archeopyle, four with a hyperepeliform archeopyle, five with a latiepeliform archeopyle, five with a soleiform archeopyle, and one with a hypersoleiform archeopyle. The earliest-known wetzelielloideans, which occur around the Paleocene–Eocene boundary, have an equiepeliform archeopyle. Other archeopyle types evolved rapidly: taxa with hyperepeliform, latiepeliform and hypersoleiform types are known from the Ypresian. Latiepeliform and hyperepeliform types are restricted to the Ypresian and Lutetian. Forms with the soleiform archeopyle appeared in the late Lutetian, but were rare until the Bartonian, when they became the dominant type, and they were the only type in Priabonian and younger strata. Wetzelielloideans became extinct in the middle Oligocene. Applying our criteria increases the usefulness of wetzelielloideans in determining the ages of Paleogene strata, as well as providing a better understanding of evolutionary trends within the group.

Superimposed mineralizing events involved in making giant ore deposits: evolution of the telescoped Chuquicamata porphyry Cu-Mo deposit in Chile

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Emphasis on generalized ore deposit models may result in misleading expectations in the exploration for hidden new deposits. Metal or alteration zoning may not reflect a single event in time and P-T space. Many giant metal deposits are telescoped, meaning early, deep, hot mineralization was overprinted by late, shallower, cooler pulses of notably different chemistry. Furthermore post-ore processes may have modified the original geometry and mineralogy. The giant Chuquicamata porphyry Cu-Mo deposit (Chuqui) in the northern Chilean Andes is a good example of this complexity:

1. Chuqui developed within an active volcanic arc since the late Eocene (40 Ma), within the roots of a stratovolcano undergoing uplift and erosion. The first mineralizing intrusions were emplaced at ca. 36 to 35 Ma and are associated with Cu and potassic alteration. Thermochronology and mineralogical data suggest that the mineralized rock was more than 6 km deep and at ca. 535°C. Ductile and brittle structures indicate an orogen-parallel dextral shear regime.
2. Unmineralized porphyries of similar geochemistry were intruded at ca. 33 Ma (Oligocene).
3. Large Mo-rich quartz ("blue") veins followed at ca. 32 Ma, still under a dextral regime and rapid exhumation.
4. At ca. 31 Ma, a new hydrothermal influx invaded the previously mineralized rock, now located at a depth of ca. 2–3 km. This pulse was highly acidic, at a temperature of 335–400°C, and produced sericite and argillic alteration. It was rich in Cu, Au, Ag, but also in (metallurgically) detrimental As, Sb, Zn, and Bi, and anhydrite. The anisotropy of distribution of useful and deleterious elements reflects the evolving permeability in response to changing structural regime.
5. The tectonic system reversed drastically to sinistral brittle shear, now localized along a regional NS fault. This fault truncated one third of the Chuqui orebody and displaced it several km to the south.

6. Exhumation and erosion slowed down and exposed the mineralization to surface weathering and supergene enrichment, during a time of climate desertification. Oxidation of pyrite produced great amounts of sulfuric acid that leached the Cu in the upper portions of the orebody, and deposited it at the level of the paleo groundwater surface. Some of this Cu was carried by groundwater and deposited as "exotic" oxides as far as 10 km downstream within thick Cenozoic gravels that covered the displaced portion of Chuqui (ca. 22 Ma; Miocene). All of these superimposed processes together determined the mining and metallurgical history of the deposit.