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Atlantic Geoscience Society 2014

ABSTRACTS

40th Annual Colloquium & Annual General Meeting 2014

Greenwich, Nova Scotia

The 2014 Colloquium & Annual General Meeting was held at the Old Orchard Inn, Greenwich, Nova Scotia, on February 7 and 8, 2014. On behalf of the society, we thank Colloquium organizers Rob Raeside, Ian Spooner, and Elisabeth Kosters, and the numerous student volunteers for facilitating an excellent meeting. We also wish to acknowledge support from the corporate sponsors: Acadia University; Encana Corporation; Agile Geoscience; New Brunswick Department of Energy and Minerals; Corridor Resources Inc.; and the Potash Company of Saskatchewan.

In the following pages, we are pleased to publish the abstracts of oral and poster presentations from the of meeting, which included the following symposium and sessions: (1) The Last Fifty Years; How Geology has Evolved in Atlantic Canada, a symposium in honour of the publication of Volume 50 of Atlantic Geology; (2) Research at the Joggins Fossil Cliffs - celebrating 5 years as a UNESCO World Heritage Site; (3) Palaeontology in Atlantic Canada; (4) Environmental Geoscience; (5) Geology offshore southeastern Canada with a focus on the Nova Scotian margin; and (6) Current Research in the Atlantic Provinces.

In addition, a public discussion took place on Geoheritage Sites in Nova Scotia. Also included with the conference were a short course on "Computer Programming for Geoscientists using Python" and a Wikithon workshop to help improve Wikipedia with items relating to the geology of Atlantic Canada.

The Editors

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Heavy metal concentrations in residential soils in the Halifax Peninsula, Nova Scotia: A pilot study*

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A number of possible natural, anthropogenic, widespread, or point source contaminants can cause high levels of heavy metals in soils. Coal burning, leaded paint and gasoline, and bedrock can all have a potential effect on the metals found in the soils of the Halifax Peninsula. The objectives of this pilot study were to: (1) determine the metal concentrations in the top 15 cm of soil in approximately 120 samples from over 30 residences on the Halifax Peninsula; (2) establish which, if any, metals have concentrations above CCME (Canadian Council of Ministers and the Environment) guidelines for residential soils; (3) investigate the difference in metal concentrations between the house dripline, roadside, and "ambient" samples; and (4) assess the geographic distribution of elevated levels of metals. Samples were sieved to <1 mm and were analyzed using a portable XRF. Potentially toxic metals analyzed and included in this study are: Pb, As, Cr, Cu, Zn, Ba, V, Cd, Co, Se, Mo, and Sn. Cadmium, V, Co, Se, Mo, and Sn had only rare values above CCME guidelines for residential soils; however, levels of Pb, As, Cr, Cu, Zn, and Ba varied from below guidelines to well above guidelines for individual samples.

Lead values ranged from 11–4869 ppm, with 81% of ambient values >140 ppm (CCME guideline). Copper values ranged from 15–381 ppm with 58% of ambient values above 63 ppm (CCME guideline). Zinc values ranged from 38–1778 ppm, with 45% of ambient values above 200 ppm (CCME guideline). Arsenic ranged from below detection to 245 ppm, with 94% of ambient values above 12 ppm (CCME guideline). Chromium values ranged from 31–218 ppm, with 71% of ambient values above 64 ppm (CCME guideline), and Ba ranged from 237–1209 ppm, with 32% of ambient values above 500 ppm (CCME guideline). The percentage of dripline samples above guidelines was greater than or equal to ambient percentages, whereas roadside values where consistently lower, but always with some samples above guidelines. The high values for dripline samples are consistent with the possible contributions of metals from paints in these older homes. It is proposed that the relatively high ambient values of metals are the result of a combination of bedrock, fill-related materials, and airborne pollutant contributions. Roadside values were lower than expected, and may be attributable to mobilization of these metals by chlorine from road salt.

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

Biotite chemistry as a monitor of magma fertility and mineralisation potential: Results from the Devonian granitoids of New Brunswick

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There are over 150 granitoid intrusions in the New Brunswick; however, all the mineralised intrusions formed in relation to Acadian and Neoacadian orogenic phases of Appalachian accretion. These granitoid intrusions range in age from ca. 423 to 360 Ma, and include examples of pre-, syn-, late-, and post-tectonic emplacement with affinities ranging from primitive to highly evolved A-, S-, and I-type granitoid rocks along with their hybrid varieties. Many of these plutons are spatially and temporally related to specific styles of mineralization, producing deposits of Sn, Ta, Li, Sb, W, Mo, Cu, and Au, as well as other base metals and U.

Igneous biotite crystallises over a wide range of conditions and reacts very sensitively to physio-chemical conditions like halogen and oxygen fugacities, pressure, temperature and chemical composition of the magmas. This sensitivity makes biotite a suitable mineral for identifying the petrogenetic processes, mineralization, and alteration of the host granitic rocks. The following features make biotite a valuable probe of magma composition: (1) it is the most important reservoir of any excess aluminium in granites that do not contain modal garnet, cordierite, or the Al_2SiO_5 polymorphs; therefore, it directly reflects the peraluminosity of the host magma in such rocks; (2) it is the most readily available indicator of oxidation state; and (3) it can provide information about the F and Cl composition of the magma.

Previous studies have shown that biotite, and to lesser extent hornblende and magnetite, continuously equilibrate with host liquids. Consequently, a core-to-rim study of these minerals and their compositional zoning can provide a record of magma evolution so that the origin and evolution of granitoids can be documented.

The aim of this study is to calculate fluoride and chloride activity of aqueous fluids based on measuring F and Cl contents in the minerals containing hydroxyl and halogens, using a combination of electron microprobe and Laser Ablation ICP-MS. These data will be combined and compared with whole-rock trace element geochemistry. The results are expected to help constrain crystallisation conditions, volatile exsolution, and fluorine-chlorine activity of fluids associated with these intrusions, and also to examine the degree of subsolidus re-equilibration using various geothermobarometry techniques. By linking these

results to the various styles/types of granitoids and their associated mineralisation it is hoped to establish biotite composition as a robust indicator of the ore potential of an intrusion.

Late Neoproterozoic plutons in the southern Cobequid Highlands, Nova Scotia, Canada: Field relations, petrology, and petrogenesis

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The Cobequid Highlands of northern mainland Nova Scotia form an enigmatic part of Avalonia in the northern Appalachian orogen. Historically the Cobequids have been divided into two blocks separated by the Rockland Brook Fault, the Jeffers block to the north and the Bass River block to the south, although the position of the boundary in the east (Mount Thom area) is uncertain. This study focuses on known or inferred Late Neoproterozoic plutons (Frog Lake, Debert River, Gunshot Brook, and McCallum Settlement) in the main Bass River block, (between the Rockland Brook and Cobequid faults) and does not include plutons in the east (Mount Thom area) which appear to be both older and younger than Late Neoproterozoic. The Debert River, Gunshot Brook, and McCallum Settlement plutons include diorite, tonalite, granodiorite, granite, and alkali-feldspar granite. In contrast, the Frog Lake pluton consists of heterogeneous, variably mylonitic bodies of diorite, gabbro, and locally tonalite which are scattered throughout the southwestern part of the study area. Eight previously reported U-Pb (zircon) ages for samples from the Debert River, Gunshot Brook, and McCallum Settlement plutons range from ca. 575–612 Ma. However, not all of the published analyses are concordant and these plutons may be more similar in age than previously suggested. Hornblende from a dioritic body of the Frog Lake pluton yielded a previously published $^{40}Ar/^{39}Ar$ age of 622 ± 3 Ma, suggesting that it is older than the other plutons. Mylonitic granodiorite in Economy River yielded a previously published U-Pb (zircon) age of about 734 Ma, suggesting that it may be related to the ca. 750 Ma Mount Ephrairn Plutonic suite in the eastern highlands. Plagioclase in gabbroic and dioritic samples from the Frog Lake and McCallum Settlement plutons has labradorite compositions, whereas more granitic samples are less calcic. Amphibole is classified as calcic and mainly of magnesio-hornblende to actinolitic composition. Biotite compositions are consistent with those of biotite formed in calc-alkalic suites. New whole-rock chemical data from 54 samples, together with previously published data for about 55 additional samples, suggest that the dioritic to granitic units of the Debert River, Gunshot Brook, and McCallum Settlement plutons are a co-genetic calc-alkaline suite rocks formed in a subduction-related Andean-type continental margin. However, some of the dioritic samples from the Frog Lake bodies have higher Ti, V, and FeO^t/MgO ratios, and display tholeiitic trends, indicating that they may not be genetically linked to the calc-alkaline suite.

The possible role of the petroleum system in the metallogenesis of gold in Meguma metaturbidites: Geochemical investigation in the Touquoy deposit, Moose River, Nova Scotia

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At the onset of the Acadian orogeny in the Early Devonian, the Meguma Supergroup represented an ideal petroleum play with abundant source rock, laterally continuous sand layers, suitable permeability contrasts with shales overlying greywackes, and numerous trap structures in the form of developing anticlines and domes. Coincidentally, most important (orogenic) gold deposits in the Meguma occur within domal and anticlinal structures, as arrays of quartz-carbonate-arsenopyrite veins or as disseminations associated with black metapelites. Basinal processes would have generated abundant hydrocarbons, which probably affected cementation, effective pressure, and structure. Stable isotopic studies suggest that the carbon in vein carbonates formed by oxidation of organic matter, and fluid inclusions at Touquoy contain methane. Gold was deposited at temperatures above 300 °C (greenschist-facies conditions); hence, any residual petroleum occurs as bitumen or graphite.

Published genetic hypotheses for orogenic gold suggest that the metal could have been scavenged from turbidites, black shales, or from gold-rich diagenetic iron sulphides. Gold would have been mobilized during prograde metamorphism by oxidized complexes, migrated following hydraulic gradients imposed by tectonics and the rise of magmas, and precipitated where these complexes were destabilized by sudden decompression or reaction with reducing pore fluids. Others suggest that petroleum could have contributed to gold transport, whereas some authors dismiss petroleum as a significant agent.

The Touquoy disseminated deposit occurs on the hinge and limbs of the Moose River – Fifteen Mile Stream

Anticline. Our limited sample set hinders answering fundamental questions, yet they provide some insight when combined with data from previous studies. The host strata at Touquoy (Lower Goldenville Group) contain up to two orders of magnitude more carbon (total) and CO_2 than unmineralized Goldenville strata elsewhere. Within the ore zone, Au shows a positive correlation with As, S, K/Na, Y, and Eu, and negative with Ca and W.

Although the Meguma Supergroup has been long assumed to represent a passive margin, the metagreywackes and argillites analyzed have a composition indistinguishable from volcanic dacite to andesite, rocks generally associated with active margins and volcanic arcs. This volcanic affinity supports recent interpretations by others that suggest the Meguma was deposited adjacent to a volcanic arc of Avalonia, and that the Acadian orogeny occurred in and Andean type setting. Gold and arsenic are known to be preferentially enriched in subduction-related arcs such as the Andes. It is likely that Meguma strata provided an adequate disseminated source for these elements now concentrated in gold deposits.

Development and collapse of the Pliocene western Canadian Arctic coastal plain*

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The Beaufort Formation is part of a dissected clastic wedge on the western margin of the Canadian Arctic Archipelago and constitutes a rich record of paleoenvironmental, paleoecological, and paleoclimatic change. It has been shown that the Canadian Arctic Archipelago mean annual temperature was between 15 to 22 °C warmer than today, at a time when ocean-atmosphere-biosphere feedbacks amplified the mid-Pliocene (+2 °C) global warming.

In the western Arctic, the Ballast Brook valley on northwest Banks Island exposes more than 20 km length of section through sandy and pebble sandy braided stream deposits and detrital organic beds. Farther north, fluvial and estuarine facies have been examined on Meighen Island. In the High Arctic, the High Terrace Gravels at the Fyles Leaf Bed and Beaver Pond sites on Ellesmere Island are not formally considered part of the Beaufort Formation but have similar quality paleoenvironmental records. The Fyles Leaf Bed site has recently yielded the first fossil evidence for a High Arctic camel, identified with the help of collagen fingerprinting from a fragmentary limb bone (tibia). Until now, because the records were poorly dated, it was impossible to distinguish if temporal (e.g., climatic) or spatial (e.g., latitudinal, sea ice distribution) variations were the cause for differences in estimated mean temperatures and seasonality from various deposits. Minimum-limiting cosmogenic nuclide burial ages of 3.4 and 3.8 Ma recently obtained for the Beaver Pond and upper part of the Fyles Leaf Bed sites, respectively, are consistent with vertebrate and floral biostratigraphic evidence. A maximum burial age of 6.1 Ma for the Beaufort Formation on Meighen Island, although older than previous age estimates of ~3 Ma, supports paleomagnetic stratigraphy and biostratigraphy at the same location. This apparent age difference between the deposits on Ellesmere and Meighen Islands may account for some of the paleoenvironmental variation.

The Beaufort Formation appears to have once filled at least the western portions of the 100 km-wide channels that currently separate the islands of the Canadian Arctic Archipelago. Intervals of Pliocene continental-shelf progradation are recorded in the lower Iperk Formation. A key objective of our research is to derive new age estimates and improved correlations between the High Terrace Gravels, Beaufort, and Iperk Formations to test hypotheses about the causes for the dramatic deposition and incision of the clastic wedge, and to estimate rates of incision and sediment flux to the Beaufort Sea Shelf at particular times during the Pliocene.

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

Tracking the top predator of the Pennsylvanian tropical biome: Implications for assumptions of the fossil record at Joggins

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One of the greatest misconceptions that became apparent in developing the case for World Heritage nomination of the Joggins Carboniferous section was that most everything was known about its paleontology and depositional environments. The example of the largest terrestrial predator of the Joggins ecosystem - and probably the tropical rainforest biome of the Pennsylvanian – is perhaps the most significant of these. First identified at Joggins (as usual in these matters) by Sir William Dawson as an unconvincing, solitary, footprint , the record grew dramatically a full century later in the 1990s when both Don Reid and Brian Hebert began to recognize the large, deeply

impressed, and puzzling footprints that became nicknamed "Rex" in recognition of their unrivalled size – and unknown affinity. In the early 2000's, key osteological discoveries were made by Brian Hebert in what became known as the Hebert Sandstone: a mandible and pelvic girdle of a tetrapod large enough to make the footprints. The most likely candidates come from the stem tetrapod group Baphetidae. Footprints of the largest tetrapod have been discovered by us from a 1500 m stratigraphic interval comprising the Boss Point, Little River, and Joggins Formations of the Bashkirian. The scant record of skeletal remains throughout this section is remarkable given their recurring footprint record, but not inconsistent with the record of smaller tetrapods, which are rarely preserved external to fossilized lycopsid tree interiors. Fossil-bearing horizons occur in a wide range of depositional environments including well drained and poorly drained floodplains and under paleoclimates inferred to range from semi-arid through dry seasonal to humid seasonal. Apart from their assumed tie to water during times of reproduction, it would seem that the trackmakers were not circumscribed (endemic) to a narrow ecological habitat.

Detailed geomorphology and surficial geology of the outer Nova Scotia margin

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Most of the western North Atlantic margin has a relatively steep, eroded upper slope and a gentle, constructional lower slope. Along the lower slope south of Nova Scotia, a second break in slope occurs between the 4500 m and 5000 m isobaths. This subtle but consistent reduction in slope gradient tends to divide slopes >0.5° from slopes <0.5°. Prior to this study, it was not apparent if this gradient change coincides with a major change in surficial depositional processes, subsurface depositional processes, or if it is structurally controlled. During August 2012, 135 000 km² of multibeam bathymetry and 10 000 km-line of sub-bottom profiler data were collected along the outer Nova Scotia margin, from the area seaward of Georges Bank to Laurentian Fan. The purpose was to accurately map the geomorphology of this area and determine surficial geological processes.

The data reveal that canyons on the upper Scotian Slope coalesce to form valleys on the lower slope. Most of the valleys extend seaward of the new data limits, beyond the 5000 m isobath. Exceptions are several canyons on the central slope that terminate in a 100 km-wide, escarpment-bound depression that likely formed through seabed failure. Inter-valley areas on the lower slope are dominated by mass transport deposits sourced from upslope sediment failure, or well-stratified deposits of interbedded turbidites and hemipelagic deposits. Along the western slope, sandy deposits of Northeast Fan, a major glaciogenic submarine fan, dominate the surficial geology and likely extend as far south as the New England Seamounts. An extensive zone of mass transport deposits lies immediately west of Verrill Canyon and may have initiated on the flanks of shallow salt diapirs further upslope. The western levee of Laurentian Fan forms a major morphological feature on the margin. These new data show that mass transport deposits are the main depositional feature of the seabed and shallow sub-surface of the levee. Results of this study do not show a significant change in surficial slope processes across the lower slope gradient change suggesting that the change is inherited morphology due to processes that occurred earlier along the margin.

Seismic stratigraphy and attribute analysis of the Mesozoic and Cenozoic of the Penobscot area, offshore Nova Scotia

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The Penobscot area is located within the Scotian Basin, northwest of Sable Island, offshore Nova Scotia and comprises geological formations with representative properties for petroleum system in the basin. The Penobscot dataset includes a 3D seismic survey covering 87 km², two well logs and corresponding cored intervals totaling nearly 52 m. The cored intervals provide a detailed analysis of the Abenaki and Lower Missisauga formations, both known reservoirs within the Scotian Basin. Penobscot L-30 and Penobscot B-41 are 2 of 180 exploratory wells that have been drilled in the Scotian Basin since 1980. Both wells had hydrocarbon shows; however, they were not considered to be economic.

This study has been designed to determine whether seismic inversion, in conjunction with 3D seismic and well datasets, provides a valuable analytical tool of the rock properties of strata in the Scotian Basin. The analysis of the 3D seismic is completed using geologic software (e.g., Petrel) to interpret the seismic facies, structure, sequence stratigraphy, and seismic attribute analysis. The focus of this study is on seismic inversion that solves for acoustic and elastic properties from the 3D seismic data. Inverting the seismic data from a reflector to a layer property provides a clearer understanding of the subsurface geology and the potential hydrocarbon reservoirs within the survey. Seismic

inversion is used to correlate the well logs across the seismic survey to define the reservoirs of interest. The cored intervals from both wells are studied, examining the characteristics of different lithofacies and their corresponding depositional environments. The lithofacies from the core are tied to the well logs to develop petrophysical facies, and then tied to the seismic data to define the seismic facies. The inversion result confirms the correlation of the lithofacies to the petrophysical facies and enables the geological properties to be known within the entire survey area.

An exhumation history of Hall Peninsula, Baffin Island, Canada derived from low-temperature thermochronology and 3D thermokinematic modeling

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The eastern Canadian Arctic Rim (eCAR) is a rugged, high-relief terrain, spanning from southeastern Ellesmere Island to northern Labrador. While much of the relief along the eCAR may be related to rift-flank uplift and incision during and after rifting between Canada and Greenland, there has recently been much debate over our understanding of passive margin evolution and the processes responsible for the development of their modern landscape. Furthermore, thermal histories derived from previous thermochronologic studies from the northern and southern regions of the eCAR, as well as in West Greenland, are incompatible with a single, continuous exhumation history for the eCAR. This study aims to characterize the long-term exhumation history of Hall Peninsula, and, by linking together previous thermochronologic studies in the eCAR, we will test various models of tectonic and climate-driven landscape evolution of Baffin Island.

In total, 33 samples have been analyzed by low-temperature (U-Th)/He thermochronometry (26 apatite-He (AHe), 7 zircon-He (ZHe); 5 aliquots each) to help define the cooling history of the rocks on Hall Peninsula. Results from these samples reveal cooling ages that are heavily influenced by the effects of radiation damage, with strong positive or negative correlations between effective U concentration (eU = U + 0.235Th) and He age for AHe and ZHe, respectively. Preliminary modeling of the t-T path of individual samples using thermal modeling program HeFTy suggests a history of protracted, slow cooling across Hall Peninsula, with cooling events initiating from middle Paleozoic to late Mesozoic. However, many samples cannot be modeled using HeFTy, likely due to the large dispersion in the age data. Thus, to aid the thermal model in adjusting the cooling ages for the effects of radiation damage, select samples will also be analyzed using apatite fission track thermochronometry. A three-dimensional thermokinematic finite-element modeling code, Pecube, will also be used to determine the collective t-T history of the rocks on Hall Peninsula, and test whether the spatial distribution of adjusted cooling ages can be explained through a simple (vertical) exhumation mostly by erosional processes, or if it requires a more complex exhumational history (e.g., faulting).

Volcanism at the western termination of the Charlie-Gibbs Fracture Zone, offshore Newfoundland

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We describe a previously unrecognised mid to Late Cretaceous volcanic province developed on thinned continental crust located along the rifted northeastern Newfoundland margin at the western termination of the Charlie-Gibbs Fracture Zone. Using seismic data, we mapped fourteen volcanic seamounts, now buried below more recent sediments. The seamounts rise 0.5 to 1.7 s twt above the surrounding basement, are about 15–20 km wide, possess a conical to flat-topped morphology, and are generally highly magnetic (up to 801 nT). These features are associated with underlying volcanic flows and sills. Based on magnetic modeling of the associated large positive magnetic anomalies, the total thickness of igneous rocks locally reaches 8 km. This magmatic upwelling occurred in the vicinity of the Charlie-Gibbs Fracture Zone and extends approximately 150 km north along the rifted continental margin. The volcanic province forms the northern boundary to the Jurassic-Early Cretaceous Orphan Basin. At this boundary, deep crustal reflectors abruptly terminate against the volcanic province, suggesting the presence of a transform margin. Similar terminations of crustal reflectors extend further into Orphan Basin along trends similar to those of pre-rift Appalachian terrane boundaries on the adjacent shelf. This suggests the existence of a pre-existing weak zone in the continental lithosphere within which a leaky transform margin developed, and may have controlled the location of final continental breakup between the Rockall and North American plates in the Late Cretaceous.

Salt marsh migration in Prince Edward Island

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Salt marshes are an important link between land and sea. Due to sea-level rise (SLR) and anthropogenic effects they are in danger. To determine the best management and possible land acquisition practices to ensure suitable salt marsh habitat in the future, GIS analysis was applied to six representative coastal areas in Prince Edward Island (PEI). PEI was selected as the study site because orthophotographs of 1968 and 2010 as well as a 1.5 m DEM constructed from LiDAR were available for the entire island. The DEM was modified to include hydrology that connected the ocean to low lying areas inland where culverts and bridges occurred but were not represented originally. The orthophotos were interpreted to map salt marshes and calculate their respected areas. Elevation of mean sea-level (MSL) and highest high water, large tide (HHWLT) were defined by tidal predictions for each site. The prediction of salt marsh from the DEM for this range of elevation (MSL-HHWLT) was compared to that interpreted from the 2010 orthophotos. A relative SLR of 1 m/century was used to linearly project the elevation boundaries into the future for 2050, 2100, and 2200. The potential salt marsh area for these periods was determined by using the elevation ranges (MSL-HHWLT) and the DEM. The area of salt marsh was calculated and compared between years. This analysis can be used as a management and planning tool to determine the most suitable lands for acquisition in order to preserve salt marsh habitat today and into the future.

Interpretation of 2-D multichannel seismic reflection data across the Sohm Abyssal Plain along the Scotian margin

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In 2006, as part of Canada's effort to define its Extended Continental Shelf in accordance with the United Nations Convention on the Law of the Sea (UNCLOS), Natural Resources Canada collected 6900 line km of 2-D multichannel seismic reflection data over the Sohm Abyssal Plain off of the Scotian margin. These lines were integrated with existing data sets and interpretations to determine the nature and the thickness of the sedimentary succession. Five seismic horizons were extended from the Scotian shelf and slope regions and correlated across the Sohm Abyssal Plain. Jurassic units are widespread near the slope, but appear only in isolated basins between localized basement highs distally. Cretaceous units are mapped everywhere across the region except where sediments lap out against the seamounts of the New England Seamount chain. A prominent Upper Cretaceous or lower Paleocene unconformity manifests significant uplift that is likely related to the emplacement of the Gregg and San Pablo seamounts. Post-Oligocene units thicken dramatically toward the northeast as a result of sediment input from the Laurentian Fan. Using a seismic velocity model derived from numerical filtering of existing sonobuoy records and seismic refraction data to convert reflection data to the depth domain, the sediment thins from 15–19 km beneath the slope to less than 1 km at the distal edge of the survey area.

Mobilization of uranium in groundwater in Nova Scotia

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Naturally occurring uranium was first identified in groundwater in Nova Scotia in 1978, after elevated uranium levels were discovered in hair samples from a person who obtained their drinking water from a drilled well. Subsequent province-wide investigations have shown that uranium occurs in concentrations greater than drinking water guidelines in approximately 4% of water wells across the province, making it the second most important well-water contaminant in Nova Scotia after arsenic. More recently, elevated uranium levels were identified at a site in Nova Scotia where anthropogenic activities had introduced dissolved calcium into an aquifer. In response to this finding, the Nova Scotia Department of Natural Resources investigated the association between calcium and uranium using the provincial groundwater chemistry database and aqueous speciation modelling. The results of this study showed strong positive correlations between uranium, calcium, and chloride. Speciation modelling indicated that calcium can be an important influence on the mobility of uranium in groundwater in Nova Scotia, due to the formation of a zero-valent calcium-uranyl-carbonate complex ($Ca_2UO_2(CO_3)_3^0$). Furthermore, the addition of salt to groundwater (i.e., from road salt or seawater intrusion) produces a similar effect on uranium mobilization, due

to either the direct addition of calcium from road salt or seawater, or via the release of calcium from the aquifer by ion exchange. Therefore, caution should be exercised when planning anthropogenic activities that could release calcium to groundwater in areas with naturally occurring uranium.

Neoproterozoic peritidal phosphorite, Sete Lagoas Formation, Brazil: Implications for the Precambrian phosphorus cycle*

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The Sete Lagoas Formation is a ca. 150-m-thick basal unit of the Neoproterozoic Bambuí Group located in the São Francisco Basin of central Brazil. Lithofacies stacking patterns indicate deposition of this siltstone-carbonate-phosphorite succession occurred during an overall marine transgression that flooded the São Francisco Craton ca. 610 Ma. The phosphatic sequence is punctuated by higher order fluctuations in relative sea level that produced three parasequences. Parasequences are 40 to 50-metre-thick, defined by a basal flooding surface that is generally overlain by interbedded carbonate mudstone and wavy laminated siltstone that grades into flaser bedded silty sandstone and intertidal phosphatic microbial laminites. Each cycle is interpreted to record progradation of phosphatic intertidal flats over subtidal deposits as accommodation filled. The presence of beach facies, mudcracks, absence of coarse terrigenous clastics, and the abundance of silt with fine, abraded quartz grains indicate deposition along an arid coastline dominated by aeolian input. The shallow nature of phosphorite in the Sete Lagoas Formation suggests that redox-controlled phosphogenic mechanisms were restricted to nearshore environments. This is unlike younger, larger late Neoproterozoic-Phanerozoic phosphorites. These giant phosphorites generally formed in distal shelf environments in association with coastal upwelling. The increasing size of phosphatic deposits through the Neoproterozoic is interpreted to reflect the expansion of oxygenated environments across shelves that were favourably positioned for upwelling. This codependence of seafloor oxygenation and phosphogenesis highlights the importance of ocean redox state on the Precambrian phosphorus cycle.

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

Geochemical and isotopic signatures as proxies for source mantle composition in a post-collisional tectonic setting: An example from SW England

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The Late Carboniferous/Permian geology of SW England has long been interpreted to reflect Variscan collisional processes associated with the closure of the Rheic Ocean and the formation of Pangea. The Cornish peninsula is composed largely of Devonian and Carboniferous volcanic-sedimentary successions that were deposited in shallow, syn-collisional basins and were subsequently metamorphosed and deformed during the Variscan orogeny. Late Carboniferous granitic magmatism is voluminous and widespread, and is broadly coeval with the emplacement of Late Carboniferous-Early Permian lamprophyre dykes, sills,- and flows. Although these lamprophyres are well mapped and widely documented, the processes responsible for their genesis are less understood. Syn-rift basalts from the Devonian/Carboniferous sedimentary basins are moderately enriched in LREE, and have HREE profiles that indicate a shallow mantle source. They have trace element concentrations characteristic of alkaline within-plate basalts. Geochemical analysis shows the lamprophyres are extremely enriched in light rare-earth elements (LREE) and large-ion lithophile elements (LILE), which suggests they were generated from a deep, previously metasomatized mantle. Sm-Nd isotopic data indicate a continental lithospheric mantle source and those compositions of the magmas were modified by crustal contamination. By combining the data from mafic rocks spanning the Devonian and Carboniferous periods (and hence the Variscan orogeny) we can gain insight into how the mantle evolved during a continental collision and how rocks generated in a collisional setting are affected by mantle evolution.

Identification of new vertebrate diversity within the Scots Bay Member of the Early Jurassic McCoy Brook Formation, Wasson Bluff, Cumberland County, Nova Scotia

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The McCoy Brook Formation at Wasson Bluff near Parrsboro, Cumberland County, is now recognized as one of the most productive sites for preservation of small terrestrial vertebrates and dinosaurs immediately following the end-Triassic mass extinction. Syn-depositional faulting along the margin of the Minas Basin rift basin resulted in rapid topographic changes and positive sedimentation, preserving abundant faunal remains from several distinct ecosystems. Today, there is very rapid erosion (~1 m / year) of the coastal sandstone cliff exposures due to the extreme tidal range in the Bay of Fundy. The abundance of fossils and rate of erosion provide a unique opportunity for continuous collecting of new fossil specimens and detailed facies mapping.

During the past five years the "fish-bed" of the Scots Bay Member at Wasson Bluff has experienced particularly rapid erosion that has exposed new bedding features and fossil specimens. In 2008, approximately 5 kg of sediment samples from a rapidly eroding "fish bed" layer were collected (NS Heritage Permit# P2008NS02) for laboratory processing for small vertebrate remains. Processing of the sediment was completed in a separate study that identified a productive processing methodology. The current study reports on several significant specimens that were identified in the matrix samples prior to processing.

Three specimens of particular significance include an isolated serrated (theropod) dinosaur tooth, a small and elongate cervical vertebrae from a small, possibly juvenile dinosaur, and a dentary of the tritylodontid cynodont *Oligokyphus*. The three specimens preserved in the layer rich in semionotid scales and hybodont shark teeth, which suggests a shoreline depositional facies, with detailed sedimentological context being considered elsewhere. The identification of *Oligokyphus* is a first report of a tritylodontid cynodont in the Fundy Basin and further supports the earliest Jurassic age of the fauna.

Computer tomography (CT) examination of the *Oligokyphus* dentary fragment provides additional anatomical details of the root morphology of the well preserved in situ tooth as well as the posterior (empty) socket. Taphonomic details of all three specimens provide additional evidence for paleo-shoreline deposition of the currently exposed beds of the Scots Bay Member of the McCoy Brook Formation. The results demonstrate the importance of continuing collecting from this unit, especially considering the ecological context of these paleo-shoreline facies at a time of biological recovery following the end-Triassic mass extinction.

Coastal erosion: A geotechnical examination of successful and unsuccessful stabilization methods used in Nova Scotia

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Nova Scotia has a long, geologically diverse coastline that is responding to long-term sea-level rise in an equally diverse manner. Segments of coastline, typically within individual littoral cells, may show minimal erosion and stable or even prograding shorelines. On a regional basis, however coastal erosion is widespread, and coastal communities are reacting by implementing extensive armouring solutions. Parts of the Bay of Fundy coast and large areas along the Northumberland Strait and Gulf of St. Lawrence may represent some of the most at-risk coastlines in Nova Scotia. The north shore of the Minas Basin has rates of erosion estimated at 0.3 to >1 m per year.

Despite high rates of erosion, local infrastructure development is accelerating, often characterized by (historic) summer cottage development that, similar to other parts of Nova Scotia, are becoming multi-season dwellings as owners retire and extend the cottage season. Extensive coastal stabilization, most commonly construction of stone revetments, is being utilized in an attempt to protect property and infrastructure. Most of the stabilization is being undertaken by local contractors with highly variable levels of expertise. The quality of the armouring solutions varies both locally and regionally. It is not unusual to observe well-constructed revetments juxtaposed with failing or failed structures.

The presentation compares and contrasts various examples of armouring in Nova Scotia. Geotechnical aspects of a properly designed revetment will be discussed along with the coastal process that need to be considered when designing and constructing revetments. Environmental as well as geotechnical aspects of best practices are examined.

Developments in Early Paleozoic plate tectonics of the New Brunswick Appalachians over the last fifty years

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Fifty years ago, H. Williams proposed a two-sided model for the Newfoundland Appalachians with a Central Mobile Belt flanked by opposing stable continental platforms of Laurentia and Avalon. The following year, in 1966, J.T.Wilson showed that the distribution of Early Paleozoic sedimentary facies and trilobite fauna on both sides of the present Atlantic Ocean could be explained by opening and closing of an older Proto-Atlantic Ocean. In 1970, J. Bird and J. Dewey presented a model of the Northern Appalachians in which northward subduction of oceanic crust beneath a chain of island arcs provided a mechanism for closing the Proto-Atlantic. Ordovician volcanic rocks of the Tetagouche Group in northern New Brunswick were considered by Bird and Dewey to be part of this arc system.

In 1973, L. Fyffe mapped an unconformity at the base of the Tetagouche Group on the Tetagouche River that coincided with the Penobscot unconformity recognized by R. Neuman at the base of the Shin Pond Formation in Maine. In the same year, R. Irrinki mapped a calc-alkaline mafic volcanic sequence exposed in the core of the Popelogan Inlier, and sitting unconformably below Late Ordovician sedimentary rocks of the Matapedia Basin. In 1977, G. Pajari, N. Rast, and P. Stringer described an Ordovician ophiolitic assemblage within the Fournier Group, exposed in the Elmtree Inlier along Chaleur Bay in northern New Brunswick. Early to Middle Ordovician volcanic rocks of the Meductic Group in west-central New Brunswick were shown by J. Dostal in 1989 and by L. Fyffe in 2001 to have chemical compositions typical of an ensialic arc setting. Recently S. Johnson, M. McLeod, and L. Fyffe documented the existence of a Late Cambrian to Early Ordovician (Penobscot) arc system in southern New Brunswick.

In 1986, C. van Staal of the Geological Survey of Canada began a comprehensive field mapping program in the Bathurst Mining Camp of northern New Brunswick. His work over the next 25 years provided strong evidence that the volcanic rocks of the Tetagouche Group were formed in an ensialic backarc basin rather than in an island-arc setting and that the mafic rocks of the Fournier Group represented the complementary oceanic part of this basin. Furthermore, opening of this backarc basin in the Middle Ordovician led to the separation of the remnant Early Ordovician Meductic arc from the still active Popelogan arc. Subduction of ocean crust led to final closure of the Iapetus Ocean by successive accretion of the Popelogan arc and the Tetagouche backarc to the Laurentian margin during the Taconic orogeny in the Late Ordovician and Salinic orogeny in the Early Silurian, respectively.

A newly discovered first-order cross-orogen transtensional shear zone: The Western Nepal Fault System

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The Himalayan orogen is viewed as a compressional wedge with the distribution of great earthquakes (Mw>8) and highest seismic risk along the range front. New field and numerical modeling results indicate that this view is incomplete owing to the curvature of the orogen. Plate convergence becomes increasingly oblique away from the central axis and highest peaks, and the strain mechanisms vary as obliquity changes along strike. We hypothesize that strain becomes partitioned such that the western parts move northwestwards with respect to the central Himalaya. A previously unrecognized first-order system of northwest-striking transtensional faults, which we refer to as the Western Nepal Faults System (WNFS), can be traced more than 265 km, extending from the normal-convergent Main Frontal Thrust to the range-parallel Karakoram strike slip fault at the rear of the orogen.

The kinematics of the WNFS varies along strike. Multiple dextral strike slip segments are connected with extentional stepovers. A measured minimum rupture length of 63 km in the central WNFS has an average displacement of 5 m, maximum vertical displacement of >10 m, and maximum width of 500 m. Radiocarbon dates, including buried yak dung in a deformed terrace and macro-fossils in a sagpond buried under a colluvial wedge indicate that this last rupture occurred between 1145 and 1400 AD. This event, which approaches Mw~8 if the full 265 km ruptured, draws attention to a new seismic risk north of the range front, and may be a source of coeval seismicity that led to devastation in Nepal at 1255 and 1505 AD.

The dynamics of a geometrically-similar 3D segmented obliquely convergent orogen with a critical wedge thrust belt and plateau are demonstrated with the creeping flow program DOUAR. The model predicts a dominantly dextral strike slip shear zone traversing the western portion of the orogenic wedge, which mimics the WNFS. While the Karakoram and Main Frontal Thrust faults may be analogous to previously recognized strain portioning along the Sumatra Fault and Java Trench, the WNFS adds an additional cross-orogen transtensional shear requirement where convergence obliquity changes along strike.

Celebrating five years of research at the Joggins Fossil Cliffs UNESCO World Heritage Site

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The Joggins Fossil Cliffs, a Carboniferous coastal section in the Bay of Fundy, has recently celebrated its fifth anniversary as a UNESCO World Heritage Site. The Cliffs represent the finest example in the world of the terrestrial tropical environment and ecosystems of the Pennsylvanian (Late Carboniferous). The Joggins Fossil Cliffs have a long history of scientific research with more than 100 site-specific publications in over 150 years. Recent research has become broader, reaching far beyond the broad categories of paleontology, geology, and historical study. Inscription on the World Heritage List and its close proximity to the Fundy Biosphere Reserve has also made the site of interest to economists, biologists, and geographers. Highlighted here are very recent studies (recently published or in progress) that span the broad range of research at the site: from trace fossil taxonomy to bird migration to regional economic impacts of a World Heritage Site. Much of this work has been undertaken by Maritime institutions that include universities and provincial and federal governmental departments. While research from the past 150 years has made large strides in our understanding of the Late Carboniferous, many questions remain to be resolved and interest in the site is clearly expanding into new fields.

Assessment of the "Passey method" for discrimination of organic-rich intervals in wells from offshore Newfoundland (Canada)

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Sonic and resistivity borehole wireline data can be used to obtain information about the location and amount of organic matter in a determined sedimentary series. The "Passey method" (Δ Log R) is a specific approach to source rock analysis, where a scaled porosity log (usually sonic transit time curve) and a resistivity curve (preferably from a deep-reading tool) are overlain and calibrated to estimate the amount of organic matter in a given stratigraphic interval. The "Passey method" can be used to differentiate mature and immature source rocks, determine TOC content and organic matter type.

The Jeanne d'Arc Basin, located off the eastern coast of Newfoundland, has been proven to contain a large amount of oil and gas, producing from multiple fields. A significant source rock for this basin is thought to be the Egret Member (Upper Jurassic) of the Rankin Formation. The Egret Member is organic-rich shale that was deposited during a marine transgression in the Late Jurassic. The proven reservoirs in the Jeanne d'Arc Basin are Upper Jurassic (Jeanne d'Arc and South Tempest sandstones) and Cretaceous (South Mara, Ben Nevis, Avalon, Catalina, and Hibernia sandstones).

In this study, we have analyzed several wells from offshore Newfoundland to test the applicability and limitations of the "Passey method". The dataset includes lithological and biostratigraphic data, gamma-ray, resistivity, and sonic (representative of porosity) logs, and geochemical data (primarily TOC). Preliminary results from the well Egret K-36 show that there are a few intervals where a relationship between porosity logs and resistivity can be observed, including the Egret Member of the Rankin Formation.

The results and methodology from this study, linking source rock intervals identified by the "Passey method" in close proximity with oil and gas accumulations, can be applied to the Nova Scotia margin where there are current oil exploration programs.

Carbon capture and storage: Overview, reservoir options, and future possibilities

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Climate Change is of significant concern in the world today. Anthropogenic sources are adding to the amounts of Greenhouse Gases (GHGs) in our atmosphere, which in turn, are leading to an increased warming of the planet. A notable option for mitigating the effects humans are having on the planet is carbon capture and storage. In order to select reservoirs for potential storage, there are multiple criteria which must be considered. These reservoirs provide different kinds of storage and each poses various obstacles. Potential areas for carbon capture and storage in Nova Scotia include the Joggins Fossil Cliffs, the Sydney Carboniferous Strata, and the North Mountain Basalt. The reservoir with the highest long-term storage potential is basalt formations, due to the fact that their minerals have the ability to react with the injected CO_2 and convert it into a solid carbonate material. Importance also lies on the pore sizes, which affect porosity and permeability of a material, which in turn, can determine the storage capabilities of reservoirs (Sydney Carboniferous strata and their reservoir potential due to its lithology type). Overall, Nova Scotia has multiple opportunities for carbon capture and storage that should be further investigated in future studies.

Detectability of fugitive emissions at an enhanced oil recovery site

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Enhanced oil recovery (EOR) is a fundamentally important technology for securing future oil production. However, this technology requires the use and transportation of fluids at high pressures above and below ground, which can lead to surface or subsurface seepage, especially as infrastructure ages. The EOR project located in Weyburn, Saskatchewan consists of more than 1000 active wells, several processing plants, and hundreds of kilometres of pipeline infrastructure over a 100 km² area. This highly distributed operation presents challenges for gas leakage monitoring in terms of size and complexity of gas signals, and stretches conventional techniques beyond their limits. By comparing the ratios of observed atmospheric trace gases against the ratio fingerprints of known industrial, potential emission sources have been constrained. This presentation discusses the development of new large footprint techniques for identifying sources and magnitudes of fugitive emissions, and to understand targeted gas evolution across multiple land uses and through time.

To observe changes in the atmospheric composition of select gases, and to ascertain how those might be related to industrial activities, we used two Cavity Ringdown Spectroscopy (CRDS) instruments and a novel trace gas detection strategy to identify atmospheric emissions in this large domain (10×10 km). These instruments measured atmospheric concentrations of CO_2, methane and its stable carbon isotopic ratio (δ13C-CH_4), and hydrogen sulfide (H_2S). Both instruments alternated as stationary and mobile (vehicle-based and geo-located) receptors during field campaigns in 2013–2014. This presentation focuses on our mobile receptor techniques for constraining the location of potential emissions.

Anomalies in gas ratios of CO_2:CH_4 and CH_4:H_2S detected along route by the mobile receptor were compared to known ratios of likely industrial sources (e.g., pipeline, injection fluid, formation gases, etc.). This geochemical fingerprint was used to distinguish these sources from one another, and from other potential confounding sources including biological emissions, combustion engines, and atmospheric pooling. Our results identified several anomalies that were found to correspond with oilfield activities at the time of the survey, which were known to have gas emission potential. Here we give case study examples showing how potential emission events were pinpointed and investigated. This multi-gas component approach allows us to extend the utility of analyzers beyond single-mode deployments, to constrain the location and better estimate the source of potential emissions in the Weyburn field. It is a promising package for EOR, Carbon Capture and Storage (CCS), unconventional gas and hydrofracturing, and other fugitive gas monitoring programs where sensitivity and specificity are required.

The role of vegetation in shaping the architecture of an Early Pennsylvanian braided river: The Boss Point Formation of Atlantic Canada

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Vegetation greatly influences modern river dynamics, but its role within fluvial facies models has been difficult to determine due to poor preservation in fluvial strata and anthropogenic effects in modern rivers. Ancient fluvial systems such as the well exposed Boss Point Formation, studied in the type section in Nova Scotia, have much to offer in exploring this role. This braided-fluvial unit comprises sandy bars and bedforms, large foreset bars that accreted downstream and less commonly laterally, high flow-strength sheets with antidune bedforms, and climbing-ripple bedsets. Erosion surfaces of varied prominence and lateral extent dominate the architecture, outlining bars, discrete channels, channel belts, and regional paleovalleys.

Compacted, coalified, and locally permineralized logs up to 6 m long are abundant in the formation, with one report of a 14 m log. Most logs are cordaitalean, an extinct group of large, slow-growing trees related to conifers that forested well drained floodplains and uplands. Their exceptional preservation reflects rapid burial in channels below the groundwater table, a process that probably limited their decay. Scattered *in situ* cordaitaleans are also present in the channel sandstones, mainly associated with rooted horizons. The Boss Point biome included subordinate calamitaleans, which pioneered disturbed, shifting substrates along and within the channels, and rare lycopsids, which preferred poorly drained undisturbed areas such as small peat-forming swamps.

In measured sections, beds rich in woody debris constitute at least 18% of the channel deposits. Accumulations

of woody debris are found: (1) in extensive channel-base lags up to 2 m thick in channel bodies of varied size; (2) as discrete fills of minor channels with bedsets of sediment and logs (~25% by volume) up to 6 m thick; and (3) at the core of sandy macroforms that accreted and built up around stranded logs. Type 2 and 3 accumulations occur mainly in the uppermost strata of channel belts where they contributed strongly to the filling of smaller channels. Abandoned-channel mudstones overlie some accumulations, suggesting that the woody debris choked channels and aided avulsion. The abundance of logs implies that the channel belts were bordered by forests, and rooted channel deposits indicate the presence of vegetated islands, some developed over log accumulations.

The Boss Point strata are analogous to modern anabranching island-braided rivers such as the Tagliamento of Italy, and arguably represent the oldest island-braided system known. It is apparent that vegetation greatly influenced the dynamics and architecture of the fluvial system.

New tools for an old problem - Constraints on contact metamorphism in Halifax from RSCM thermometry and thermal models

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Intrusion of the South Mountain Batholith produced a low-pressure contact metamorphic aureole in its host rocks of the Meguma Supergroup. The effects of contact metamorphism are particularly well developed in pelitic rocks of the Cunard and Bluestone formations of the Halifax Group. Contact metamorphic isograds have recently been mapped across the Halifax Peninsula and vicinity, with P-T conditions at the contact estimated at ca. 650 °C and 2.5–3.0 kbar. However, quantitative assessment of prograde metamorphism and the overall thermal structure of the contact aureole have been hampered by uncertainties in key thermodynamic parameters and extensive retrogression of low-grade assemblages. In this study, Raman spectroscopy of carbonaceous material (RSCM) was used to obtain temperatures from graphite, which is common throughout the contact aureole. Temperature estimates range from ca. 360 °C just outside the cordierite-in isograd to ca. 640 °C in the sillimanite-K-feldspar zone near the contact, the latter consistent with the temperature estimated from the corresponding mineral assemblage. A thermal profile constructed from the RSCM data was used to constrain a 2D numerical model for heat transport associated with post-intrusion conductive cooling of the batholith along its eastern margin. For the parameters used, the model predicts that peak temperatures in country rocks within 1 km of the contact were reached within 50 ka of intrusion. Comparison of RSCM vs model thermal profiles also places constraints on the subsurface geometry of the contact in the study area. Based on this work, we infer that the area around Williams Lake is underlain by granite at shallow depth, with the contact steepening beneath the Northwest Arm; the pluton apparently does not extend beneath the Halifax Peninsula.

Baseline hydrological monitoring at Big Meadow Bog, Brier Island, Nova Scotia: Preliminary results

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Agricultural ditching of the Big Meadow Bog (BMB) that occurred in the 1950s has destabilized the peatland ecohydrology, resulting in successional changes to the peatland, which may threaten the long-term survivability of the Eastern Mountain Avens (EMA), a globally rare plant species associated with the wetland complex. The ecohydrological changes observed at BMB have also been associated with the establishment of a herring gull colony, resulting in nutrient inputs to BMB and the physical removal of vegetation by gulls around their nesting habitat.

A hydrological field program was initiated in the summer of 2013 to characterize baseline conditions, involving the installation of monitoring wells and the collection of water level and geochemistry data. The results indicate that the hydrological functioning of the BMB system has been impacted by site disturbances. These impacts include a lowered and more variable water level in the central area of BMB due to the effect of the drainage ditch, which can affect peatland morphology and the survival of Sphagnum, the primary peat-forming vegetation. Significantly higher nutrient levels were also detected in BMB, which may be attributed to nutrient enrichment from gulls, ingress of upland minerotrophic water, or mobilization of in-situ nutrients through mineralization.

The combined effect of hydrological modifications to BMB and nutrient enrichment from herring gull populations favours afforestation and displacement of native or pre-disturbance species such as Sphagnum. More study is needed to improve our understanding of the effect of the observed BMB disturbances on EMA populations, although given that EMA is associated with moist, cool habitats, the drying trend observed at BMB could threaten the long-term survivability of the rare species. Additional site characterization is needed to evaluate restoration feasibility, objectives and strategies, and ensure that EMA habitat is preserved or enhanced.

Selected activities of the Hydrogeology Program

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Recent activities of the Nova Scotia Department of Natural Resources (DNR) Hydrogeology Program include the assessment of the relative vulnerability of coastal groundwater supplies to seawater intrusion and the identification of high potential areas for surficial aquifer groundwater supply development in unserviced growth areas of the Halifax Regional Municipality. Hydrogeology program activities are also focused on the organization, compilation and mapping of provincial groundwater information and outreach initiatives, such as the Groundswell project.

Mesoproterozoic Oaxaquia-type basement in the exotic Paleozoic terranes of Mexico, the Appalachians, and Europe: Faunal, paleomagnetic, and T_{DM} age constraints on paleogeography

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The basement of most exotic Paleozoic terranes in Mexico, the Appalachians, the Caledonides, and the Variscides is generally buried beneath younger cover. However, it is exposed in the Oaxaquia terrane of Mexico, which records: (1) ca. 1300–1200 Ma arc magmatism and sedimentation; (2) ca.1160–1100 Ma backarc magmatism and migmatization; (3) ca. 1035–1010 Ma AMCG magmatism; (4) 1000–980 Ma granulite facies tectonothermal event; (5) gradual exhumation at 750 and/or 545 Ma; and (6) uppermost Cambrian and Silurian platform rocks containing a fauna of mixed affinities: mainly endemic brachiopods, and rare Laurentian, Avalonian, and Baltic brachiopods, trilobites, and molluscs. Oaxaquian igneous rocks have depleted mantle model ages (T_{DM}) of 1.35–1.77 billion years. Similar T_{DM} ages occur in Ediacaran arc rocks in Suwannee (Florida), NW Avalonia, Ganderia, Iberia, Armorica, and Bohemia, and in lower Palaeozoic plutons cutting adjacent Palaeozoic passive margin rocks (Acatlán Complex, Gander Group), suggesting that Oaxaquia-type basement underlies these regions. These T_{DM} ages are intermediate between those of SE Avalonia/Carolinia (0.75–1.1 billion years) and the ca. 2.0 Ga basement typical of NW Africa and the Channel Islands of the United Kingdom. Avalonia (here defined as those Neoproterozoic blocks that are overstepped by Cambrian strata containing unique Avalonian fauna), Ganderia, and Carolinia are grouped into Greater Avalonia. The polarity of the T_{DM} ages in Greater Avalonia (younger to the SE) suggests that these exotic terranes rotated clockwise through ~90° before accretion to Laurentia. The predominantly endemic, Cambrian-lowest Ordovician fauna in regions underlain by Oaxaquia-type basement indicates an island chain. Reconstructions initially linked Greater Avalonia with northwest Africa based on Pan-African correlatives, then with Amazonia based on the occurrence of 1 Ga detrital zircons, and recently with Bolshezemel block in the Timanides of Baltica based mainly on paleomagnetic data. The main difference between these complexes is the degree of latest Ediacaran deformation, mild in Avalonia and polyphase in the Bolshezemel block, which may be interpreted in terms of isolation of Greater Avalonia versus collisional between Baltica and the arc-related Bolshezemel block in the Timanides, respectively. Orthogonal transfer of Greater Avalonia from NW Gondwana does not explain the reversed polarity in Greater Avalonia, which led initially to an Ordovician lateral transfer model. However, paleomagnetic data indicate that Greater Avalonia lay at 20–30°S paleolatitude at 550 Ma and rotated anticlockwise through 150° during the Cambrian followed by orthogonal migration across Iapetus to amalgamate with eastern Laurentia by the Late Ordovician-Early Silurian.

Facies changes in the Upper Albion Member of the Carboniferous Stellarton Basin, Nova Scotia

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The Stellarton Basin displays rapid facies changes both laterally and vertically throughout the stratigraphic section. These facies changes are observed to occur mostly between coals and shales (oil shales). The upper Albion Member interval of the Stellarton Formation encompasses examples of stratigraphy that displays these facies changes. The prominent and laterally continuous coal seams in this upper Albion Interval were used as stratigraphic markers to aid with correlations of the stratigraphy across the basin for the examination of: lateral and vertical facies transitions from shales (oil shales) to coals; regional thickness and compositional facies variations of organic-rich and interbedded clastic units; indications of tectonic and depositional controls on the organic-rich deposits and

potential hydrocarbon reservoir units; whether depositional environments were restricted to only lacustrine/deltaic (or was there some marine influence?). The upper members of the Stellarton Formation (Coal Brook and Thorburn members) have been subject to a significant amount of scientific scrutiny, with less emphasis on the Albion Member (aside from its coal seams), making this interval an excellent area of study. Analytical techniques used for analysis include: geophysical logs and drill core for correlations; thin sectioning and microscope analysis; XRD; Rock-Eval Pyrolysis; and X-Ray Fluorescence. A close and detailed examination of this interval reveals the origins and controls on these facies changes, deposition, and interaction of the stratigraphic units of the upper Albion Member which will garner more interest and research into the remainder of the Albion Member and other lower members of the Stellarton Formation.

Reconciliation and implications of SEM-EDS microscopy and fluid inclusion chemistry for the origin of the Meguma gold deposits, Nova Scotia

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The quartz vein-hosted gold deposits of the Meguma terrane, southern Nova Scotia, are well recognized as a classic example of orogenic slate-belt-hosted gold mineralization. Decades of work examining their regional geological setting, structural style, vein types, and contained mineralogy, time of formation, and geochemical signatures has not resulted in consensus regarding their origin and a range of models are still promoted. Whereas there may be agreement on the nature of the fluid, this being of metamorphic origin, the timing of fluid generation and source of this fluid and its contained metals, in particular Au, remain contentious, as occurs for most gold deposits settings globally. Here are reported recent observations and data that may reconcile these polarized views and, at the same time, advance our understanding of some aspects of these deposits. The new contributions are limited to SEM-EDS microscopy and fluid inclusion (FI) chemistry from a variety of gold deposits. The SEM-EDS observations focus on the nature of the thin layers or septa within the veins, these features commonly referred to as crack-seal (CS) layers, and two observations about these features are noted: (1) evidence for extensive fluid-rock reaction, which is generally absent in the wall rocks, is recorded both texturally and chemically by the presence of new mineral domains (e.g., Fe-rich chlorite, muscovite, tourmaline, apatite) which formed after wall rock material was entrained during antitaxial vein growth; and (2) the CS layers are rarely composed of carbonaceous material characterized by a black-shale like chemistry, that is enriched (to wt.%) in S, As, Zn, Cu, Co, Ni, and Pb. The chemistry of FIs, determined using the evaporate-mound method for >550 mounds, indicates distinct fluid types in terms of Na:K:Ca occur within (e.g., Beaver Dam, Caribou) and among deposits (18 deposits studied). These data support results of earlier LA ICP-MS analysis of FIs. The new observations and data are reconciled with previous work and ideas for the Meguma deposits as follows: (1) more than one fluid type, hence source and/or process, may be involved in vein formation; (2) some metals, including Au, and volatiles (S, C) may originate within carbonaceous layers in the local strata, but their extent and abundance is not constrained; (3) the biogenic signature for vein sulfides ($\delta^{34}S$) and carbonates ($\delta^{13}C$), which is globally anomalous, are consistent with the chemistry of the carbonaceous layers reported.

The Gardners Meadow Sn-Zn-Cu showing of southwest Nova Scotia: A small but not insignificant ca. 360 Ma metallogenic event

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Gardners Meadow is one of several Sn-base metal occurrences in the southwestern Meguma terrane hosted by metasedimentary rocks, in this case the Goldenville Group, rather than within or proximal a progenitor granite. The occurrence is significant due to its ca. 360 Ma age, as constrained by Re-Os dating of molybdenite associated with sphalerite-fluorite mineralization, which contrasts with the more important ca. 380 Ma lithophile-metal mineralization in the Meguma terrane, such as the East Kemptville Sn deposit. Mineralization (to 1% Zn, 1% Cu, 0.45% Sn, anomalous In) occurs within quartz veins and garnet-rich layers of the metasedimentary host rocks. Isotopic data (O, S, C) and fluid inclusion microthermometry are used to constrain the PTX conditions of the mineralizing event which also has implications for regional metallogeny in the SW Meguma terrane at this time. Isotopic data for vein assemblages (350 to 400 °C) indicate $\delta^{18}O_{H2O}$ = 2.3 to 5.1‰ for quartz (n=5), $\delta^{34}S_{H2S}$ = 5.5 to 6.6‰ for pyrrhotite-sphalerite (n=3), and $\delta^{13}C_{H2CO3}$ = -9.6 for calcite (n=1). Fluid inclusion studies indicate three fluid types occur, two aqueous (L-V, L-V-Halite) and a much less abundant aqueous-carbonic. An unusual textural feature of the inclusions is both the

abundance and varied nature of decrepitate textures present. The L-V aqueous inclusions have salinities of 7 to 23 wt.% eq. NaCl + $CaCl_2$, with X(Na/(Na + Ca)) between 0.15 and 0.5–0.9, whereas the L-V-H inclusions have salinities of 31 wt. % eq. NaCl. Evaporate mound analysis indicate two fluid compositions occur, one Na-K and the other Na-K-Ca. The aqueous inclusions have Th values of 115 to 270 °C, whereas the L-V-H types homogenize via V bubble disappearance at 200 °C and indicate a minimum entrapment P of 1500 bars. The carbonic inclusions, with X_{CO2} = 0.01–0.07, have salinities of 7 to 11 wt. % eq. NaCl and Th values of 250 to >290 °C. Collectively these data suggest ascent at ca. 360 Ma of a moderate-salinity aqueous, magmatic-derived fluid to near 4.5 km depth (P_{H2O} = 1.5 kbars); subsequent exchange of this fluid with the wall rock is considered responsible for its Ca-rich nature, carbonic chemistry, and depleted $\delta^{13}C_{H2CO3}$ signature. Incursion and mixing of a surficial fluid, likely meteoric water, with the magmatic fluid is inferred from both the $\delta^{18}O_{H2O}$ values (2–5‰) and lower salinities. The abundant fluid inclusions decrepitate textures indicate a later PT event affected the area which we suggest is the ca. 300 Ma Alleghanian orogenic event.

Lithogeochemistry and chemostratigraphy of the Hanson Lake Assemblage, west side of Hanson Lake, Saskatchewan

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The Paleoproterozoic Flin Flon Greenstone Belt (FFGB) extends from central Manitoba into east-central Saskatchewan. It is part of the Reindeer Zone of the Paleoproterozoic Trans-Hudson Orogen. The Hanson Lake Assemblage (HLA) comprises the western end of the FFGB, and is located near Hanson Lake, Saskatchewan, approximately 100 km west of Flin Flon Manitoba. To the south, it is unconformably covered by Phanerozoic sedimentary rocks. The HLA is host to a number of volcanic hosted massive sulphide Cu-Zn showings and prospects, including the McIlvenna Bay and Hanson Lake (Western Nuclear) deposits. Both of these deposits are covered (the Hanson Lake deposit by Hanson Lake, and the McIlvenna Bay deposit by Ordovician cover). Host lithologies for all of these VHMS occurrences are volcanic and volcaniclastic rocks. These are interbedded with subordinate clastic sedimentary rocks and silica/Fe-oxide exhalative horizons. Metamorphic conditions in the HLA reached upper greenschist to upper amphibolite facies, depending on location, and thus a 'meta' prefix is implied for rocks of the HLA. The host rocks to these mineral occurrences are generally not well understood, and a comprehensive stratigraphy for the exposed part of the HLA has never been constructed, largely due to complexities arising from thickness variations, changes in volcanic facies, and difficulties in rock identification due to hydrothermal alteration, deformation, and metamorphism. Nevertheless, many data sets from past mineral exploration and regional mapping surveys have provided an abundance of historical data from the area, consisting primarily of regional geological maps, drill core logs, and regional and drill core lithogeochemical datasets. As such, data exist that allow the construction of fully integrated lithostratigraphic and chemostratigraphic models for the HLA that can be used to correlate exposed stratigraphy north of the shield margin with rocks encountered in drill core beneath cover south of the unconformity. Molar element ratio (MER) analysis of new lithogeochemical data, collected from the western side of Hanson Lake and constrained by petrographic analysis, has provided important chemical constraints for the classification of host rocks located there, and has allowed the development of a stratigraphic model for that part of the stratigraphy. This dataset will serve as a foundation for the incorporation of other historical datasets, and the resulting stratigraphic model will assist explorationists prospecting for VHMS mineralization south of the unconformity.

Examination of trace metals in gastropods to determine the potential for accumulation in the Border Marsh Region

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The Border Marsh Region (BMR), located on the Isthmus of Chignecto at the head of the Bay of Fundy, is a major feeding ground for waterfowl and contains significant coastal wetland systems including salt marshes, ponds, lakes, and impoundments created by Ducks Unlimited Canada. The purpose of this study was to examine various open water wetland sites across the BMR to explore the potential for bioaccumulation of Pb and As in higher-trophic level species through natural and anthropogenic sources. Gastropods were chosen to sample as vectors for metal transfer to waterfowl because they are effective indicators

of metal accumulation and are an important food source for breeding birds. A previous study indicated significant lead and arsenic concentrations in bottom sediments at most wetland sites. It was hypothesized that gastropods would accumulate these metals in similar concentrations to the sediments. Eleven sites (two natural brackish ponds, eight freshwater impoundments and one natural freshwater lake) were sampled and element concentrations in gastropods were analyzed using an XRF spectrometer. Relative levels of metals in gastropods were analyzed, without removing small debris, and compared to sediment concentrations. Preliminary analysis indicates there were no significant correlations between lead and arsenic concentrations in sediment and gastropods. Although metal concentrations in gastropods were not toxic, there were three important observations: (1) greatest proportions of lead and arsenic concentrations in gastropods to sediment were detected in the natural brackish ponds; (2) arsenic was detected in gastropods from all sites whereas lead was only detected in gastropods from the brackish ponds and the freshwater lake; and (3) arsenic concentrations in gastropods were higher in recently constructed freshwater impoundments. The results of this study indicate that the salinity and redox properties of the wetlands, rather than concentration in sediments, may be the critical factors in determining whether lead and arsenic will bioaccumulate in gastropods.

A survey of climate change knowledge and attitudes of Nova Scotia teachers

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We report the results of a survey of Nova Scotia in-service teachers' climate change knowledge, attitudes, and comfort levels; current climate change teaching practices; perceived or actual barriers to teaching climate change; and needed resources for climate change instruction. This survey was designed to identify strengths and weaknesses of Nova Scotia climate change instruction to help target professional development efforts. 427 teachers at 24 schools in three school boards (Halifax Regional, Cape Breton-Victoria Regional, and Strait Regional) were invited to participate. 188 teachers completed an anonymous online survey (44% response rate), with 58% of respondents teaching at the high-school level and 42% at the elementary level. Overall results found that teachers were highly concerned about climate change impacts and were supportive of adaptive and mitigative efforts, as well as broad integration of climate change instruction across the curriculum. Survey respondents had high-levels of general scientific literacy, but showed serious gaps in climate science knowledge, confused priorities for climate change adaptation/mitigation, and held misconceptions about the causes and effects of climate change. The majority (87%) of respondents already address climate change in some manner in their classrooms, but half of those teachers report that lack of knowledge or lack of time limits their instruction. Lack of support materials (29%) and curriculum integration (75%), rather than concerns about the uncertain nature of climate science (4%) or negative reaction from parents (4%), are the primary reasons teachers fail to teach about climate change. These results indicate an opportunity for Nova Scotia geoscience professionals and educators to influence climate change instruction in Nova Scotia public schools through materials development and mentoring.

The geology of the Zuun Mod-Khuvyn Khar Porphyry Complex, southwestern Mongolia

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The Zuun Mod-Khuvyn Khar porphyry complex is located in the southwestern part of Mongolia near the western end of the Gobi desert, within a Late Paleozoic magmatic arc terrane termed the Trans Altay terrane. Current work coupled with previous geochronological data indicates that Carboniferous biotite granodiorite rocks, the dominant rock type in the complex, intruded a large Carboniferous monzonite – quartz monzonite batholith that intruded a Carboniferous volcanic sequence of andesite with minor rhyolite. Recent mapping and re-logging of drill core indicated the porphyry complex was subjected to dip-slip block faulting, presumably related to the Himalayan Orogeny (ca 55 Ma–present). The southeast portion of the complex is mostly biotite granodiorite and hosts the Zuun Mod Mo-Cu deposit (measured and indicated resource of 218 Mt @ 0.057% Mo, 0.069% Cu), interpreted as the first mineralizing event in the complex. The rest of the complex consists mostly of fine-grained porphyry phases and is host to a second phase of Cu ± Ag mineralization. A detailed ground gravity survey (200 m grid spacing) completed in 2013 has identified two pronounced gravity low features in the Khuvyn Khar part of the complex that coincide with hydrothermal intrusive breccias with Cu- and Mo-mineralized clasts and matrix, indicating the presence of mineralized porphyry intrusion(s) at depth. These areas will be the focus of future mineral exploration.

Toppling tetrapod trees at Joggins, Nova Scotia

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First described by J.W. Dawson in the early 1800s, the Upper Carboniferous lycopod tree stumps from Joggins, Nova Scotia are famous for their enclosed terrestrial fauna, including millipedes, gastropods (*Dendropupa*), and tetrapods. Particularly notable is the occurrence of the oldest-known amniote, *Hylonomus*. The taphonomy of the stump assemblage has been a matter of some debate since it was found. Dawson considered several hypotheses, but favoured the "pit-fall trap" model where tetrapods fell into a pit formed as sediment piled around the hollow tree. The persistent association with charcoal has suggested fire played an important role, possibly producing fire scars on the trees that were used as entry points for long-term occupation of the stumps (denning), or perhaps even immolating the inhabitants in their refuges.

Until recently, differentiating these hypotheses and other scenarios has been hindered by the limited amount of Dawson's original material that was preserved in museums, usually only the thin charcoal- and bone-bearing layers. A concerted effort by the authors and by others to recover new tetrapod-bearing trees from Joggins has yielded several new discoveries. Rather than the single horizon recognized by Dawson, tetrapod-bearing trees are now known from much of the Joggins Formation. Thus, the preservation was not a unique taphonomic event. Additionally, a new tree from Dawson's horizon itself was recovered last year, allowing direct comparison of the taphonomy of the "classic" horizon with the new discoveries. The material discovered to date demonstrates fair sedimentological diversity, from mudstone-infilled to sandstone infilled, yet still consistently shows a stratigraphic pattern similar to Dawson's original description: blocky charcoal with rare bones followed by fine-grained, laminated, bone-bearing charcoal, followed by decreasing charcoal abundance and more clastic sediments. A mud-intraclast conglomerate is also present in many stumps, the significance of which is unknown.

Besides detailed microstratigraphy, the newest trees have also shown in-situ tilting of a tree trunk that affected its infill, a new specimen of "scales" originally attributed to tetrapods by Dawson, and a variety of millipede remains. Recovering stumps and managing their analysis in the field and lab is a logistical and technical challenge, but results to date with photogrammetry and computed tomography X-rays show great potential for unraveling their story.

Tectonic and climatic controls of growth and shape of the Himalayan foreland fold and thrust belt: A numerical study

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According to the critical taper model, there are three processes that determine the morphology of foreland fold-and-thrust belts: (1) the removal of material by erosion; (2) the accretion of material, determined by sedimentation and plate convergence rates; and (3) steady-state critical growth, determined by the rheological properties of the materials that comprise the wedge. The Himalayan orogeny provides a unique opportunity to study collisional orogens and active fold-and-thrust belts (FTB) in an environment where processes 1 and 2 (above) vary systematically along strike. The Siwalik Group consists of synorogenic sediments of Miocene to Pleistocene age, and constitutes the presently active foreland FTB of the Himalayan orogen. Recently constructed balanced cross-sections revealed two important observations concerning foreland FTB morphology across the Himalayan arc: (1) west to east increase in strain and strain rate correlates with plate convergence rates, and (2) annual rainfall amounts are inversely correlated with FTB morphology. From these observations, it was proposed that surface properties exert more control on wedge morphology than tectonic processes in the Himalayan FTB. In this study we use critical taper model to numerically test the relative contribution of surface processes on the morphology of the present-day foreland FTB of the Himalaya. Internal parameters such as: friction, both along the wedge (μ) and decollement fault plane (μb); the Hubbert-Rubey fluid pore ratio, both within the wedge (λ) and along the basal decollement (λb); and the critical taper ($\alpha+\beta$) were held constant. Key parameters including: thickness of accreted material (T), depth of the decollement (D), rock erodibility (K) and material flux (vT) were varied within the range of observed values along-strike of the Himalayan FTB. Comparison between experiments allows for the estimation of model sensitivity to each parameter individually. The calculated critical taper morphology and growth rate are consistent with those observed in the Himalayan FTB, indicating that it develops in accordance with the critical Coulomb wedge theory. Comparative analysis of parameters indicates that within a narrow range of high values of the erodibility factor K, climatically induced erosion is the principal control on Himalayan foreland FTB morphology. Conversely, when the erodibility factor (K) is low, tectonic accretion of the material (vT) is the dominant growth parameter.

Complex cold-based glacier coverage histories and timing of last glacial plucking of tors on Cumberland Peninsula, Baffin Island, Eastern Canadian Arctic

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Highly weathered rock outcrops (tors) often occur on regolith-covered, low-relief upland plateaus in formerly glaciated polar landscapes. Owing to their advanced weathering degree and lack of glacial erosional or depositional features, they have traditionally been interpreted to have escaped ice sheet coverage. However, in many places terrestrial cosmogenic nuclide (TCN) exposure dated erratic blocks deposited on the regolith and the asymmetric streamlining of tor outcrops allude to past ice coverage. Complex cosmic ray exposure histories of ice cover have been deciphered using two radiogenic nuclides with dissimilar decay rates. However, while $^{26}Al/^{10}Be$ ratios can indicate that the rock had been previously buried by ice, the ratios alone cannot determine when the cover occurred. Thus, interpretations that ice cover occurred during the last glacial maximum (LGM) may be flawed.

We have developed a novel approach to interpret ratios of TCN in the context of complex exposure histories accounting for recurring burial by cold-based ice and address the problem of episodic glacial plucking. First, we establish the average exposure:cover ratio for the tor sites we visited. Assuming orbital pacing of glacial-interglacial cycles, we model plausible exposure histories of periodic exposure and burial intervals. The majority of the 26 samples collected from tors on Cumberland Peninsula interfjord plateaus require average relative exposure durations of 20% within a glacial-interglacial cycle (i.e., 20 ka of exposure and 80 ka of ice coverage). Three samples located along narrow coastal ridges indicate ice-free conditions throughout their entire exposure history. Minimum total exposure durations range from 320 ka up to 1.8 Ma, which are approximately twice as long as previous estimates of total exposure histories. This model assumes ice coverage during LGM, but a Monte Carlo simulation has shown that several summits could also have been ice free since oxygen isotope stage 3 (i.e., the last 60 ka).

Second, we determine when the last glacial plucking event occurred. TCN concentrations decrease exponentially below surface, but the $^{26}Al/^{10}Be$ increase with depth due to increased muogenic production of ^{26}Al relative to 10Be with depth. By modelling the variation in TCN ratio and concentrations with depth and time, we are able to constrain the timing of last plucking of any sampled surface for different thicknesses of overlying tor blocks. Assuming reasonable thicknesses of bedrock blocks of 50–120 cm (based on horizontal joint spacing), we calculate that most sampled surfaces were plucked either between 200–350 ka and 500–800 ka.

Petrology and geochemistry of ca. 2680 Ma pillow lavas at Sharrie Lake, southern Slave Province, Northwest Territories

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Neoarchean (ca. 2680 Ma) transitional to calc-alkaline volcanic rocks in the Tumpline Lake subarea of the Cameron River - Beaulieu River volcanic belt in the southern Slave province are being assessed to determine their potential as a prospective volcanogenic-hosted massive sulphide (VMS) environment. Bedrock mapping at Sharrie Lake, approximately 70 km ENE of Yellowknife, was completed at 1:7 500-scale in 2012 and 2013. Samples of pillowed mafic and intermediate lava flows from this strongly bimodal suite were collected for further study. In addition to some true pillowed basalt and andesite, many flows have basalt-like textures yet have the weathered appearance and silica values of a dacite or rhyolite. The VMS-potential of these pillowed lava flows will be assessed by characterizing the rock geochemistry and alteration characteristics, and constraining the timing of alteration and deformation relative to metamorphism.

Geochemical discrimination diagrams demonstrate that primary lithology varies from basalt to andesite, and several flows can be identified based on their distinct geochemical signatures. Lava flows have variable REE patterns although all show arc-like characteristics. Preliminary petrography demonstrates that alteration mineralogy is dominated by carbonate, chlorite, quartz, epidote, and minor sericite. In thin section, disseminated groundmass carbonate is common and ovoid aggregates of quartz and carbonate, interpreted as deformed amygdules, display textures indicating recrystallization during regional metamorphism. Lithogeochemical characterization of least altered - most altered sample pairs indicates that alteration is pre-metamorphic and possibly syn-volcanic. The principal components gained or lost in the metasomatic alteration reactions vary between flows of different primary lithology. The relative timing of alteration, particularly involving carbonate and quartz, is ambiguous owing to the effects of heterogeneous strain; sericitization is spatially associated with small veins cross-cutting amygdules and is interpreted

to be late. Peak greenschist to lower amphibolite facies metamorphism was syn- to post-kinematic based on syn- to post-foliation hornblende growth and post- foliation garnet growth.

Examination of surface features on kimberlitic iron-titanium oxide minerals

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Fe-Ti oxides, chromite and ilmenite, are minerals common in kimberlite diamond deposits. They are brought to the surface during the eruption of a kimberlitic magma from the upper mantle. Previous studies have shown that, similarly to diamonds, partial dissolution and interaction of Fe-Ti oxides with kimberlite magma results in complex reaction rims and dissolution patterns. The nature of this interaction reflects the chemical composition of the magma and fluid phases. The goal of this study is to investigate a connection between the morphology of surface features and the composition of reaction products occurring on kimberlite oxide minerals to geological features of the kimberlite body.

This study uses chromite and ilmenite grains from two kimberlites with different geological features. Kimberlite A is a small pipe, filled with coherent kimberlite facies. Kimberlite B is larger and has two lobes filled with two different types of coherent kimberlite facies; the pipe also contains massive volcaniclastic and resedimented volcaniclastic facies. 75 grains were selected for examination of dissolution features under Scanning Electron Microscope: from Kimberlite A, 20 chromites and 21 ilmenites; from Kimberlite B, 10 chromites and 24 ilmenites. After the grains were imaged, they were mounted and polished to investigate reaction zoning and phases using Back Scatter Electron imaging, X-ray mapping and Wavelength Dispersive Spectroscopy methods. Most of the examined chromite samples are rounded ovoid grains with oriented euhedral octahedral nodules. Very few of the imaged ilmenite grains display dissolution features, and most are covered with reaction phases (perovskite and titanite). The results of the WDS analysis and BSE images show that chromites from Kimberlite A are slightly zoned with chromium and titanium enriched rims. Chromites from Kimberlite B are less zoned, with only a thin rim of titanium enrichment and some visible pitting in BSE images. Ilmenites from Kimberlite A show visible zonation in BSE images as well as in X-ray maps. The grains have Mg-enriched, Fe-depleted rims with some reaction products (both perovskite and titanite) on the grain surface. Kimberlite B ilmenite grains are not visibly zoned; however, WDS analyses show depletion in Ti around the rim of the ilmenite grains. Kimberlite B ilmenites also have large volumes of reaction products on the surface of the grains, both perovskite and titanite. In both kimberlites the concentration of Niobium appears to decrease towards the rim of the ilmenite grains. The data and compositional information obtained from this study will be used to infer the composition of fluids present in the melt, as well as composition and evolution of the primary kimberlite magma.

Increasing concentrations in aluminum in southwest Nova Scotia from 1980 to present

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Elevated aluminum levels in rivers is known to be toxic for aquatic species, in particular Salmo salar; however it was only recently aluminium has been identified as a potential threat to Salmo salar populations in southwestern Nova Scotia, Canada (SWNS). Previously, it was thought SWNS rivers contained enough DOC to render the aluminium in rivers inactive. A key remaining question is whether aluminium levels are declining following atmospheric pollution reductions. Here we make a first assessment of long term (1980–2011) aluminium concentration trends in three watersheds located in SWNS, as measured by weekly grab samples. Our results show that total aluminium levels have significantly increased from 1980–2011 in all three sites. Estimates of ionic aluminium levels indicate that the ionic aluminum concentration frequently exceeds the threshold for the level of aquatic health determined by the European Inland Fisheries Advisory Commission. Data also indicates that calcium levels have yet to recover even with declining concentrations of riverine sulfate. This new knowledge that aluminium is at toxic levels and is worsening will have implications for policy on acidification mitigation in SWNS; this is an urgent issue as the local salmon population numbers currently are declining to near extirpation levels.

A comparative study of anthropogenic impact on dimictic lakes in Halifax Regional Municipality, Nova Scotia: Implications for restoration and management*

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Lakes occurring in watersheds that have undergone urban development are known to be subjected to an array of anthropogenically-induced impacts. Since 1920, First Lake in Lower Sackville, Nova Scotia has been the focus of significant watershed development and lake water quality degradation is an ongoing concern. Second lake is located nearby, is of similar size, and is located in an undeveloped watershed. Stable isotope ($\delta^{13}C$, $\delta^{15}N$) and x-ray fluorescence spectroscopy data from lake sediment gravity cores were used to construct a ca.600-year record of environmental change for each lake in order to de-couple natural water quality variability from anthropogenically-induced variation. Spikes in specific elements (Nb, Y, Sr, and Cu) associated with local gold mining were used to cross correlate and date the lake sediment records. Increases in Pb concentrations above background were also used for temporal control. Modern water quality data indicated that though both lakes stratify strongly over the summer, First Lake alone experiences hypolimnetic anoxia. Though both lake proxy records indicated significant natural water quality variability, stable isotope ($\delta^{13}C$, $\delta^{15}N$) and XRF (Fe, Mn, S, and Ti) data indicated that First Lake alone was subject to substantial and persistent increases in natural autochthonous productivity during the past 70 years that can be attributed directly to local watershed development. Data indicated that though logging and/or mining as well as commercial development has impacted both lakes, residential development has had the strongest negative impact on water quality. This study has shown that the paleolimnological method can be used to quantify the relative impact of different types of development on lake water quality, a fundamental step in developing effective watershed management strategies.

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

An investigation into UV fluorescence in feldspar group minerals

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Feldspar group minerals are among the most abundant mineral groups in the Earth's lithosphere. These minerals have been documented, studied and analyzed for a wide range of petrologic purposes, including examining igneous phenocrysts to investigate crystallization conditions and compositions of parent melts. The range of methods used to examine feldspars, both qualitatively and quantitatively, are also wide ranging and include cathodoluminescence, petrographic Michel-Levy compositions, scanning electron microscope (SEM) and X-Ray Diffraction (XRD). Due to the extensive history of study of these minerals, most of their physical properties and paragenesis are well understood. However, their ability to react to long- or short-wave UV light, i.e., fluorescence, has long been documented but had, to date, not been fully quantified. The fluorescence of a selected suite of feldspar group minerals is being examined to investigate the link between fluorescence, crystal chemistry through determination of major and trace elements, and crystal structure. The methods used include petrographic characterization, X-ray diffraction analysis, electron microprobe analysis, UV spectroscopy analysis and crystal-structure modeling. Samples from Canada and the United States will be used in this study focusing on compositions of alkali feldspars including microcline (including amazonite) and orthoclase (including adularia) and plagioclase feldspars (albite, oligoclase, labradorite, bytownite, and anorthite). Using these samples, we will look for intercrystalline impurities known as activator elements, characteristically metal cations (Fe^{2+}, Fe^{3+}, Ti, and Mn) or rare earth elements. Electrons within these elements become excited at an atomic level by photons at UV wavelengths which in turn cause the electron to jump to a higher orbital. The de-excitation of this electron causes a loss in energy. This energy is subsequently released in the form of light, at a different wavelength than that absorbed, which, in the case of UV fluorescence, is visible to the human eye. Preliminary results show different compositions fluorescing at different colors along with strongly variable intensities. One note is the observation that different samples of similar bulk compositions show different wavelengths and intensities. Furthermore, it is been evident that certain parts of the minerals, microcline in particular, fluoresce with different intensities. This indicates that the cause of UV activated fluorescence is most likely to be trace element-activator variations. Detailed microscope and petrographic analysis will be carried out, along with electron microprobe analyses, to determine which elements are responsible for the fluorescing phenomena.

An integrated water quality forecasting model to restrict the harvesting of shellfish following extreme weather events

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Prince Edward Island (PEI) is well known for its thriving agriculture industry and is also host to one of Canada's largest estuarine shellfish industries. Designated areas for shellfish cultivation exist near the confluence of the Orwell, Seal and Vernon rivers, eastern PEI. Licensed species being farmed include the Blue Mussel, *Mytilus edulis*, Eastern Oyster, *Crassostrea* virginica and Soft-Shell Clam, *Mya arenaria* all of which are filter feeders. The contamination of shellfish aquaculture sites by fecal coliforms is strongly correlated with runoff from livestock farms during severe rainstorms. A more accurate system of forecasting nearshore fecal coliform concentrations under varying environmental conditions is required to strategically and effectively manage shellfish operations. A combination of topographical, hydrological, hydrodynamic and meteorological factors and associated processes affect the microbial quality of these waterways and need to be considered when developing an effective forecasting tool. In this study, Geographic Information Systems (GIS) as well as a fluvial and estuarine modeling platform are used to simulate processes related to fecal coliform growth and decay. These complex models required the input of many continuous variables (field measurements) in order to accurately simulate the transport and fate of fecal coliforms. The three rivers were flow gauged during the 2012–2013 field season and stream rating curves were established. Two barometric pressure sensors and a weather station were also installed in the watershed. Water samples taken during the study period indicate a significant relationship between high fecal coliform concentrations and high stream discharge in the three rivers. Drive-by surveys, in addition to air photo interpretation, indicate many agricultural point sources of pollution in the watershed. Modeling scenarios will be calibrated to reflect these results and a precipitation driven forecasting tool will be developed which will provide a model of the spatial extent of contamination. Effective forecasting will promote the strategic management of aquatic resources while reducing closures and revenue loss.

Meguma terrane, Nova Scotia, and the Harlech Dome, Wales: A petrological comparison of sills and dykes in metasedimentary rocks

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The Meguma terrane of southern Nova Scotia and the Harlech Dome of North Wales have similar Cambrian metasedimentary successions consisting of thick basal units of quartzose turbidite deposits, grading upward into early to middle Cambrian mud-rich and sand-rich units, containing manganese-rich layers, and overlain by turbidites deposited in anoxic environments and Tremadocian mudstone. Coarse clastic units low down in both successions contain similar detrital zircon age populations, and both areas are considered to have originated as peri-Gondwanan terranes. Their similarities have led to the suggestion that both areas were part of one palaeogeographic domain, for which the name Megumia has been proposed.

In addition to their stratigraphic similarities, both areas are characterized by abundant sills and dykes. In the Harlech Dome, most of the sills and dykes, and small, likely related, plutons, are of mafic to intermediate composition, and generally assumed to be related to the Ordovician Rhobell and Aran volcanic groups. In the Meguma terrane, northwest of the Chebogue Point Shear Zone, mafic sills and dykes are abundant. Some are Cambrian–Early Ordovician based on evidence for syn-sedimentary emplacement in their host rocks, and some are Silurian-Devonian based on their presence in the Rockville Notch Group. A comparison of petrographic and chemical characteristics of the intrusions has been undertaken to shed additional light on the possibility of a paleogeographic relationship between the Harlech Dome and the Meguma terrane, using a compilation of petrological data from previous studies as well as analyses of new samples collected in both areas for the present study. Samples from the Harlech Dome range from mafic to felsic whereas those from the Meguma terrane are mafic. The Harlech Dome samples are calc-alkalic and likely formed in a magmatic arc setting at a convergent plate margin. In contrast, the mafic sills in the Meguma terrane are tholeiitic, transitional to alkalic, and formed in a within-plate tectonic setting. Differences also exist among the Meguma terrane sills, such as between younger coarser grained sills and the older smaller sills, which may be more alkalic.

Barrachois evolution in the Bras d'Or Lakes under past, present, and future sea-level rise

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'Barrachois' is an Atlantic Canadian term describing coastal ponds and lagoons that are fully or partially separated from the open sea by a barrier beach. More than 10% of the Bras d'Or Lakes shoreline in Cape Breton Island, Nova Scotia, consists of barrachois, some of which have been developed into harbours, roads and recreational areas. Little is known regarding the age and stability of the barrachois, particularly under future storm conditions (unknown) and relative sea-level rise (~0.7–1.4 m above present levels by 2100). Multi-beam bathymetry data collected from deeper parts of the Bras d'Or Lakes by the Geological Survey of Canada revealed similar coastal landforms (when relative sea level was 7–24 m lower than present, ~3000–6350 years ago) that have since drowned, likely due to rapid sea-level rise and local bathymetry. Modern barriers may either be overstepped (drowned), eroded, or migrate landward under future sea-level rise, storminess and sediment supply conditions. Increased effort and expense will be necessary to maintain coastal defenses and other structures. The study aims to develop a basic understanding of the age of the barrachois, the nature of the sediments underlying them, and their stability (i.e., how quickly they evolve from growing or stable phases to landward-migrating or submerging phases). To date, 25 line kilometres of sidescan and high resolution (low penetration) echo-sounder profiler data were collected across three barrachois in East Bay and West Bay of the Bras d'Or Lakes, including: Irish Vale, Campbell, and Amaguadees ponds. Preliminary results indicate that all of the ponds, which were up to 12 m deep, have some organic mud fill in their centres and sandy-gravelly margins. The largest, Amaguadees Pond, has several metres of mud and a preserved stratigraphy, including unconformities. Bioherms, shallow methane, and buried channels and overwash were also observed. This information will provide the basis for mapping, further interpretation, targeted sediment coring, and long-term reconstruction of the paleoenvironmental and relative sea-level history of the ponds/lagoons.

Recent Nova Scotia Department of Natural Resources coastal process studies and geohazard assessments

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The majority of Nova Scotia's population and associated infrastructure and economic activities are concentrated along the coast. Geological and natural coastal processes, such as storms, sea-level rise, sedimentation and erosion, are important to understand as they can have a significant impact on public safety, land use and coastal development. Coastal geologists with the Nova Scotia Department of Natural Resources (NSDNR) study these natural processes and aim to provide relevant, user-friendly applications for public and government (local, provincial, and federal) use. The poster presented describes the province-wide and diverse nature of geoscience activities undertaken by staff within NSDNR's Coastal Program during 2012 and 2013.

Inorganic geochemical analysis of fine-grained rocks from the Carboniferous of Maritimes Basin Complex in New Brunswick: Preliminary data analysis

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The Carboniferous Maritimes Basin Complex is host to the only known commercially producing onshore petroleum system in Atlantic Canada. In New Brunswick, strata are divided into six lithostratigraphic groups: Horton, Sussex, Windsor, Mabou, Cumberland, and Pictou. However, various complications such as restricted outcrop exposure, lithologically similar fine-grained strata, absence of radiometrically datable materials, and reworking of rare microfossils throughout the succession often render it difficult to identify potential intervals of economic importance. Chemostraigraphic methods recently have become more widely accepted as invaluable tools in the differentiation of other stratigraphic successions with similar complications. Accordingly, samples are being collected from fine-grained strata in outcrop and borehole from each of the Carboniferous groups at different locations around New Brunswick for bulk geochemical analysis using ICP-MS. The data is being statistically analyzed to determine if unique major, minor, or trace elemental composition characterize any or each of the stratigraphic units. To date, 51 samples from the Horton Group; exclusively in the Albert Formation, have been assessed to determine the elemental variability present within this one unit. Future work of this project will extend collection of samples into the entire lithostratigraphic column, which could possibly result in a chemostratigraphic characterization of the Carboniferous rocks of the basin.

Geology and geophysics of a Proterozoic mafic sill, Cape St Francis, Newfoundland

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In the northeast Avalon of Newfoundland, near the tip of Cape St Francis, is a prominent ENE-trending ridge about 600 m long and up to 85 m in elevation above its surroundings. As well as being a distinct topographic feature, the ridge also shows up as a positive anomaly in regional magnetic maps. The ridge owes its existence to the presence of a tilted mafic sill within more easily eroded sandstones and siltstones, and a protective cap of basalt flows. The sill is exposed in a steep scarp on the south side of east part of the ridge: further to the west it is not exposed. The Neoproterozoic rocks in this area are well preserved, showing only minor alteration and some faulting. There are three main mafic igneous units: fine-grained basalt occurring as pillows and thin flows; basalt containing plagioclase phenocrysts which is stratigraphically at the same level as the first unit; and the sill unit, which, based on its geochemistry, would be classified as a trachyandesite. The sedimentary units sandwiched between the flow units and the sill are arkosic sandstones and siltstones. Based on field relations and geochemistry, we developed a model for the origin of the rock units, which we believe are closely contemporaneous. According to our model, thin, submarine basalt flows were emplaced over wet sand, and the heat from the flows baked the upper layer of the sand. Subsequent basalt intrusion into wet sand underlying the baked zone led to a sill with a composition reflecting contamination of the basalt by the sand.

The ridge rock units have distinct physical properties, opening the possibility of geophysical modelling to further define the extent and geometry of the sill and flows in the subsurface. The first basalt unit and the sill rocks have a strong magnetic susceptibility, the basalt with plagioclase has a weaker magnetic susceptibility, and the magnetic susceptibility of the sedimentary units is effectively zero. A ground magnetic survey shows a strong magnetic signal over the east part of the ridge. To the west of the ridge it appears that the sill splits into thinner units. Results of a preliminary gravity survey show the importance of terrain corrections.

Using light detection and ranging (LiDAR) to validate the use of ground penetrating radar (GPR) in the reconstruction of internal rock from braided channel deposits - an example from the Lower Wolfville Formation, Minas Subbasin, Nova Scotia

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Braided channel deposits of the lower Wolfville Formation display well-developed and cyclic channel sandstone and overbank mudstone deposits along multiple kilometres of seaside cliffs. Juts along the cliff face, into the intertidal zone, have presented researchers the opportunity to study the architectural elements of braided channel siliciclastic deposits in varying profiles, in essence giving three-dimensional characterization. Researchers have proposed the use of GPR to provide insight on the internal and subsurface makeup of rock, allowing for the true three-dimensional geometry and distribution of rock units to be characterized. However, no comparison has been made between GPR subsurface profiles and actual cross sections in paleo siliciclastic fluvial deposits. This research intends to check the validity of GPR in demonstrating the true stratigraphy of paleo-fluvial units using LiDAR. Additionally, the data gathered can be combined with properties from the outcrop (permeability and porosity) to form a realistic geocellular hydrocarbon reservoir or aquifer model.

The 20 m-high seaside cliffs along the Minas Subbasin, Nova Scotia, provide a true representation of the stratigraphy of the braided channel complex of the lower Wolfville Formation. A georeferenced GPR study was conducted on an open grass field above at the top of the cliff using 25, 50, and 100 MHz antennas to detect the varying dielectric properties of the fluvial and interfluve rock units. A georeferenced LiDAR study was performed on the exposed cliff face, capturing an exact stratigraphic representation of the braided channels as a digital "point-cloud". The true stratigraphy of the cliff face was then extrapolated from the point-cloud and into the subsurface, ground trothing the GPR profiles.

This work provides a measure of validity showing that GPR can be used in visualizing the internal and subsurface stratigraphy of paleo-fluvial siliciclastic successions. The 50 and 25 MHz antennas clearly show the geometry and distribution of large continuous subsurface geobodies which can be correlated to the stratigraphy of the cliff face. The 100 MHz antennas show small scale reflections, possibly caused by singular clasts, but fail to reach a depth suitable for this study (20+ m).

Understanding the exact architecture of sand bodies (reservoirs) and mudstone deposits (barriers) is essential to understanding maximum hydrocarbon recovery in clastic

reservoirs. This work provides a realistic model, populated with permeability and porosity data, to be used as an analogue for similar global fluvial systems.

Hydrothermal circulation of REE in the Cobequid Shear Zone: The importance of timing and style of hydrothermal alteration

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The Cobequid Shear Zone, in mainland Nova Scotia, consists of a series of subparallel faults, which were active from late Devonian to late Carboniferous. The development of the shear zone is associated with a regional-scale magmatic event that resulted in the emplacement of substantial volumes of volcanic rocks and a number of plutonic bodies along the faults. The plutons consist principally of REE-enriched A-type granite and variable amounts of gabbro, whereas the volcanic rocks consist of chemically equivalent rhyolite and basalt. Different styles of hydrothermal alteration have been identified after the emplacement of the plutons, for over a period of millions of years, including sodic, potassic, and iron alteration. The REE-minerals found in one of the Wentworth plutons present a paragenetic sequence from magmatic to hydrothermal stages. However, the extent and nature of REE-enrichment in the rest of the plutons of the Cobequid Shear Zone was unknown. This study reveals that the REE were mobilized and introduced from the host granites to hydrothermal solutions across the shear zone. Textural relationships and mineral associations provide evidence of repeated REE circulation that resulted in the formation of several types and generations of minerals such as bastnäsite-(Ce), parisite-(Ce), synchysite-(Ce), cerite, thorite, hingannite-(Y), chernovite-(Y) and Nb-rich minerals. Bastnäsite-(Ce) and thorite were among the first REE-minerals to precipitate in epidote veins in the eastern part of the shear zone, under rather reducing conditions. The majority of the REE-minerals such as cerite, parisite-(Ce), synchysite-(Ce) and hingganite-(Y) are hosted in chlorite-magnetite and biotite veins in the central and western parts of the Cobequid Shear Zone. The highest abundances of hydrothermal REE-minerals are observed in late magnetite-rich veins, formed under strongly oxidizing conditions, in the central part of the shear zone close to the Cobequid fault. In such veins, chernovite-(Y) forms after the alteration of hydrothermal hingganite-(Y). The relative timing of fracturing and hydrothermal circulation, along with the type of circulating fluids, appears to be crucial controlling factors for the formation and distribution of post-magmatic REE-minerals across the Cobequid Shear Zone.

Controls on uranium, rare earth element, and radionuclide mobility at the decommissioned Bicroft Uranium Mine, Ontario

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Uranium ores have been mined in Canada since the 1930s, resulting in the production of approximately 214 million tonnes of mill tailings. These tailings may pose a risk to ecosystems and human health because of their long-lived radioactivity, and their potential to release radionuclides, metal(loid)s, radon gas, and milling reagents to the environment. The main objective of this study was to characterize the processes controlling the release, transport, and fate of U, radionuclides (^{226}Ra, ^{210}Pb), and rare earth elements (REEs) downstream from two decommissioned tailings impoundments at the Bicroft Uranium Mine near Bancroft, Ontario. The Bicroft Mine operated from 1957 to 1963, and milled approximately 2,470,000 tonnes of U ore from granitic pegmatite dykes. This type of U deposit is relatively widespread throughout the Grenville Province in Ontario, Québec, and Labrador, and has recently been the focus of exploration as a source of REEs and other strategic metals. Samples of tailings, sediments, surface waters, and colloids were collected from the Bicroft Mine between 2010 and 2012. Regional-scale sampling of sediments and waters, as well as reanalysis of archived stream and lake sediments, were undertaken to determine natural background variation. The concentration of U in the Bicroft tailings samples varies from 3.1 to 210 mg/kg (median 19 mg/kg). Much higher concentrations were found in stream and pond sediments below the tailings impoundments (54 to 730 mg/kg; median 150 mg/kg). Uranium concentrations in regional lake sediments range from 0.4 to 140 mg/kg (median 4.2 mg/kg), and regional stream sediments range from 1.2 to 110 mg/kg (median 4.6 mg/kg). Seasonal sampling of tailings effluent shows that these waters are circumneutral (pH 6.6–8.3) and that the downstream concentrations of U and ^{226}Ra are generally highest in the fall. Comparison of filtered and unfiltered effluents, combined with synchrotron microanalyses of colloids, shows that the downstream mobility of REEs is limited by sorption to Fe- and Mn-oxyhydroxides. In contrast, U occurs mainly in the dissolved phase and its mobility does not appear to be limited by sorption to colloids or precipitation of secondary U phases. Geochemical modeling of the effluent demonstrates that the aqueous speciation of U is dominated by calcium-uranyl-

carbonato complexes [e.g., $Ca_2UO_2(CO_3)_3$], which are known to diminish the sorption of U to mineral surfaces and suppress the reduction of U(VI) to less soluble U(IV). The results of this study provide improved understanding of the long-term stability of U tailings, and have implications for the design of environmental monitoring plans.

Diagenetic barite and sphalerite in middle Mesozoic sandstones, Scotian Basin, as tracers for basin hydrology

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Cementation of sandstone by minor late barite and sphalerite is widespread in the Scotian Basin at burial depths >2 km, providing information on fluid flow in the basin. The texture and geochemistry of these minerals was analysed by scanning electron microscopy and electron microprobe on samples from conventional core. Barite and sphalerite post-date silica and carbonate cementation, occurring in veins or occupying secondary porosity. They occur with diagenetic chlorite, kaolinite, pyrite, titania minerals, kutnohorite, and Mn-siderite. This study relates barite and sphalerite to the salt-tectonic evolution of the basin, based on previous seismic interpretation, and the thermal history of the basin, based on previous fluid inclusion studies. Barite is readily transported in basinal fluids >100 °C, yet is consistently a very late diagenetic mineral, implying that the source of Ba is due to late diagenetic breakdown of K-feldspars at 2–3 km depth, confirmed by co-variation of Ba and Rb in sandstones. Sulphur isotope data suggest that the SO_4^{2+} was derived from Argo Formation evaporites which include 1–7% anhydrite. The abundance of diagenetic barite in the eastern Scotian Basin reflects the abundance of feldspar supplied to this area. Sphalerite transport takes place only at temperatures >140 °C and salinities of at least 10 % NaCl. Zn is most abundant in Lower Cretaceous sandstones with important supply of Fe-Ti oxides from Labrador, and is less abundant in all mudstones, limestones, and in Jurassic sandstones. Sphalerite thus requires dissolution of Fe-Ti oxides during passage of saline formation waters through sandstone pathways. Active detachment faults on salt welds provide both pathways and a source of salt for such formation water. The particularities of source and transport of both barite and sphalerite allow the pathways of basinal fluids and their relationship to active salt tectonics to be inferred, providing indirect dating of the later stages of diagenetic paragenesis corresponding to times of hydrocarbon charge. For example, sphalerite distribution and fluid inclusions show that hot saline fluids are related to late Cretaceous–Paleogene movement on the Banquereau detachment, long after the regional Aptian-Albian high heat flow event. Such fluids contributed to the apatite fission-track signature in the basin. This study shows how small amounts of late barite and sphalerite cement provide important constraints in understanding fluid flow in the Scotian Basin, a technique that should be applicable to other basins with complex salt tectonics.

Orphan Knoll: A dynamic part of a passive margin

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Almost 44 years ago, a young Alan Ruffman sailed on the Glomar Challenger to drill to basement on Orphan Knoll. This was one of the early steps in a process that led to Orphan Knoll being defined as Canadian territory under UNCLOS in December 2013. In the intervening years, Orphan Knoll has proved to be more mysterious than the early workers could have imagined. This presentation will summarize recently reported or published work and present previously unpublished studies.

East of Orphan Knoll, an irregular chain of seamounts runs parallel to the continental margin, the largest of which has a flattish top and mineralogical evidence of emergence. The eastern scarp of Orphan Knoll has shed thick blocky landslides in the early Quaternary, whereas gentler slopes provide a record of passive margin earthquakes away from the influence of glacial eustasy. Orphan Knoll is famous for its enigmatic seabed mounds, which are probably of two types. Previous unpublished studies by S. Meredyk have reported Neogene faulting and uplift, forming small mounds at the crest of the Knoll. On the periphery of the Knoll, larger mounds appear to be rooted in shallow water Cretaceous strata. Seismic data suggests that they may be reef-like structures, but their upper part consists of a winnowed drape of Quaternary sediments with no evidence for active growth of deep-water corals. Quaternary sediment was supplied to the Knoll by the outer part of the Labrador Current and records both fluctuations in current velocity and variations in glacial sources of sediment through time.

Multiple sclerosis and geology: Is there a correlation?

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Multiple Sclerosis (MS) is a chronic inflammatory disease of the Central Nervous System. Nova Scotia has one of the highest prevalence rates in Canada and in the world. A review of the literature though did not show published data of the rates by county or postal codes. Based on personal experience there seems to be a higher rate of MS in certain geologic areas but a review of the literature did not show a correlation between the disease and geology. To further the understanding of the etiology it may be beneficial to do a formal study to obtain data on the MS cases from the Nova Scotia database including their present and childhood postal codes. If a correlation is possible we may be able to extend the assessment to other provinces including Alberta which also has a very high prevalence of MS.

Petrographic analysis of Lower Cambrian sandstones from central Iran

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Lower Cambrian deposits are widespread in Iran. Iran was part of Gondwana at that time, and these deposits are broadly correlative with widespread basal Paleozoic clastic units that rest on cratons elsewhere in the world. The Lower Cambrian Lalun Formation in central Iran is less than 250 m thick and is divided into lower sandstone, middle shale, and top quartzite units. In the central area and elsewhere in Iran, the strata rest conformably on the Precambrian Zaigun Formation. The contacts between all units are conformable in central Iran but the lower sandstone and middle shale units are in unconformable contact elsewhere. Earlier studies suggested that the Lower Cambrian deposits formed in tidal flat to shoreface settings, but marine fossils have not been identified and the stacked sandstones are probably fluvial. The provenance is not known.

Petrographic analysis of ~200 sandstone samples from four sections through the formation indicates that the grains are mostly quartz (monocrystalline and rarely polycrystalline), feldspars, and in some samples lithic fragments of chert, metamorphic and rarely igneous origin. Accessory minerals include mica, and heavy minerals that include zircon, tourmaline, and opaque minerals are present in most samples. The sandstones have a wide compositional range from quartzarenite to arkose, feldspathic litharenite and rarely litharenite (chertarenite). Based on plots of feldspar, total quartzose grains, and total unstable lithic fragments, they were derived from craton interior, transitional continental, and recycled orogen sources.

The Lalun Formation sandstones experienced diagenetic events that included compaction and pressure solution, cementation (mostly by silica and rarely by carbonate, Fe-oxide, and clay), grain fracturing, and alteration of unstable grains. In most samples, feldspars are altered and replaced by authigenic carbonate and sericite, but in some samples clean feldspar grains occur. The feldspars locally underwent dissolution.

Lithofacies of the Early Jurassic vertebrate-bearing Scots Bay Member at Wasson Bluff, Nova Scotia

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Ongoing sedimentological research on the Scots Bay Member of the McCoy Brook Formation at Wasson Bluff provides evidence of lacustrine facies that locally overlie the North Mountain Basalt. Since the first vertebrate fossils were found at Wasson Bluff in 1976 by Paul E. Olsen, the site has been the focus of extensive paleontological research. The Scots Bay Member extends as a series of micro-basin successions for several kilometres. Although it has been described in general terms as lacustrine or playa deposits a detailed sedimentological study is needed to constrain this interpretation.

The initial 10 m of strata overlying the North Mountain Basalt were measured in a trench on the beach. The basal 1.9 m corresponds to the Scots Bay Member. From this section and small exposures, four lithofacies were established using field observations and petrographic analysis. The strata lie unconformably on the basalt, filling the uneven topography on the basalt surface. The lowermost bed is a fine-to-medium-grained red-brown sandstone 0.1–0.4 m thick. Succeeding lithofacies in the trench are red claystone, grey-green mottled siltstone, and ostracod-rich biomicrite (two beds, 5 cm and 12 cm thick). The member is overlain by red fluvial sandstone with dinosaur bone fragments.

In a cliff separated from the trenched area by faults are three lithofacies not observed in the trench: vertebrate-bearing purple-grey fine-grained sandstone, green quartz-rich sandstone, and nodular limestone (a single bed 12 cm thick). The purple-grey sandstone and nodular limestone are noteworthy lithofacies. The purple-grey sandstone, draped over basalt clasts, shows a distinctive reflection of light

from the abundant semionotid fish material and crumbles along laminae defined by densely packed fish material. The nodular limestone has a disrupted fabric with discontinuous concave-up laminae of varied colour, sediment-filled cracks, and minor continuous red-brown laminae. This lithofacies contains abundant pale nodules of sparry calcite that increase in proportion upwards. Disrupted fabrics are common also in the grey-green mottled siltstone, red claystone, and ostracod-rich biomicrite in the trenched section.

The sedimentology and taphonomy of the Scots Bay Member, with fish and ostracods, imply an extensive shallow lake that ponded on the basalt in the earliest stages of basin subsidence after the eruption. Disrupted fabrics indicate that the lake locally dried up periodically and the strata may represent a regressing shoreline. Dinosaur fragments imply transport of bone material into the lake and a shoreline facies.

Petrography and geochemistry of drill core from the Taylors Brook property in the Stirling belt, southeastern Cape Breton Island, Nova Scotia

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The Stirling belt in southeastern Cape Breton Island, Nova Scotia, is one of several belts of Precambrian rocks in the Avalonian Mira terrane of the northern Appalachian orogen. The belt consists of ca. 670 Ma volcaniclastic rocks, flows, porphyries, breccias, and clastic sedimentary rocks (Stirling Group), intruded by ca. 620 Ma dioritic to granitic plutons and overlain by Cambrian sedimentary rocks. This project is the first petrological study of rocks in core from three new exploration holes drilled in 2012, along with data from two holes drilled in 1991, to depths of 500 m at the Taylors Brook property, site of a copper-gold mineral occurrence in the southern part of the Stirling belt. Petrographic descriptions of the drill core and 58 samples in thin section showed that the rock types of the Taylors Brook property include quartz-feldspar porphyries, basalt flows, mafic and felsic tuffs, cherty ash tuffs, rhyolite, pyritic siltstone and hornfels, and correlate with rock units previously described at surface in the area. Over 500 analyses were obtained representing all rock types in the drill core using a portable X-ray fluorescence (XRF) instrument and an additional 27 whole-rock chemical analyses were obtained using inductively coupled plasma mass spectrometry (ICP-MS) with lithium metaborate/tetraborate fusion. These data were used in conserved element and Pearce element ratio (PER) studies of the basalt flows and the mafic dykes. The PER diagrams show that the basalts and the mafic dykes appear to have consisted originally of the same minerals and that the mafic dykes are more evolved and likely formed by crystal fractionation from the parent basalt magma. Preliminary assessment of the whole-rock chemical data suggests that the mafic and felsic rocks are calc-alkalic and formed in volcanic-arc setting. Sulphide minerals in 10 polished sections were analyzed by electron microprobe. The analyses show that the pyrite is the dominant sulphide mineral and that it is intergrown with chalcopyrite and sphalerite that result in elevated levels of copper and zinc in XFR analyses.

Low-level meteor terminations over the Maritimes and New England previously misinterpreted as felt earthquakes

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Meteoroids may "burn up", or vapourise, very high in the atmosphere and are seen as but a brief streak in the night sky. Larger asteroids, or bolides, survive to reach the lower atmosphere and where their disintegration can cause potentially hazardous effects at the Earth's surface.

The 1908 Tunguska fireball in remote Siberia detonated as an "airburst" at an altitude of ~ 6–10 km and was the equivalent of ~ 5–15+ mt of trinitrotoluene (TNT). A 1930 'mini-Tunguska' event near Curuçá in the Brazilian Amazon was barely 0.1–0.5 mt of TNT. The February 15, 2013 Chelyabinsk meteor entered the atmosphere at a low-angle, fragmented at ~30–50 km height, and released energy of ~500(+/-100) kt at an altitude of ~25 km.

The impetus for our study began when one of us (F-St L) started to re-examine our 1986–87 accounts of historical seismicity in Nova Scotia and New Brunswick (AR, JP, and KB) looking for accounts of earthquake lights. She quickly realised that some of the descriptions of events could be explained by meteor airbursts in the lower atmosphere and their seismic effects. The authors have now found accounts of three meteor terminations over the Maritimes and New England, where meteor airbursts created acoustically-heard sound and coupled with the Earth's surface to create felt seismic vibrations.

One event on December 21, 1863, had been identified previously by AR and JP as a meteorite strike in the vicinity of Parrsboro and Amherst, Nova Scotia. Meteorite fragments may have reached the ground in the Parrsboro area since a strong odour of 'brimstone' nauseated residents shortly after

the airburst. The "New Year's" January 1, 1883 event was originally listed in felt-earthquake epicentre databases as being located in the Passamaquoddy Bay region. No seismic effects were observed at St Andrews on the coast of the Bay, but the meteor was observed as far south as Taunton, Massachusetts. The strongest effects were observed and felt in southwest Nova Scotia and the hypothesis being tested is that this was a meteor termination just to the south of Yarmouth with meteor ablation over the Halifax region.

A third event has been in the historic felt-earthquake database for southern New England for over 131 years but is clearly the result of a meteor airburst. This origin was flagged at the time but ignored in subsequent USGS tectonic earthquake catalogues. Continuing studies are showing that certain historic felt-earthquake events are attributable to meteor airbursts.

Mineralogy as a controlling factor on recoverable Ni-grade in the Minago Nickel Deposit, southwestern Thompson Nickel Belt

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In the Thompson Nickel Belt (TNB), Manitoba, nickel deposits are genetically and spatially associated with Early Proterozoic ultramafic sills which intruded sulphur-rich Opswagan Group sedimentary rocks that unconformably overlie Archean Superior craton basement rocks. The Minago Nickel Deposit (MND) is considered to be part of a SW extension of a series of these ultramafic hosted nickel deposits in the TNB, consisting of a vertical to near vertical package of ultramafic rocks folded about a steeply SE- plunging synclinal axis. The deposit has resource estimates of 20.5 Mt at 1.02% Ni and is considered among Canada's largest unexploited nickel resources. However, nickel content among sulphide- and silicate-rich rocks throughout the deposit can be highly variable which has resulted in uncertainties in resource recovery estimates. Nickel recovery from the mineralized ultramafic rock is strongly influenced by the abundance and distribution of the type of nickel sulphide assemblage present and nickel tenor (Ni concentration in 100% sulfides) among the sulphides. This study shows a strong correlation between sulphide assemblages and depth in the MND. From the Precambrian -Ordovician interface (~70 m) to about 400 m depth, the dominant sulphide assemblage is millerite + violarite + pyrite ± polydymite sharply transitioning to a dominantly pentlandite + pyrite ± millerite ± heazlewoodite ± troilite assemblage at lower depth. This shift in Ni-sulphide assemblage corresponds with a vertical transition from strongly serpentinized ultramafic rocks above about 400 m to relatively fresh dunite and pyroxenite below. Ni-rich millerite + violarite ± polydymite assemblages in the "upper zone" (>400 m) are accompanied by a loss of nickel in secondary silicate minerals related to the serpentinization of olivine and pyroxene minerals. In addition, EMP analyses show strong variations in nickel content among Minago pentlandites (from 0.20–0.45 wt% Ni). The variability of nickel content in pentlandite appears to depend on the sulphide assemblage. The lowest nickel grade pentlandites are found associated with troilite ± pyrite. In contrast, pentlandite from the millerite + pyrite ± heazlewoodite assemblage is relatively enriched in nickel. These findings are important to recognize when considering extraction methods of nickel sulphides from MND mineralized rocks and the potential influences on final nickel concentrates.

Fifty years of Environmental Geoscience in Atlantic Canada

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Atlantic Canada has a rich history of environmental geoscience research, consulting, teaching and outreach much of which has been published in the Journals Marine Geology and Atlantic Geology. Environmental geoscience broadly involves applying an earth systems science approach to the solution of environmental issues as they apply to human affairs. Throughout the 1960s and 1970s much environmental geoscience activity was catalyzed by resource development, major energy developments and regional mapping initiatives. This activity led to a surge in Quaternary environmental research for which the Atlantic Provinces has become internationally known. This work has advanced the fundamental understanding of the geotechnical properties of glacial sediments, exploration in glaciated terrain and the timing and magnitude of climate change events of global significance. Work on natural hazards (mass wasting, tsunamis, sea level rise, subsidence, ARD) became significant in the 1990s and has led to a number of important publications and recognition that both the onshore and offshore landscape of Atlantic Canada is dynamic and prone to substantial environmental impact. The environmental impact of resource extraction and processing in Atlantic Canada is significant. Important research, in particular by the consulting community has taken place on the mitigation and management of the environmental impact from past practices, especially coal and precious metal mining.

Applied hydrogeological and geochemical research has done much to advance our understanding of the impact of highly varied geology on water quality and metals in the environment. Of note as well is recent research on radon and arsenic in Nova Scotia and New Brunswick and lead in Newfoundland. Looking towards the future, Atlantic Canada has developed significant capacity in applied geomatics and geophysical research and projects focused on ocean mapping, contaminant transfer, subsidence, eutrophication to name but a few have gained national recognition and led to the development of innovative technologies.

Records of Late Holocene moisture regime from wetlands in Nova Scotia, Canada

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At Baltzer Bog, Brier Island Bog and Pleasant River Fen, Nova Scotia, data from excavated sections and core samples were used to elucidate the timing of effective moisture variability during the Late Holocene. Baltzer Bog is located in an elevated, closed basin on an extensive Wisconsinan glacial deposit. A 2.3 m thick peat deposit contains three distinct wood mats that are interbedded with sphagnum-dominated organic deposits. An upright stump at the base of the section was dated at 3260 cal BP. A rapid transition to wood-free sphagnum and an increase in the bog surface wetness index indicates an increase in local water table occurred shortly after this time. Two other woodland – wetland transitions were dated at 1640 cal BP and 1045 cal BP. Sphagnum humification data indicate that these paleobotanical transitions were also associated with significant effective moisture variability. At Brier Island Bog a thin wood mat in sphagnum at 90 cm depth was dated at 1760 cal BP. At Pleasant River Fen, pollen and stratigraphic data indicate that around 1950 cal BP a transition from open water to fen environment occurred which is broadly correlative with woodland development at Brier Island Bog and Baltzer Bog; an increase in local arboreal pollen at 1050 cal BP is correlative with woodland development at Baltzer Bog. Though other high resolution paleoclimate records from the region indicate that the Late Holocene was a time of increasing precipitation and cooler air temperatures, these wetland records demonstrate that in Nova Scotia this time period was characterized by rapid variations in effective moisture and that significant and sustained dry periods likely occurred.

The *Diplichnites aenigma* enigma: Ichnotaxonomic implications of a restudy of Dawson's type locality at Coal Mine Point, Joggins, Nova Scotia

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In 1862, Sir William Dawson, while exploring the celebrated Coal Mine Point strata at Joggins, Nova Scotia, discovered the first example of footprints that would later be attributed to the largest terrestrial invertebrate in the fossil record, *Arthropleura*. Dawson later named the trace fossil *Diplichnites aenigma*, the first species of the new *ichnogenus Diplichnites*. Unfortunately, no type specimen was selected, presumably due to the gigantic size of the sandstone blocks at Coal Mine Point that preserve these traces. The lack of a type specimen for Dawson's trackway, its illustration only as a wood cut drawing, and a limited description have caused major problems for ichnotaxonomists over the past 150 years. In light of the nonexistent type specimen, a new ichnospecies (*D. cuithensis*) from Arran, Scotland was erected, abandoning Dawson's species because of these uncertainties. More recent exploration since the 1960s by multiple researchers has added new specimens of *Diplichnites* for study. Key specimens recovered by the late Dr. Laing Ferguson, Bob Grantham, and recent exploration by the authors permit an ichnotaxonomic re-evaluation of the ichnogenus and its original type species. New observations from the type horizon at Coal Mine Point, supplemented by specimens elsewhere from the Joggins Formation, have also shed new light on the morphological variability of *Diplichnites*. These observations better circumscribe the type by accounting for underprint fallout, gait variability, substrate variability and microbial mat sediment stabilization. This work lays the foundation for a long-overdue reevaluation of all *Diplichnites* and related arthropod ichnospecies.

Petrographic observations and evaporate-mound analysis of quartz-hosted fluid inclusions: Applications to assess metal fertility in granites

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The Devonian South Mountain Batholith (SMB), Nova Scotia, is a large (7300 km2), contiguous, epizonal granitoid intrusion consisting of 13 coalesced plutons hosting a variety of mineralization (Sn-W-Mn, Cu-Au). Given the hydrothermal nature of this mineralization, it might be expected that a geochemical fingerprint of the fluids could be preserved as fluid inclusions (FIs) in the granites on a scale equal to or larger than the mineralized zones. This study seeks to investigate this possibility using the SMB to assess granite fertility by integrating petrographic features of FIs and their chemistry via SEM-EDS analysis of evaporate mounds. Data from this work will then be used to establish a mineral-fertility indicator which may in theory be applied to any granitoid environment. The protocol uses bedrock samples from each square of a 10×10 km grid superimposed on the SMB. These samples were organized into 16 groups, each group representing 1 of 16 NTS map sheets. Results reported here include the analysis of samples from 3 of these 16 groups (e.g., 21A/09, 21A/16, and 11D/12). Petrographic observation of the FIs from all samples reveal: (1) the FIs are secondary (i.e., they display linear arrays along fracture planes); (2) the long-axis lengths vary between <1–50 μm, but predominately fall between 5–20 μm; (3) liquid (L)-vapour (V) ratios in FIs range between 95:5 and 90:10; 4) L–V type FIs are common with rare L- V-Halite types also present. Inclusion-rich quartz grains (i.e., magmatic quartz) were cut from ~200 μm thick wafers of the granite samples and subsequently heated in a 500 °C oven to promote FI decrepitation and form salt mounds. SEM-EDS semi-quantitative analyses of the mounds were then obtained. The diameters of the evaporate mounds are 2 to >100 μm and X-ray mapping indicates that mounds may be heterogeneous. Chemically the evaporate mounds are invariably multi-component and are dominated by Na-Ca-K, but in consistently different proportions which obviates the need to treat the data in multi-component space. When plotted together, therefore, distinct inclusion populations are observed: a Na-rich fluid, a Na-Ca-rich fluid, and a Na-K-rich fluid. Minor cations, in descending order, include Fe, Mn, Cu, Zn, and Sn. The dominant anions are Cl and F, but minor sulphur occurs in select samples.

Sedimentology and paleoenvironment of an Early Jurassic dinosaur bone bed at Wasson Bluff, Parrsboro, Nova Scotia

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The Early Jurassic McCoy Brook Formation at Wasson Bluff has been a site of dinosaur bone discoveries for over thirty years. The formation crops out on the north side of the Minas subbasin, deposited during the break up of Pangea and prior to the opening of the Atlantic Ocean. The first discovery of dinosaur bone was in 1976, and numerous excavations in 1998–2006 yielded several articulated prosauropods within a confined bone bed. This bed represents the richest prosauropod site in North America and contains the oldest dinosaur bones discovered in Canada. During field work in August 2013, led by Dr. Tim Fedak, 15 disarticulated bones and bone fragments were collected in an eastern extension of the bone bed. The dinosaur material has been well documented and the detailed sedimentology of the bone-bearing bed is of interest. Assessing the stratigraphy at Wasson Bluff is complicated by syn-depositional faulting in the Fundy rift basin. Faults are present on a metre to centimetre scale as displayed by offsets of some bone.

A 5-m section beginning at the bone-bed was described at a centimetre scale during the 2013 excavation. Based on grain size analysis with laser diffraction, poorly sorted, fine- to medium-grained sandstone predominates. In the lower part of the section, interbedded thin, red, micaceous mudstone and orange-brown sandstone show cross-beds, desiccation cracks, ripples, concave-up surfaces, and outsized, moderately rounded grains. In the upper part of the section, laminated, grey-brown sandstones have large cross-sets.

Half-grabens that formed on the surface of the North Mountain Basalt during extension produced an 8-m high paleo-cliff. As the McCoy Brook Formation infilled these grabens, basalt boulders eroded from the cliffs were incorporated into the Early Jurassic sediments. Boulders in the stratigraphic section are up 40 cm in diameter.

Prosauropod bones were found in two beds of trough cross-bedded sandstone in the lower part of the section. Both beds contain scattered basalt boulders and, although some boulders are in contact with the bone, there is no direct correlation between boulders and bone.

These sediment characteristics indicate that the dinosaurs were preserved in a river channel with episodic flow and periodic desiccation. The outsized rounded grains suggest eolian additions to the river sediment, and the overlying cross-bedded grey-brown sandstone is probably eolian.

Brittle overprints in the high-grade metamorphic rocks of the Bras-b'Or terrane, Nova Scotia: Can they be linked to exhumation history or major faults?

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This study investigates the possibility of using brittle overprints and retrograde mineral assemblages in various high grade metamorphic rock packages within the Bras d'Or terrane to put constraints on exhumation history or activity on major faults in the area. The Boisdale Hills area contains the Proterozoic Frenchvale Road metamorphic suite, a package of rocks containing carbonate rocks, amphibolite, and paragneiss ± andalusite, sillimanite and/or cordierite. The Georges River fault, with its youngest period of motion documented in the Carboniferous, forms the southeastern boundary of the metamorphic suite. The northeastern boundary is the Late Neoproterozoic Boisdale Hills Pluton which intruded the metamorphic rocks by ca. 560–530 Ma. The metamorphic rocks in this area are not well-characterized with respect to specific P-T conditions or structures relating to exhumation of these rocks. In order to compare brittle overprints in different metamorphic packages within the Bras d'Or terrane the initial work has focussed on the higher grade metamorphic rocks in the Frenchvale Road metamorphic suite, particularly carbonate rocks and amphibolite. Brittle structures overprinting the main metamorphic assemblages in the Frenchvale Road carbonate rocks include outcrop scale fractures trending N-NW and dipping moderately to the NE, fracture surfaces with associated SW plunging slickensides, and fractures within carbonate rocks and amphibolite filled with chlorite and epidote. Some impure siliceous carbonates show micro-fractures filled with chlorite and others which crosscut individual minerals grains without fracture fills. Preliminary data indicates that the dominant brittle fracture patterns are not kinematically linked to the interpreted NE-trending, subvertical orientation of the Georges River fault. The overprinting mineral assemblages associated with these brittle structures likely pre-date the latest movement on the Georges River fault. In order to investigate this hypothesis, future work will focus on attempting to constrain the age of formation of the retrograde mineral assemblages, and investigating the kinematics of brittle faulting over a larger area, including the lower grade metamorphic rocks of the Benacadie Brook metamorphic suite and the plutonic rocks of the central Boisdale Hills area.

History of ideas on the Silurian-Devonian tectonic evolution of the northern Appalachian orogen: 1980–2014

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By the end of the 1970s, first order geological analysis had identified the major building blocks of the northern Appalachian mountain belt. At this stage reasonable consensus existed that the orogen comprised at least 5 major zones or terranes: Humber, Dunnage, Gander, Avalon and Meguma. The major differences in geological evolution between these terranes hinted at a complex tectonic evolution, yet the standard tectonic model at that time was very simple and conservative. It generally involved an east-dipping subduction zone, because this was the simplest way to explain Taconic obduction of ophiolites onto the Humber margin of Laurentia. However, little was known what happened tectonically after the middle Ordovician and how and when the various terranes were assembled into one mountain belt. The Silurian was considered a period of tectonic quiescence, whereas the tectonic processes responsible for the Devonian Acadian orogeny were highly contentious, if not a mystery to most. Yet the Acadian orogeny affected almost the whole width of the mountain belt. A major hindrance to orogenic analysis was an apparent lack of what were considered critical tectonic indicators (e.g., ophiolites and high pressure-low temperature (HP-LT) metamorphic rocks) east of the Early to Middle Ordovician Taconide belt. Theoretical considerations as well detailed studies of recent orogens such as the Taiwan mountain belt, has subsequently shown that the presence or preservation of such indicators are not necessarily a common phenomenon.

Multidisciplinary studies initiated during the 1980s and 1990s, mainly involving thematic mapping combined with geochemistry and modern U-Pb zircon geochronology, changed our views on the tectonic evolution of this mountain belt considerably. Evidence indicated orogenesis during the Silurian (Salinic), which was causally related to closure of the Tetagouche-Exploits backarc basin and accretion of the trailing Gander margin to composite Laurentia. Development of a Silurian arc on the latter while the Salinic affected other parts of Ganderia indicated that Avalonia at this time was still separated from composite Laurentia. Several lines of evidence indicated that its accretion had started at ca. 420 Ma, during the waning stages of the Salinic orogeny. At this stage, Ganderia occupied a relatively unique tectonic setting. Its leading edge was underthrust beneath composite Laurentia, while subduction and extension was taking place beneath its trailing edge. Dating of foreland basin deposits associated with both the Salinic and Acadian orogenies showed they are time transgressive, with the deformation fronts progressively becoming younger to the southeast and northwest, respectively.

Fifty years in the tectonics of the Maritimes Basin

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Late Paleozoic strata in Atlantic Canada fill a large and deep sedimentary basin, the Maritimes Basin. At its thickest point beneath the Gulf of St. Lawrence the basin occupies ~30% of the continental crust, and its subsidence has been the subject of speculation and argument for 50 years. In a series of papers from 1964 to 1968, Edward S. Belt outlined several hypotheses for basin development, including extensional, wrench, and compressional scenarios. Subsequent analyses have focussed on one or other of these hypotheses, but the cause of the extreme subsidence has not been fully resolved. Subsidence analysis is complicated by the expulsion of substantial thicknesses of Viséan salt at different times in different parts of the basin, resulting in anomalous and rapid subsidence events.

Comparison of sedimentary and volcanic successions in the early basin history shows major contrasts across steep NE-SW-striking faults, including the Belleisle, Kennebecasis and Clover Hill faults of southern New Brunswick, and probably the Cabot Fault of Newfoundland. The Rockland Brook Fault of Nova Scotia also separates contrasting successions, though it has a more E-W orientation currently. These stratigraphic contrasts are best explained by dextral strike-slip movements measured in tens or even hundreds of kilometres, which must have occurred during Late Devonian to Mississippian time. Dextral strike-slip motion on the NE-SW faults would have led to oblique extension on faults with more east-west orientations; asymmetric extension on these faults can explain the apparent northward migration of extensional igneous activity during the Late Devonian and Mississippian.

From about 340 Ma onward, strike-slip displacements on E-W faults became more prominent, with the result that some earlier extensional faults were inverted, accommodating oblique shortening. Expulsion of evaporites began early, soon after deposition, but the timing of evaporite expulsion varied between, and even within, individual sub-basins. The most likely driver of evaporite expulsion was loading by clastic wedges derived from adjacent fault scarps. Evaporites beneath the western Cumberland sub-basin survived longest, into the Pennsylvanian. At this time, rapid loading, probably by alluvial fans derived from the Cobequid Highlands, led to evaporite expulsion, accounting for the extraordinarily rapid subsidence recorded in the Joggins area, where ~ 5 km of sediment was accommodated in less than 5 million years.

Thus the evolution of the Maritimes took place in a tectonic environment that involved concurrent extension, strike slip, and shortening, all of which influenced the sedimentary record of the basin fill.

Advanced lidar mapping in the coastal zone and freshwater aquatic environments

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The Applied Geomatics Research Group (AGRG) within the Nova Scotia Community College (NSCC) has been awarded a Canada Foundation for Innovation infrastructure grant to support sustainable harvesting and coastal development and analysis of freshwater systems in Canada through the innovative use of topo-bathymetric lidar and mobile laser scanning. The AGRG has used airborne and ground-based lidar to map flood risk and erosion respectively in the coastal zone. Under this research grant, NSCC is partnering with a variety of industry leaders that represent end users to consulting engineering and mapping firms and data acquisition companies. The industry partners include: Acadian Seaplants, GeoNet Technologies, Nova Scotia Power, McGregor GeoScience, and Leading Edge Geomatics. Previous airborne bathymetric lidar sensors were large and required a significant amount of power to achieve adequate depth penetration of the water column and thus required larger survey aircraft and thus increased the cost of surveys. Recently, topo-bathymetric lidars are smaller and can be operated in smaller aircraft thus reducing operating costs. The new sensors achieve 1–2 times Secchi depths of penetration in the water column compared to 2–3 times Secchi depth for the larger sensors. Airborne Hydrography (AHAB) from Sweden has developed the Chiroptera which consists of a NIR and green laser and is reported to achieve 1.75 Secchi depth. The sensor will be used to conduct surveys with our partner companies and other groups interested in exploring this area of research. The purpose of the surveys will be to conduct research into mapping the coastline, near-shore bathymetry and the composition of the seabed and fresh water lakes and river channels for the purposes of: (1) determining of more accurate rates of erosion to assist stakeholders to make more informed decisions about placement and protection of critical infrastructure; (2) acquisition of the near shore bathymetry and land elevation for improve wave modelling and storm surge flood risk mapping; (3) enhancing mapping

of aquatic vegetation and varieties to improve sustainable exploitation and management of Canada's economic and ecologically significant natural resources; (4) improving mapping of hydroelectric reservoirs to allow increased efficiency of power generation; and (5) enriching river channel mapping to facilitate more accurate watershed run-off models to predict and mitigate flooding.

The presentation will outline the theory behind topo-bathymetric lidar and show examples of data collected by different sensors and will demonstrate how this technology can be used to address a variety of coastal geoscience issues.

Fifty years of geological study of the Meguma terrane as recorded in the journal "Atlantic Geology"

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Paul Schenk in 1967 wrote in the third issue of "Maritime Sediments" that little research had been conducted up to that time on the Meguma Series or Group of southern Nova Scotia. All that was known was that the group consists of the basal sandstone-dominated Goldenville Formation and the upper slate-rich Halifax Formation. The presence of Bouma Sequence sedimentary structures led Schenk to interpret these units as likely deep-water deposits. He and later his students described the rocks as a "monotonous package" of lower Paleozoic eugeosynclinal sandstone and shale deformed into NE-trending folds and intruded by Devonian to Mississippian plutons.

By 1975 Rb-Sr and K-Ar ages had enhanced understanding of southern Nova Scotia. They confirmed that plutonism ranged from Devonian to Mississippian and suggested that the upper part of the Goldenville and lower part of the Halifax formations may in part be laterally equivalent, Early Ordovician, and conformably overlain by the Ordovician to Early Devonian White Rock, Kentville, and Torbrook formations. With the acceptance of plate tectonics, all of these units and associated plutons in southern Nova Scotia were termed the Meguma Zone, later terrane, and interpreted to have originated in western Africa.

By the 1980s and early 1990s improvements in radiometric dating ($^{40}Ar/^{39}Ar$ and U-Pb methods) and lithogeochemistry corroborated many earlier assumptions. Although somewhat ambiguous, the strongly peraluminous South Mountain Batholith appears to exhibit both 'S- and A-type' affinities but southward the satellite plutons display volcanic-arc signatures. In 2010, as a result of detailed mapping over the western half of the terrane, combined with U-Pb and $^{40}Ar/^{39}Ar$ dating, acritarch ages, and lithogeochemical studies, regional formations were established and the Goldenville and Halifax justifiably became groups. Their ages are now well defined—Early to Middle Cambrian for the Goldenville Group and Late Cambrian–Early Ordovician for the Halifax Group, with a 35 Ma time gap before deposition of the overlying Early Silurian to Early Devonian White Rock, Kentville, and Torbrook formations. As a result of the Neoacadian orogeny (ca. 415–365 Ma), these rocks were folded, variably metamorphosed (greenschist to amphibolite facies), and intruded by the late syntectonic to post-tectonic Late Devonian to Early Carboniferous plutonic units. Similarities in the Cambrian to Tremadocian successions of the Meguma terrane to those of the Harlech Dome of North Wales and the Brabant Massif in Belgium suggest these areas may have been part of a 'Megumia domain' that occupied a rift on the margin of Gondwana.

Variation in style of overpressure in Scotian Shelf wells, Scotian Basin

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The Scotian Basin lies to the southeast of Nova Scotia and has been actively explored for oil and gas over the last five decades. Many of the reservoir sandstones occur in overpressured rocks, where pressures greatly exceed normal hydrostatic pressure. There are three main causes of overpressure: disequilibrium compaction, clay diagenesis, and hydrocarbon generation. The relative importance of these three processes in the Scotian Basin is uncertain. The purpose of this study is to assess variability in the style of overpressure in different wells in the Scotian Basin, and to interpret the causes of this variability. Down-well variation in velocity vs. density of shales based on wireline logs showed several different styles of variation in overpressured section. For example, wells in the Venture field show a drop in velocity without change in density below the top of overpressure, classified as a type 3 pattern, whereas Louisbourg J-47 shows a curved gradual drop in velocity with some change in density after the top of overpressure, a type 9 pattern, and South Desbarres O-76 shows a drop in velocity followed by a rise, without change in density, a type 10 pattern. The Venture style of variation in other basins is associated with hydrocarbon generation, whereas the origin of the patterns for Louisbourg and South Desbarres is at present uncertain, but may be related to bedding-parallel

fractures. Different styles of overpressure are correlated with variation in burial diagenesis in shale samples, based on <2 μm X-ray diffraction analysis.

Tracing the geology of offshore eastern Canada: a fifty year saga

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Prior to 1964, little was known about the ages and types of rocks forming the bedrock offshore eastern Canada, as most studies had focused on geophysics. The presence of Cretaceous and Tertiary rocks was suspected but there were no in situ bedrock samples other than from Georges Bank. How has this changed over the past fifty years and what led to our deeper understanding of the offshore geology? The most influential factor has been the growing understanding of plate tectonics and the realization that our offshore represents the western passive margin of the still-opening North Atlantic Ocean. This has underpinned the new views of our margins and their evolution. Other key developments accompanied the search for oil and gas. Exploration has led to extensive seismic surveying and the drilling of more than 300 wells and several core holes by industry. Government and the universities have also played a crucial role in collecting and interpreting paleomagnetic, gravity, and reflection and refraction seismic data, and establishing lithostratigraphic and biostratigraphic frameworks for the offshore basins. We now know that Precambrian, Paleozoic, Mesozoic and Cenozoic rocks, as well as extensive salt deposits, are all present offshore. Breakthroughs have included insights into the evolution not only of the North Atlantic Ocean but also of the Labrador-Baffin Seaway. Geodynamic modelling has shown how physical processes within and below the lithosphere control the evolution of our margin. As well, maturation studies, including visual kerogen, vitrinite reflectance, and Rock Eval have helped in the prediction of source rock occurrences. The advances in the first twenty-five years were reflected in the 1990 Decade of North American Geology (DNAG) volume "Geology of the Continental Margin of Eastern Canada" and in comprehensive basin atlases published by the GSC. Twenty years later, with the application of 3D reflection seismic, sequence and biostratigraphic-event stratigraphy, plus the increasingly sophisticated computer software and hardware, we are heading into a new era. It would be fascinating to be around for the 100-year review.

Stratigraphy and geochronology of backarc oceanic rocks of the Fournier Supergroup, northern New Brunswick

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In northern New Brunswick, the main elements of Ganderia are Early Paleozoic rocks of the peri-Gondwanan Popelogan arc and associated Tetagouche backarc basin. Late Ordovician to mid-Silurian closure of the Tetagouche backarc culminated with the piecemeal accretion of Ganderia to composite Laurentia (Salinic orogenic cycle) and led to formation of the Brunswick subduction complex. The latter comprises volcanic and sedimentary rocks that represent successive stages of backarc extension, arc rifting and seafloor spreading. Formerly, these rocks were all assigned to the Bathurst Supergroup, consisting of four groups (California Lake, Tetagouche, Sheephouse Brook, and Fournier) juxtaposed as major thrust nappes. The lower parts of the first three groups comprise thick sequences of felsic volcanic rock that reflect the presence of Ganderian continental substrate and were emplaced during arc rifting and backarc extension. The stratigraphic succession within each nappe represents the same temporal range and exhibits consistent younging to the north. In contrast, the Fournier Group, which includes a partial ophiolite sequence, contains virtually no felsic volcanic rocks (solely represented by ash beds) and represents deposition that occurred in the oceanic domain during seafloor spreading. Thrust faults and mélanges define a series of nappes within which younging is consistently north and, as shown by recent geochronological work, represent coeval time intervals. A distinct parallel with the Bathurst Supergroup is thus demonstrated; hence, the Fournier Group is upgraded to Supergroup status and the various formations assigned to different groups and complexes. The newly erected Fournier Supergroup consists, from structurally highest to lowest, of the Devereaux (ophiolitic) Complex, the Pointe Verte Group and Sormany Group. The Devereaux Complex comprises, from base to top, the Black Point Gabbro (including minor pyroxenite and trondhjemite), the Belledune Point sheeted dikes, and pillow basalt of the Turgeon Road Formation. The tectonic contact between the Devereaux Complex and the structurally underlying Pointe Verte Group is marked by a zone of mélange. The Pointe Verte Group comprises the Prairie Brook Formation (a generally fining-upward sequence of sedimentary rocks) and the overlying Madran

Formation (high-Cr alkalic pillow basalt). The Sormany Group is separated from the overlying Pointe Verte Group by the Belledune River mélange and comprises the Armstrong Brook Formation (pillow basalt), Millstream Formation (turbiditic wackes, fine-grained sedimentary rocks and limestone) and Val Michaud Formation (quartzofeldspathic sandstone) in the northern Miramichi Highlands and the Elmtree Formation (fine-grained sedimentary rocks) in the Elmtree Inlier.

Carboniferous lamprophyres in the central Cobequid Highlands, Nova Scotia: Precipitation of REE minerals

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A series of late Paleozoic A-type granite plutons was intruded along an active shear zone in the Cobequid Highlands. The majority of these granites host primary REE minerals, and present evidence of several events of hydrothermal REE remobilization. Granites of the West Moose River Pluton, however, contain exclusively secondary REE minerals. The West Moose River Pluton is located in a stepover zone between two major late Devonian faults, and just north of the Carboniferous Cobequid fault. It intrudes Horton Group rocks and has been dated at 361 +5/-3.5 Ma (U-Pb on zircon). Small mafic dykes and sills in the area post-date the granite (ca. 334 Ma $^{40}Ar/^{39}Ar$ on whole-rock, biotite), and some mineralogically resemble minette (biotite-rich lamprophyre). These minettes contain mineralized veins of different relative age and mineralogy. Based on cross-cutting relationships, the types of veins from oldest to youngest include albite, chlorite and calcite-fluorite-filled fractures. Rare late pyrite-barite veins are also present. Re-opening of old fractures led to the formation of composite veins. The only REE mineral found in the minettes is synchysite-(Ce) which occupies late cross-cutting veins. The remobilization of REE was enhanced by fluorine-carbon-rich fluids, which caused the simultaneous precipitation of fluorite, calcite and synchysite-(Ce). The precipitation of synchysite-(Ce) in the minettes was governed by the interaction of REE-bearing fluids with the Cl-bearing biotite of the host-rock. This study underlines the importance of halogens during fluid-rock interactions for the precipitation of REE, and identifies minettes as possibly important hosts of hydrothermal REE-minerals.

Reservoir characterization and forest density of the Joggins Formation, Joggins, Nova Scotia

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The Carboniferous Joggins Formation outcrops along the shoreline of Chignecto Bay, Nova Scotia, within the Cumberland Basin. The Joggins Fossil Cliffs present a 2D and 3D exposure of the channel and floodplain deposits and preserved fossils of the Joggins Formation. These outcrops demonstrate the stratigraphy of the formation and the preserved flora in the Carboniferous rocks. Within the Joggins Formation, the study focuses on the Coal Mine Point section, which comprises interbedded sandstone, shale and coal seams, with sediment deposition assisted by salt withdrawal from the region, creating accommodation. This study uses LiDAR as a survey technique with spatially-calibrated Differential Global Positioning System (DGPS) to capture high-resolution images of the meanderbelt channel architecture and the fossils of upright lycopsids and calamitaleans. This high-resolution imaging provides a 3D survey of the cliff with details of the channels and the fossil tree trunks. Adding previously acquired surveys of the region allows a time spatial analysis due to cliff retreat, and a 3D model of the study area can be constructed. The model will enable increased understanding on the changing forest density and channel architecture of the Joggins Formation. Scintillometer measurements recorded at outcrop are used to generate a pseudo-gamma log (based on counts per minute, CPM), and permeameter measurements are recorded to better understand permeability of the corresponding lithologies. Integrating the LiDAR imaging, pseudo-gamma log, permeability data and outcrop exposure leads to a 3D depositional model for (1) forest-density, and (2) meanderbelt channel architecture for the strata at Coal Mine Point within the Joggins Formation.

Preparations for a mega-earthquake in northern Chile: How to convey geoscience to the authorities

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Not unlike western Canada's, the geological setting of Chile overlying active plate subduction implies periodic recurrence of mega earthquakes such as the Magnitude 9.5

Valdivia Earthquake that killed 1655 persons and displaced millions. The imminence, magnitude, epicenter, probable duration and extent of the threatened region of a mega earthquake to be feared in southern Chile near Concepcion were published in an international refereed journal in June 2009. A Chilean doctoral student defended a thesis in Germany on February 23rd 2010; yet when the Magnitude 8.8 earthquake hit the exact region February 27th, it caught the civil and military authorities by surprise. More than 525 people died, 120 due to a tsunami that affected a coastal area similar to that documented by Charles Darwin after a comparable mega-earthquake in 1835. A few informed geoscientists had tried to convey the urgency through public lectures and the press, but were ignored or dismissed as alarmist. The legal and political fallback has affected emergency organizations and even the Chilean President at the time.

Now we must prepare for another major earthquake and tsunami in Northern Chile, between Antofagasta and southern Peru (600 km). There is a worrisome seismic gap, where the subducting plate is jammed, and accumulating elastic energy since 1877. Solid data such as measurable deformation and uplift of the land area as recorded by GPS and satellite tools, visible fault scarps, and micro-seismicity indicate that the threat is real. The sudden release of this accumulated elastic energy will result in an earthquake of Magnitude 8 to 9, and create a tsunami such as that experienced 137 years ago in the same region. The consequences will be disastrous in a region with many large mines (tailings dams and metallurgical installations) and pipelines that are essential to the economy. Along the coast, thermoelectric and desalinisation plants, as well as industrial port facilities and populated cities, will endure effects predictable from historical records.

In an effort to minimize the impact of the unavoidable natural disaster, we organized successful workshops and field excursions in Vancouver in 2010 and port cities in northern Chile in 2011 that involved civil and military emergency management authorities. These activities attracted valuable press publicity and we believe contributed to awareness. University teams with international collaboration are carrying out research associated to seismic risks, to better understand the seismic cycle, the role of crustal deformation and specific seismic danger in priority areas.

How porosity and permeability vary with diagenetic minerals in the Scotian Basin, offshore eastern Canada: Implications for reservoir quality

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Reservoir quality is one of the key controls on prospectivity during petroleum exploration, and porosity and permeability are major indicators of reservoir quality. Detailed understanding of where to expect high porosity and permeability is important in risk assessment of a petroleum basin. Porosity and permeability depend on a range of parameters such detrital supply, lithofacies, tectonics and diagenetic processes. This study integrates plug porosity, permeability, diagenetic minerals and whole rock chemical analysis of 35 sandstone samples of lower Jurassic–early Cretaceous age from conventional cores from 20 wells in the Scotian Basin, to examine if there is a link between high reservoir qualities with diagenetic mineral assemblages on a basin-scale. Most samples are from thick sandstone beds of estuarine channel or river-mouth turbidite origin, known to be the principal reservoir sandstones. Image analysis of backscattered electron (BSE) images is used for mineral identification and modal counting, based on the different gray-scale brightness of different minerals, and is complemented by whole-rock X-ray diffraction (XRD). Correlation matrix and principal component analysis (PCA) are used to extract the main element variables (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, P, La, Eu, Y, Yb, Sc, Cr, Zr, Sr, and U) that control the large variation in whole-rock elemental composition, which can help to understand the roles of diagenetic processes and detrital supply. Then cluster analysis is also applied on porosity, permeability, and diagenetic minerals.

The study shows: (1) discrepancies between plug porosity and BSE image porosity resulting from the bias of using a single thin section for image analysis; (2) diagenetic mineral content analysed from BSE images is consistent with XRD analysis only for calcite, illite, and Fe-chlorite, as peaks of minor diagenetic minerals are severely overwhelmed by quartz in the diffractograms; (3) porosity negatively correlates with CaO (calcite) and positively with Ge, which is enriched in detrital organic matter. Permeability has a negative correlation with Al_2O_3, TiO_2, Na_2O, P_2O_5, Ga, Sc, and REEs; and (4) cluster analysis shows a strong cluster of carbonate cemented sandstones, with no systematic distribution with geography or depth. Highest porosity samples tend to be from shallower than 3000 m. Previous studies suggest the regional scale influence of provenance

on sandstone mineralogy and diagenesis. However, in detail, major diagenetic minerals do not show strong variations with geography, facies or burial depth. This suggests that similar diagenetic processes occur throughout the basin, but variability is also strongly controlled by local factors.

Mantle metasomatism: constraints from surface features on diamonds from nature and etched in experiments

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The footprints of mantle metasomatism on dissolved diamonds capture the latest diamond-destructive event. Natural diamonds (total 603 stones) from Ekati kimberlites, Canada, are proposed to be classified into kimberlite-induced (e.g., ditrigonal outlines of {111} faces and trigonal etching pits) and mantle-derived (e.g., trigonal shape of {111} faces and hexagonal pits) groups in terms of surface features. To examine mantle fluids using diamond resorption morphology, we conducted experiments to investigate silica activity (a_{SiO2}), pressure (P) and temperature (T) effect on diamond dissolution in H_2O and CO_2 fluids, and applied our results to the natural diamond.

Experiments were conducted in piston-cylinder apparatus using natural octahedral diamonds and synthetic systems $H_2O \pm CO_2$ - $MgO \pm SiO_2$ and CO_2 - CaO - $SiO_2 \pm H_2O$ at 1–3 GPa and 1150–1400 °C. The products were examined using Field-Emission Scanning Electron Microscopy and Atomic Force Microscopy. Fluid compositions were monitored by synthesizing fluid inclusions in olivine and quartz, and inclusion isochores pass through the P-T conditions of the runs, confirming trapping conditions. In the aqueous system, we found: (1) formation of circular and negative trigonal etch pits on {110} and ditrigonal {111} faces, individually; (2) the suppressing effect of silica activity and pressure on circular pits; (3) positive correlation of diamond dissolution rates with T and negative with P; and (4) the accelerating effect of P on diamond morphology transformation from octahedron to dodecahedron. $CO_2/(CO_2 + H_2O)$ molar ratio increasing from 50 to 100% is accompanied by the development of hexagonal etch pits on {111} faces switching from ditrigonal to trigonal shape. Similarly, P increase from 1 to 3 GPa at constant $CO_2/(CO_2 + H_2O)$ molar ratio changes ditrigonal to trigonal outline of {111} faces. At $CO_2/(CO_2 + H_2O)$ =50 mol.%, diamonds while showing apparent H_2O-style resorption, still bear typical irregular hexagonal pits.

Comparison of our experimental results with natural diamonds from Ekati kimberlites shows that dissolution features of diamond in H_2O- and CO_2- dominated environments are comparable to the most rounded natural diamond in the kimberlite-induced group and to natural diamonds with mantle-derived resorption, respectively. The analogous results confirm the possibility of using diamond resorption features to probe the composition of the diamond dissolution medium. Our data show that presence of circular pits only on fragmented diamond faces indicates a latest H_2O-dominated aqueous fluid regime with maximum $aSiO_2$ buffered by olivine in kimberlites, and the $CO_2/(CO_2 + H_2O)$ ratio was >50 mol. % in diamond-destroying mantle metasomatism to create hexagonal etching pits.