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The 2009 Colloquium & Annual General Meeting was held at the Delta Beausejour Hotel, Moncton, New Brunswick, on February 6 and 7, 2009. On behalf of the society, we thank Colloquium Chairman Reg Wilson and his organizing committee (Marc Desrosiers, Grant Ferguson, John Gosse, Nicole Hatheway, Susan Johnson, Pierre Jutras, Dave Keighley, Elisabeth Kosters, Sean McClenaghan, Mike Parkhill, Brian Roulston, Ian Spooner, Kay Thorne, and Jim Walker) for providing an excellent meeting. We also wish to acknowledge support of the corporate sponsors: Association of Professional Engineers and Geoscientists of New Brunswick; EnCana Corporation; New Brunswick Department of Natural Resources; PotashCorp; Mining Association of Nova Scotia; Université de Moncton; Xstrata Zinc Canada.

In the following pages, we are pleased to publish the abstracts of oral presentations and posters from the Colloquium, which focused on the following themes: Quaternary Geology; Surficial Geochemistry; Current Research in the Atlantic Provinces; a Workshop on the Rationalization of the Mississippian stratigraphy of the Maritimes Basin through inter-regional correlations and nomenclatural debate; and a tour of the Sussex Potash Mine.

THE EDITORS

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The sedimentology of phosphatic iron formation from the Labrador Trough: implications for the accumulation of Precambrian phosphorite

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The Paleoproterozoic Sokoman Formation (ca. ~1.87 Ga) near Schefferville, Quebec, is a ~100 m thick succession of iron formation, terrigenous clastic, and phosphatic sedimentary rocks. It accumulated during the first major phosphogenic episode in Earth's history and, therefore, provides important information on the physiochemical and biological processes that led to the deposition of Precambrian phosphorite. Understanding such processes illuminates how the bioessential elements Fe and P were cycled in Precambrian chemical sedimentary systems.

Lithofacies stacking patterns in the Sokoman Formation are interpreted to record flooding and deposition on the Nuna continental margin through two sea level cycles. Lowstand sediments in both sequences consist of stromatolitic supratidal chert and lagoonal mudstone that contain phosphate-encrusted microbial mats. The transgressive systems tracts are characterized by tidally deposited chert and hematite grainstone with reworked sedimentary apatite grains. Highstand systems tracts are formed entirely of nonphosphatic, storm-deposited, subtidal chert and magnetite grainstone.

Phosphorite is exclusive to shallow-water settings in both sequences. Precipitation is interpreted to be the result of coupled Fe and P cycling through Fe-redox pumping of porewater phosphate. As in Proterozoic terrigenous clastic-dominated depositional systems, Fe-redox pumping is restricted to nearshore paleoenvironments where photosynthetic stromatolites produced a suboxic seafloor. Such shallow-water phosphorite contrasts with many Phanerozoic phosphatic deposits, which formed in the full spectrum of shelf environments. This relationship is interpreted to reflect the marked difference in oxygenation state of the seafloor between the Precambrian and Phanerozoic. In the Precambrian, Fe-redox pumping of porewater phosphate and thus, phosphogenesis, was constrained to nearshore settings where photosynthetic oxygen was produced. Phanerozoic phosphorite forms across the shelf because all environments are generally well oxygenated. The proximal location of Precambrian phosphorite suggests that the evolution of some benthic microbes was likely restricted to neritic settings where bioavailable P was concentrated in the sediment.

An investigation of spatial and temporal variations of chloride concentrations in selected watersheds of southwestern Nova Scotia

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Environment Canada has monitored the aquatic chemistry of the Kejimkujik region of southwestern Nova Scotia for thirty years and researchers have long recognized a chloride imbalance of outputs and inputs. A comparison of chloride output in streams to the chloride inputs of wet (precipitation) and dry (aerosols) deposition has revealed consistent and significant excess chloride in streams up to an order of magnitude greater than that measured in wet and dry deposition.

The focus of this study is to identify and quantify the source(s) of the excess chloride. Presented here are preliminary synthesis results of the Environment Canada data set. These results display spatial and temporal variation of chloride concentrations offering insight into potential sources of excess chloride. Chloride concentrations are variable between watersheds, suggesting a geological or anthropogenic source of excess chloride. Seasonal variations of excess chloride suggest a possible unmeasured atmospheric source. Comparison of Na:Cl ratios in deposition and streams show the chloride in the stream is influenced by solid-phase sodium chloride, rather than the ionic phase in seawater.

Chloride in streams is used as a proxy for marine sulphate contributions to the acidification of fresh waters. Identification of the source(s) of excess chloride in streams has implications for the calculation of the sulphate budget in fresh water.

U-Pb detrital zircon geochronology of the South Portuguese Zone (southern Iberia): linkages to Avalonia and Meguma

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The South Portuguese Zone (SPZ) comprises the southernmost extent of the European Variscan orogenic belt. This orogen developed by the closure of the Rheic Ocean and culminated in Late Paleozoic continent-continent collision between

Gondwana and Laurussia during the formation of Pangea. The SPZ is interpreted to have accreted to the Iberian autochthon (part of Gondwana) during the closure of the Rheic Ocean, and to represent a fragment of a plate which was largely destroyed during subduction beneath the Ossa Morena Zone (OMZ). Despite exposure limited to the Upper Devonian – Early Carboniferous, the presence of older crust of unknown age beneath SPZ is indicated by seismic studies and most authors contend that this crust is equivalent to Avalonian or Meguma basement.

U-Pb isotopic data from at total of 260 detrital zircon grains from one clastic sample in the SPZ (PQ quartzite) and three clastic samples in the so-called Pulo do Lobo accretionary complex (PDL) were collected using laser ablation inductively coupled mass spectroscopy. The PDL outcrops along the northern margin of the SPZ. Two samples were taken from a sedimentary mélange within the PDL, one from a quartzite cobble within the mélange and the other from quartzite matrix. A final sample was taken from a polydeformed bedded quartzite unit, structurally beneath the quartzite mélange. Samples from the oldest exposed unit in the SPZ (PQ quartzite) suggest a potential Gondwanan provenance (Neoproterozoic and Paleoproterozoic age clusters) with limited Grenvillian input. Conversely, all samples from the PDL are dominated by Mesoproterozoic zircons with minimal Paleoproterozoic and Archean input. These data suggest that the provenance of the sediments within PDL have a common source that is not the Gondwanan craton or the Upper Devonian clastics of the SPZ, which is difficult to explain with a Gondwanan upper plate and SPZ lower plate subduction scenario. This suggests that current models for subduction beneath the OMZ may need re-interpretation. These data also show neither a clear Avalonian nor Meguma affinity for the Upper-Devonian clastics of the PQ. This implies that either SPZ basement is not genetically related to Avalonia or Meguma, or sediments for the PQ clastics were derived from an alternate source.

Central and South Atlantic conjugate margin pre- and post-salt successions: implications for rift models and petroleum systems

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Data from offshore basins along the Nova Scotian–Moroccan (considered non-volcanic and transitional) and Brazilian–West Africa (volcanic) conjugate margins reveal the presence of stratigraphic sequences below the late synrift salt lying above the unconformities that define the onset of rifting, and the elusive breakup unconformity corresponding to oceanic crust inception. These sequences are observed in proximity to basin margin hinge lines in shallow water, and in deep water at the distal basin margins extending towards the abyssal plain.

Recent industry-acquired deep crustal and regional seismic lines have improved resolution of these pre-salt features as well as post-salt troughs controlled by basement-involved faults. In shallow water, they are manifested as isolated salt evacuation synclines and half-grabens composed of fluvial and playa redbed sediments. Unusual deep-water structures, appearing as highly rotated fault blocks with growth geometries, have alternative interpretations of continental or oceanic, synrift or post-rift features. Originally interpreted as structural relief on magnetically quiet oceanic crust, the features' internal geometries and occurrence below the assumed breakup unconformity suggest that the basement may not be oceanic. Some evidence supports the presence of attenuated, serpentinized mantle in these areas.

The extremely thick pre-salt sedimentary sequences seen in the Atlantic margins are probably related to rift shoulder uplift at the continental border, and at the future rift spreading axis immediately prior to rifting. A rapidly deposited sedimentary succession was thus directed towards the main salt (rift) depocentres on both the South and Central Atlantic conjugate margins. The successions underlying the salt in deep waters are not rotated by synrift faults, and in the South Atlantic the depocentre lies above a deep seismic reflector which may correspond to the Moho or to lower crust detachments.

Recognition of these features, identification of basement type, definition and age of breakup events, and their interpreted temporal and tectonic association, has significant implications for different styles of rifting, salt tectonics, and basin petroleum systems (source facies, heat flow and maturation, trap formation, and migration pathways).

Application of (U-Th-Sm)/He analysis in apatite: assessing the paleothermal effect of salt structures on Sverdrup Basin rocks, Axel Heiberg Island, Nunavut

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Salt conducts heat better than other sedimentary rocks, and therefore evaporite structures can affect the thermal history of basins, for example leading to higher maturation of hydrocarbon source rocks above diapirs. The (U-Th-Sm)/He analysis of apatite provides a measure of when a rock most recently cooled

through a temperature of ca. 75 ± 15 °C (equivalent to 2 to 3 km below the surface) and thus is particularly suited to detect anomalous paleothermal effects of salt in a basin.

Gem-quality apatite crystals are extracted from the crushed rock sample and measured to apply corrections for He diffusion. The crystals, held in platinum crucibles, are heated using a laser, and the expelled ^{4}He is measured using a quadrupole mass spectrometer. Finally, the degassed apatite is analyzed by Induced Coupled Plasma Mass Spectrometry (ICP-MS) for U, Th, and Sm. The computed (U-Th-Sm)/He apparent ages are then interpreted, taking into account geological constraints and data from apatite fission track-length modelling on correspondent samples.

The superbly exposed evaporite diapir fields at the head of Expedition Fiord, Axel Heiberg Island, Nunavut (ca. 79°24'N / 90°50'W) provide an ideal laboratory to study the interaction of salt with basinal rocks. A sequence of up to 12 km of Mesozoic to Cenozoic marine and continental strata accumulated in the Sverdrup Basin and was intruded by Cretaceous diabase sills and dikes during two events possibly related to hot spot activity (ca. 125–90 Ma). The basin underwent inversion in the Paleocene-Eocene (ca. 60–40 Ma) during the Eurekan Orogeny. Late Carboniferous salt with anhydrite has risen to the surface over time in a variety of diapiric structures, and led to intense deformation of the strata.

A suite of surface samples was collected from Expedition Fiord to Geodetic Hills, across the Princess Margaret Range, Axel Heiberg Island. (U-Th-Sm)/He dating of apatite from Mesozoic sandstones and Cretaceous igneous rocks in the eastern Sverdrup Basin yield apparent ages reflecting exhumation cooling during the Eurekan Orogeny (ca. 45 to 60 Ma). However, in the vicinity of evaporite diapirs – e.g., Gypsum Hill, Little Matterhorn, and Colour Peak – (U-Th-Sm)/He apparent ages are considerably younger (ca. 20 to 31 Ma) indicating that rocks now at the surface cooled to He – retention temperatures more than 20 My later. These data are compatible with the thermal history previously suggested by apatite fission track-length modelling. The rocks now at the surface near evaporite structures remained anomalously warm into the Neogene.

Coincidentally, this thermally anomalous region is also abnormal in that it includes perennial springs that yield brines at +5°C year round, irrespective of air temperature, not expected in an area where permafrost is more than 500 m deep. Previous workers interpreted the springs to represent glacially controlled (Quaternary) phenomena, but our data and the discovery of hydrothermal developments with veins of carbonate and metal sulphides in the area of the diapirs suggest that the perennial springs may be the current expression of long-lived systems, locally melting the permafrost due to thermal effects of salt-related structures.

Bedrock and till indicator minerals of the Halfmile Lake Zn-Pb-Cu volcanogenic massive sulphide deposit, New Brunswick

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Indicator minerals have become an important exploration method in the past 30 years and now include suites for detecting a variety of ore deposit types including diamonds, gold, Ni-Cu-PGE, porphyry Cu, massive sulphide, and tungsten deposits. An indicator mineral is a mineral or suite of minerals that suggest the presence of a particular deposit type. Ideally, an indicator mineral is visually and chemically distinct, moderate to high density, medium sand-sized (0.25–2.0 mm), abundant, survives weathering and/or glacial transport, and is readily recoverable. Glacial till and bedrock sampling were conducted during the summer of 2007 around the Halfmile Lake Zn-Pb-Cu volcanogenic massive sulphide (VMS) deposit, Bathurst Mining Camp as part of the Geological Survey of Canada's Targeted Geoscience Initiative-3 (TGI3). This project is a collaborative effort between the Geological Survey of Canada, the New Brunswick Department of Natural Resources, and Queen's University. The purpose of conducting this study is to document the till indicator mineral and geochemical signature of the Halfmile Lake Zn-Pb-Cu VMS deposit.

The Halfmile Lake deposit consists of massive, breccia, and stockwork Zn-Pb-Cu sulphide mineralization hosted by the volcano-sedimentary sequence of the Ordovician Tetagouche Group. Sulphide minerals in the deposit include sphalerite, galena, chalcopyrite, pyrrhotite, and pyrite. Subcropping preglacial gossan is preserved over parts of the deposit. Epiclastic rocks, interbedded fine-grained felsic pyroclastic rocks, crystal-rich felsic tuffs, quartz-feldspar porphyritic intrusions, and intermediate and basic dikes are the main rock types found surrounding the Halfmile Lake deposit.

A thin (<2 m) layer of silty sand, locally derived subglacial till covers most of the deposit area. The till contains 20–40% pebble to cobble sized clasts that are angular-subangular in shape. Till sample sites for this study were selected based on previously defined east, northeast, and southeast ice-flows that crossed the study area and the east-trending till geochemical dispersal train from the deposit.

Till and bedrock samples were processed at Overburden Drilling Management Ltd.'s heavy mineral processing lab in Ottawa to recover indicator minerals. A preliminary set of indicators identified in various bedrock lithologies include chalcopyrite, pyrite, galena, sphalerite, ferro- and nonferromagnetic pyrrhotite, ilmenite, goethite, beudantite, and

jarosite. Indicator minerals identified in till include chalcopyrite, pyrite, gold, goethite, and beudantite.

Snow pack modeling using LiDAR derived elevation data

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In this research snow pack modeling was attempted in the Elbow River watershed west of Calgary, Alberta, using LiDAR-derived elevation data. The City of Calgary and the Department of Sustainable Resources Development (SRD) were interested in determining whether a winter and summer LiDAR dataset can be used to estimate the mean snow depth. LiDAR is an airborne laser system that calculates the distance to the ground by determining the return time of emitted laser pulses spatially located by a survey grade global positioning system (GPS) and an inertial motion unit (IMU). Subtraction (Digital Elevation Model (DEM) change detection) of the summer dataset from the winter dataset provides a snow depth dataset that is used to determine mean snow depth. Mean snow depth and average field-measured snow densities were used to calculate snow water equivalent (SWE). An estimate of snow volume was determined using three methods: (1) mean snow depth; (2) terrain attributes (slope, aspect, elevation, and canopy fractional cover) individually; and (3) a multiple terrain attribute GIS approach. Application of an average snow depth ($3.4 \times 10^7 m^3$) rendered a similar approximate value for snow water equivalent for the study site as the results from slope ($3.6 \times 10^7 m^3$), aspect ($3.5 \times 10^7 m^3$) and canopy fractional cover ($3.5 \times 10^7 m^3$) terrain attributes. Elevation ($4.2 \times 10^7 m^3$) and the GIS model ($4.3 \times 10^7 m^3$) gave higher estimates of snow water equivalent in the Elbow River watershed as elevation plays a strong role in snow accumulation.

Preliminary results indicate that the use of LiDAR to estimate snow depth is a viable option for the determination of snow depth in a mountainous region. Future research will include validation of LiDAR runoff values with stream gauge data. As well, these methods will be re-evaluated in an area of greater snow depth (the average snow depth in the Elbow River watershed was 18 cm, which is the accuracy limit of current LiDAR systems). The results of this study indicate that this research can be used in conjunction with current water resource management strategies to assist in prediction of seasonal runoff volumes. More accurate watershed water volume prediction strategies can aid city planners with regulating water supply as well as preparing for flooding events.

Lower Palaeozoic alluvial systems: the sedimentological impact of evolving vegetation in terrestrial environments

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In present-day alluvial environments, the impact of vegetation on sedimentological processes and deposits is well known. A vegetated catchment may decrease sediment yield, sediment erodability, Hortonian overland flow, aeolian winnowing of fines, the proportion of sediment transported as bedload, may increase bank stability, infiltration into substrates, bed roughness, and can promote the production of chemically-weathered clays and soils and the adoption of a meandering style. As such it is generally understood that, prior to the evolution of terrestrial vegetation during the Lower Palaeozoic, ancient alluvial systems were markedly different from modern systems, with many systems adopting a "sheet-braided" style. This understanding has previously informed the interpretations of many Precambrian pre-vegetation alluvial successions, but there has been relatively little work regarding Lower Palaeozoic alluvial successions that existed during the active colonization of terrestrial substrates by plants.

In this study, a comprehensive review of 141 Cambrian to Devonian alluvial successions documented in published literature was combined with original field data from 20 alluvial successions from across North America and Europe (including locations in New Brunswick and the Gaspé Peninsula), in order to identify changes in the sedimentary style of alluvial strata while vegetation was evolving and colonizing alluvial environments. This approach has established clear trends indicating an increase in mudrocks and sandstone maturity, and a decrease in overall sand grain size through the Lower Palaeozoic, suggesting that primitive vegetation cover was able to promote the production and preservation of muds and increase the residence time of sand-grade sediment (and thus sediment reworking) in the alluvial system. It has also enabled the first stratigraphic occurrence of certain vegetation-dependent sedimentary features to be pinpointed and tied directly to the onset of specific evolutionary adaptations recorded in the palaeobotanical fossil record. Examples of these include the first markedly heterolithic alluvial sequences (which first appear at the same time as the most primitive vegetation), pedogenic calcite (which appears at the same time as the first vascular plants), and vertisols, coal, and lateral accretion surfaces (which only appear after the evolution of deep rooting).

Marketing geoscience data: challenges and progress in 2008

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What do you think the response would be if you stood in a community meeting and posed these two questions to the audience? (1) What is that white rock exposed along the edge of the parking lot? (2) Does it pose a risk to this building? The geologists in the room would recognize it as gypsum and wonder why they constructed the new P3-school at this location. Unfortunately, the planners, engineers, architects, and builders did not recognize the rock type or the risks involved with building on it. Why didn't they know? If you asked the same group how many have taken a geology course in their life time you would have your answer. This question was posed at several municipal council meetings and various other public presentations over the past three years. The response is generally <10% of meeting attendees. There are a number of reasons for this low number, but they will not be discussed in this presentation. What will be presented are the Geological Services Division's efforts to address this issue.

The division has adopted a new approach to marketing its geoscience data, moving it from the dusty library shelves into the hands of community decision makers. Two topical issues, coastal-zone management and climate-change adaptation, provided the division with new marketing opportunities in 2008. These two issues are currently the subject of intense study by federal, provincial, and municipal governments, providing the geoscientists at the Department of Natural Resources an opportunity to build new partnerships.

This work is not without its challenges, the lack of geological education being one of the largest. The effort is justified, however, because it provides communities with essential information required for their socio-economic and land-use planning projects. It also benefits the Geological Services Division by raising the profile of geoscience research, which may lead to new research funding.

Borehole geophysical characterization of the fractured bedrock aquifer underlying Black Brook Watershed, near Saint-André, New Brunswick

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The upper Saint John River valley represents an economically important agricultural belt that suffers from high nitrate levels in the groundwater as a result of fertilizer use. This study focuses on the fractured bedrock aquifer beneath the Black Brook Watershed, near Saint-André, New Brunswick, where prediction of nitrate migration is limited by the lack of fracture characteristics. Bedrock geology is broadly subdivided into a fine-grained, lower siliciclastic unit of the Grog Brook Group and an upper carbonate unit assigned to the Matapédia Group. Groundwater flow through the fractured bedrock is primarily influenced by the distribution and orientation of fractures dispersed throughout the rock units.

The objective of this study is to demonstrate the effectiveness of the select suite of borehole-geophysical tools used to identify and describe the fractured bedrock characteristics, and to assist in understanding the migration pathways of agrochemical leachate from farm fields. Fracture datasets were acquired from five new vertical boreholes that ranged from 50 to 170 metres in depth, and from three outcrop locations along the new Trans-Canada Highway, approximately two kilometres away. The borehole-geophysical methods used included natural gamma (GR), single point resistance (SPR), spontaneous potential (SP), slim-hole optical borehole televiewer (OBI) and acoustic borehole televiewer (ABI). The ABI and OBI tools delivered high-resolution, oriented images of the borehole walls. This enables visualization of fractures *in situ*, and provides accurate information on the location, orientation, and aperture of fractures. The GR, SPR, and SP logs were used to identify changes in lithology, bed thickness, and hydraulically conductive fracture zones.

ABI and OBI images were used to identify 390 fracture surfaces that intersect the boreholes. Fracture sets identified by plotting the data on stereographic and rose diagrams have a mean strike of 076°/256° and a mean principle dip of 51° towards the south-southeast. Histogram data show a bimodal distribution of fracture dips, dominated by shallowly dipping (30°–40°) and steeply dipping (70°–80°) populations. Fracture orientations do not show an obvious pattern with respect to depth. Fracture apertures are dominantly in the range of 1 to 7 mm. Fractures exposed in outcrops along the Trans-Canada Highway exhibit a similar orientation distribution to that observed in the boreholes. However, as expected, these exposures show a greater population with dips between 80° and 90°, compared to the vertical boreholes. The combined fracture datasets provide valuable information towards understanding groundwater flow and migration pathways of fertilizer leachate into the bedrock aquifer. This borehole-geophysical approach will lead to an improved understanding of the groundwater flow system, and will aid the development of hydrogeological models.

Till geochemistry of the New Brunswick Lowlands

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Previously, regional till geochemistry surveys conducted by Geological Surveys Branch were carried out with a focus on known higher economic mineral potential areas in the northern, western, and southern parts of New Brunswick. Sampling in these earlier investigations used a standard 2-km sampling grid (1 sample/4 km²). In contrast, field work for the summer of 2008 consisted of reconnaissance-scale sampling of the New Brunswick Lowlands (central and eastern New Brunswick) using a 10-km sampling grid (1 sample/100 km²). The study area comprised: (1) the New Brunswick parts of the Cape Tormentine (11 L/04) and Amherst (21 H/16) NTS map areas; (2) the New Brunswick part of the Moncton NTS 21 I map area (all or parts of thirteen 1:50 000 scale map areas); (3) the northeastern part of the comparable Fredericton NTS 21 G map area (four 1:50 000 scale map areas); (4) the Doaktown (21 J/09) map area and the southeast corner of the adjacent McKendrick Lake (21 J/16) map area; and (5) the eastern and central parts of the Bathurst NTS 21 P map area (all or parts of nine 1:50 000 scale map areas).

The objective of this reconnaissance till sampling project was two-fold: (1) to help assess the mineral resource potential and glacial dispersal trends in eastern New Brunswick; and (2) to aid in determining where or whether future, more detailed, till sampling projects should be conducted in the New Brunswick Lowlands. Basal till samples were collected from 240 sites. In addition, 20 samples from previous surveys were reanalyzed. This material is highly variable in character from one site to the next. In texture it varies from clay loam to very gravelly sandy loam. Colour varies from grey brown to red; however, brown or dark brown is dominant, with yellowish brown and reddish brown the most common of the other colours.

The till samples have been processed in the DNR Geochemical Laboratory, separating splits for in-house grain size analysis and for geochemical analysis by 'near total' extraction techniques at an external laboratory. The geochemical results have been completed using analytical techniques comparable to those used for previous till geochemical investigations in west-central New Brunswick. The lithology of pebble samples collected from each site will also be determined in the DNR laboratory. The series of 4 open file reports will be an important contribution to the provincial basal till database, both from a mineral exploration perspective and from an environmental perspective (through defining background levels for both nutrient and toxic elements).

Field relationships, petrology, and age of granitic and syenitic plutons in the Antigonish Highlands, Nova Scotia

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The Antigonish Highlands of Nova Scotia have characteristic features of Avalonia, including Neoproterozoic arc-related volcanic and plutonic rocks and Cambrian-Silurian cover sequences. Also present in the southern part of the highlands are scattered plutons previously inferred to be of Devonian-Carboniferous age. Although contacts are not exposed, these plutons were interpreted to have intruded Neoproterozoic and Silurian volcanic and sedimentary rocks. This project focuses on the field relationships, petrology, age, and tectonic implications of these plutons.

One of the plutons, Hunters Lake, consists of tonalite and minor granodiorite, and is likely to be closely related to quartz diorite of the Neoproterozoic (based on previously determined K-Ar ages) Eden Lake Complex. Such an interpretation is consistent with the lack of contact metamorphism in the surrounding fossiliferous Silurian rocks. Preliminary geochemical analyses show these rocks to be calc-alkaline and formed in a subduction zone setting. The other plutons consist of varying proportions of granitic and syenitic rocks. The granitic rocks include distinctive alkali-feldspar granite and syenogranite with quartz eyes and interstitial granophyric texture indicative of shallow emplacement. Although predominantly subalkalic, samples from three of the plutons (Barneys River, McGraths, and Leadbetter) have chemical characteristics of within-plate granitoid rocks, whereas a fourth pluton, Gunn Lake, has a volcanic-arc granite composition. These plutons overall show fractionated compositions, including high Si (SiO_2>71%), K, Ba, Rb, and Th, and depletion in elements such as P, Ca, and Mg. The predominantly syenitic rocks in the Brora Lake area contain aegirine and in some samples riebeckite, indicative of peralkaline composition. An additional pluton (Haggarts Lake), previously mapped as Neoproterozoic diorite, is also of syenitic composition and related to the Brora Lake pluton. Geochemistry confirms that these plutons are peralkaline and have high concentrations of K, Na, P, Ti, and Fe with an intermediate range in silica content (54–64% SiO_2). Tectonic discrimination diagrams indicate a within-plate setting for these plutons.

An alkali-feldspar granite sample from the Gunn Lake Pluton yielded a preliminary U-Pb (zircon) upper intercept age of about 605 Ma, consistent with the concordant U-Pb (zircon) age of 610 ± 3 Ma reported previously for the petrographically

similar Cape Porcupine Granite at the Strait of Canso. These ages suggest that at least some (and probably all) of the plutons in the southern Antigonish Highlands previously inferred to be Devonian-Carboniferous are of Neoproterozoic age, indicating that such plutons are much more abundant than previously recognized. The recognition of widespread Neoproterozoic peralkaline granite and syenite in the southern highlands is especially significant, as similar rocks also occur in the northern Antigonish Highlands but are not known in Avalonia elsewhere in Maritime Canada.

Surface features on diamonds and water content of olivine from kimberlite as indicators of fluid systems in kimberlite magma

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Volatiles in magmas play an important role in the eruption style and the geology of volcanic landforms, determine presence of fluid phase, the depths of volatile exsolution, and the rates of magma accent. In kimberlites the original proportions of the two main volatiles, H_2O and CO_2, are obscured by complex origin of the groundmass minerals. Volatiles affect diamond preservation and determine the character of surface features produced on diamond faces during dissolution in kimberlites. Experiments demonstrated that oxidation of diamonds in magmas with H_2O- or CO_2-rich fluids and in the absence of fluid produce distinctively different types of surface features. In addition, water fugacity of kimberlitic magma can be estimated using water content in phenocrystic olivine measured by FTIR spectroscopy. We apply these two independent methods to several kimberlites in order to constrain the behavior of volatiles and their effect on diamond population and the geology of kimberlites.

The study uses diamond parcels, olivine concentrates, and kimberlite core from six EKATI Mine kimberlites, Northwest Territories, Canada. These kimberlites have similar emplacement ages, erosion level, and country rocks, but different geology, composition, and diamond populations. The surface features on diamonds studied under optical and scanning electron microscopes were compared to the diamond surfaces produced experimentally in the presence and absence of fluid. Concentration and occurrence of hydroxyl in kimberlitic olivine were measured using FTIR spectroscopy. We found that Leslie and Grizzly kimberlites filled with hypabyssal facies, with low grade and quality of diamonds, show very sharp dissolution forms on diamond surfaces. Such features indicate absence of a free fluid phase during the last stages of kimberlite emplacement. Panda, Beartooth, Misery, and Koala kimberlites filled with volcaniclastic kimberlite, with higher grade and quality of diamonds have diamond surfaces with well-developed trigon pits, rounded edges with striation, and hillocks. Such features suggest emplacement in an H_2O-fluid-rich environment. However, diamond populations of Panda and Beartooth are dominated by octahedral unresorbed stones and IR spectra of their olivines give higher concentration of water in olivines <600 ppm and the depth of fluid separation greater than 2GPa. On the contrary, Misery and Koala diamonds are mostly rounded with high degree of resorption. Their olivines contain <450 ppm of H_2O and fluid separated at more shallow depths. Group 2 OH IR absorption bands are absent in FTIR spectra of olivine from kimberlites filled with hypabyssal facies and present in olivine from all volcaniclastic-filled kimberlites. This can provide a possible link to an early loss of magmatic fluid. The excellent agreement between the two independent datasets suggests that both are linked to the activity of water in the system. We further apply these results to explain the differences between the geology of these kimberlite pipes and their diamond populations.

Putting the "geo" back in geothermal energy

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There has recently been a rapid increase in demand for alternative energy due to volatility in energy prices and growing concern for the environment. Low temperature geothermal energy systems, also known as earth energy or geoexchange, are being installed through Canada at an unprecedented rate as a result of this demand. However, there is little regulatory framework surrounding their installation with regard to their long-term impact on the environment. While these systems represent a financial benefit to the property owner and a reduction in greenhouse gas emissions, there are unresolved issues regarding subsurface energy rights and the effect of changes in groundwater temperatures. Monitoring of the long-term performance of these systems and their environmental impacts is rare but in several that have been examined the size of the resulting thermal anomaly has been of concern. These issues should be resolved with input from the geoscience community and present an important opportunity for us to become part of climate change mitigation.

Coastal hazard assessment mapping in St. Margarets Bay, Nova Scotia

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The Geological Services Division of the Nova Scotia Department of Natural Resources (NSDNR) has embarked

on a systematic mapping program of coastal hazards in Nova Scotia. This represents the first geology-based coastal hazard mapping undertaken by NSDNR. Mapping, data collection, and interpretation were undertaken at a 1:10 000 scale and the resulting products will be released as GIS-based maps. These maps will include links to photographs with accompanying detailed captions, figures illustrating important coastal processes, and explanatory captions typically describing aspects of data interpretation and predictive comment.

St. Margaret's Bay was chosen as the first area to be mapped because it encompasses a diverse spectrum of coastal attributes, examples include varying geomorphology, bathymetry, different wind exposures, different types of development, and varying degrees of infrastructure risk. The bay also offered the author an opportunity to observe and contrast the varying effects of Hurricane Juan and Post-tropical Storm Noel on the area. Though not known in the initial program planning stage, choosing St. Margarets Bay was somewhat fortuitous. In 1893, an unnamed category 3 hurricane on the Saffir-Simpson scale made landfall in Nova Scotia. A category 3 hurricane on the Saffir-Simpson scale is defined as having sustained winds ranging from 178 to 209 km/hr. This was the strongest hurricane to ever hit Nova Scotia and it tracked directly up St. Margarets Bay.

Evolution of Neoproterozoic to Ordovician volcanic arcs along the Ganderian margin of New Brunswick and coastal Maine: evidence from detrital zircons

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Detrital zircon ages were determined for conglomerate and sandstone samples from six fault-bounded belts in New Brunswick and coastal Maine. Formations sampled included Martinon (Brookville belt), Flagg Cove (Grand Manan Island belt), Matthews Lake (New River belt), Ellsworth (Ellsworth belt), Calais (St. Croix belt), and Baskahegan Lake (Miramichi belt). Their range of depositional ages based on the youngest detrital zircon population and stratigraphic, paleontological, and cross-cutting intrusive relationships are: (1) Martinon between 602 ± 8 and 546 ± 2 Ma; Flagg Cove between 574 ± 7 and 535 ± 3 Ma; (2) Matthews Lake between 539 ± 5 and 514 ± 2 Ma; (3) Ellsworth between 507 ± 6 and 504 ± 3 Ma; (4) Calais between 510 ± 8 and 479 ± 2 Ma; and (5) Baskahegan Lake between 525 ± 6 and 488 ± 2 Ma.

All of the samples are dominated by Neoproterozoic (Pan-African) zircon populations consistent with derivation largely from local magmatic arc rocks of the Brookville, Grand Manan Island, and New River belts and possibly in part from Ganderian basement gneiss and associated plutonic rocks underlying the Hermitage Flexure in southwestern Newfoundland. The samples also contain a small number of Mesoproterozoic, Paleoproterozoic, and Archean zircon grains, the latter as old as 3.23 Ga. The presence of zircons in the range 1.07 to 1.61 Ga is consistent with an origin along the peri-Gondwanan margin of Amazonia rather than West Africa.

The general similarity of detrital zircon provenance for samples from New Brunswick and coastal Maine suggests that all the Ganderian belts were formed along the margin of a single microcontinent. The Grand Manan Island and New River belts both record two distinct periods of Neoproterozoic arc magmatism (~629 to ~611 Ma and at ~553 to ~535 Ma) whereas the Brookville belt experienced only a single period lasting from ~553 to ~528 Ma. These differences are attributed to migration of the younger period of arc magmatism into the interior of the Ganderian continental margin as represented by the Brookville belt. Cambrian back-arc volcanic activity behind a Penobscottian arc system is recorded in the New River and Ellsworth belts from ~514 to ~502 Ma, following migration of the northern margin of Amazonia into the widening Iapetus Ocean. Rifting of the Ordovician Meductic- Popelogan arc along the leading edge of Ganderia led to the development of the Tetagouche back-arc volcanic activity in the Miramichi belt of central and northern New Brunswick.

Log jams caused braided-channel abandonment and avulsion in the Pennsylvanian South Bar Formation, Sydney Basin, Nova Scotia

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Log jams are a major cause of modern channel blockage, and frequently trigger abandonment of the whole channel belt (avulsion). Prior to the advent of abundant, large trees late in the Devonian, log-jam triggering was not possible. Only one ancient log jam — in an Early Pennsylvanian (Langsettian) channel fill — has been well documented to date. We document here, numerous log jams from excellent exposures of the Middle Pennsylvanian South Bar Formation (Bolsovian to Asturian) along Sydney Harbour.

The South Bar Formation comprises thick braided-fluvial sandstones and conglomerates with sparse shales, discontinuous coals, and coal fragments (former peat mats). At the top

of many sandy channel fills, stacked logs, and peat mats in a matrix of sand, gravel, and mudstone fragments are overlain by shales laid down in abandoned channels. The organic accumulations are up to 2.5 m thick, and individual logs are up to 2 m long and 0.8 m wide, with peat mats up to 3.5 m long and 0.12 m thick. The logs are flattened and the organic beds must have been much thicker prior to compaction and coalification — probably approaching the depth of some braid channels (~3–8 m). Although log orientation is variable, many logs lie normal to paleoflow as in modern log jams. Where sandstone/shale contacts lack log jams, the sandstones include sigmoidal trough cross-beds, plane beds, and antidune bedforms, suggesting that the channels were choked with sediment brought down by high-energy floods.

Plant axes in the log jams comprise a wide variety of taxa, but poor preservation resulting from entrainment in high-energy flows means that most cannot be identified. Nonetheless, members of the five main Carboniferous plant groups are represented, including the lycopsids (*Sigillaria, Lepidodendron*), sphenopsids (*Calamites*), tree ferns, pteridosperms, and cordaitaleans. Most probably grew on inactive braided tracts adjacent to the active channels, rather than on distant uplands. The close association between peat mats and logs suggests that forested peat mires on the floodplain were undercut during major floods, yielding large volumes of woody material.

We conclude that late Pennsylvanian braided-river plains were sufficiently forested to behave very like modern river plains where log jams commonly trigger intrinsic channel changes. High-magnitude floods eroded vegetated banks and floodplains, toppled trees, and destroyed peats and mud layers. The resulting accumulation of thick layers of organic material and flood sediment caused channel blockage and abandonment. Although flow may have relocated within multi-channel tracts, a radical paleoflow change above one log jam suggests that the entire channel belt avulsed.

Radon in Nova Scotia: defining areas of geogenic enrichment

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Exposure to radon is the second leading cause of lung cancer after tobacco smoking. Health Canada recently reduced the national guideline for exposure to indoor radon from 800 Bq/m^3 to 200 Bq/m^3 for an annual average exposure.

As part of the Canadian component of the North American Soil Geochemical Landscape Project (NASGLP), a tri-national geochemical initiative involving the federal, provincial, and state geological surveys of Canada, the United States, and Mexico, radon concentrations in soil gas were measured at selected sites throughout Nova Scotia.

Prior to commencement of the 2008 field season, a limited orientation program involving the Geological Survey of Canada and the Nova Scotia Department of Natural Resources was carried out to (1) test field methodologies, (2) determine the optimum sampling depth, (3) address issues of spatial variance, and (4) determine instrument accuracy and precision. The orientation study also involved the sampling of various till units as well as a number of different background and mineralized environments.

During the 2007 and 2008 field seasons, 72 regional sites were sampled for radon at an average sampling density of 1 sample per 800 km^2. At each site, soil samples from various soil horizons were also collected and analyzed for uranium and multi-element geochemistry. Measurements of *in situ* gamma ray spectrometry measurements (eU, eTh, K, and Total Counts) were also collected at each site. Soil permeability was measured at most but not all sites.

Approximately 40% of Nova Scotian residents live within the Halifax Regional Municipality (HRM), therefore, a higher density sampling program (1 sample per 70 km^2) for radon was completed within HRM. Soil samples representing the Public Health (PH) layer (0 to 5 cm depth) were also collected at each site and will be analyzed for uranium and multi-element geochemistry. *In situ* gamma ray spectrometry and soil permeability measurements were collected at all the HRM sites.

Initial results of the survey indicate that measureable radon in soil gas is present everywhere throughout the province in all geologic terrains. Radon tends to correlate positively with peraluminous granite, particularly with the highly evolved phases (leucomonzogranite) and to a lesser degree with sedimentary rocks of the Horton and Pictou groups that may be (locally) characterized by roll-front uranium mineralization.

One objective of this study is the establishment of a link between the presence of geogenic radon and indoor radon concentrations as an aid in identifying areas where exposure to radon may represent an increased human health risk.
Funding for the project was provided by the Geological Survey of Canada and by the Radiation Protection Bureau of Health Canada.

Muddying the waters: Quaternary incision of the Grand Canyon, USA

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The 150 year controversy regarding the incision history of the Grand Canyon (GC) has been rejuvenated with the recent application of numerical modeling and geochronological techniques developed in the last 20 years. Rates of incision based on fill terraces and incised basalt lavas reveal that the western GC (60 ± 20 mm/ka, uncertainty reflects range) has incised faster than the eastern GC (150 ± 20 mm/ka), possibly due to the inhibiting effect of subsidence by normal faulting in the western reach. However, these rates are too slow to have carved the entire canyon since the 6 Ma integration of the Colorado River over the Kaibab Plateau.

Cosmogenic nuclide exposure dating of canyon cliffs is used, for the first time, to directly measure stream incision rate. Twenty-seven samples collected from River Mile 75 (Shinumo Quartzite, eastern GC) and 229 (Vishnu, western GC) were analyzed for ^{10}Be in quartz using AMS. The ^{10}Be production rate was adjusted for reductions in cosmic ray flux by topographic shielding and foreshortening on the dipping sampled surfaces. Ages range from 12.1 ± 1.2 ka to 208 ± 22 ka (1σ internal + external error). The corresponding apparent incision rates range from 5500 to 95 mm/ka. Most of sampled surfaces were varnished fracture faces but some exhibited stream polishing. Using the data to delimit a maximum age-elevation relationship, which removes young ages (high incision rates) due mainly to block falls long after the river incised past the surface, we established the incision history of the two locations. At River Mile 75 (eastern GC) the rates range from 406 to 95 mm/ka over 209 ka (n = 6). At River Mile 229 (western GC) the rates range from 441 to 316 mm/ka over 60 ka (n = 4). The average incision rates are 270 and 372 mm/ka at eastern and western GC, respectively. These rates are higher than rates determined by other methods and do not support previous observations that the rate of Quaternary incision was faster in eastern GC. Additional samples currently being processed from higher on the cliff walls may help rationalize the disparity.

Extremely gold-rich sulfide melt inclusions preserved in magnesiohastingsite xenocrysts from the Mount Milligan porphyry deposit, Quesnel Terrane, British Columbia

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Amphibole xenocrysts (potassian magnesiohastingsite) from an early, weakly mineralized, trachyandesitic dyke at the Mount Milligan Cu-Au porphyry deposit, British Columbia, contain coeval sulfide and silicate melt inclusions of primary origin along early growth zones. The sulfide melt inclusions have a bulk composition comparable to Cu-rich ISS. Late growth zones in the amphibole are devoid of sulfide inclusions and contain only low salinity fluid inclusions (average 7.4 wt% $NaCl_{eq.}$). Thermobarometry constrains the minimum conditions of sulfide entrapment (amphibole crystallization) to ~8 kbar and ~700°C. LA-ICP-MS analyses of 22 sulfide melt inclusions show that it was highly enriched in Au (53 ± 21 ppm, 1σ), Ag (143 ± 74 ppm, 1σ), and Ni (5219 ± 3176 ppm, 1σ). Ratios of Cu/Au (7495 ± 2482, 1σ) and Au/Ag (0.45 ± 0.24, 1σ) overlap very closely with those metal ratios in mineralized porphyry veins, demonstrating that the metal ratios in magmatic sulfide liquids are preserved in the bulk ore, and that metals were not fractionated from one another during volatile exsolution, metal partitioning into fluid phases, and subsequent transport and precipitation of ore metals. The extremely Au-rich composition of the sulfide melt may reflect the exsolution of a small volume of sulfide liquid compared to the associated volume of silicate liquid and fractional crystallization of the sulfide liquid prior to entrapment in the amphibole.

Rare, high Mg, alkali basalt enclaves hosted in the intrusive phases of the Mount Milligan system are depleted in Co, Ni, and Cu, reflecting the sequestering of the base metals into a sulfide liquid in a mid-crustal magma chamber in which amphibole was a saturated phase. Amphibole xenocrysts containing the sulfide melt inclusions also show depletions in these elements, linking the xenoliths and xenocrysts to a common, Co, Ni, and Cu-depleted source magma. An additional compositional link is shown by a significant depletion of Cr, Th, and U in the xenocrysts and a corresponding enrichment of these trace elements in the xenoliths. This reflects the retention of Cr, Th, and U in spinel, oxides, and apatite in the source region, a suggestion confirmed by the presence of these minerals in the xenoliths.

The results of this study show that a Cu-Au-rich sulfide melt coexisted with a water-rich alkalic basaltic liquid in the mid-crustal magma chamber prior to the emplacement of the main intrusions and porphyry-stage mineralization at Mount Milligan. Identification and analysis of ore metals in sulfide melt inclusions in relatively common xenocryst phases may serve as a useful exploration tool for predicting the metal ratio of undiscovered Cu-Au porphyry deposits in the western Cordillera.

Monitoring change along an Atlantic coastline: an example linking undergraduate teaching and research in the study of a gravel shoreline

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Significant challenges exist in monitoring change in coastal environments in response to external driving forces, such as climate change, changing wave conditions, and human intervention. This is especially so in depositional coastal environments, such as salt marshes, coastal dunes, and gravel shorelines,

which are sensitive and respond quickly to change. Capturing and monitoring rapid coastal responses often presents difficulties to researchers; however, useful data may be collected by undergraduate students undertaking fieldwork at the same site over a number of years that may supplement other data.

This study reports on a decade (1997–2007) of field data collected, under the direction of the tutor, by undergraduate geography students at Ru Vein, a gravel beach and barrier site on the Atlantic coast of Brittany, France. Geomorphological and sedimentological data were collected once or twice a year over the period that establishes a time-series of morphosedimentary change. Although data quality requires consideration, the overall dataset provides a useful adjunct to other research. These data clearly indicate landward migration and reduction of sediment volume of the gravel shoreline, which may be linked to rising sea-level and changing wave conditions, perhaps related to climate change. This exercise benefits both students and researchers, as successive students were able to compare the data they collected with previous years to gain a better understanding of spatio-temporal change at the coast and felt part of a substantial research effort. The researchers acquired useful data through their regular teaching activity.

An experimental investigation of diamond oxidation in Cl^- – H_2O fluids: implications for kimberlitic fluid composition

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Primary fluid and melt compositions of kimberlite are poorly constrained due to extensive mantle and crustal contamination, degassing on eruption, and post-magmatic alteration processes. Experiments show that diamond oxidation by kimberlitic fluid strongly depends on fluid composition. Oxidation of diamonds in magmas with H_2O-rich fluid, CO_2-rich fluid and in the absence of a free fluid phase, produces distinctively different features on diamond surfaces. Thus, diamond dissolution features can be used to investigate fluid composition in diamond-bearing magmas. Geochemical data from the Udachnaya-East kimberlite (Siberia) and fluid inclusions in phenocrystal olivines show high chloride content, implying that chloride may be an important component in kimberlitic systems. Comparison of natural diamond surfaces to those produced experimentally in chloride-bearing fluids provides a means of assessing the importance of chloride in kimberlitic systems. These experiments may also elucidate the mechanism of diamond oxidation.

Diamond dissolution experiments were performed in the piston-cylinder apparatus at 1350°C and 1 GPa in NaCl – H_2O and KCl – H_2O systems. Diamond surfaces were investigated by optical and field emission scanning electron microscopy. Results showed that an increase in the Na(K)Cl:H_2O ratio reduces oxidation at the edges of crystallographic faces, promotes surface graphitization, and decreases the regularity of etch pit geometry. The shape of etch pits produced during oxidation in chloride-rich compositions is very unusual for natural diamonds. The discrepancy between the morphology of diamond surfaces produced by oxidation in these fluids and those observed on natural diamonds suggest that chloride can only be present in limited concentrations in aqueous kimberlitic fluid.

A Penobscottian arc system along the margin of Ganderia: evidence from geochemistry and U-Pb zircon dating of the Annidale Group in southern New Brunswick

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Late Cambrian to Early Ordovician rocks of the Annidale Group are preserved within a northeast-trending, fold-thrust belt along the northwestern margin of the peri-Gondwanan New River belt in southern New Brunswick. The Annidale Group is comprised of an imbricated assemblage of mafic-intermediate flows, tuffs and coeval felsic dome complexes, wacke, shale, volcaniclastic rocks, felsic tuffaceous rocks and associated intermediate and plagiogranite intrusions. Mafic-intermediate volcanic rocks are subalkaline, tholeiitic to calc-alkaline basalt, basaltic andesite, and andesite that mostly exhibit negative Nb and Ta and positive Th anomalies on extended rare earth plots and fall clearly within volcanic-arc fields on trace-element discrimination diagrams. A notable exception is a group of extreme LREE-depleted basalts that display concave-upwards REE patterns typical of N-MORB affinity, but with uncharacteristically low TiO_2 (0.48–0.54%) more typical of arc tholeiites. These basalts are also magnesian-rich (13.7–17.2% MgO) and strongly enriched in Cr (1180–4910 ppm) and Ni (390–880ppm). Overall, the mixed arc and MORB chemistry of the Annidale Group is most characteristic of basalts erupted in a rifted arc or back-arc setting.

The age and geochemistry of the Annidale Group are in accord with recent models for the tectonic development of the Penobscottian arc system in the Exploits Subzone in Newfoundland. In such a model the ca. 497–489 Ma rocks of the Annidale Group represent supra-subduction zone magmatism associated with the Penobscot arc along the Gander margin in southern New Brunswick. Preliminary U-Pb data constrain the timing of tectonic interleaving of the Annidale Group and its juxtaposition with ca. 540 Ma New River belt

basement to between ca. 489–478 Ma, which is consistent with the timing of Penobscottian obduction in Newfoundland. Post-Penobscottian magmatism (ca. 478–469 Ma) that affected both the Annidale Group and adjacent rocks of the New River belt is similar in age to the younger Victoria arc in Newfoundland and associated Tetagouche-Exploits back-arc basin in northern New Brunswick. A $^{40}Ar/^{39}Ar$ age of 444 ± 5 Ma for metamorphic muscovite in schistose felsic tuff in the Annidale Group indicates that unroofing of the arc volcanics was coincident with the final closure of Iapetus.

Facies-related diagenesis and multiphase carbonate cementation and dissolution in the reservoir sandstones of the Sable Subbasin, offshore Nova Scotia

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Lower Cretaceous sandstones of the Scotian Basin, offshore eastern Canada, are important gas reservoirs. To determine the influence of depositional lithofacies, sequence stratigraphy and fluid flux during burial, the spatial and temporal distribution and chemistry of diagenetic minerals have been determined from several wells forming a proximal to distal transect through the basin. Mineral type and paragenesis were characterized using a combination of optical petrography, backscattered electron images, electron microprobe analyses, and bulk geochemistry data.

Grains coated with illite, chlorite, and Fe-calcite and minor siderite, pyrite, and phosphates record the neoformation of minerals through seafloor diagenesis from remineralization of organic carbon. Early kaolinite, predating quartz overgrowths and likely related to meteoric water, is abundant in fluvial and river mouth sandstones. Quartz overgrowths and late carbonate cements are the major mesodiagenetic minerals cementing these sandstones during burial diagenesis. In the same sandstone bed, mesodiagenetic ankerite occurs in some wells and Fe-calcite in others. Nine siderite types (A-I) were distinguished on the basis of textures. Early siderites (A-H) predate the formation of quartz overgrowths and only one late siderite type (I) is synchronous with or postdates quartz overgrowths. Both early and late siderite have similar composition (15–35 mol% $MgCO_3$ and 65–86 mol% $FeCO_3$), with only siderite intraclasts (A) and distinctive diagenetic hemispheres (H) having a low $MgCO_3$ (~20 mol%) content. Low Mg in siderites (A) and (H) is related to a greater contribution of meteoric water. Siderite of all generations is most common where there is high availability of detrital Fe, which is responsible for the unusual presence of early siderite in marine sediments. Late siderite I is controlled by the composition of formation water. Siderite suppresses quartz overgrowths and dissolves to create microporosity. Mesodiagenetic minerals are related to flux of formation water and maturing hydrocarbon products, resulting first in pyrite and siderite I and later in other carbonates.

Seafloor diagenetic minerals are absent in fluvial sandstones. Siderite is abundant in prodeltaic sands and muds, where there was the greatest availability of detrital Fe. Transgressive units have most abundant early Fe-calcite and siderite B. Early kaolinite occurs in proximal lithofacies, where meteoric water was most likely available at the time of or shortly after deposition. There are no systematic differences in kaolinite content in such sandstones from lowstand system tracts (LST) and highstand system tracts (HST), whereas only river mouth sandstones from HST have early siderite cement. Contrary to other studies, we find little impact of sequence stratigraphy on diagenetic minerals except in the transgressive system tract (TST). Rather, lithofacies and the supply of detrital Fe exert a strong influence on both seafloor and eodiagenetic minerals, which in turn influence mesodiagenesis.

Visible/Infra-Red Spectrometry (VIRS) in economic geology research: some pilot studies from Newfoundland and Labrador

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Many common minerals exhibit characteristic absorption spectra for visible and infra-red electromagnetic radiation, and VIRS techniques can identify them and place general constraints on their compositions and relative abundances in natural samples. VIRS is ideally suited to the study of alteration assemblages, in which minerals are commonly very fine grained or entirely cryptic, and may be difficult to identify from petrography. Portable VIRS instruments are now used extensively in mineral exploration and mining for varied applications, but are not yet standard tools in research-oriented studies. The Geological Survey of Newfoundland and Labrador acquired an ASD Terraspec Pro® VIRS instrument in 2008, and is now applying it to a variety of problems.

The acquisition of VIRS data is extremely easy and rapid, to the point where proper organization of results and retention of their exact geological/locational context becomes a significant consideration. There are automated computer programs that can quickly identify the most abundant responsive mineral species in samples, but our experience suggests that a more systematic assessment of spectra, using human reasoning, is very important to extract the maximum possible amount of data and understand the significance of results. This is particularly true where samples contain more than one responsive mineral, which is commonly the case. As the method is to a large extent empirical, careful use of reference spectra is very important to ensure that minerals are not inadvertently con-

fused. As in conventional petrographic analysis, the first step in systematic assessment of results is knowing what to look for, partly on the basis of known geological associations between mineral species.

To date, several pilot studies have been completed in association with metallogenic studies projects. These include assessment of epithermal-like alteration assemblages in VMS systems, superimposed propylitic and potassic alteration facies in a Mo-Cu porphyry system, skarn-like alteration associated with uranium mineralization, and distinctive "spotty" alteration in sedimentary country rocks near mesothermal gold veins. Each investigation produced interesting results that illustrate the utility of the method, but each also raised some unexpected complications in interpretation of data. In short, these pilot studies provided valuable and illustrative learning experiences that allowed us to improve our systematic procedures for acquisition and interpretation of VIRS data. This rapid and easy technique clearly has great potential as a research tool in economic geology but, like any analytical method, it will always be most useful where it is constrained by other independent types of data such as petrography and lithogeochemistry.

Early post-glacial mass failures in St. Anns Basin on the Scotian Shelf, south of Cape Breton Island, Nova Scotia

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Gravity mass failures at the seabed in St. Anns Basin, offshore eastern Cape Breton Island, have been investigated with very high-resolution reflection seismic, sidescan and limited core, and multibeam bathymetric coverage. Quaternary mass failure features here are more abundant than in any other region of the Scotian Shelf and Grand Banks.

Most failures are rotational and/or translational slides with associated scarps, sidewalls, and depositional debrites. At least seven failure scarps are recognized on the basin flank and on topographic highs within the basin. They have associated depositional debrites occurring at the base of slopes exceeding 5° to 10°. Failure scarps are generally less than 10 m high with slopes exceeding 10° and have an amphitheater shape. They develop into chutes 1 km or less wide with run-out of <3 km. The parent material comprises stratified glaciomarine muds rapidly deposited from meltwater plumes. They are distributed on the basin flanks in thicknesses up to 25 m. Basinal equivalents are very thick (>50 m). Lobate debrites generally terminate in the thick glaciomarine sediments and structurally disturb them, both through loading with over-riding and through lateral and upward displacement. Locally block-sliding is recognized. These debrites can exceed 30 m thickness with volumes typically under 0.2 km^3.

Post-glacial muds cover the lower part of the failure scarp and the debrite. A stratigraphic marker identified elsewhere as associated with the Younger Dryas chronozone lies stratigraphically near the run-out toe of the debrite, indicating an early post-glacial failure age. All the failure deposits apparently lie at the same stratigraphic horizon suggesting that they are contemporaneous or penecontemporaneous. Sediment cores do not reach down to the debrite toe but radiocarbon dates on overlying marine muds yield an early Holocene age. Thus, timing between sediment deposition and failure is less than a few thousand years.

Basin margin faults reaching shallow strata (upper tens to hundreds of metres below the seabed) are recognized in the area. Though earthquake events are relatively small and infrequent, incidents here are greater than most areas of the Atlantic coast. A 4.6 ML event occurred during Christmas of 2006. Failure triggering in this setting and elevated seismicity, compared with other shelf settings is assumed to be seismicity-related. The timing is coincident with maximum isostatic adjustment. A similar but larger failure event on the eastern flank of the Laurentian Channel occurred at about the same time and may indicate a more widespread seismic affect. Other trigger mechanisms may include elevated shallow gas release rates, continued sea-level rise, and current erosion events. A controversial hypothesis of Younger Dryas meteorite impact on the North American continent and Laurentide ice sheet (c.f., J. Kenneth), would be sufficient to trigger mass failure.

The use of detrital rutile as a provenance indicator

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Detrital rutile, a polymorph of TiO_2, is one of the most stable heavy minerals during earth surface and diagenetic processes. It generally retains its original chemical signature making it useful in provenance determination. To improve the use of rutile for this purpose, a database of rutile grain compositions was created using high quality electron microprobe (EMP) analyses of trace elements. The trace elements selected for analysis were V, Cr, Fe, Nb, Ta, Zr, Hf, Mn, and Mo, with analysis times ranging from 150 to 600 seconds on peak and 75 to 300 seconds on background.

The morphology and texture of analyzed grains was recorded using backscattered electron (BSE) images. To better distinguish between diagenetic and detrital rutile, a set of criteria was compiled by comparing till and river sands from the Appalachians with offshore Cretaceous sandstones that have experienced diagenesis, but were derived from a similar source.

In addition, selected crystalline rock samples from Atlantic Canada have been examined.

Detrital grains of rutile are generally homogenous, lack alteration structures, and may show obvious signs of transport, such as edges that are rounded or broken and a deeply pitted surface. In diagenetic rutile, alteration structures such as parallel-oriented needles and ribbons are commonly seen. Diagenetic rutile may also contain kaolinite, show evidence for volume loss, have a wrinkled texture, or a lobate external form. Chemical variability within and differences between detrital and diagenetic rutile have been established using binary plots of selected trace elements coupled with statistical analysis of the data. The applicability of a widely used discrimination diagram (Cr vs. Nb) from the literature that provides fields for some metamorphic rocks has been extended with the addition of diagnostic fields for felsic igneous rocks, mafic igneous rocks, granulites, and low-grade metasedimentary rocks.

Future work involves applying this new information to determine the source and dispersion of Cretaceous reservoir sandstones in the Scotian Basin from a representative set of sandstones obtained from wells from different parts of the basin. Titanium-rich minerals are unusually abundant in the Scotian Basin and the equivalent fluvial Chaswood Formation and may have influenced reservoir quality.

Petrology of the mafic trigger of the Kos Plateau Tuff super-eruption, 0.16 Ma, Greece

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The Kos Plateau Tuff (KPT) eruption of 161 ka was the largest explosive Quaternary eruption in the eastern Mediterranean. It was derived from a caldera now subsided beneath the sea, just north of the active volcano of Nisyros Island, which was built since the KPT eruption. Approximately 10 km north of the caldera, on the south coast of Kos Island, we discovered a conglomerate of pumice cobbles and basaltic andesite pebbles immediately beneath the Kos Plateau Tuff at Akra Chelona. Sedimentological observations suggest that this conglomerate is an uplifted beach deposit of abraded pumice rafts that beached after the initial subaqueous phreatomagmatic phase of the KPT eruption. The presence of the beach with rafted pumice confirms the earlier interpretations of ready access of water to the early phases of the KPT eruption and of a paleoshoreline in the vicinity of Akra Chelona. The beach deposit implies a mean uplift rate of 0.6 mm/a since the KPT eruption, consistent with other neotectonic evidence in the region.

The rhyolitic pumice contains numerous pebble-sized inclusions of basaltic andesite, showing chilled margins that are highly lobate, suggesting co-existence of two magmas. The basaltic andesite is more primitive than any other mafic rock known from the Kos–Nisyros volcanic centre and contains phenocrysts of bytownite and Fo_{90} olivine, enstatite, and clinopyroxene. Many plagioclase phenocrysts show compositional zoning and spongy cellular (sieve) texture, with either (1) a spongy cellular core surrounded by a rim of clear plagioclase or (2) a clear core surrounded by a zone of spongy texture, and then a clear rim of plagioclase. Clinopyroxenes are augite, endiopside, or diopside, with cores with up to 6.6% Al_2O_3 and generally reverse grading (more Fe-rich cores). Groundmass amphibole suggests availability of water in the final stages of magma evolution.

Trace element abundances in the basaltic andesite samples with higher SiO_2 content suggest that they formed by mixing and assimilation of rhyolitic magma similar to that forming the pumice. In contrast, lithic clasts of andesite from high within the KPT deposit have lower concentrations of compatible elements such as Mg and Cr, suggesting that they were derived from more fractionated older lavas surrounding the vent. Nd isotope compositions of ε_{Nd} = +1.7 (basaltic andesite) and ε_{Nd} = -0.3 (pumice) are consistent with previous interpretations that much of the felsic component of the KPT resulted from partial melting of juvenile underplated basal crust.

Acoustic mapping of the Bay of Fundy between Maces Bay and Passamaquoddy Bay

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Extensive melt-water complexes were deposited along coastal areas of New Brunswick during the late Wisconsinan deglaciation (~14–12 ka B.P.). The Pennfield- Pocologan delta complex occurs along the coast of the Bay of Fundy in the Maces Bay and Passamaquoddy Bay area. These deltas may extend into the Maces and Passamaquoddy bays. The area exhibits geomorphological features formed during the Wisconsinan glaciation and deglaciation. High-resolution seismic profiles provide information on the deglaciation and its effect on the offshore geology.

In 2006 the Geological Survey of Canada (Atlantic) (GSCA), in conjunction with the Canadian Hydrographic Services and the Ocean Mapping Group (OMG) at University of New Brunswick, commenced a three year program to map the Bay of Fundy. Sub-bottom profiler and multibeam bathymetry data were collected simultaneously to provide information on the character and thickness of the subglacial features and overlying sediments on the sea floor.

Several marine shore surveys conducted by GSC and the OMG examined near-shore geology of the Bay of Fundy. High-resolution seismic sub-bottom and multibeam bathymetry were collected from 1992 to 2008 aboard various platforms including the CCGS Frederick G. Creed, CCGS Matthew, and the CSL Heron. The acoustic mapping instruments used in this study include a 3.5 kHz Knudsen 320M Marine Echosounder, Kongsberg EM1000, Kongsberg EM1002, Kongsberg EM3002 multibeam, and Kongsberg EM 710 bathymetric survey systems.

Preliminary results will be presented here for the surficial geology between Saint John and Grand Manan using 3.5 kHz seismic sub-bottom and multibeam bathymetry. Evidence of the low-stand of sea level, deltas, and other glacial landforms are expected to occur along the bottom of the Bay of Fundy underlying marine muds. In some areas pockmarks from gas-escape features confuse the data and make interpretation difficult.

The geology of mafic porphyry in the South Mountain Batholith, Nova Scotia

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The South Mountain Batholith (SMB) of southwestern Nova Scotia is a large (~7300 km²) composite, peraluminous batholith mostly ranging in composition from biotite granodiorite to muscovite-topaz leucogranite. Geological mapping has outlined numerous small bodies (mostly <100 m² to 1 km²) of fine- to coarse-grained, porphyritic rocks with high modal content of biotite and common metasedimentary xenoliths throughout the batholith. These rocks, termed mafic porphyry (MP), are minor volumetrically (~0.07%) but may provide insight into the early petrogenesis of the SMB. MP is mostly granodiorite to monzogranite in composition, with minor tonalite, and contains characteristic medium- to coarse-grained phenocrysts consisting of varying proportions of quartz, plagioclase, and alkali feldspar.

Several MP bodies lie at the margins of the batholith and have sharp intrusive contacts with adjoining granite phases and with the Meguma Supergroup (MSG). Other MP units are situated away from country rock contacts and typically have sharp intrusive contacts with other granitoid phases. These contacts are sinuous, ragged or lobate suggesting mingling of two magmas or crystal mushes of dissimilar composition. Numerous MP autoliths were noted throughout the batholith, mostly in granodiorite, but also in biotite and biotite-muscovite monzogranite units. MP autoliths typically contain abundant MSG xenoliths, even when observed in central regions of the batholith.

Modal concentrations of biotite vary widely in MP from 10–32%, although some bodies have a more restricted modal range (e.g. 15–20% in the Cloud Lake MP). Several MP bodies contain trace-2% reddish (almandine?) garnet. Muscovite is present only in trace amounts. The Boot Lake mafic porphyry contains trace (2%) andalusite. Several bodies and individual xenoliths have up to several modal percent sulphide minerals, including pyrite, pyrrhotite, and chalcopyrite.

Lithogeochemical analysis of MP rocks reveals a wide range in both major and trace element composition. A suite of samples from a large MP and granodiorite body in the north-central part of the SMB near Lake George underscores the compositional range in these rocks. Samples include biotite-rich MP with varying modal amounts of garnet and andalusite. The sequence is marked by large ranges in major element concentrations including 60.85–65.96% SiO_2; 4.89–7.64% Fe_2O_3; 1.12–3.21% CaO; 0.96–3.07% MgO; 0.68–1.06% TiO_2. Samples with the highest SiO_2 and the lowest Fe_2O_3, CaO, MgO, and TiO_2 closely resemble average biotite granodiorite of the entire batholith, whereas other samples have the lowest SiO_2 and highest concentrations of ferromagnesian and some 'compatible' elements (1101 ppm Ba; 209 ppm Sr; 338 ppm Zr; 27 ppm Sc; 65 ppm La) in the entire SMB.

MP rocks are interpreted as representing the first granitoids to crystallize in the SMB. The abundance of Meguma Supergroup xenoliths, coupled with the common occurrence of garnet, andalusite, and sulphide minerals, which are interpreted as xenocrystic or paraxenocrystic in origin, suggest that the MP is highly contaminated with MSG material. High concentrations of mafic minerals would result in higher specific gravity relative to other SMB rocks, resulting in 'sinking' of MP xenoliths as these rocks were subsequently intruded by more evolved granite phases.

"Passive" margin sedimentation and reservoir distribution along the Scotian margin

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A significant issue in recent hydrocarbon exploration in the deep water on the Scotian margin is the detection of reservoir rock. Existing models of deep water sedimentation have underestimated the linkages between shelf and slope sedimentation and the various roles of sea level, salt tectonism, and canyon formation as sediment transport pathways, mass failure and along-slope sediment transport processes in passive continental margin development. The overall consequence of these sedimentary processes is movement of potential reservoir rock to different locations and to greater depths than previ-

ously anticipated. The objectives of this study are to understand the complexities of shelf to slope sedimentation patterns using Neogene to Recent analogues in offshore Nova Scotia. Deciphering forcing functions, sediment pathways, and depositional processes are expected to improve exploration models for passive clastic margins. Investigation and analysis of these processes demonstrate that reservoir-grade sediments can be reworked, relocated, and transported to great water depths, and thus offer significant challenges to reservoir detection along the Scotian margin. A thorough understanding of the interplay and complexity of these processes is necessary to apply effective exploration models on passive margins.

Initial results suggest the following points. (1) Along the Scotian margin, canyons and mass-transport processes provide mechanisms for slope bypass and delivery to the rise and abyssal plain. Mechanisms of canyon incision are uncertain and may be related to deglaciation and eustatic sea level change, or in some cases relative sea level changes initiated by tectonic inversion. (2) Mass transport processes result in removal of stratigraphic section and transport of significant amounts of sediment downslope. (3) Some canyon and channels and their associated levee systems may contain reservoir quality sediments and provide conduits for downdip reservoir potential. (4) The presence of salt greatly complicates the margin. Mobile salt may provide significant trapping mechanisms and minibasin formation with sediment ponding, but may also complicate sediment pathways, destroy stratigraphic continuity, and cause mass failures through removal of lower slope buttress support. (5) Updip deltas and shelf margin deltas provide a source for downslope transport and sediment loading can contribute to mobilization of underlying salt. (6) Significant deep-water margin erosion occurred at certain periods, apparently related to development of strong along-slope bottom currents. This erosion may have led to undercutting of the base of slope, initiating sediment mass failure. These same currents produced large (10's km in wavelength) bedforms which may have reservoir potential and may force capture of down-slope sedimentation, perhaps generating local reservoir rock potential.

Lithogeochemistry of the Quebrada Blanca porphyry copper deposit, Atacama Desert, northern Chile

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Hypogene mineralization at the Quebrada Blanca (QB) porphyry Cu deposit is not well understood because the current resource includes only supergene enrichment mineralization. Nevertheless, it is likely that the geology of the supergene enrichment zone at QB can provide clues about the underlying hypogene lithologies, mineralization, and hydrothermal alteration. This project is investigating the geology intersected by nine drill cores from a NS cross-section at 19,600 m E through the QB open pit in order to understand the nature of hypogene mineralization, hydrothermal alteration, and the principle host lithologies at QB. Pre-existing major oxide lithogeochemical data (n = 7540), and new petrological and lithogeochemical data (n = 100) were examined to provide insight into: (1) the igneous and hydrothermal processes that produced the host rocks; (2) the nature of hydrothermal alteration and how host rock composition controls the resulting mineral assemblages; and (3) how weathering processes have affected hypogene rocks.

Three principle lithologies exist within the QB open pit. They consist of diorite that was intruded by quartz monzonite, and a suite of later, irregular plagioclase porphyry dykes associated with mineralization. The petrography of hypogene samples indicates the presence of minor propylitic alteration (mostly in diorite), weak to moderate potassic alteration overprinted by strong phyllic alteration in quartz monzonite, and potassic alteration in plagioclase porphyry. Phyllic alteration consists of quartz and sericite, the latter occurring incipiently replacing both igneous feldspar and feldspar formed during potassic alteration, within veins with quartz, and as polycrystalline masses replacing the igneous matrix. Intense phyllic alteration typically obliterates original textures in quartz monzonite. Potassically altered plagioclase porphyry units generally contain plagioclase altered to potassium feldspar.

Pearce element ratio analysis was undertaken using lithogeochemical data from pre-existing supergene samples. These data indicate that most historic samples are phyllically altered and that phyllic alteration at QB exhibits a range of quartz/muscovite ratios (from 1 to 3) that exhibit spatial patterns. Within individual phyllic alteration zones, quartz/muscovite ratios gradually increase from 1 in the southeast to 3 in the northwest. These zones are rooted along muscovite-rich northeast-southwest-trending faults from which phyllic alteration flares upward and to the southeast.

The tale of two shelves: palynology records of red tides off Nova Scotia vs. Ukrainia

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Red tides are harmful algal blooms (HABs) that include outbreaks of toxic dinoflagellates causing paralytic shellfish poisoning and human death. Increased frequency of red tide outbreaks in Atlantic Canada have been linked to shellfish farming, ballast discharge from ships, and or climate warming, but Canadian historical records are too short to verify these possible causes. Previous studies of Holocene sediment from Emerald Basin on the Scotian Shelf provide a centennial-scale

record of the history of red tides in the Atlantic Region for the past 10 000 years, and show that periods of greatest red tide frequency were linked to early Holocene sea surface warming. As part of the IGCP 521 program on the history of sea level and climate change in the Black Sea – Mediterranean Sea corridor, we are now beginning to apply this palynological technique to a decadal-scale study of the history of red tides in shelf sediments of the southwestern Black Sea. Initial results of a 9,000 yr palynological record shows that red tide outbreaks were largest during the relatively dry warm mid-Holocene thermal maximum. However, recent increases in the diversity of toxic dinoflagellates and HABs are linked to historical events recorded over the past 3,000 years in literary works ranging from Homer's Odessy (ca. 3,000 yr BP) and Strabo's histories (ca. 2,000 yr BP) to detailed scientific papers published over the past 30 years. Other changes are linked to palynogical evidence of deforestation as well as livestock and grain farming during the Bronze Age. As part of a new PhD study at Odessa National University named after I.I.Mechnikov, a description will be given of the collection and laboratory processing of >100 box core samples to provide a new palynological database for the Black Sea Shelf off the Ukraine. The data from the cross-shelf and long-shelf transects will allow future quantification of nearshore – offshore changes in assemblages and evaluation of the influence of freshwater discharge from large rivers such as the Danube, Dnieper, and Dniester on the paleoecology of the northern Black Sea Shelf.

^{40}Ar-^{39}Ar white mica ages reveal Neoproterozoic/Paleozoic provenance and an Alleghanian overprint in coeval Upper Ordovician-Lower Devonian rocks of Meguma and Avalonia

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^{40}Ar-^{39}Ar analyses (IR single grain, total fusion) of white micas from Upper Ordovician-Lower Devonian sedimentary strata in the Meguma (Annapolis section) and Avalon (Arisaig section) terranes of the Canadian Appalachians complement recent detrital zircon studies by providing constraints on local source areas and identifying the age of low-temperature (<350°C) events along this portion of the northern margin of the Rheic Ocean. In the Annapolis section, pre-depositional muscovite ages range in age from Cambrian to Early Ordovician but occur only in the arenaceous ca. 440 Ma White Rock Formation, reflecting the relatively inert behavior of the quartz sandstone compared to overlying argillaceous rocks. Pre-depositional ages of muscovites from coeval strata in the Arisaig Group range from Cambrian to Middle Ordovician. In younger Arisaig strata, detrital muscovite ages typically range from Late Neoproterozoic-Early Ordovician, but some are similar to the depositional ages of the formations. The detrital muscovites in both Annapolis and Arisaig sections are interpreted to have been derived from neighboring terranes (e.g. Ganderia) during the accretion of Avalonia to Baltica and Laurentia.

A remarkable outcome of the study is that many muscovite ages are significantly younger than the depositional age of the strata. They do not record the (middle-late Devonian) age of Acadian folding or adjacent intrusions, but instead preserve a precise age of (322.6 ± 2.1 Ma, 16 analyses). Although the sections sampled display no discernable evidence for Carboniferous tectonism, these ages are coeval with documented Alleghanian deformation in both Avalonian and Meguma terrane rocks and we interpret them to reflect distributed fluid flow coeval with dextral shear along the Avalon-Meguma terrane boundary.

Geochemistry of the Three Mile Plains uranium deposit, Nova Scotia

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Heavy metal mineralization occurs in the clastic and chemical sedimentary units of the Maritimes Basin, Nova Scotia, Canada. The Carboniferous MacCumber Formation contains carbonate-hosted Pb-Zn massive sulphide mineralization at Gays River, and the Devonian-Carboniferous Cheverie and Horton Bluff clastic rocks of the Horton Group host roll-front uranium mineralization at Three Mile Plains. These uranium occurrences are presently poorly understood, partly because of the uranium exploration moratorium that has been in effect for over 25 years. This study investigates the geochemistry of the Three Mile Plains uranium occurrence to determine what other metals exist in the deposit.

Over 1100 rock samples from 16 drill cores through the deposit, stored since 1979 at the provincial core storage facility in Stellarton, Nova Scotia, were analyzed by aqua regia digestion for 37 major and trace elements. Enrichments of elements other than uranium indicate that well-defined geochemical zoning exists in the deposit, and several of the elements exhibit anomalous concentrations (Mo, Cu, Pb, Zn, Co, Ni, As, Ag, Cd, Se, and V). The geometry of this geochemical zoning can be related to the primary and/or secondary permeability of the host rocks, illustrating the importance of authigenic and diagenetic reactions and their control on groundwater flow. Furthermore, petrographic observations suggest that the host rocks have undergone a complex history of oxidation, due to the influx of oxidized water, possibly during intense weathering episodes, and reduction, due to maturation of organic matter in the underlying Horton Bluff Formation. Petrographic data

do not preclude the accumulation of additional uranium mineralization today, derived from weathering of local rocks with anomalous uranium concentrations (e.g., the South Mountain Batholith, or even the Millet Brook uraninite vein deposit). Geochemical zonation within the Three Mile Plains deposit can be adequately defined once marker horizons within the Cheverie Formation have been identified and used to establish correlations within the host sedimentary sequence.

Results from this study have both local and regional importance. Many residents derive their domestic water from local wells that could be impacted by the presence of soluble heavy metals in the Horton Group. In addition, these strata exist throughout Eastern Canada, and thus geological features existing at Three Mile Plains could be widespread.

The relationship of transgressive systems tracts to sea-floor diagenesis, Lower Cretaceous, Scotian Basin

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Diagenesis in the Lower Cretaceous of the Scotian Basin is an important control on reservoir quality. Diagenetic processes include the effects of seafloor redox-controlled changes in pore-water and the re-mineralization of organic matter. The Lower Cretaceous rocks of the Scotian Basin are deltaic, with cycles of delta progradation with high sedimentation rates, capped by Transgressive System Tracts (TST) with low sedimentation rates. Seafloor diagenetic phases influence the entire diagenetic mineral assemblage, thus affecting reservoir quality. More so, these diagenetic mineral phases are commonly preserved where there is abrupt change in sedimentation rates, and also in coated grains found in the TST. This study assesses the role of seafloor diagenesis in the diagenetic system of the Lower Cretaceous of the Scotian Basin by studying the sedimentology, mineralogy, and geochemistry of TSTs and underlying sediments (defined as a sediment packet) from conventional core in two wells, Peskowesk A-99 (a proximal well, with 7 cores) and Thebaud C-74 (a distal well, with 6 cores). Cores were logged, photographed, compared with wireline logs, and sampled. Minerals were identified by petrographic microscope, SEM, and electron microprobe. Bulk geochemistry was determined by ICP-MS.

Several different types of TST are recognized, principally on the basis of the character of the TST sediments and the underlying depositional lithofacies. Some TST sediments include abundant shell fragments, others have very little siderite. Some overlie prodeltaic progradational facies, others overlie fluvial sediments capped by tidal flat facies or coastal marsh coals. The sediments in the studied TSTs include siderite cemented conglomerate, including intraclasts of reworked concretions, passing up into sandy mudstone, and eventually into black shales representing the maximum flooding surface (MFS). The TST sediments are strongly bioturbated. Most are characterized by the presence of glauconite and chlorite (identified by electron microprobe analysis), some coated grains, and the presence of patchy siderite. Geochemical data show concentration of phosphorus (P), sulphur (S), and strontium (Sr); a proxy for calcite, a few metres below the TST. The abundance of P appears to correlate with abundance of iron (Fe). Geochemically, the Lower Cretaceous sedimentary rocks of the Scotian Basin are unusual in having high titanium (Ti) and iron and very low calcium (Ca). As a result, the early diagenetic system is dominated by Fe minerals and locally by P. Mineral concentrations may result from the rapid change in sedimentation rate at the TST. The observed variation in mineralogy and geochemistry of the different TST packets can be tentatively related to their different facies associations and can be compared with modern sea-floor diagenetic systems in areas of high Fe availability.

Preliminary results from an ongoing study of acritarchs in Cambrian and Lower Ordovician rocks of Nova Scotia and New Brunswick

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Acritarchs have been used as biostratigraphic tools in the study of Cambrian and Ordovician successions in Newfoundland, but in contrast have been largely neglected in the study of rocks in this time span in Maritime Canada. Hence, we have initiated an ongoing collaborative study of acritarchs in classic Avalonian Cambrian and Lower Ordovician sequences in Nova Scotia and New Brunswick, as well as in age-equivalent units in the Meguma terrane. Most of the more than 200 samples collected from these areas have yielded acritarchs, and preliminary results indicate that these microfossils have potential to make significant contributions to stratigraphic comparisons and regional and global correlations.

Particularly well-preserved material was obtained from the upper part of the MacLean Brook Formation (early Late Cambrian) in the Mira River area of southeastern Cape Breton Island, including new species of *Stelliferidium* and the first record in Maritime Canada of the age-diagnostic *Pirea orbicularis.* These finds suggest that any stratigraphic gap between the MacLean Brook Formation and the overlying MacNeil Formation is smaller than previously interpreted. In the same area, the type section of the MacCodrum Formation (Early

Cambrian) yielded a low-diversity acritarch assemblage typical for the basal Cambrian *Asteridium tornatum-Comasphaeridium velvetum* Acritarch Zone in Poland and elsewhere. In New Brunswick, the classic Lower to Middle Cambrian Hanford Brook section yielded acritarchs throughout the sequence. The upper half of the Ratcliffe Brook Formation (Early Cambrian) contains *Archaeodiscina umbonulata* and abundant *Skiagia ornata*, *S. orbiculare*, and *S. scottica.* This assemblage of acritarchs has a first appearance close in time to the rise of trilobites, conflicting with the established view that all of the Ratcliffe Brook Formation is pre-trilobitic. The upper part of the Hanford Brook Formation (late Early Cambrian) yielded well-preserved material of *Comasphaeridium silesiense*, *Heliosphaeridium notatum*, *Eliasum llaniscum*, and *Liepania plana*, taxa with a first appearance close to the base of the Middle Cambrian. Further studies of the Hanford Brook section promise to help constrain the age and regional correlation of the *Protolenus elegans* Trilobite Zone, which at present are problematic.

In the Meguma terrane of southern Nova Scotia, acritarchs have been recovered from various levels of the Halifax Group in sections at Bear River and Black River. Preliminary identifications include several species of *Acanthodiacrodium*, *Veryhachium*, and probable *Stelliferidium trifidum,* consistent with the Tremadocian age for this unit inferred from the sparse graptolite record, but the study of acritarchs offers the possibility for better constraints on the age of the upper part of the Halifax Group.

Structural evolution and deformation of the Caledonian Highlands, New Brunswick: a preliminary model

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The Caledonian Highlands comprise a deformed continental magmatic arc formed over a period of some 70 million years during the Late Neoproterozoic. The oldest component is the arc itself, which is represented by ca. 620 Ma clastic, volcaniclastic and volcanic rocks of the Broad River Group and co-magmatic plutonic rocks of the Point Wolfe River plutonic suite. These rocks are overlain by volcanic, volcaniclastic, and clastic rocks of the Coldbrook Group, deposited between 560 and 550 Ma, and intruded by a suite of plutonic rocks of similar age. Geochemical studies imply that the Coldbrook Group formed in a post-arc extensional setting. The youngest component of the Caledonian Highlands is the Cambrian-Early Ordovician Saint John Group, a shallow water marine succession of fine- to coarse-grained clastic rocks and minor carbonate rocks. Two regional unconformities separate these three components.

Preliminary studies in a major high-strain zone that crosses the Caledonian Highlands from NE to SW demonstrate a complex history of deformation. Earliest deformation produced augen gneiss and foliated granite in the Point Wolfe River plutonic suite, and textures in these rocks imply fabric development under subsolidus conditions in the cooling plutons. The implication is that earliest deformation began soon after intrusion of these rocks and probably prior to deposition of the Coldbrook Group. Progressive non-coaxial deformation in this high-strain zone, consistent with north-over-south thrusting, affected both the plutonic rocks and the Broad River Group, imposing a strongly transposed 'grain' and obscuring original stratigraphy.

Deformation in the Coldbrook Group imposed a regional fabric that is more heterogeneous in expression than in the older Broad River Group but that shares both overall geometry and the sense of north-over-south thrusting. This deformation generated major overfolds with isoclinal profiles overturned to the south. Cambrian-Ordovician Saint John Group rocks share this history of folding and thrusting.

In the Big Salmon River area the main high-strain zone also contains other fabrics, such as a sporadic shallowly inclined lineation indicating a strike-slip component to deformation. In the same area the zone forms a boundary between a section to the south where a very restricted Coldbrook Group assemblage (only the Seeley Beach, Hosford Brook, and Silver Hill formations) is preserved, and a section to the north where all the Coldbrook Group succession is preserved. The implication is that this high strain zone served as an extensional fault during Coldbrook Group deposition.

Dating this deformation history at present consists of data providing maximum and minimum constraints. The age of the Point Wolfe River plutonic suite (ca. 620 Ma) is the maximum, and if initial deformation of the plutonic rocks was subsolidus, then the actual age of initial deformation cannot be substantially younger than this. The interleaving of Saint John Group with the Coldbrook and Broad River groups by thrusting and isoclinal folding must have been post-Early Ordovician. $^{40}Ar/^{39}Ar$ ages from muscovite at two locations in the high-strain zone indicate cooling after this deformation to be advanced by mid-Devonian time (ca. 390 Ma).

Developing a geoenvironmental model for Canadian orogenic lode gold deposits

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Without appropriate environmental management controls and regulatory guidelines, the mining and milling of gold can result in significant risks to the environment and human health. Orogenic lode gold deposits, in which gold is hosted mainly by quartz-carbonate veins, occur in deformed greenstone and metasedimentary terranes around the world. These deposits are the main source of gold in Canada, and are presently the focus of considerable exploration and development. The purpose of this study is to develop a geoenvironmental model to describe the environmental behaviour of orogenic lode gold deposits through the exploration, mining, and post-closure phases of their development.

From 2006 to 2008, samples of stream water, sediment, waste rock, tailings, and mine drainage were collected around the past-producing Bralorne, King, and Pioneer gold mines in British Columbia. Together, these three mines represent the largest historical gold producer in the Canadian Cordillera (>4.15 million ounces Au between 1932 and 1971). Samples were also collected from several antimony (Sb) and mercury (Hg) deposits in the Bridge River Mining District, which may represent the epizonal portions of the Bralorne-Pioneer gold system. Metal (loid) concentrations in waters and sediments upstream and downstream of historical mine sites throughout the district demonstrate that the environmental impacts of past operations are generally restricted to the immediate vicinity of former mines. Background concentrations of arsenic (As), Hg, and Sb in stream sediments range from 3–82 mg/kg, 9–2700 µg/kg, and 0.16–2.0 mg/kg, respectively. In contrast, historical tailings and rock flour associated with recent mining have much higher concentrations of As (220–13 000 mg/kg), Hg (49–29 000 µg/kg), and Sb (2–700 mg/kg). The highest Hg concentrations occur in tailings at former mill sites where Hg was used for gold amalgamation, and in stream sediments at an abandoned Hg mine (Hg>100 000 µg/kg). Background concentrations of As, Hg, and Sb in filtered stream waters throughout the district ranged from <0.1–2.6 µg/L, 0.56–3.3 ng/L, and 0.03–0.43 µg/L, respectively. Dissolved concentrations of As and Sb were typically much higher in waters draining from mine workings, whereas the concentrations of Hg were relatively low (<12 ng/L) in all waters sampled. Drainage from the main portal of the Bralorne Mine contains high concentrations of As (~2300 µg/L). Ongoing measurements of the effluent chemistry and flow rates are providing a better understanding of processes controlling As release from this mine.

The results of this study will be combined with data from recent studies of gold mines in Nova Scotia and across Canada to develop a geoenvironmental model for orogenic lode gold deposits. This model will assist industry and regulators in understanding the key environmental characteristics of this type of ore deposit, and will help to minimize the environmental impacts associated with past, present, and future gold extraction.

The German Bank pluton, offshore SW Nova Scotia: age, geochemistry, and regional significance for the Alleghanian orogeny

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Permian plutonism is widespread in the US Appalachians, but has not previously been recognized in Canada. The German Bank pluton, offshore southwestern Nova Scotia, was previously sampled by short boreholes. Two rock types were distinguished: (1) a magnetite-bearing granite with no equivalent on land; and (2) an ilmenite-bearing granite similar to the ca. 363 Ma Seal Island granite. Previous $^{40}Ar/^{39}Ar$ dating of biotite from magnetite granite gave a total-gas age of 254 ± 7 Ma. In this study, U-Pb ID-TIMS dating of chemically-abraded zircons from a borehole sample of magnetite granite gave an intrusion age of 300.0 ± 0.4 Ma, at the Carboniferous–Permian boundary. Additionally, electron-microprobe dating of monazite yielded an age of 308 ± 13 Ma.

Other evidence of Alleghanian tectonism is widespread on the Scotian Shelf. Previously published whole-rock K-Ar ages on Meguma Group metasedimentary rocks from the Naskapi N-30, Argo F-30, and Wyandot E-53 wells are 300 ± 19 Ma, 302 ± 19, and 302 ± 10 Ma, respectively, and a previously published $^{40}Ar/^{39}Ar$ plateau age on biotite from the Mohawk B-93 well is 321 ± 1.6 Ma. The significance of the Alleghanian orogeny on the Scotian Shelf may thus be greater than previously appreciated.

To extend the lithological range of samples from the German Bank pluton, additional granite samples have been obtained from winnowed thin glacial till overlying an extensive area of bedrock outcrop of granite imaged by multibeam bathymetry. Geochemical analysis shows that the German Bank magnetite-bearing granite is a high Sr-Ba granitoid, with both trace elements steadily decreasing with increasing SiO_2. Such granitoids are characteristic of settings involving shoshonitic volcanism.

We suggest that the Sr-Ba granitoid plutonism at German Bank resulted from melting of lower crust and/or lithospheric mantle by a rising asthenospheric diapir related to slab detachment or tear following the final stages of closure of the Rheic Ocean. Such slab detachment has been previously suggested as the origin of the similar Permian granites in the southern US Appalachians. For the US Appalachians, subduction was to the southeast, so that plutons have Nd isotope compositions influenced by Grenvillian crust. Late Paleozoic plutonism in the Canadian Appalachians was dominated by northwestward subduction of the Rheic ocean, also prevailing in Europe, so that Saharan crust was thrust under the Meguma terrane, resulting in the more strongly negative Nd isotopes of the German Bank pluton. The boundary between these two subduction domains would have been characterized by the lateral margin of the sub-

ducted lithosphere (a slab tear) and was thus a favoured site of asthenospheric upwelling. Such upwelling may later have been responsible for the mid-Triassic alkalic dykes of the Central New England province, also found in SW Nova Scotia.

Holocene stratigraphy and micropaleontology of an urban lake, Dartmouth Nova Scotia

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Lake Banook in central Dartmouth, Nova Scotia, has been one of the major waterways for local transportation in the past, as Halifax and Dartmouth developed; however, little work has been done on the geological history of this body of water. Here, reflection seismic, multibeam bathymetry, and sediment cores have been used to investigate the late glacial and Holocene history of the lake. Interpretations of high-resolution seismic data (10 kHz profiler) and six short sediment cores (maximum 1.2 m) are presented together with preliminary data on thecamoebian assemblages. Six seismic facies have been defined in the 12 m thick sediment column, interpreted from the base up as glacial till, two glaciolacustrine units, mass failures, and two Holocene units. Lowstands are identified from unconformities, and the cores are correlated using the seismic interpretations. The cores sampled the upper glaciolacustrine unit and both of the Holocene units, generally across the unconformity. The glaciolacustrine (varve-like) unit is locally unconformably overlain by a reddish-brown, poorly stratified sandy diamict, overlain in turn by a series of dark brown post-glacial muds. Thecamoebians, freshwater protozoan microfossils, provide the opportunity to develop a viable paleoenvironmental interpretation since they can be indicators of former eutrophication, water depth, terrigenous influence, and brackish water influence, all of which could have occurred since the end of the last glaciation.

Quaternary geology and till geochemistry of the Grand River map area (NTS 21O/05), northwestern New Brunswick

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During the 2004 and 2006 field seasons the New Brunswick Department of Natural Resources, conducted a till geochemical survey in the Grand River map area (NTS 21O/05) in northwestern New Brunswick. A total of ninety seven C-horizon samples, all basal till, were collected. Approximately 75 pebbles were collected at each site to determine glacial transport distances. Sampling was done on a rough 4 km spaced sampling grid, following standard NBDNR-GSB protocol.

The NBDNR geochemical laboratory in Fredericton processed the till samples and separated splits to produce two subsamples, one for determining the sand/silt/clay size fractions and the other for the geochemical analysis. From a fine fraction split (0.063 µm) of each till sample a suite of 37 elements (Ag, Al, As, Au, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Te, Th, Ti, TI, U, V, W, and Zn) was analyzed at an external laboratory by inductively coupled plasma mass spectrometry (ICP-MS). A 1:50 000 scale basal till sample site location map with ice flow indicators, including bedrock geology, will be produced. The results will be published as a New Brunswick Department of Natural Resources Open File Report.

The study area is mainly covered by a till blanket with an average thickness of 1 m. The till blanket is absent (sporadic) in some parts of the study area. The lithological and geochemical results indicate that the till is locally derived (<1 km transport distance). Some geochemical anomalies could warrant further analysis (Cu, Co, Cr, Mg, Ni, and U), especially in the southeastern part of the region underlain by Ordovician Boland Brook Formation sedimentary rocks. A strong correlation (≥0.5) exists between Zn and Ni, and Co and Mn. The only observed glacial striations are located in the southwestern part of the Grand River area and they indicate an east-southeast and west-northwest (113°–293°) ice flow. Stoss-and-lee landforms, for example Quisibis Mountain, support these directions. Some pebbles and boulder erratics from eastern Quebec and the Canadian Shield were observed in the west part of the region, suggesting glacial transport from the northwest.

The birth and death of Quaternary turbidity currents: what those who study turbidites on land need to know

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Modern marine studies show the varied ways in which turbidity currents can be born. All die and deposit as their energy (derived principally from gravity) diminishes to the point where sediment can no longer be maintained in suspension. Fundamentally, turbidity currents require an initiation process that disperses a plentiful supply of sediment with water and a sufficient gradient for flow to be maintained.

Numerous local studies have proposed initiation mechanisms for turbidity currents, based either on sparse real-time

data for historical flows or on inferences based on the age and contemporary paleogeography, erosional features, and depositional record of well-studied Holocene and late Pleistocene flows. Three major types of initiation processes are recognized: (1) sediment failure (slumping or landsliding) involving liquefaction of granular sediment and breakup of more cohesive sediment on pre-existing steep slopes, with retrogressive failure sustaining turbidity current flow for many hours; (2) direct hyperpycnal freshwater flow of rivers and sub-glacial meltwater, occurring on various scales and with various sediment types and concentrations; and (3) oceanographic processes that suspend shelf sediment may lead to flows down canyons and channels. Fallout of mud from plumes or shelf-edge re-suspension in storms may also concentrate sufficiently to form organised turbidity currents.

The initiation process determines the duration of the turbidity current, ranging from tens of minutes for short lived surges from sediment failure, to many hours for flows evolved from retrogressive failures or oceanographic processes on the shelf, to days for some direct freshwater flows and perhaps weeks for flows from muddy plumes. The initiation process determines whether flows are highly turbulent and erosive, or have a hyperconcentrated basal portion, or form short-lived surges. Highly turbulent flows are characteristic of oceanographic initiation processes, of prolonged flows evolved from retrogressive failures or plume fall-out, and of some less concentrated hyperpycnal flows. Hyperconcentrated flows are characteristic of high-bedload freshwater discharge and failure and liquefaction of sandy sediment leading to surgesHighly turbulent flows tend to flush out conduits and deposit sediments on low gradients of the basin plain. High-concentration flows deposit preferentially in conduits and on steeper gradients (<0.4°) on the mid fan or at the foot of slope, or in ponded slope basins. Conduit flushing is an under-appreciated process and accounts for the majority of sediments in some megaturbidites. It explains why the volume of megaturbidites is much greater than the volume of sediment transport in a single river flood.

In most basins, there is a complex feedback between different types of turbidity current initiation, the transformation of the flows, and the associated slope morphology. As a result, there is no simple relationship between initiating process and type of deposit. Understanding the variability of initiation and flow processes provides a basis for interpreting depositional facies in ancient rocks.

Triassic core stratigraphy of the Wolfville Formation in the Bridgetown area, Nova Scotia and associated uranium in groundwater

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The town of Bridgetown, Nova Scotia, is considering switching its fresh water supply from surface water to groundwater to help lower operational and maintenance costs. Preliminary chemical analysis of the groundwater has shown elevated uranium concentrations. The purpose of this study is to determine if the source of uranium in the groundwater is within the Triassic Wolfville Formation aquifer, which underlies the Bridgetown region. Drill core from Paradise, near Bridgetown, and well cuttings from the test wells at Bridgetown were analyzed and logged to better understand the stratigraphy of the Wolfville Formation and to determine which, if any, horizons has elevated uranium that can be leached in the groundwater. Gamma logging of the Paradise drill core indicates that some layers within the core have twice the background levels of radiation, suggesting that the Wolfville Formation may indeed be the source of elevated uranium in the groundwater.

Using LiDAR-derived digital elevation models to identify areas of unregulated surface mining in the Sydney Coalfields of Cape Breton Island, Nova Scotia, Canada

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Cape Breton Island is well known for its long-lived coal mining industry. When mining was at its peak, small-scale unregulated and unauthorized ('bootlegged') surface mining was common. Families or community groups would manually dig pits (approx. 1–3 m in diameter) at a coal outcrop or along a seam and extract coal for personal use. These pit locations have not been recorded and now represent a significant risk to personal safety and a potential conduit for groundwater contamination.

A LiDAR (Light Detection and Ranging) survey was completed in June 2008 in three study areas where unauthorized mining was known to have occurred, in order to identify and characterize these pits. The LiDAR point data was used to generate digital elevation models (DEMs), which are accurate to within 2.5 cm. Unauthorized surface coal pits were found in five distinct locations based on visual interpretation of the hillshade of the DEMs combined with the Nova Scotia coal seam shape digital maps. The pits occur primarily in a linear distribution along the mapped coal seams. The shortest string of pits measures roughly 350 m in length and the longest is nearly 900 m. Each pit is roughly circular in shape, and is filled with water up to approximately 50 cm below the surface, thus giving no indication as to the actual depth of each pit. The land between each pit exhibits some topographic relief (approximately 1 m at most), producing a somewhat mottled appearance in the DEMs.

The occurrence of acid mine drainage in the northernmost study area highlights a problem of groundwater seepage to the surface resulting in contamination from runoff. Further

research will include using the LiDAR-derived DEMs to map surface drainage characteristics and identifying potential locations of surface acid drainage.

The Golden Promise deposit, central Newfoundland: structurally controlled, mesothermal, auriferous quartz veins in the Upper Victoria Lake Supergroup

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The Golden Promise gold deposit is located ca. 10 km southwest of the community of Badger in central Newfoundland. The initial discovery, by prospector William Mercer, consisted of coarse-grained, comb-textured, and stylolitic quartz boulders exposed on sub cropping ridges, from which a composite sample from ~10 boulders assayed approximately 30 g/t Au. The deposit has since been explored under a number of joint venture agreements involving Rubicon Minerals, Paragon Minerals, Placer Dome, and Crosshair Exploration. A 2008 NI-4101F1 resource calculation on the deposit outlines a total of 921,000 tonnes averaging 3.02 g Au/t (89,500 contained ounces of gold), with a cutoff grade of 1 g/t Au. Golden Promise represents the first significant gold discovery in this part of central Newfoundland, where low-grade sedimentary rocks were previously considered non-prospective.

The gold mineralization is located within 070–090°-trending quartz vein systems hosted by fine-grained clastic sedimentary rocks of the uppermost Victoria Lake Supergroup. These are dominated by grey, tan, and black siltstones and mudstones, intercalated on a decimetre- to decametre-scale with poorly sorted, medium- to coarse-grained, plagioclase-rich greywackes containing abundant mudstone clasts. Collectively the sequence fines upwards and is capped by black, pyritic Caradocian shales. The sedimentary package is cross-cut by 2 sets of dykes: (1) fine-grained, buff-grey, plagioclase porphyritic intermediate dykes with chill margins; and (2) medium-grained sheared and chloritized gabbroic dykes locally exhibiting chills and commonly cut by quartz veins. Both sets are typically sub parallel with, and occur proximal to, the main quartz veins.

The main Au deposit, termed the Jaclyn Zone, comprises a series of steeply-dipping, roughly E-W-trending stylolitic and massive comb-textured quartz veins containing abundant free gold and trace pyrite, arsenopyrite, pyrrhotite, sphalerite, and galena. High-grade zones range up to 4 m, but individual mineralized veins are typically <1 m in thickness. The veins are mantled by variable but thin (<2 m) selvages of quartz-chlorite ± sericite alteration developed in the host siltstones and plagioclase-rich greywackes. A distinct, "bleached spot" texture is developed in host siltstones up to 10 m away from the veins. Field, drill hole and limited petrographic information suggest that the mineralized systems at Golden Promise are comparable to turbidite-hosted gold mineralization of the Meguma Zone in Nova Scotia and those of southeastern Australia. Future work will incorporate $^{40}Ar/^{39}Ar$ geochronology, regional and downhole lithogeochemistry, mineral geochemistry, and fluid inclusion studies. These will emphasize the relationships between the vein systems and two generations of co-spatial mafic dykes and will examine the origin and distribution of the notable "spotty" alteration in the host rocks which may provide a vector towards such mineralization.

Origin of garnet in the Liscomb Complex, north-central Meguma terrane, Nova Scotia

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The Liscomb Complex, north-central Meguma terrane, consists mainly of ca. 373 Ma granitoid rocks with subordinate metasedimentary rocks. Detailed bedrock mapping in the 2008 field season, combined with aeromagnetic maps, showed that the metasedimentary rocks are correlative with formations mapped elsewhere in the Goldenville and Halifax groups of the Meguma terrane, in particular the distinctive manganiferous coticule-bearing Beaverbank Formation, the uppermost unit of the Goldenville Group. Garnet, up to 3 cm in diameter, is abundant in contact-metamorphosed Beaverbank Formation and its enclaves in the granitoid rocks, as well as in the granitoid rocks themselves. The purpose of this project is to investigate the origin of garnet in the granitoid rocks of the Liscomb Complex, in particular the relationship of the garnet to magma contamination by the Mn-rich country rocks of the Beaverbank Formation.

Based on petrographic examination of garnet shape and texture, combined with preliminary results of analyses by electron microprobe, four different types of garnet have been tentatively identified. Garnet of type 1 occurs in both metasedimentary and granitoid rocks, and contains inclusions of country rock minerals (quartz, biotite, and plagioclase). Type 1 garnet is subhedral to euhedral, has moderate Mn content (8–14 wt.% MnO), and is zoned, with higher Mn cores and lower Mn rims. This garnet is of inferred regional metamorphic origin, and hence in granitoid samples is of xenocrystic origin. Larger type 1 garnet crystals may have formed by coalescence of smaller type 1 garnet grains as a result of energy constraints

during metamorphism. Garnet of type 2 is similar to type 1 in shape, inclusion mineralogy, and compositional zoning but has higher Mn (~19–28 wt.% MnO), and occurs mostly in metasedimentary samples but possibly in some granitoid samples. Type 2 garnet is interpreted to be of contact metamorphic origin. Garnet of type 3 occurs only in granitoid samples. It is typically euhedral and has zoning similar to that of contact metamorphic type 2 garnet grains but with lower Mn (~8–16 wt.% MnO). It contains abundant inclusions of quartz, plagioclase, apatite, biotite, and ilmenite, and is of inferred peritectic origin, meaning that it crystallized from partially melted manganiferous country rock. Garnet of type 4 is euhedral and low in Mn (2–5 wt.% MnO). It is zoned, with lower Mn core to a higher Mn rim, and contains inclusions of igneous minerals (plagioclase laths, elongate apatite). Type 4 garnet occurs only in tonalitic granitoid samples and is interpreted to be of primary magmatic origin. The preliminary results of this study suggest that contamination by the manganiferous Beaverbank Formation was a major factor in producing the unusually garnet-rich granitoid rocks of the Liscomb Complex.

The geography of first human habitation in Nova Scotia

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The Debert/Belmont archaeological site (DB) is the oldest site of human habitation in eastern Canada. The key problems of the site from a geological perspective can be summarized as follows. (1) what is the origin of the surface (surficial) materials, landforms, and soils at Debert? The interpretation of the sediment hosting the artifacts has profound implications for the reconstruction of paleoenvironments. (2) What are the stratigraphic relationships between the surface materials, soil units, and the artifacts at the Debert site? (3) What is the timing of first occupation in relation to the Younger Dryas (YD); a catastrophic cooling event at the end of the last glaciation? (4) How do geological units that span the Allerød/YD found in sections throughout Nova Scotia correlate to strata associated with artifacts at the Debert site? (5) What is the nature and timing of natural and manmade disturbances of the postglacial soil sequences that would affect the zone of artifacts at Debert?

Artifacts and spruce charcoal at the DB site are found within a massive sand unit and are YD in age based on stratigraphy and radiocarbon dates done in the early 1960s. Recent data obtained on buried soils and lakes near Debert and elsewhere in Nova Scotia show a pronounced warming during the Allerød (15–13.0 ka), with soil formation and abundant radiocarbon dates, then cooling and a gap in radiocarbon data during the YD (13.0–11 ka). Pollen associated with hearths at the DB site suggests open woodland, but recent studies show that the area during the YD was either under ice or periglacial shrub tundra. A solution to this paradox may be that artifacts and charcoal/hearths are late Allerød in age, reworked by debris flows during the YD and Holocene pedogenic processes.

Geochemical profiling as an indicator of potash in Windsor Group evaporites in the Sackville Subbasin

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The characteristics and depositional history of Windsor Group evaporites of the Pugwash Mine and Limekiln Brook formations, occurring in the Sackville Subbasin of southeastern New Brunswick has not been examined in detail. Results from drill holes near Dorchester indicate substantial thicknesses of halite, but demonstrate little or no direct evidence for potash mineralization. To date, the geochemical signature of the halite cuttings from these holes has not been determined.

The distribution of bromine in marine evaporites has been shown to provide very useful information in interpreting paleosalinities in evaporite basins. It is considered an important diagnostic tool in determining whether a salt deposit is in its original depositional condition or whether significant recrystallization and other post depositional changes have occurred affecting its primary mineralogic and textural characteristics.

Geochemical profiles, including the distribution of bromine are to be studied from evaporite drill cuttings from the Dorchester area. These will be compared with bromine profiles from stratigraphically equivalent, potash-bearing Windsor evaporites in the Moncton Subbasin, near Sussex. It is important to determine if depositional conditions within the western half of the Sackville Subbasin were favourable for the precipitation and preservation of potash mineralization.

Mineral Liberation Analysis (MLA) study of detrital mineralogy of the Appalachian hinterland to the Cretaceous Scotian Basin deltas

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Understanding dispersal patterns of the Cretaceous rivers

that supplied heavy minerals to the Lower Cretaceous deltaic reservoir sandstones of the Scotian Basin is hampered by the lack of regional information on mineral characteristics in potential source areas. Identifying detrital sediment provenance is also hampered by parallelism of the Appalachian terranes to the margin of the Scotian Basin, so that recognition of early Ordovician or mid Devonian monazite or zircon is not particularly diagnostic of source. In this study, we have attempted to identify the occurrence, character, and abundance of distinctive heavy minerals in the Appalachian hinterland that are also found in Cretaceous sandstones offshore. Samples from modern river sands (derived principally from erosion of tills and outwash) and local Pleistocene stony tills are used to obtain mineralogical samples from Appalachian source rocks on a regional scale. Selected Carboniferous sandstones were sampled to evaluate the character of polycyclic detrital minerals, in particular to determine whether any textural parameters such as size, shape, or roundness of minerals might be useful as an indicator of polycyclic compared with first cycle origin.

Chemical variation diagrams from our present database of >4000 Cretaceous offshore heavy mineral analyses define different chemical types of garnet, tourmaline, zircon, spinel, monazite, amphibole, biotite, and muscovite. These chemical types were then used as the basis for classifying, identifying, imaging, and counting the same mineral types in potential source rocks using the Mineral Liberation Analysis (MLA) facilities at the Inco Innovation Centre at Memorial University, through the cooperation of Paul Sylvester and Michael Schaffer.

Preliminary results show that many of the mineral types recognized in the offshore Cretaceous rocks can be matched to similar minerals in samples collected on land. Some minerals identified as relatively abundant on land are sparse or absent offshore. Different types of spinel and garnet, for example, on land have different size modes despite almost identical densities, suggesting that size is inherited from source rocks. Subsequent size sorting during transport may concentrate or diminish the abundance of particular types of garnet or spinel. Simple shape measures such as aspect ratio, angularity, and shape factor do not appear dependant on sample type (till, river, unconsolidated rock, crushed rock), but aspect ratio empirically allows the proportion of zircons of different ages to be estimated.

The data suggest that it will be possible to match many offshore heavy minerals more precisely and faster to sources and to evaluate the role of sorting in determining offshore mineral assemblages. Identifying criteria for polycyclic vs. first cycle minerals appears more challenging.

Revised surficial geology mapping based on LiDAR, Halifax, Nova Scotia

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In 1846 Louis Agassiz — en route to Boston from Europe where he developed the idea of continental glaciation — recognized the first 'glacial markings' in North America near Halifax Harbour. Since then, the area's glacial geology has been mapped based on air photos and the Quaternary history developed from striae records, drumlin orientations, and numerous coastal sections that cut through drumlins. Now, thanks to a LiDAR survey by the Halifax Regional Municipality, spectacular images of the area's glacial geomorphology features, especially drumlins and flutings, allows for improved surficial mapping and new insights into the glacial history of the area.

Subtle variations in drumlin orientation and shape are clearly defined on the LiDAR imagery; variations that were not possible to discern on air photos. LiDAR allows for identification of previously unmapped features such as eskers and small drumlins that can be used to interpret the glacial history. Downice of one zone of drumlin-free granitic bedrock is an area of landforms transverse to ice-flow. Geomorphologically these landforms can be compared to interpretations of hummocky-active ice moraine in Finland, or Rogen moraine formed along the boundary of sliding to non-sliding ice in northern Canada.

Northeastern Appalachian geology project: combining small-scale digital geological maps from disparate sources

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This presentation is the result of an investigation into the difficulties that today's geologists might encounter when attempting to combine into a single project several public-domain State/Provincial and Federal computer-based geological maps. The project area extends from Maine to Newfoundland and includes both the onshore and offshore. The main term of reference for the project was to use the data as obtained via the web and/or in digital format from the relevant organizations and not edit the available maps and/or databases in any significant way. The software used for this project is "Carta for Geology", a GIS-based mapping system developed and marketed by CARIS. This software is designed to create geological map files and to incorporate in its layered structure different map formats in their native language without translation. The final result of the project will be a web-enabled, 1:5 000 000 scale, coloured geological map for part of the Northeastern Appalachian area, classified by Era. The map can be queried further on its stratigraphy.

The maps were obtained in either ESRI Shapefiles or CARIS format. All maps, except for Maine, included a database on the stratigraphy either in .dbf or .xls. Microsoft Access was used to create a stratigraphy database for Maine from data supplied by the Maine State Geological Survey. Similarly, the digital geo-

logical map and database for Prince Edward Island had to be created as part of this project.

The main difficulty was the lack of uniformity in the way the attribute data was organized and displayed in the respective databases. Solving the problem required insertion of a new field, named ERA, in each of the databases. Prior consultation and agreement between the relevant organizations on naming-issues and a common geological terminology would have been helpful. Creating a standardized database format would have simplified cross-border incongruities of the project and also would allow the display of several colour-classified maps instead of just one (e.g., Rock Type, Age, etc.).

A Welsh Meguma? Comparison of the Meguma Supergroup of Nova Scotia with the Harlech Dome succession of North Wales

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The Meguma Supergroup of southern mainland Nova Scotia is an Early Cambrian to Early Ordovician deep-water peri-Gondwanan succession. The base is not seen, but isotopic and geochronologic evidence suggest broadly 'Avalonian' basement. The lower part of the succession (Goldenville Group) comprises relatively quartz-rich, thickly bedded turbidites and interbedded green slates. Abundant turbidite structures indicate sedimentation continuously below wavebase, and the great thickness of the succession attests to major subsidence. The trace fossil *Oldhamia* indicates Early Cambrian age. At the top of the group the stratigraphy is more diverse; alternating finer and coarser units show enrichment in manganese and spectacular bioturbation. A rare trilobite-bearing horizon indicates Middle Cambrian age. A unit of manganiferous laminated slate marks the transition into the overlying Halifax Group. The overlying Cunard Formation comprises rusty-weathering black pyrite-rich slate, siltstone, and sandstone with turbidite structures. Higher parts of the group possibly show a transition to shallower water conditions, with more abundant trace fossils, and rare Tremadocian graptoloids. The group is overlain with angular unconformity by the Early Silurian White Rock Formation.

The succession in the Harlech Dome in North Wales is also an Early Cambrian to Early Ordovician deep-water peri-Gondwanan succession. Underlying basement is not seen but drilling has revealed 'Avalonian' volcanics in the subsurface. The lowest part of the Harlech Grits Group comprises Early Cambrian cross-bedded, probably deltaic sandstones which pass up into fully marine slates. The overlying Rhinog Formation consists of relatively quartzose thickly bedded turbidites and green slates. Abundant turbidite structures indicate sedimentation continuously below wavebase, suggesting significant subsidence. At the top of the group the stratigraphy is more diverse; alternating finer and coarser units show enrichment in manganese and spectacular bioturbation. Rare trilobite fragments indicate Middle Cambrian age. A unit of carbonaceous laminated slate marks the base of the overlying Mawddach Group. The overlying Maentwrog Formation comprises rusty-weathering black pyrite-rich slate, siltstone, and sandstone with turbidite structures. Trilobites indicate Late Cambrian age. Higher parts of the group show a clear transition to shallower water conditions above wavebase, with linguloid brachiopods and trilobites indicating Tremadocian age. The group is unconformably overlain by the Early Ordovician Rhobell and Aran volcanic groups.

Lithological and chronological analogies between the two successions are striking. However, significant differences include: (1) the greater thickness of the Meguma succession; (2) the presence of shallow marine to non-marine strata at the base and top of the Harlech succession; (3) the possible presence of an unconformity between the two groups in Harlech; and (4) the presence of volcanics near the base and top of the Welsh succession. Nonetheless, the similarities indicate closely similar evolution for the two basins, and would be consistent with deposition in connected parts of a peri-Gondwanan rift system.

Opportunities for geoscience students to apply geomatics techniques to mapping and exploration programs in northern Canada

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A new Geo-mapping for Energy and Minerals program (GEM) has been initiated by the Government of Canada to provide geoscience information necessary to guide investment decisions leading to the discovery and development of new energy and mineral resources of Canada's north. Part of this 5 year, $100 M program involves the harnessing of new technologies to help provide more timely geological information in the form of digital maps and mineral resources assessments. This involves the use of geomatics technologies, including GIS, remote sensing, and GPS to compliment traditional geological mapping techniques. This "Remote Predictive Mapping" utilizes various types of geoscience data and analysis procedures to provide geologists with predictive maps before they embark on field work. It also helps focus their activities on areas that have more complex signatures in the field.

For example, key outcrop locations can be determined from such mapping prior to field work. When combined other information, such as geophysics or remote sensed data, this can reduce the number of traverses required in order to define

the contact between two units. Additionally, remote predictive maps can be updated in the field and also offer first-order geologic information in areas that cannot be mapped in the field. The lack of vegetation cover and the generally good rock exposure in the north makes it an ideal location to utilize optical and radar satellite data and imagery to differentiate different rock units, based on topographic and colour variations resulting from different mineral groups and their associated weathering patterns.

Several funded opportunities exist for geoscience graduates wishing to continue their studies at the Centre of Geographic Sciences (COGS) in Nova Scotia, where these geomatics tools can be applied to traditional fields of science. Natural Resources Canada, through the Research Affiliation Program (RAP), is seeking students with geomatics skills to participate as information officers in the summer field camps, as well as to work on geomatics research projects at COGS or joint geoscience MSc (Geomatics Research or Earth Sciences) research projects between COGS and local university earth science departments. The application of geomatics techniques to aid traditional geological mapping reflects the new methods of compilation and preparation prior to and during fieldwork. People with these combined skills (geology & geomatics) are in high demand.

Ground penetrating radar transect of the Gilbert-type, glaciomarine Pocologan delta, southwestern New Brunswick

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The Pocologan delta is one of several glaciomarine delta complexes in southwestern New Brunswick that formed where large meltwater drainage systems discharged into the Bay of Fundy during Late Wisconsinan deglaciation (~14–12 ka BP). Post-glacial rebound has exposed the delta and its extensive sand and gravel aggregate resources. In August, 2007, ground penetrating radar (GPR) and seismic refraction surveys were acquired over the delta to investigate its thickness and stratigraphy. The study was motivated by interest in exploring how geophysical methods could be used to help assess the extent and quality of New Brunswick's granular aggregate resources.

GPR profiles following the general paleo-drainage direction were acquired along the entire length of an unimproved road that extends 5 km south from Route 780, from a point 100 m east of the Pocologan River. Orthogonal profiles were collected in adjoining blueberry fields, and seismic refraction surveys subsequently targeted features observed in the GPR data. Instrumentation included a GSSI SIR System III GPR unit employing 100 and 200 MHz shielded monostatic antennas, and a 36-channel Geometrics Geode seismic system with a sledgehammer source. In June, 2008, we returned to the site with a Mala GPR system employing a pair of 50 MHz unshielded, rough terrain (RTA) antennas arranged in an in-line configuration.

Previous geological investigations had suggested that the Pocologan deposit could be interpreted as a Gilbert-type delta with: (1) topsets comprising horizontally stratified outwash gravel, cobbles, and sand deposited by meltwater streams flowing on the delta surface; (2) foresets consisting of dipping beds of sand and fine gravel that were deposited in the subaqueous environment at the distal margin of the delta; and (3) bottomsets consisting of silt and clay. The GPR profile confirm this general model, revealing well defined topset, foreset, and bottomset stratification with foreset beds exhibiting apparent dips of up to 18 degrees. Fluvial scour and channel-fill deposition, as well as enigmatic zones of chaotic, discontinuous reflections and diffractions are also observed. The water table was evident as a strong GPR reflection and distinct seismic refraction, varying in depth from 3.5 to 13 m in August, 2007. GPR surveys penetrated up to 25 m in the northern third of the study area but were unable to image the bedrock surface – possibly due to signal attenuation in electrically conductive bottomset beds or underlying glacial till. Seismic refraction surveys indicate that overburden is underlain by bedrock having a high P-wave velocity (~5000 m/s) and significant topography, at depths ranging from 25 to 50 m.

The Liscomb Complex, Meguma terrane, Nova Scotia: basement or urban legend?

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In 2008, a detailed (1:10 000 scale) bedrock mapping and sampling project was initiated in the Liscomb area in the central Meguma terrane to better constrain the metamorphic and structural history of the area. The oldest units exposed in the area are the Late Neoproterozoic to Early Ordovician Goldenville Group and overlying Halifax Group. The lower part of the Goldenville Group is the metasandstone-dominated Taylors Head Formation, whereas the upper part consists of the distinctive manganiferous coticule-bearing metasiltstone of the Beaverbank Formation. Units in the overlying slate-rich Halifax Group are the Cunard Formation and overlying Glen Brook Formation. These units are similar to those established elsewhere in the Meguma terrane. The metasedimentary units

are deformed into regional, east- to northeast-trending F_1 folds with well-developed axial planar cleavage (S_1), produced during the Devonian Neoacadian Orogeny. Intersection lineations (L_1) plunge gently to the northeast and southwest. Deformation was accompanied by greenschist-facies (biotite-grade) metamorphism.

A suite of ca. 375–370 Ma igneous units intruded the Goldenville and Halifax groups in the Liscomb area. They include: (1) tonalite to quartz diorite with magma-mingling textures, and minor gabbro; large garnet crystals are locally abundant; (2) granodiorite with magma-mingling textures and tonalitic enclaves; (3) coarse-grained to megacrystic biotite-muscovite monzogranite; (4) medium- to coarse-grained muscovite monzogranite; and (5) fine- to medium-grained muscovite monzogranite to syenogranite. These plutons produced a narrow contact metamorphic zone, 200–400 m in width, consisting of spotted hornfels to granofels containing sillimanite, andalusite, cordierite, ± garnet, and ± staurolite superimposed on biotite-zone regional metamorphic assemblages.

The results of this project do not support previous interpretations of the presence in the Liscomb area of basement gneissic units with upper amphibolite- to granulite-facies metamorphic assemblages. Units previously identified as gneiss appear to be igneous units with magma-mingling textures or superimposed protomylonitic fabric. No extensional structures were observed to support the previously proposed core-complex scenario. Therefore we propose that the term 'Liscomb Complex' should be abandoned.

Seismic Rayleigh wave method for imaging subsurface cavities

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Subsurface anomalies, such as cavities, faults, unknown tunnels, etc., can cause public safety hazards. Recent developments using seismic Rayleigh waves allow us to detect and image subsurface anomalies. Instead of using the conventional spectral analysis of surface waves (SASW), or the multichannel analysis of surface waves (MASW), we developed a strategy to isolate Rayleigh waves from raw field data, and apply wavelet transforms to pair-channel analysis of the Rayleigh wave data for dispersion calculation. Finally, a simple steady inversion technique was applied to yield shear velocity as a function of both depth and distance, i.e. shear velocity field (SVF) images.

The technique was tested at three locations in Nova Scotia with different geological settings: (1) moderately dipping coal seams in the Stellarton coalfield; (2) steeply dipping gold-bearing veins in the Waverly Gold District; and (3) horizontal strata in Liverpool. The results from the seismic surface wave technique introduced in this research are in agreement with field observations, documented history, and borehole logs. The satisfactory interpretations and success of these trials means that the Rayleigh wave technique for determining the SVF is a valid technique for shallow subsurface investigations.