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Atlantic Geoscience Society

A B S T R A C T S

2008 Colloquium & Annual General Meeting

DARTMOUTH, NOVA SCOTIA

The 2008 Colloquium and Annual General Meeting were held at the Holiday Inn Harbourside, Dartmouth, Nova Scotia, on February 1 and 2, 2008. On behalf of the society, we thank Colloquium Chairs Michael Parsons and Jennifer Bates and their organizing committee (Sonya Dehler, Grant Ferguson, Martin Gibling, John Gosse, Elisabeth Kosters, Nelly Koziel, Mike MacDonald, David Mosher, Rob Naylor, Georgia Pe-Piper, Lawrence Plug, Anne-Marie Ryan, John Shimeld, Deb Skilliter, Ian Spooner, Charlie Walls, Chris White, Graham Williams, and Reg Wilson) for providing an excellent meeting. We also wish to acknowledge support of the corporate sponsors: Nova Scotia Department of Energy; Canadian Space Agency; Potash Corporation of Saskatchewan; Natural Resources Canada; Nova Scotia Department of Natural Resources; Corridor Resources Incorporated; Geological Association of Canada; Mining Association of Nova Scotia; New Brunswick Department of Natural Resources - Geological Surveys; and Natural Sciences and Engineering Research Council of Canada.

In the following pages, we are pleased to publish the abstracts of oral and poster presentations from the Colloquium, which focused on the following themes: Soil Geochemistry: Influences of Genetic and Environmental Factors; Mineral Deposits Research; Dendrochronology; Climate Change; Sediment Dynamics, Oceanography and Ecology of the Greater Bay of Fundy, Scenarios Resulting from Tidal Power Development; Geochronology: Timing, Timescales, and Tempo of Crustal Processes; Earth-based Studies of Planetary Surfaces; Education in the International Year of Planet Earth; and Current Research in the Atlantic Provinces.

THE EDITORS

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A Raman and X-ray absorption spectroscopic investigation of the structure and speciation of aqueous zinc bromide solutions at hydrothermal conditions

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A Raman spectral study was carried out on three aqueous solutions of varying concentration and bromide/zinc ratio. Spectra were collected at 11 different temperature-pressure conditions ranging from ambient to 500°C and up to 0.9 GPa. Raman band assignments for aqueous zinc bromide complex species reported in previous studies were used to determine the relative concentrations of $ZnBr_4^{2-}$, $ZnBr_3^-$, $ZnBr_2$, and $ZnBr^+$ species at various temperatures and pressures. Our results are in close agreement with X-ray absorption spectroscopic (XAS) data, and confirm that the tetrabromo zinc complex, $ZnBr_4^{2-}$, is the predominant species up to 500°C in solutions having high zinc concentrations (1 *m*) and high bromide/zinc molar ratios ([Br]/[Zn] = 8). This result is consistent with the observed predominance of the $ZnCl_4^{2-}$, complex in chloride-rich fluid inclusion brines at high temperatures. In agreement with previous solubility and Raman spectroscopic experiments, our measurements also indicate that species with a lower number of halide ligands and charge are favored with increasing temperature in dilute solutions, and solutions with low bromine/zinc ratios ([Br]/[Zn] < 2.5). Raman and X-ray absorption spectroscopy are complementary techniques that were used in this study to obtain speciation and structural data on aqueous zinc bromide solutions at elevated temperatures and pressures. Furthermore, we show that Raman spectroscopy, in some cases, may be used to independently evaluate XAS data obtained from high temperature disordered systems such as supercritical fluids.

Pleistocene landscape evolution of the southern Central Andes quantified with cosmogenic nuclide techniques

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Landscape evolution studies depend critically on the quantification of long-term denudation rates. These are difficult to obtain in active mountain belts, because sediments are normally rapidly eroded in these environments. Terrestrial in situ cosmogenic nuclides (^{10}Be and ^{36}Cl) have been used in this study in different ways to estimate denudation rates in the southern Central Andes of Chile. An inventory of large bedrock involved landslides, with a chronology supported by ^{10}Be and ^{36}Cl exposure dating provides reconstructed sediment volumes to estimate denudation rates from landslides during the Pleistocene. Simultaneously, ^{36}Cl basin-wide average erosion rates were obtained for small catchments inside the same area. Both long-term (10^3–10^6 a) estimates were compared to short-term estimates based on suspended sediment records for the last 30 years.

Rates of denudation of ~0.1 mm/a were obtained using the landslide inventory data, similar to the ^{36}Cl basin-wide average erosion rates (0.15–0.23 mm/a). The estimations from suspended sediment records for the last 30 years show variable values, depending on their position along the orogen, between 0.03 to 0.15 mm/a. As accumulation inside the range is minor, there are two possibilities that can explain these observations, setting aside scale differences for the studied areas. Although for one area all estimates are similar within uncertainty, for others present day sediment transport by large rivers is out of equilibrium with long-term transport. The system might be currently transport-limited but during the Pleistocene it must have had periods of increased sediment discharge. A second alternative is that the bedload component of sediment transport needs to be incorporated more precisely into the estimations from suspended sediment records. Application of three bedload transport theoretical formulations to major rivers of the region supports this asseveration, suggesting that in this environment bedload can represent up to 80% of the sediment transport.

The future for geology –3D interactive data: an example from the Sussex area of the Moncton sub-basin, New Brunswick, Canada

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The fault-bound Moncton sub-basin in southern New Brunswick is part of the larger Maritimes Basin which extends throughout much of eastern Canada. It is within this sub-basin that the potash deposit mined at Penobsquis occurs. In 2001 a new potash discovery was made in the Picadilly region just

south of the Penobsquis mine. This discovery initiated a potash exploration program that involved drilling, 2D seismic, 3D seismic, airborne EM, and analysis of existing gravity data. These data were analysed and integrated to create a spatially accurate regional model of all formations in the Sussex area of the Moncton sub-basin. This regional geological information is considered important for understanding the processes that created / altered the observed potash mineralization in this area. Initial surfaces of formation interfaces were created from seismic reflections and regional geological maps. Underground surfaces were calibrated using borehole data and deep layers lacking drillhole pierce-points were calibrated using surface gravity data. The process of creating these surfaces, constrained using all available data, will be described. The current best-fit model of each geological interface in the basin will be shown, formation-top by formation-top, and in cross-section, using real-time, interactive, and 3D visualization software.

Field relations, structure, and provenance studies of Cambrian rocks in the Saint John area, southern New Brunswick

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Cambrian sedimentary rocks in the Saint John area of New Brunswick are assigned to the Saint John Group, and divided into (from oldest to youngest) the Ratcliffe Brook, Glen Falls, Hanford Brook, Forest Hills, Kings Square, Silver Falls, and Reversing Falls formations. The lowermost four formations are preserved only in fault-bounded slivers along the northern and, to a lesser extent, southern margins of the Cambrian belt in Saint John, and in folds associated with thrusting in the Mystery Lake area. Most of the exposed area of the Saint John Group is intensely folded Kings Square Formation. The overlying Silver Falls and Reversing Falls formations are preserved only locally in synclinal keels. The Ratcliffe Brook Formation is age-equivalent to the Chapel Island Formation in eastern Newfoundland and likely extends back into the Ediacaran Period of the Late Neoproterozoic. Redbeds in the Ratcliffe Brook Formation differ from similar rocks in the underlying Seeley Beach Formation of the Coldbrook Group (equivalent to the Rencontre Formation of eastern Newfoundland) in containing abundant detrital muscovite and less abundant pyroclastic material. New $^{40}Ar/^{39}Ar$ data from the detrital muscovite indicates a maximum age of ca. 620 Ma, and a minimum age of 550 Ma. The depositional age of the upper part of the Ratcliffe Brook Formation is constrained by a U-Pb (zircon) age of ca. 531 Ma from an ash horizon, previously published by Isachsen and others. As originally defined, the overlying Glen Falls Formation consisted of grey to white quartz arenite and overlying black phosphatic and glauconitic quartz arenite. Based on paleontological evidence, only the white quartz arenite is considered to be equivalent to the lithologically similar Random Formation of eastern Newfoundland, whereas the upper phosphatic and glauconitic part is included with the Hanford Brook Formation. Laser ablation MC-ICPMS analysis of 100 detrital zircons from the white quartz arenite in the Glen Falls Formation yielded a nearly unimodal age population with a peak at ~540 Ma, similar to the age of zircon grains in the dated ash unit in the underlying Ratcliffe Brook Formation. The age of the Hanford Brook Formation is constrained to Late Early Cambrian by fossils and also by a U-Pb (zircon) age of ca. 511 Ma from an ash horizon, previously published by Landing and others. The unconformably overlying Forest Hills Formation is mainly shale, equivalent to the Middle Cambrian Chamberlains Brook and Manuels River formations in eastern Newfoundland. The Kings Square Formation consists of interbedded, muscovite-rich, fine-grained sandstone, shale, and siltstone, and is equivalent to the Middle to Upper Cambrian MacLean Brook Group of Cape Breton Island. The overlying Upper Cambrian to lower Ordovician Silver Falls and Reversing Falls formations have been assigned to the Chesley Drive Group by some other workers. Nd isotopic data indicate that the provenance changed during deposition from more juvenile sources in the Seeley Beach, Ratcliffe Brook, and Glen Falls formations to more evolved sources in the Late Cambrian part of the sequence.

Metallogenic and Tectonic Significance of mafic volcanism in the Early to Middle Jurassic Hazelton Group, northwestern British Columbia

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The Hazelton Group comprises the youngest pre-accretionary rocks of the Stikine terrane in NW British Columbia. The group is dominated by several successions of Early to Middle Jurassic subaerial and submarine calc-alkaline island-arc volcanic and sedimentary rocks. One of them, the Salmon River Formation (SRF), which represents a brief period of volcanic activity at the boundary between the Aalenian and Bajocian, is compositionally distinct. The SRF is host to three economic VMS deposits, including the world class Eskay Creek Ag-Au and base metal deposit, as well as over 60 other VMS prospects. The Formation is preserved as several fault-bounded erosional remnants or separate sub-basins along a 200 km belt. The ba-

sins are filled with thick piles of pillow and pillow breccia basalt with minor amounts of rhyolite and sedimentary rock. Unlike other volcanic successions of the Hazelton Group, the SRF basalts are not accompanied by intermediate volcanics; they are island-arc tholeiites with a back arc basin affinity. There are two distinct varieties of the SRF basalt: type 1 basalts have a slight negative Nb anomaly accompanied by a slight depletion of the most incompatible elements, a flat REE pattern and absolute incompatible element abundances similar to MORB; type 2 basalts have moderate negative Nb and Ti anomalies, enrichment of the most incompatible elements, and a negative LREE slope. Epsilon Nd values for the basalts cluster between +3 and +4 (n=4) and between +6 and +7 (n=3). Type 1 basalts are the most juvenile isotopically; their +6 to +7 epsilon Nd values are unusual and represent a derivation from a more juvenile source than typical subduction-related basalt, whereas positive 3 to 4 epsilon Nd values of type 2 basalts are typical of Stikine Terrane island-arc volcanic rocks. Decompression melting of asthenospheric mantle is responsible for the type 1 basalts, whereas varying influences of subduction-modified lithospheric mantle account for the characteristics of type 2 basalts. The SRF basalts are critical to the formation of VMS deposits: i) heat from hypabyssal mafic magma bodies drove hydrothermal convection; ii) metals were scavenged from basalt in the volcanic pile; and iii) basalt caps the deposits aiding in preservation. The SRF has characteristics consistent with other VMS bearing bimodal-mafic dominated sequences (e.g., Kidd Creek and Noranda); it is associated with extensional, syn-volcanic structures and has geochemical features that are consistent with an extensional tectonic environment. Exploration for VMS deposits in the Hazelton Group should focus on a) targeting tracts of thick basalts; b) determining the structure of the depositional basin (i.e. syn-volcanic, graben or half-graben bounding faults); and c) geochemical analysis to determine the basalt characteristics. Only type 1 basalts are associated with known economic deposits in the SRF.

Evidence from LiDAR and multibeam data of post-glacial relative sea level change in the Bay of Fundy region, Nova Scotia

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The post-glacial isostatic and eustatic history of the Bay of Fundy region is poorly resolved. Ongoing landscape evolution combined with the macrotidal shoreline environment complicates both the identification and resolution of indcators of past sea level. Research in ice sheet modeling, tidal power development, Mi'kmaq habitation patterns, and coastal erosion dynamics requires a better understanding of relative sea level change in the region. To date, few paleoshoreline features have been recognized and those that are known to exist exhibit little continuity making the resolution of isobases for the region problematic. In this study, LiDAR (Light Detection and Ranging) data have been combined with multibeam bathymetric data in order to identify both submerged and exposed paleoshoreline features along the North Mountain from Brier Island to Cape Split.

As paleoshoreline features (beaches, deltas, terraces etc.) have specific geomorphic form, methods that are being employed include using surface profiles to examine the lateral continuity between raised shoreline features, detailed slope analyses, lineament identification, and surface roughness coefficient discrimination. Preliminary results indicate that discrete shoreline features are best developed in association with paleo-drainage corridors. Linear features (beaches and terraces) are most commonly evident where glaciogenic deposits are extensive. At a number of sites multiple terraces indicative of episodic isostatic or eustatic adjustment are evident on LiDAR imagery. Multibeam imagery shows promise in resolving discrete low stand shoreline features and ice sheet dynamics.

The challenge of collaborative environmental geoscience

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The nature of environmental geoscience challenges the geoscience community to better its interaction with the public. Researchers need to be ready to discuss their scientific results and to address questions about non-geoscience topics such as implications for human health risk and property assessment values. Perhaps what is not as obvious, although equally important, is the need to accurately convey the same science to collaborators from other disciplines in multi-partner projects. Partners in these science teams initially need to define the problem to be addressed. Perhaps this is the first challenge of the group. Then, the varied aspects of the study must be divided up among the specialists in the team. Delineation of the responsibilities is critical and could require negotiation. All partners need to agree on the ways by which the results will be shared among project members, and how these can be integrated to better understand complex natural systems. Generating a common understanding of terms and processes that will act as a foundation for communication can be a learning experience for all. The science collective also needs to decide how it will address society's right to know and the anticipated questions from the public. Material prepared for specific audiences, appropriate venues, timeliness, and informed and media-savvy presenters are key factors. For many projects, conveying sci-

ence to politicians of various levels, community leaders and regulatory agencies can be an important requirement. While the level of language is often similar to that of the public audience, these groups likely have a specific focus and objective and have an interest in the information that matches their mandate. This poster will introduce some of the challenges faced by the interdisciplinary, multi-partner project team investigating the environmental impacts of historical gold mines in Nova Scotia.

Erosion-induced reactivation of the Main Central Thrust zone: Comparison of model results with tectonic and thermochronologic data

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Recent thrust-sense deformation in the vicinity of the Main Central Thrust (MCT) zone in the Himalaya of central Nepal can be attributed to tectonics, erosion, or a combination of both. In the same area, contrasting cooling-age patterns in medium- and low-temperature thermochronometers have been interpreted to imply a recent (2.0–0.9 Ma) significant increase in erosional exhumation rates, likely attributable to recent climate changes. No comparable evidence exists for changes in local plate convergence rates. We use numerical models with constant convergence velocity but contrasting erosion rates to show that increased erosion and recent thrusting may be directly connected. In the models, increasing erosivity by a factor of 3 over 3 Ma fundamentally changes the style of deformation, reactivating the dormant model MCT system in the region corresponding to observed thrust faults. The high-erosion model also reproduces the observed cooling-age patterns, whereas the equivalent low-erosion model does not reproduce either observation. Other model predictions, and their implications for the effects of increased erosion on the southern flank of the Himalaya, include: 1) no associated reactivation of normal faulting on the South Tibetan Detachment (STD) system; 2) enhanced upper-crustal extension in the vicinity of the north Himalayan gneiss domes (NHGD); 3) reinvigorated mid-crustal channel flow beneath the NHGD; 4) possible destabilization and wholesale southward flow of the upper crust between the MCT and NHGD, with the potential for catastrophic earthquakes. The first three questions are testable and address the persistent question of the existence and current location of the low-viscosity channel. In particular, the model predicts that it has been stagnant beneath the Tibetan plateau under a relatively low-erosion regime, but has been, or could be, reactivated by more aggressive erosion driven by climate change. The potential for destabilization of the south flank of the orogen has important geological and societal implications.

MicroCT analysis of mineral phases, total and effective porosity in the Abenaki Formation, Scotian Shelf offshore eastern Canada

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Ongoing research on petroleum reservoirs offshore Nova Scotia includes analyses of carbonate material from the Abenaki Formation utilizing MicroComputed X-ray Tomography (microCT) a non-invasive procedure for imaging the internal structure of opaque objects. This method records spatial variations in the X-ray attenuation coefficient caused by mineralogical and porosity variations in a rock. The large differences between the attenuation of X-rays by solids, relative to that of air (i.e. pore space), ultimately permits the imaging and quantification of interparticle-, intraparticle- and fracture-porosity in a sample.

To date 22 core fragments from 6 wells, namely Panuke H-08, Panuke IA/1, Demascota G-32, Acadia K-62, Margaree F-70 and Albatross B-13, have been sampled in the form of small plugs approximately 11 mm in diameter. A variety of carbonate textures have been sampled in order to identify limitations and error ranges under differing analytical conditions using a Skyscan 1072 MicroCT scanner, with spatial resolution of approximately 10 µm. Textures include intercrystalline limestone with pinpoint vugs, stylolites, inclusions and fractures (H-08), intercrystalline limestone to dolomitic limestone with vugs (Panuke IA/1), intercrystalline limestone to dolomitic limestone having pinpoint vugs (G-32), intercrystalline dolomitic limestone with vugs in association with horizontal fracturing, oolites, pisolites and sporadic stylolites (K-62), intercrystalline limestone to dolomitic limestone with vugs, with sporadic fractures and stylolites (F-70) and pelloidal, oolitic lime grainstone, with intercrystalline pore cement (B-13). With reference to effective porosity, preliminary analysis of sample plug 12 from Panuke H-08 with bulk porosity of ~8% shows an average of 4.44% effective porosity. This means that approximately 50% of the total pore space (for this sample) that are sufficiently interconnected to provide conduits for fluid movement.

Carbonate samples tend to have a limited number of mineral phases present. This leads to the additional possibility of quantifying each phase by recognition of discrete grey-scale values. Preliminary microCT scans of a hydrothermal dolomite were undertaken at relatively low X-ray energy (< 100 keV). At such energies the photoelectric effect is primarily responsible for attenuation and the attenuation coefficient is a function of the effective atomic number (Z_{eff}), with attenuation increasing

with Z_{eff}. Consequently, as well as total and effective porosity, carbonate mineral grains that are sufficiently large to be resolved by the instrument, and display contrasting Z_{eff} can be distinguished. In this case, the contrast in Z_{eff} between calcite (15.88) and dolomite (13.94) is sufficient to distinguish between the two minerals, though the presence of iron in ferroan dolomite decreases the Z_{eff} contrast.

Communicating the natural and cultural history of the Joggins Fossil Cliffs: A demonstration of innovation and collaboration.

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Paleontology is highly relevant to the modern and future world as this discipline can provide the public with an understanding of the depth of earth history and an ethic that includes, at its core, long-term stewardship for planetary wellness. Specifically, the grand exposure of the Joggins Fossil Cliffs offers an opportunity for the public to understand the Carboniferous Period of the Earth's history where a significant evolutionary milestone is recorded. The Cumberland Regional Economic Development Association and three levels of government have collaborated to establish the Joggins Fossil Institute to present, promote and manage the Fossil Cliffs through a state of the art research and interpretive centre. The Joggins Fossil Institute has addressed challenges in communicating volumes of often complex scientific knowledge to varied audiences in a short period of time. In collaboration with various stakeholders and concurrent with an application for UNESCO world heritage site designation, interpretive planning and design was conducted to define the approach to telling the story of the natural and cultural history at Joggins. Interpretive planning promoted free choice learning through varied delivery mechanisms. As a result, audiences are not alienated as underlying evidence is presented in many ways and support individuals in developing their own conclusions. The Institute has developed educational materials that permit the teaching of science in a way that prepares lay people to not only understand geology but to also approach it critically. Ongoing research at the new Joggins Fossil Centre further supports visitors in appreciating the degree of uncertainty in Paleontology and engages those visitors in scientific methodology. Through integrating architectural and interpretive design processes, natural and cultural history is conveyed formally and informally. Scientists, educators, designers, and lay people provided validation of the messaging and approach in communicating the significance of the Joggins Fossil Cliffs in innovative, engaging and even fun ways.

The Early Jurassic Heracles Sequence, Scotian Basin, Canada: Recognition of a latest stage synrift / pre-breakup tectonic and sedimentary event

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Seismic profiles on the Scotian shelf, slope and abyssal plain offshore Eastern Canada reveal a previously unrecognized earliest Jurassic post-salt / pre-breakup stratigraphic succession. The Heracles Sequence is observed on the shelf margin as an eastward-directed infill succession within a series of half grabens having counter-regional, northwest-dipping boundary faults. On the slope, its inferred presence in the salt depocentre adjacent to the basin hingeline is masked by a thick wedge of later Mesozoic and Cenozoic sediments and salt structures. In deep water, it is recognized as a poorly-imaged but apparently extensive sequence between interpreted basement and the late Sinemurian breakup unconformity. At the eastern extremity of this region, it appears as westward-thickening wedges in highly rotated fault blocks.

The Heracles Sequence is interpreted as the product of the last phase of synrift tectonism prior to separation of the Nova Scotian and Moroccan conjugate margins in the late Sinemurian. Post-salt (early Hettangian) uplift of the mainland Nova Scotia shoulder region and the eventual rift spreading centre provided sources for sediments that prograded east- and westwards respectively into the main salt basin. Interpreted fluvial sequences advanced over marine evaporites ponding in depressions on a rifted basement setting and induced syndepositional halokenesis and the formation of salt-evacuation synclines. Where thin on the margins (especially near the future spreading axis), the salt provided a detachment surface and facilitated the observed high rotation on loading-induced fault blocks during a final uplift phase. This interpretation buttresses other geophysical evidence that suggests the underlying basement may not be oceanic crust, as previously proposed, but rather highly attenuated and fractured continental crust or serpentinized mantle.

The recognition of this late stage pre-breakup synrift sequence in the Scotian Basin offers important insights on this phase of the rifting process, and possibly its Moroccan conjugate and other margins. It thus has significant implications regarding the recognition of the continental crust and crustal boundaries, age and timing of syntectonic deposition and salt tectonism, original distribution and extent of marine evaporite sequences, timing and style of rifting, modelling of crustal heat flow, and petroleum systems attributes and modeling.

Silver-bearing alkali feldspars in experiment – and in nature?

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Most naturally occurring feldspars have compositions close to the fundamental K-Na-Ca plane, but other cations, such as Rb, Cs, Pb, Ba, Sr, and Ag, can extensively substitute for the alkali and alkali earth elements in the feldspar structure. Published low-temperature (ca. 300 ºC) ion-exchange experiments have produced pure end-member silver feldspar ($AgAlSi_3O_8$) from a natural sanidine starting material. New high-temperature (600 ± 50 ºC) synthetic granite melts can crystallize magmatic feldspars with a wide range of compositions ($K_{0.06\text{-}0.88}Na_{0.07\text{-}0.88}$-$Ag_{0.0\text{-}0.46}$), showing the familiar miscibility gap between the potassium-rich and sodium-rich end-members, and much lower maximum of Ag in the K-rich feldspars (~$Ag_{0.20}$) compared with the Na-rich feldspars (~$Ag_{0.46}$). The ability of alkali feldspar to accommodate Ag cations in its structure potentially makes it an indicator mineral wherever it occurs as a coexisting gangue mineral (e.g., albite, cleavelandite, adularia) in epithermal silver mineral deposits. If so, coexisting feldspars from epithermal silver deposits, such as in the Freiberg District of the eastern Erzgebirge in Germany, the El Barqueno District in Mexico, the Comstock Lode in Nevada, and the Debert Lake prospect in the eastern Cobequid Highlands, now require re-investigation to assess their potential as indicator minerals, even though their silver concentrations may not exceed the parts-per-billion level.

Lithogeochemistry of hydrothermally altered host rocks about the Amaranth low sulphidation epithermal gold-bearing quartz vein, Waihi, New Zealand

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The Waihi epithermal vein system is located at the southern end of the Coromandel Peninsula, on the North Island, New Zealand. It is the largest of ~50 known deposits in the Hauraki Goldfield, which hosts a number of producing and past-producing, low sulphidation epithermal gold- and silver-bearing quartz veins. Veins presently being mined in the Waihi area are hosted by Miocene to Pliocene volcanic rocks of andesitic to dacitic composition of the Coromandel Group. Two main lithologic host units have been identified in previous studies and consist of a subjacent quartz-plagioclase-porphyritic andesite and superjacent plagioclase-porphyritic andesite; the former generally hosts wider and higher-grade veins. Much of the Waihi area is overlain by younger ignimbrite, tuff, alluvium, and volcanic ash from the currently active Taupo Volcanic Zone to the southwest.

The Amaranth Vein, one of several large veins in the Gladstone Hill area of the Waihi gold camp that have yet to be mined, is located just east of the town of Waihi, several hundred metres to the east of the high grade Martha open pit mine, and a few hundred metres to the west of the Favona underground mine. Rocks in the Gladstone Hill area are characterized by strong to intense hydrothermal alteration that is manifested by the presence of abundant clay minerals (muscovite, illite, interlayered illite-smectite, smectite, and chlorite) that have mostly replaced phenocrysts and groundmass. Typical alteration consists of an adularia-dominant assemblage of variable intensity overprinted by sericite and clay in the more extensively altered rocks. A commonly less pervasive propylitic chlorite-calcite-dominated alteration assemblage is also locally present. Pyrite and quartz are ubiquitous throughout the area and vein calcite, though prevalent in the nearby Martha deposit, is restricted to relatively isolated zones in the Gladstone Hill area. Alteration zonation is inconsistent with distance to the Amaranth Vein. Alteration intensity estimates based on textural criteria may be correlated with the abundance of pyrite and hydrous minerals, but like the alteration zonation, exhibits little correlation with distance to the vein.

Spectroscopic analysis of alkali feldspar from the Georgeville Granite, Nova Scotia: Evidence for pervasive metasomatic alteration

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The late Proterozoic Georgeville Granite is an A-type granite situated about 20 km north of Antigonish, Nova Scotia. The bulk granite composition is characterized by high SiO_2, Th, Nb, Y and Zr and low CaO, TiO_2, MgO, FeO and MnO. Cathodoluminescence (CL) images, obtained from several thin sections of the granite, show that most feldspars display red luminescence. However, the inner regions of some plagioclase grains display a blue colour. These grains with blue inner regions and red rims are optically continuous and show no obvious signs of alteration when observed with a petrographic microscope. Previous studies of feldspars in other igneous intrusions have attributed the red CL colour to the presence of ferric iron introduced by late-stage fluids. In order to understand the metasomatic modification of the feldspars in the Georgeville Granite, the structure and chemistry of the red and blue CL regions was characterized using X-ray Excited Optical Luminescence (XEOL), X-Ray Absorption Spectroscopy (XAS), Synchrotron X-Ray Fluorescence (SRXF) and electron microprobe analyses. The XEOL results show that blue CL is strongly correlated with a UV feature at *ca.* 290 nm, and red

CL is strongly correlated with an IR feature at *ca*. 720 nm. Both the 290 and 720 nm features are visible when the XEOL source was tuned below the excitation energy of the Fe K-edge. Using the XEOL spectra as a guide, XAS and SXRF spectra were recorded from red and blue CL regions. The XAS spectra indicate no change in either the coordination or the valance state of Fe between the red and blue CL regions. The SXRF data show that the red CL regions have higher concentrations of Fe^{3+} and Mn and lower Ca, Ti, and K than the blue CL regions. The blue CL regions within individual grains may therefore represent relicts of original plagioclase. Fe^{3+}-enriched metasomatic albite is wide spread and readily identified by red CL.

Marketing geoscience data

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Homeowners with groundwater wells, road builders, land developers, tourism operators, regional economic development agencies, farmers and land-use planners form part of a long list of Nova Scotians who should be users of geoscience data, but unfortunately, they are not. This should be an issue of concern for all provincial decision makers, including MLAs and municipal councilors, because a failure to consider geology in the decision-making processes has implications for many aspects of society, including public health and safety, the natural environment, groundwater quality and economic development. The geoscience community needs to ask itself why its data are not being used? If you take the time to do the analysis required to answer the question you will likely reach the same conclusion made by the author. For the most part, we should all receive failing grades in marketing 100. The opportunity to change this grade has never been better than it is in 2008. The geoscience community is aware of the strong connection between geology and the environment. This year, while the environment tops the political agenda at every level of government, we all need to dedicate some time to drawing those connections for decision makers.

The changing landscape of the lower Saint John River valley, New Brunswick

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A 67 m continuous core was recovered through drilling at Grand Lake Meadows, located at the junction of Grand Lake and the Saint John River, approximately 55 km south of Fredericton, New Brunswick. Sediment samples were collected from the core to identify stages of development of the marsh land area and surrounding environs since de-glaciation and to assess the possibility of glacial occupation of the Lower Saint John River valley during the Younger Dryas.

Analytical tests included grain size (% gravel, sand, silt, and clay), loss-on ignition, and chloride and bromide content. Data collected were plotted with depth to identify sedimentary units overlying till as identified from earlier drilling in the area. Changes in concentration of variables with depth demonstrated an evolution of the Lower Saint John basin through five interrelated environments of deposition. Data were averaged over 0.5 m sections of core to facilitate Spearman Correlation between variables, Q-mode Cluster analysis and Multivariate Discriminant analysis used as unbiased statistical methods to confirm the major depositional environments interpreted from core data.

Finite radio carbon dating (actual dates not discussed here) indicates that the area has likely remained as an open body of water since deglacial time (<12 000 BP). High chloride and bromide content throughout most of the core suggests that the water was brackish, varying in salinity since deglaciation when marine water was able to mix with fresh water over the study area.

As a result of this study, the Grand Lake Meadows, located approximately 70 km upstream from the Bay of Fundy, is interpreted as having evolved through five stages of development from glacial deposition of till, followed by a marine incursion, with water over the area changing to brackish/lacustrine, then fluvial, and finally development of the present floodplain environment. The increase in the chloride and bromide content in more recently deposited sediments indicates a return to higher saline content in surface and groundwater in the study area that will likely be exacerbated by climate warming and continued rise of relative sea level. This has serious implications for the future supply of potable water in the surrounding areas and for the flora and fauna of the Grand Lake Meadows marsh lands.

Element mobility as a result of chemical weathering of a Carboniferous saprolite near Valparaiso, Chile

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A saprolite is preserved when the erosion rate is less than the weathering rate and thus not all weathered material is removed. The partially weathered material is therefore preserved in situ and displays varying weathering intensities through a vertical profile with an increased degree of weathering closer to the surface. As the saprolite develops, the more mobile elements can be released into the environment. Some of these mobile elements, in turn, form into new minerals; others are released into water and soil systems in the vicinity. There are many factors affecting the rate of chemical weathering and thus the flux and dispersion of mobile elements through a saprolite. Factors

include lithology, pH, presence and nature of overlying soils, precipitation, humidity, possible sea water incursion, temperature and microbial action.

A Carboniferous (290 Ma) granitic saprolite profile in the Chilean Coastal Range outcrops along a recently constructed highway near Valparaiso, Chile. Overlying sediments have protected the profile from erosion since the Miocene. The area is part of a larger study examining the history of the Andes from formation through the tectonic regime to uplift and weathering of the constituent rocks. The profile was sampled at varying depths through the vertical exposure, including fresh granite at the base of the section. Preliminary results suggest that there is indeed a change in the more mobile of the major, trace, and even REEs with depth in the weathering profile. CaO, Na_2O, Ba, Sr, Nd, and the light rare earths appear to increase with depth, whereas loss on ignition (LOI) and TiO_2 decrease with depth. Analyses also show a general slight increase of boron and chlorine in the upper more weathered layers which might reflect a marine influence. This study analyses the progress of weathering with depth, as part of an attempt at deriving a mass balance of the granite and its weathered products.

Sapping channels in a glaciofluvial complex: A possible Martian analog?

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A number of short and wide channels occur in the Sandilands Interlobate Moraine in southeastern Manitoba. Estimates of flow rates based on the Manning equation suggest extremely flow rates well beyond could be expected as runoff given their surficial catchment areas and suggest that groundwater sapping was important in their formation. These features are truncated by the Campbell Strandline, which has an age of approximately 9900 to 9400 ^{14}C B.P. Hydrogeologic modeling suggests that during the drop the level of Lake Agassiz to the Upper Campbell level, the subsurface hydraulic gradients generated would have been sufficient to allow for groundwater sapping. A number of bowl-shaped depressions located above Upper Campbell Beach strandline likely have a similar origin as piping features. These sapping and piping features are of interest as a possible Martian analog due to their resemblance of similar geomorphological features that occur on the surface of Mars.

A tale of two microbialites – the Late Jurassic extremes: the #9 Limestone beneath the shelf margin delta of the Venture gas field in the Sable Island area versus the Albatross B-13 slope of the Abenaki shelf margin on the Western Shelf, offshore Nova Scotia, Canada

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Carbonates are not like siliciclastics. In fact carbonates, especially modern coral reefs, do not like siliciclastics and their often-associated nutrients. Yet in the Late Jurassic offshore Nova Scotia, the large Sable Island paleodelta and the thick Abenaki carbonate shelf with coral reefs are contemporaneous. Two different shelf morphologies are associated with the respective bodies – prograding ramp for the delta and its thin interbedded limestones versus steep-sloped platform for the carbonate shelf to the west. Microbial mud mounds are common in deeper water and slopes of the Abenaki margin showing a consistent pattern of changes depending on their distance from the Sable Island delta. This is most readily seen in color changes that reflect closely J.L.Wilson's (1975) observation that "sedimentary rocks have three significant colors - dark, light and red"! The slope sediments in the most distal Albatross B-13 are cyclic red and whites and may represent some of the geologically youngest red stromatactis mud mounds that had their acme in the mid-Paleozoic. Slope colors become increasingly dark more proximal to the delta. And within the delta, cores in Penobscot L-30 and South Venture C-62 show both dark colors and limited biotic diversity. The C-62 cores are particularly interesting because they give an independent check on the shelf margin delta model and sequence stratigraphic scenario presented for the Venture gas field by Cummings and Arnott (2005). Changes from a biotically depauparate marl up into a microbial mud mound then an argillaceous sponge reef mound with some stromatoporoids and possible red algae in less than 7 meters reflect a forced regression and falling sea level. This can be fitted well to the published deltaic sequence stratigraphy as long as it is appreciated that the "condensed limestone facies" is actually a distal composite recording of changes in sea levels, nutrient supply and ultimately sediment type that replaces the carbonate as the delta progrades. As well the maximum flooding surface is during the microbial mound stage below the abrupt change across a pyritized hardground upward into laminated black shale. This reflects problematic differences in sequence stratigraphic concepts as applied to carbonates versus siliciclastics. Relative to understanding the Abenaki platform, C-62 core gives insights into the relationships seen only in cuttings and sidewall cores in Queensland M-88 which drilled the slope and basin immediately in front of the Deep Panuke gas field in the Abenaki. M-88 and C-62 also hold some promise to be potential links for correlating and dating the massive carbonates and the Sable Island deltaic si-

liciclastics. Relative to the thick siliciclastics, it shows the utility of thin carbonates to be sensitive indicators of the surrounding sand and shale sedimentation.

A conceptual model of horse mussel reef formation, Bay of Fundy, Canada

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Horse mussel reefs (bioherms) in the inner Bay of Fundy continue to be the focus of study. Research indicates that populations grow fastest on sand with bioherms, closely followed by those growing on gravel/scallop bed; the slowest growing are found on gravel/cobble and mottled gravel geological provinces. Multibeam bathymetric and backscatter data have been collected in an area of mussel reefs in the central part of the Bay where they were first discovered. The data indicates that the mussel reefs largely occur on the eastern side of small glacial ridges of the seabed and form a variety of single and multiple, long and short reefs that rise above the seabed up to 3 m high. They are associated with sand in transport at the seabed in a variety of bedforms. A conceptual model of formation and location has been developed that considers sediment transport, current velocity and turbulence, well-mixed water masses, seabed morphology, and sediment distribution.

The presence of limited amounts of sand in transport as well as the location of minor morphological features (glacial till ridges) is critical for reef formation. As the horse mussels become gradually surrounded by sand, upward growth is promoted and successive generations of horse mussels build on top of the older and dead shells. The location of the reefs on the east side of the ridges results from ridge vortices that are formed during flood conditions on the eastern side as spiral vortices with horizontal axis. This provides increased seston to the back ridge regions with associated lower velocity water flows that would encourage the formation of the horse mussels reefs.

Geology of the Ice Cu-Au deposit, Yukon

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The Ice copper-gold deposit is located in the Carmacks copper belt, UTM zone 08V, 417935E, 6905900N, Yukon. First staked in the early 1970s, it is being explored by BC Gold Corporation of Vancouver. Exploration has focused on the eastern edge of a bulls-eye positive aeromagnetic anomaly, measuring roughly 1000 m by 700 m. The Carmacks copper belt contains economic porphyry-type copper type deposits, such as the Minto and the Carmacks Copper. This study is based on field mapping, petrography, ore microscopy, microprobe analyses and rock geochemistry. It reviews exploration history in the context of genetic models and the known geology of other deposits in the region.

The Ice surficial rocks studied so far contain malachite and other copper oxides in pores and fractures, probably previously occupied by sulphides. Small irregular particles of gold and silver are present. Disseminated magnetite partially oxidized to hematite (martite) accounts for the relatively high magnetic susceptibility of the rocks. The low-grade copper is hosted in variably sheared and altered hornblende-biotite granodiorite phases of the early Jurassic Granite Mountain Batholith. Fabrics and recrystallized quartz veinlets suggest that hydrothermal mineralization preceded deformation. It is suggested that, as previously established for the Minto and Carmacks Copper, the Ice deposit formed in the Jurassic at considerable depth (> 5 km) in a porphyry copper system, and that tectonic deformation (ductile shearing) followed the main mineralization event. Exhumation and extensive weathering occurred in the Cenozoic.

Four Billion Years and Counting: a book to celebrate Canada's geological heritage and International Year of Planet Earth

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In 2006, the proposed multi-authored, popular book, "Four Billion Years and Counting: Canada's Geological Heritage" was identified as one of Canada's primary contributions to International Year of Planet Earth (IYPE, 2007–2009). To achieve this goal, a seven-person editorial board is marshalling the work of more than fifty expert contributors in order to publish both English and French editions in late 2008. Initial chapter drafts are now being woven into a narrative that will make sense to the reader and be coupled with new graphics and hundreds of contributed photographs. The book will highlight Canada's fascinating geological record, spanning the last four

billion years. Canada has some of the oldest rocks on Earth, a record of the break-up and reassembling of land masses, and spectacular modern geological features such as mountains, canyons, waterfalls even volcanoes. Equally vital is Canada's wealth of minerals and energy resources, and its changing climate over the eons. The book's first few chapters will explain such basics of geology as plate tectonics, geological time and the fossil record. This section will be followed by eleven chapters outlining Canada's geological evolution in a series of time slices. Novel paleogeographic maps are being developed to illustrate how the geography of Canada has changed over four billion years. The final section of the book, Health and Wealth, looks at ways in which geology directly affects Canadians and covers mining and energy, health, and the future. "Four Billion Years and Counting" should appeal to the non-geologist, and also attract the attention of geologists interested in regions or topics outside their specialty. The book will include a number of "hooks" to capture readers' attention, such as attractive photographs, paintings and schematics, and an easy-to-read text that will have been reviewed by specialists (for accuracy) and non-specialists (for readability). It is an ambitious project but one that will be a worthy legacy of International Year of Planet Earth.

Climate-change impacts and adaptation: a coastal geoscience perspective

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Projected global surface temperature changes over the coming century range from 1.1–2.9 °C to 2.4–6.4 °C depending on the emissions scenario, a function of the development pathway (Fourth Assessment Report, 2007 [AR4]). At constant year 2000 GHG concentrations (i.e. irrespective of future emission reduction accomplishments and not accounting for 2000–2008 emissions growth), the existing commitment to warming is 0.6 ± 0.3°C (all projections for global mean at 2090–2099 relative to 1980–1999). Changes are projected in a range of other climate variables, including precipitation and water balance, storm intensity, ocean circulation, and sea levels. For the same time frame and scenarios, the projected rise in global mean sea level ranges from 0.18–0.38 m to 0.26–0.59 m, compared to the observed sea-level rise over the past 50 years equivalent to 0.18 m/century (AR4). In other words, sea level will rise at least as fast as in the past and likely faster. In Atlantic Canada, the apparent rise in mean water level against the coast is amplified by widespread crustal subsidence. Sea-level rise over the past century has already increased the frequency of coastal flooding in this region, with implications for coastal erosion and shoreline change. Coastal erosion rates are spatially and temporally highly variable, but rising sea levels, increased storm intensity (with associated storm surges and waves), and reduced extent and duration of sea ice are likely to produce accelerated erosion. Rates of coastal wetland loss may increase, in part due to structures preventing landward migration, and salt-marsh biodiversity may be diminished (AR4). Population growth in coastal areas, combined with rising property values, leads to increased vulnerability in some regions including Atlantic Canada, where the current level of adaptation is predominantly poor and uneven. Thus we are already challenged by the existing climate and ill-prepared for faster change. Our conventional development practices are often maladaptive. Vulnerability depends on the timing and effectiveness of adaptation and on coping capacity (AR4). The latter can vary widely and often depends on individual champions as well as economic and technical resources and institutional arrangements. In this context, as for geohazard mitigation, geoscience expertise can play a key role limiting vulnerability. Examples include measurement and modelling of vertical motion, estimates of past and future sea-level rise, detailed topographic data and flood projections, and understanding of coastal response processes, enabling informed projections of future environmental change. Sound geoscience and geomatics information is a critical foundation for robust adaptation. Through establishment of collaborative partnerships between scientists and planners, geoscience can inform policy development and the planning process in coastal communities, thereby enhancing resilience in the face of a changing climate.

Late Paleozoic felsic volcanic rocks in southwestern New Brunswick: relevance to uranium mineralization in the region

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Uraniferous felsic volcanic and volcaniclastic rocks of the Late Devonian Harvey Group occur along the northern margin of the Maritimes Basin in southwestern New Brunswick. The group crops out as an elongate belt 16 km long and 2 km wide, comprises the base of the Devono-Carboniferous basin in that area and has been stratigraphically and petrographically correlated the rocks of the Piskahegan Group of the Mount Pleasant Caldera on the southern margin of the basin.

The Harvey Group has been subdivided into three formations: York Mills, Cherry Hill and Harvey Mountain. The York Mills Formation (~60 m thick) includes sedimentary rocks, lithic tuffs and rhyolites frequently containing cavities lined with quartz and fluorite crystals. The Cherry Hill Formation (~100 m thick) contains mainly two ash-flow sheets accompa-

nied by ash-fall tuffs and quartz-feldspar porphyry. The Harvey Mountain Formation (75–150 m thick) is composed mainly of rhyolites that are intercalated with minor ash-fall tuffs and contains fluorite as a groundmass mineral and in cavities. The uranium mineralization mainly occurs in the Harvey Mountain Formation as pitchblende associated with sulphides in fluorite veins and veinlets.

The felsic volcanic rocks in the Harvey Mountain Formation are high-K peraluminous F-rich rhyolites. They are high in SiO_2 and alkalis with $K_2O/Na_2O > 1$ and low CaO, TiO_2 and P_2O_5. Compared to typical calc-alkaline rhyolites, the volcanic rocks are enriched in Rb, U, Th, Nb and Y but depleted in Ba, Sr and Zr, in addition to Ca, Ti and P, features typical of highly evolved rhyolites. These felsic volcanic rocks share many similarities with uranium-rich topaz rhyolites of the southwestern USA and topaz granites that are commonly associated with U-mineralization, although topaz has not yet been found in the Harvey Mountain volcanic rocks. These features indicate the volcanic rocks could either represent more fractionated facies of the Piskahegan volcanic rocks or they are not co-magmatic.

The Harvey Mountain Formation felsic volcanic rocks are a result of an extensive fractional crystallization where fluid fractionation played an important role in late-stages of magmatic differentiation. Although not yet known, these rocks could be a source for uranium mineralization in the younger Carboniferous sedimentary strata upon their erosion. Continental tholeiitic basalts, which are associated with both the Harvey and Piskahegan felsic volcanics are mantle-derived. They probably represent a heat source which triggered a partial melting of metasedimentary crustal material producing felsic magma. Basaltic magma was probably emplaced into the crust at the early stages of lithospheric extension associated with the basin formation. The high K content and peraluminous nature of the felsic rocks also point to a metasedimentary source, probably containing metapelites.

Geographic Information System for terrestrial analogue research and planetary databases

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The Canadian Space Agency (CSA) is involved in several space exploration research projects carried out through the Canadian Analogue Research Network (CARN). All these projects require the visualization, manipulation, analysis, and interpretation of geospatial terrestrial information for comparison with the existing planetary databases. The large amount of data gathered through these projects require easy access and processing ability for principal investigators and their students at Canadian universities, CSA staff, and stakeholders in government, industry, and at space agencies worldwide.

We present the results of a project in development to create an Internet-based Geographic Information System (WebGIS) for terrestrial analogue research and planetary databases at the CSA The project has three objectives: (1) to promote and facilitate research at analogue sites in Canada; (2) forge stronger links with the international earth and planetary science community by sharing geospatial information and (3) give visibility to the CSA in the field of analogue and planetary database management.

For this project, we are testing an OpenGIS architecture made available on the Internet and built according to the international standards developed by the Open Geospatial Consortium. In addition to reducing costs, this approach allows: (1) flexibility in database management, (2) interoperability with a Web Map Service (WMS), (3) the ability to create multilayered databases and queries for comparative studies, and (4) regular updates to include data from ongoing terrestrial analogue and planetary missions. Similar solutions already exist but are largely dedicated to terrestrial databases except in a few cases for global planetary information. The particular feature of the proposed WebGIS solution will be to focus on a detailed comparison of terrestrial and planetary geospatial databases using a list of specific queries developed in collaboration with experts from the scientific community in Canada and internationally.

Paleolithic to Neolithic sites in the Belan Valley of India: early agriculture under an unstable monsoonal climate following the Last Glacial Maximum

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Considerable evidence is emerging that early human settlement and migration across Asia and Europe were influenced by rapid climate changes, as global climate adjusted to reduced ice cover following the Last Glacial Maximum. Along the Belan River in northern India, archeological sites have yielded a remarkable assemblage of Paleolithic to Neolithic settlements, with evidence for some of the world's earliest agricultural activity including Neolithic rice cultivation and domestication of animals.

Alluvial strata in the Belan valley yield dates between 85 and 72 ka B.P., implying sustained fluvial activity in Marine Isotope Stage 5 and later, probably under active monsoonal conditions. However, the youngest channel fills below the settlements were abandoned and filled with windblown silt with shell fragments, interbedded with fluvial sediments. Mounds of shell-bearing silt lie inland from the river. Five OSL dates for the channel fills and mounds span the 14 to 7 ka B.P. period, corresponding broadly to the period of Mesolithic settlement. Above the

eolian beds, the main Neolithic settlement rests on floodplain muds, indicating renewed fluvial activity.

The Belan eolian material has a small volume and reflects local deflation of sediment from the nearby river. However, no eolian deposits were observed in the older strata, and the post-LGM period was probably unusually dry in the Belan area. We suggest that the Mesolithic settlements developed against a backdrop of regional climatic instability, with periods of active river flow and drought. This would have been a difficult time for agriculture. In contrast, Neolithic sites were probably established during a period of more intense monsoon rainfall after about 7 ka, when stable agricultural settlements could have been established and rice cultivated.

A unique Neoproterozoic to Cambrian trace fossil assemblage from the Goldenville Group, southwestern Nova Scotia.

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The High Head member is a ~860 m interval of fine-grained metasedimentary rocks, in the middle of the generally sandy Goldenville Group of southwestern Nova Scotia. The stratigraphy is punctuated by only rare coarser sandstone beds, and one interval of mafic intrusions, which appear to have been intruded while the sediments were still wet. Paleocurrents, deduced from flutes and grooves in the immediately underlying sandstone beds, and from rare washed-out ripple marks that are the largest physical sedimentary structures in the mudrocks, show flow towards the south and west, in contrast with paleocurrents recorded from Atlantic coastal outcrops of the Goldenville Group, which are almost all toward the north or east.

The High Head member contains spectacular trace fossils. In the lower part of the section, the trace-fossil assemblage comprises *Oldhamia radiata,* large, sparsely branching *Chondrites acutangulus, Curvolithus sp. Gordia sp., Planolites sp.* and *Taenidium sp*. Up-section, large *Glockerichnus sp.* are also rarely observed. Near the middle of the section *Trichophycus pedum* (formerly known as *Phycodes pedum*) is commonly observed. Also present are taphonomic variants of the *Trichophycus pedum* (i.e. *T. pedum* truncated and preserved at a different level); they appear as evenly spaced, reamed intrusions that some researchers have referred to as *Hormosiroidea*, *Saerichnites* or *Neonereites uniserialis.* The upper half of the section is bioturbated sporadically, and dominated by *Gordia marina, Helminthopsis sp., Taenidium sp.*, and rather persistent, if rare *Phycodes sp.* and *Trichophycus pedum*. Thick sand beds characterize the uppermost part of the High Head section and trace fossils become rare in that area.

Of interest in the High-Head ichnology is: (1) the relatively high diversity of trace fossils observed; (2) the presence of *Trichophycus pedum*; and (3) the occurrence of *Gordia marina* with *Trichophycus*. The observed assemblage is very similar to those in late Precambrian to Early Cambrian sequences of southeastern Newfoundland (Chapel Island Formation), which yielded (in common with the Goldenville Group) *Curvolithus sp., Gordia sp., Neonereites uniserialis, Phycodes pedum, Planolites sp.*, and *Skolithos sp*. In Newfoundland, the diverse ichnofaunas were reported below the oldest trilobite-bearing strata. *Trichophycus* has been reported almost globally, with its first occurrence in strata with or immediately above Ediacaran fossils. *Trichophycus pedum* is taken to indicate the presence of the first well-developed, metazoan animals, and thereby indicative of the boundary between Precambrian and Phanerozoic strata. The occurrence of *Trichophycus pedum* and the similarities of the observed assemblage suggest that the High Head exposures may indeed straddle the Precambrian-Phanerozoic boundary.

Summary of the Nova Scotia component of the North American Soil Geochemical Landscape Project

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The objective of the North American Soil Geochemical Landscape Project (NASGLP) is to establish a continental framework of inorganic, organic and microbiological soil geochemical data and to ensure the data are available to a wide range of applications, issues and disciplines. The project is a tri-national initiative that involves the co-operative efforts of the federal, provincial and state geological surveys of Canada, the United States and Mexico, and will result in the first-ever continental-scale map of the geochemistry of North America based on 13,215 sample sites yielding an overall sample density of 1 sample per 1600 km^2.

All sampling protocols, including (1) identification of the various soil horizons to be sampled, (2) the type, number and size of samples to be collected, (3) the type and proper use of accepted sampling equipment, (4) laboratory preparation and (5) analytical procedures were designed by the Geological Survey of Canada in conjunction with numerous partners, including the National Forestry Service, Agriculture Canada and Health Canada.

The 2007 field season began in early June with a one week field orientation program in the Amherst area to introduce the Nova Scotia sampling team to the field equipment, sample data sheets and identification of the various soil horizons to be sampled. Fifty-four sites across the province were sampled (and three field duplicates were collected for a total of fifty-seven samples). All samples were collected by shovel from hand-dug

pits averaging approximately 90 cm in depth. Detailed field descriptions including sample depth, colour, redoximorphic features, texture, clast type/percentage and root size/quantity were recorded for each site. A digital photograph of the site was taken and annotated for future reference. Sample sites were geo-referenced (NAD 83) by GPS to the Universal Transverse Mercator (UTM) grid (Zone 20).

In addition to collecting soil samples for geochemical analysis, measurements of (1) soil gas radon, (2) radiometrics (U, Th, K, and Total) and (3) soil permeability were also collected at each site. Soil samples were also collected to determine bulk density and/or moisture content.

Analytical results are expected in the spring of 2008. Funding for the project was provided by Natural Resources Canada (Geological Survey of Canada) and Health Canada.

What are Hoodoos and how do they form? Cosmogenic nuclide insights into Holocene landscape evolution in the Colorado Plateau

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Recent dendrological, stratigraphic, ecological and soil-geomorphic studies of catchment-scale landscapes associated with weakly cemented soil-mantled weathering-limited slopes of Jurassic sandstones in northeastern Arizona have indicated that minor climate changes can strongly influence landscape evolution by controlling the rates of erosion. To test this hypothesis, direct measurement of slope erosion is needed. Terrestrial in situ cosmogenic nuclides (TCN) provide a means to directly establish slope retreat history in the Blue Gap region of Arizona. There, hoodoos (or tent rocks) capped with resistant concretions which protect the underlying sandstone from erosion, form along actively retreating slopes. Exposure of the hoodoo begins as the concretion is exhumed and separated from the retreating slope. The hoodoos occur predominantly in basins where the slopes are steep (> 25°), soil is thin, and rapid surface runoff retards weathering rates. Here, successions of hoodoos extend as far as 200 m from cliff faces and are ideal erosion markers to track slope retreat in multiple basins where dendro-stratigraphic weathering and soils work has been completed.

Surface samples from the tops of eleven concretions on hoodoos up to 8 m high were analysed for cosmogenic ^{10}Be in quartz. The durations of concretion exposure range from 400 to 5800 years, and in all basins the ages increase with distance from the slope. This is the first time hoodoo development has been dated. The corresponding slope retreat rates range from 3 to 10 mm/a support the hypothesis of a strong climate sensitivity of slope erosion in arid regions and provide insight into the development of arid region landscapes with and without the presence of caprocks.

Chlorite diagenesis in reservoir sandstones of the Lower Missisauga Formation, offshore Nova Scotia

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Diagenetic chlorite rims on quartz grains preserve porosity by preventing the formation of secondary, pore-filling quartz overgrowths in wells from the Venture and Thebaud fields. Elsewhere, in the Norwegian Sea and the US Gulf Coast, such chlorite rims have been interpreted as an early burial diagenetic feature related to the input of iron from rivers or volcanic activity, or to later diagenesis by basinal fluids. The purpose of this study is to evaluate which hypothesis is applicable to the Scotian Basin.

A set of 45 sandstone samples from conventional cores were analyzed for mineralogy in thin section, mineral composition by electron microprobe, whole-rock chemistry, and X-ray diffraction.

From analytical data, it can be argued that a precursor iron-rich clay has diagenetically altered to form chlorite rims during early burial diagenesis, before widespread precipitation of pore-filling kaolinite and quartz overgrowths.

The depositional environment, including the degree of bioturbation, may influence formation of early Fe-rich clay coatings. The quality of the final chlorite rim depends on the sea floor diagenetic environment, apparent from the correlation between the quality of chlorite rims and phosphorus. The conditions that favour precipitation of phosphate must also result in Fe-rich clay coatings and may also make some coatings a better precursor than others for the conversion to chlorite during burial diagenesis. The presence of other Fe-rich minerals may also indicate an abundant supply of iron in the early diagenetic environment.

Impact cratering: A planetary process as seen from Earth

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Planetary exploration highlighted impact as a ubiquitous solar system geologic process for surface and upper crustal modification, particularly in early solar system history. The Earth, however, is the most endogenically active of the ter-

restrial planets and has the poorest preserved record of impact cratering, with the current known sample consisting of ~ 175 structures or crater fields and ~ 20 events in the stratigraphic record (some of which are related to known structures). The sample is biased towards (< 200 Ma), large (> 20 km diameter) impact structures on the geologically better-known cratonic areas, which has implications for cratering rate estimates and claims for periodic or clusters of impacts. This relatively small, biased sample, however, plays a critical role in understanding cratering process, as it is the only current source of ground truth data on the third dimensional structural and lithological character of natural, large-scale impact craters. Observations at terrestrial impact structures have led to such fundamental concepts as: shock metamorphism (including impact melting) and its attenuation, formation of a transient cavity by the cratering flow-field, and subsequent modification of this cavity, including structural uplift to form a positive topographic feature in large complex craters. Observations at the three largest structures: Vredefort, Sudbury and Chicxulub are consistent with models of peak ring formation but the models can not be independently confirmed, due to the small sample. While terrestrial structures were initially studied to understand impact as a planetary process, impact has also played a role in Earth evolution. Biological evolution was affected directly through the Chicxulub impact 65 Ma ago and the associated mass extinction. More important, however, was the formation of the Earth's moon as the result of a massive impact on the proto-Earth, which resulted in lunar tides and the creation of littoral zones to the world's oceans. On the time-scale of a million years or less, relatively small impacts are a continuing threat to the long-term survival of human civilisation. The creation of large, localized thermal anomalies and specific structural and morphological forms has resulted in historical and current economic quantities of natural resources in ~ 25% of terrestrial craters and related deposits. Some of these are world-class, e.g., Sudbury, Vredefort and the Campeche Bank oilfield, with the net result that impact structures produce ~ $20 B of natural resources per year. Although no rocks are preserved on Earth from the time of the heavy bombardment of the moon, a similar bombardment, scaled to terrestrial conditions, would have resulted in major remelting of the Earth's early crust. Thick impact melt sheets differentiate and such massive remelting would have led to secondary, felsic differentiates from basaltic materials of the early crust. Thus, these early massive impacts could have played a role in establishing the crustal dichotomy of felsic (continental) and mafic (oceanic) crust that distinguishes the Earth from the other terrestrial planets.

Evidence from fluid and melt inclusions for synchronous sulfide melt oxidation and aqueous-carbonic fluid exsolution in intrusion-related gold deposits

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Granitic rocks within the giant intrusion-related Au-Bi-Te deposit at Fort Knox, Alaska, contain a well-preserved inclusion record of magmatic-hydrothermal transition and processes that were potentially critical for the development of the sheeted ore system. Early magmatic titanite grains contain (in their cores) inclusions of an iron sulfide melt that were trapped coevally with silicate melt inclusions at a minimum temperature of 780 ºC (based on O_2 geobarometry). Textural and mineralogical evidence indicates that this sulfide melt phase was stable until a relatively late stage in the crystallization history of the granites, but was destabilized due to a progressive increase in oxygen fugacity. Laser ablation ICP-MS analyses of the sulfide melt inclusions show that they contain between 200 and 1800 ppm Cu, and concentrations of Ag, As, Bi, Sb, Te, W, Mo and Ni in the 10–100 ppm range. Notably, Au was detected in the sulfide melts at concentrations in the 1–3 ppm range. Analyses of the coeval silicate melt inclusions allow the calculation of sulfide-silicate melt partition coefficients. Values of D(sulfide/silicate) are between 10 and 100 indicating that the sulfide droplets would have contained the majority of the ore metals present in the system while they where stable. Remarkably, selected metal ratios in the sulfide melt droplets (e.g., Bi/Au) are identical to those in the sheeted ore veins at Fort Knox, suggesting that the sulfide melts. This would suggest that ore-forming processes that occurred after the destabilization of the sulfide droplets (i.e., silicate melt-fluid partitioning, and metal coprecipitation) did not fractionate the ore metals from one another. Textural evidence shows that during titanite growth, apatite saturation occurred. Apatite grains trapped coexisting primary inclusions containing silicate melt and a low salinity (~ 4–6 wt% eq. NaCl based on clathrate melting temperatures), aqueous-carbonic fluid (CO_2 ~ 21–39 vol%). These coeval melt and fluid inclusions in apatite provide unambiguous evidence for the saturation of the granitic magma in fluid phase. The fluid inclusions decrepitate at ~ 400 ºC; however, apatite-biotite halogen exchange thermometry indicates that the inclusions were trapped at a minimum T of 560–680 ºC.

The results show that ore-forming granitic magmas were saturated in a Au-Bi-Te-rich sulfide melt phase. Resorption of the sulfide melt appears to have coincided with saturation of the crystallizing magma in a low salinity aqueous-carbonic fluid. Sulfide melt that persists to a relatively late stage of magma crystallization may act as an important storage phase for ore metals, preventing the loss of ore metals to (i) fluids

that exsolve early on when the magma is insufficiently brittle to auto-generate mineralized sheeted veins, and (ii) crystallizing minerals in which metals such as Au are compatible (e.g., magnetite, biotite, titanite). Systematic identification and analysis of sulfide melt inclusions in granitic ore-forming settings significantly "inboard" of convergent plate margins may find application in locating highly mineralized granites and predicting the metal associations and metal ratios to be expected in the ores.

Understanding the origin of deformed Albert Formation sandstone reservoirs: An analogue study with the northeastern Uinta Basin, Utah

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The Albert Formation (Horton Group, Mississippian) of the Moncton Basin in New Brunswick is currently divided into three lithostratigraphic units, two of which are the Frederick Brook Member and interfingering – overlying Hiram Brook Member. These units are interpreted to represent a complex interbedding of lacustrine shale (Frederick Brook Member) with deltaic and lacustrine shoreline sandbodies (Hiram Brook Member). Such sandbodies, some of which are up to 30m thick, have been the successful target for oil and gas exploration in the province. However, the understanding of the original large-scale geometries of these sandstone reservoir rocks remains limited. This is because the Formation has undergone extensive deformation, and its present-day surface exposure is very patchy. Therefore, analogue studies can be a potentially useful tool to improve our understanding of the reservoir.

Greiner, in 1962, first noted the "remarkable resemblances" of the Albert Formation to the Eocene lacustrine formations of Colorado, Wyoming and Utah. For instance, the stratigraphic succession in northeastern Uinta Basin of Utah includes a thick, fine-grained siltstone and oil-shale interval (Green River Formation), overlain by a mixed fine-coarse grained siltstone-sandstone and locally evaporitic unit (Uinta Formation). Interpretation of basal Uinta Formation strata (potentially analogous to the basal Hiram Brook Member) and the nature of its contact with underlying shale and oil shale of the Green River Formation (Frederick Brook Member equivalent) is also complicated by deformation.

The extensive and high quality outcrops in the Uinta Basin permits identification of a localized nature to the deformation at the Green River – Uinta Formation contact. At the meter scale, beds have been dewatered and folded, with large flame structures also punctuating the contact. At the decameter scale, domal and diapiric mudstone structures are common. These structures, which were originally interpreted to represent delta-front clinoforms, appear to be more indicative of flat-lying sheetflood deposits that have been subsequently dewatered and tilted after loading and diapirism, suggesting that Lake Uinta at the time of oil shale deposition subsequently experienced a major base-level fall before any of the observed coarser grained units were deposited. Such an interpretation may be applied as a working model for further investigation of the Albert Formation.

The Severn Estuary (UK): Quaternary investigations and human exploitation

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The Severn Estuary in southwest Britain has, due to its funnel-shaped morphology, the second highest tidal range in the world, second only to the Bay of Fundy in Canada. Interdisciplinary investigations of the Quaternary history of the Severn Estuary have shown that it occurred at the ice-limit, occupying the junction between a Welsh ice-sheet to the north and a periglacial environment to the south. Glacial and periglacial meltwaters were important for channel erosion and deposition of sediments within the basin. Holocene sea-level rise forced a coastal transgression up-estuary, flooding Pleistocene valleys in which marine sedimentation occurred resulting in extensive coastal wetlands. These depositional environments appear to have fluctuated in concert with changes in the rate of sea-level rise, being characterized by marine silt-dominated tidal flat to salt marsh environments during periods of high sea-level rise rates, but becoming peat dominated when the sea-level rise rate decreased. Evidence suggests these wetlands were exploited by prehistoric communities, but were reclaimed during the Roman occupation from AD 43 to 410 and converted to agricultural lowlands, locally known as Levels; reclamation of remaining wetland continued into the Medieval period. Much of the Levels are below the level of high tide and are vulnerable to extreme flooding events, such as in AD 1607 when either of storm surge or tsunami claimed around 2000 lives and caused much socio-economic damage. Sea level continues to rise at a rate of ca. 2 mm yr, which places pressure on existing coastal defences. National political debates on sustainable energy are now calling for a tidal barrage to be constructed across the mouth Severn Estuary, the impacts of which are now initially being discussed.

Graphite thermometry in the Halifax contact aureole

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Intrusion of the South Mountain Batholith at ca. 380 Ma produced a well-developed contact aureole in graphitic slates of the Halifax Formation in peninsular Halifax. Two chemically

distinct lithologies (Cunard and Bluestone members) show different mineral isograd sequences. The outer rim of the aureole is defined by the cordierite-in isograd in both units. The andalusite-in isograd appears before the biotite-in isograd in the aluminous Cunard member, while the opposite is observed in the less aluminous Bluestone member. Simple phase diagrams for silicate mineral assemblages suggest that P-T conditions ranged from < 400°C in the outer aureole to > 550°C near the contact, at pressures of ca. 2.5–4.0 kbar. However, the associated reactions are subject to large uncertainties, making precise P-T estimates difficult. A graphite thermometer has been calibrated from the temperature-dependent progressive evolution of Raman spectra of carbonaceous material (RSCM). The graphite thermometer was applied to several samples along a transect perpendicular to the South Mountain Batholith contact between Halifax Harbour and the Northwest Arm. Temperatures range from ca. 360°C at the outer limit of the aureole to ca. 570°C at the contact. This independent assessment of temperature can be used in conjunction with silicate phase equilibria to provide better estimates of P-T conditions within the contact aureole.

Variations in sedimentation rates to the western Gulf of Mexico over multiple glacial-interglacial cycles

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Terrestrial cosmogenic nuclides (TCN) are being used to measure sedimentation rates from two non-glaciated and tectonically quiescent river systems (Colorado and Trinity Rivers) draining into the western Gulf of Mexico. The goal of this study is to provide insight into the magnitude of sediment flux variability over the past 5 million years and to quantify the response of non-glaciated catchments to glacial-interglacial climate change.

Deposits already associated with specific glacial or interglacial intervals in the past 200 ka are the main focus of the climate-response portion of this study; however, older deposits are also being analyzed. Preliminary results have been acquired for one TCN depth profile in the Lissie surface (ca. ~640 ka), and a single shielded sample in the chronostratigraphically well-defined Beaumont surface (ca. ~155 ka) along the Colorado River. Each sample consists of 355–500 μm quartz grains derived from unmixed fluvial sediment. The depth profile consists of five regularly-spaced samples excavated from a gravel pit; the lone Beaumont sample was acquired from a cut bank along the present Colorado River. Cosmogenic ^{10}Be concentrations were measured with 2σ precisions of ~5% and were used to determine average inherited concentrations of 1.6 ± 0.1 x 10^5 atoms g^{-1} for the Lissie surface, and 2.9 ± 0.2 x 10^5 atoms g^{-1} for the Beaumont surface. Monte Carlo simulation of TCN concentration vs. depth allowing parallel variability in erosion rate, exposure age, bulk density, and inheritance indicate an insensitivity of inheritance to these other parameters. The optimized inherited concentration corresponds to a basin-wide average erosion rate of 0.029 ± 0.004 mm a^{-1} for the Lissie surface. The single shielded sample in the Beaumont surface yields a basin-wide average erosion rate of 0.019 ± 0.002 mm a^{-1}. Integrating these measurements with a digital elevation model of the Colorado River catchment returns sedimentation rates of 6.3 ± 2.8 Mt a^{-1} and 4.2 ± 0.4 Mt a^{-1} for the Lissie and Beaumont surfaces, respectively.

The relationship of actively migrating sand bodies to the tidal streams and eddies in the Bay of Fundy – new insights through combined mapping and modeling

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The Bay of Fundy has seen ongoing multibeam mapping for 15 years now. Combined results currently provide a view of surficial sediments and morphology over about 60% of the Bay. As well as obvious relict glacial morphology, there are clear regions in which intense modern active sediment transport is resulting in the development and apparent concentration of mobile sand sheets. Most notably, headland-associated lens-like bodies of sand are found to be common, the most notable one being the Scots Bay sand wave field. It is apparent that for most significant coastal protrusions into the tidal stream, at least one, and often a pair, of these lens-like banks develop. In order to try to understand the association of these headland-associated sand bodies with the tidal stream, a series of nested, high resolution 3D barotropic finite-element hydrodynamic models have been developed, forced using the lower-resolution but spatially more extensive DFO Webtide models.

Many of the headlands develop eddies downstream of the flow. These eddies variously develop over the tidal cycle and advect away from the headland depending on the form factor of the headland. Although the instantaneous eddies clearly are not stationary, they result in a clear tidally-averaged residual inshore flow toward the headland. This is reflected in a ubiquitous development of asymmetric dunes in the inshore side of these lens-like bedform fields. In contrast the offshore side normally exhibit near symmetric bedform characteristics.

By coupling a sediment transport model to the variation in bottom bed shear stress observed over an M2 tidal cycle, residual sediment transport vectors have been calculated. The headland-associated banks are clearly related to, but offset from, local minima in the tidally averaged sediment transport vectors. The relatively simple geometry of the main coastal protrusions is reflected in the paired bedform fields.

More complex residual sediment transport systems develop in and around the islands immediately to the south of Grand Manan including several lens-like sand bodies. The combination of a hydrodynamic and a sediment transport model help understand the more complex circulation in these areas.

Glacial and environmental history of Lake Banook, Dartmouth, Nova Scotia, Canada

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Lake Banook in Dartmouth, Nova Scotia is an 11.5 meter deep glacially carved lake created during the Wisconsin glaciation and is located within a regional meltwater corridor. A small-craft geophysical survey was conducted on the lake during summer and fall of 2007, with methods including multibeam bathymetry, sidescan sonar, high resolution seismic (10 kHz) and underwater video data. The seismic character of the different units was used to define different facies spatially and temporally within the lake basin. Sub-bottom profiles show acoustic basement overlain by up to 10 m of well-stratified sediments mimicking the topography of the basement. This is in turn overlain by a ponded, weakly stratified unit up to 4 m thick. The acoustic basement is interpreted as basal till, correlated to onshore drumlins and tills. The well stratified sediments are tentatively interpreted as glaciolacustrine. A local unconformity at their top may be deglacial low-stand or flood related. Sub-basins in the lake show facies and thickness variations which may be influenced by ice configuration. The ponded uppermost unit shows some temporal evolution and potential for links with microfossil studies from nearby Penhorn Lake. Glacial boulders are common between the present lakeshore and 5 m water depth. These are likely washed from the till and will help constrain the low stand. Geological features include drumlinization, overdeepening, fluvial channels, paleo-shoreline, shallow gas, and slumps or debris flows. Observed biological and anthropogenic features in this study may be useful in understanding the more recent processes in the area. Freshwater mussels, bacterial mats, and abundant water plants were found in shallow areas less than 3 m. The degree of anthropogenic impact from deforestation, urbanization, and flooding from construction of the early 19th century Shubenacadie Canal can be assessed from these data. Recent dredging provides a baseline for very recent sedimentation and biological recovery rates. Future work will characterize the lake sediment geometry and stratigraphy, and will include coring for lithologic, environmental, and chronological control.

Getting geology into the grade IV classroom: The FENOREX collection

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Geological and mining societies and institutes have always been concerned about supplying competent young scientists and engineers to sustain the mining and environmental sectors. This concern has been more evident during the recent cycle of global mineral exploration and mining activity. The supply shortage is exacerbated by the short-term approach by industry and governments who do not tend to look beyond a 2–3 year window of technical requirements. Universities have a responsibility to alleviate this problem which could help cure the feast-and-famine cyclic nature of enrollments. This presentation will examine an individual, grassroots approach which may help solve this problem by consistently sparking interest at the elementary school level. This idea is not original. It has been modified from EdGeo and other professional programs. You cannot begin to educate students if the teacher has not been exposed to the subject they are to teach. Therefore, this presentation will demonstrate one method of getting rock and mineral collections into the classrooms to assist these teachers. We will examine the concept of phenomenology as a teaching style, a methodology which initiated this project. To date, 17 local Cape Breton consulting, construction, and well drilling companies as well as the Strait-Highlands Regional Development Agency have purchased and placed 39 collections in 35 Grade IV classes in the 2 Cape Breton Island school boards. Response by teachers is extremely positive. Grade VII and XII classes are the next target market. Over the past 3 years, a total of 140 kits have been distributed across Canada. This idea works because it has been created with passion and an entrepreneurial spirit.

Old marine seismic and new satellite radar data: exploring for petroleum in the northern frontiers

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This paper provides a review of hydrocarbon discoveries and presents some new concepts in the petroleum systems of the offshore northern Labrador Shelf and Baffin Bay region in eastern Canada. The focus of this work was the Hekja O-71 gas discovery of 1979, one of only five wells drilled between 1976 and 1980 from an area covering some 166,000 square kilometres, roughly one quarter the size area of Alberta.

This study emerged from the New Energy Options for Northerners (NEON) project, a broad scale re-examination of the petroleum potential of this area "from the crust up" using regional geophysical data sets to complement the usual seismic reflection interpretation and make an integrated compilation.

An opportunity to use SAR (synthetic aperture radar) data from RADARSAT-1 was taken as an exercise to incorporate alternative data sources to support this exploratory review and resource assessment.

Preliminary examination of the final map of interpreted slick-like features was under whelming, but closer inspection revealed a close correlation of some of these occurrences to several previously overlooked bathymetric features which had underlying seismic signatures similar to previously identified gas hydrate "pipes" or chimney anomalies seen, for example, in data from offshore Nova Scotia and western Ireland. Worldwide many active marine hydrocarbon seeps appear on the sea floor as "pockmarks"; in this case no sea floor depressions were seen to be associated with active seepage. Instead, very distinct mound-like structures are seen associated with seeps at two locations.

The seismic evidence of these probable mud volcanoes as the sea floor structures in close proximity to the seepage features observed in the RADARSAT-1 SAR images makes a compelling argument for re-examining additional areas for petroleum prospects as well as the potential for considering new stratigraphic as opposed to purely structural plays in a new exploration fairway.

The carousel: a thinking activity for geoscience outreach enthusiasts

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Generating an awareness of the many linkages between geoscience and people's daily lives is an ongoing challenge for the geoscience community. Geologists can find the absence of understanding somewhat frustrating because they are already aware of society's co-dependence on natural resources. They also know how important it is for everyone to better understand the Earth and our interaction with it. Geologists who are active in education outreach are constantly on the hunt for activities that convey the importance of understanding the Earth in ways that are fun and educational. The carousel activity is a great way for students, teachers and or workshop participants to brainstorm about geoscience topics. Educators can use it to introduce geoscience into the classroom or to help focus a class or group before any unit of study. In the first part of the activity, station facilitators help to reveal what the participants know and understand about pre-determined topics. Any preconceived notions and inaccurate information are also revealed. As the activity proceeds, summaries of each station are shared and discussion ensues. The activity leader or station facilitators must be ready to rectify any inaccuracies in geoscience knowledge. At the conclusion, participants acquire a better understanding of geoscience and they begin to appreciate its role in our daily life. A condensed version of the carousel will be organized for the Colloquium session participants. Participation will not be mandatory but it will be encouraged.

Acoustic velocity and elastic moduli profiles and corresponding fracture density and orientation patterns in artificially shocked granite: preliminary results

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Impact events can be simulated at a small scale in the laboratory and the subsequent crater can be examined to learn more about cratering processes. This work investigates subsurface fracture patterns beneath craters and the relationships between fracture density and orientation and acoustic velocity anomalies. Previous research in the laboratory and larger scale seismic surveys across impact craters on the Earth's surface show that shock damage reduces the compressional wave velocities in the rock. Shear wave velocities measured as a part of this study complement the compressional wave velocities reported in the literature. The collection of a more complete data set allows calculation of Vp/Vs ratios and the derived elastic moduli profiles across an artificial crater produced by the Lindhurst Laboratory of Experimental Geophysics at the California Institute of Technology, Pasadena, California. Preliminary results show that shear wave velocities are more sensitive to the presence of fractures and resolve more widespread damage than compressional wave velocities, thus shear wave velocities or Vp/Vs ratios can be used to map a more complete picture of impact induced damage. Shear wave velocity measurements in three directions show anisotropy which has been attributed to the presence of different fracture populations and orientations. Future work will compare crack orientation in more detail with acoustic velocity and elastic moduli profiles; thin section observations will allow better characterization of fracture populations. Results from this study have implications for understanding cratering effects on solid surfaces throughout the solar system.

Cement timing and distribution in Lower Cretaceous sandstones: Glenelg, Thebaud and Chebucto fields, offshore Scotian Basin

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Diagenetic cements have been studied in conventional core of Lower Cretaceous sandstone from the Glenelg, Chebucto and Thebaud fields in the Sable Subbasin, offshore Nova Scotia. The spatial and temporal distribution of diagenetic cements and para-sequences has been constrained in relationship to lithofacies, depth and the well position in both the distal (Glenelg and Chebucto) and proximal (Thebaud) parts of the basin.

Clay minerals in the sandstones include early grain-coating clays, kaolin, illite and chlorite. Grain-coating illitic clays occur in Glenelg N-49 forming coated grains cemented, initially, by Fe-rich calcite (CI), then low Fe-calcite (CII). Kaolinite occurs as booklets and vermicular stacking textures. It fills large intergranular pores in the Chebucto well and in some samples from Thebaud I-93 and Thebaud #3. Kaolinitized mica exhibits expanded texture that inflates into adjacent intergranular pores. Illite occurs also as fibrous crystals, which in the Chebucto K-90 well are included by ankerite. Fe-rich chlorite (chamosite) rims are found only in the Thebaud samples examined and demonstrably have developed from earlier Fe-rich clay. Early pore-filling chlorite occurs in contact with detrital quartz and lithoclast grains and is often associated with illite. Both this chlorite and chlorite rims are formed around quartz grains lacking quartz overgrowths. Quartz cement (overgrowths) is well developed principally in medium and coarse sandstones. It postdates kaolinite cement and predates most of the other cements.

Carbonate cements (calcite, Fe-calcite, Mg-calcite, ankerite and siderite) are the major cementing minerals filling the large intergranular pores in Glenelg, Chebucto and Thebeaud wells. In Glenelg H-59, two siderite cements were defined; the earliest one is formed by large and corroded crystals and it is low in Mg. The late microcrystalline siderite (< 10 μm) is Mg-rich (8 to 9%). It forms the tiny crystals that fringe detrital grains and fill intercrystalline micropores between quartz and Fe-calcite cement. In Thebaud I-93 siderite nodules contain less Mg than the siderite cement (1%, 8.5% respectively).

The neo-formation of framboidal pyrite in carbonate cement indicates a burial under both reducing and alkaline conditions. In samples from the Glenelg field, perthite is partially replaced by Fe-calcite, with only K-feldspar patches and albite left. Rare traces of francolite (samples with 1 to 6 wt.% P_2O_5) are found in the Glenelg wells associated with illite and calcite cements.

These observations on diagenetic minerals are related to the position of host sediments within parasequences. Coated grains are restricted to transgressive system tracts. Abundant early kaolinite and siderite are found principally in sandstones immediately beneath transgressive system tracts, particularly in cross-bedded coarse channel sandstones.Early calcite cement, predating quartz overgrowths, is found principally in bioturbated sandstones and mudstones with bioclasts, typical of the HST.

Reservoir quality, diagenetic history and provenance of the Late Triassic sandstones of Wolfville Formation, Cambridge Cove, Bay of Fundy, Nova Scotia

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The sandstones of the Triassic Wolfville Formation at the Cambridge Cove at the Bay of Fundy were investigated petrographically. The study included grain size analysis, diagenesis, porosity, heavy mineral analysis and reservoir characteristics depending on these properties. These studies indicated that these fluvial sandstones are calcite cement- supported feldspathic litharenites to lithic felsarenites. They consist of quartz (33.6%), lithics (17.3%), feldspars (9.8%), minor amounts of mica and heavy minerals (2.6%) and cement (36.7%). The sandstones have a recycled orogenic provenance derived from metasedimentary and granitic rocks postdating the collision type setting and during the early stages of rifting. Their heavy minerals consist of iron oxides (76%), garnet (13.6%), apatite (3.3%), chlorite (3.3%), zircon (1.4%), tourmaline (1.3%), biotite (1%) and few others. The main sources of these deposits are the Early Paleozoic Meguma Supergroup, South Mountain Batholith and the carbonate rich Carboniferous formations exposed in Nova Scotia, with possible minor contribution from the Appalachian Mountain exposures in New Brunswick. The Wolfville Formation, which is overlain by the Blomidon Formation, has limited exposed area relative to its wide subsurface extension beneath the Bay of Fundy, where it is underlain by the Horton Bluff Formation in the Minas Basin area, and by Meguma and/or Avalon zones in the southwestern parts of the Bay of Fundy. The Wolfville sandstones have a porosity ranging from 2 to 17% which gives them the potential to be moderate to good reservoir rocks for hydrocarbons, especially where they overlie the potential source rocks such as the organic-rich shales of Horton Bluff Formation, or other younger shales within the Mesozoic rocks in the subsurface section beneath the Bay of Fundy.

Microlite in the Greenbushes pegmatite, Western Australia

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The Greenbushes rare-element pegmatite, Western Australia, is currently mined for lithium and tantalum and is among the largest tantalum producers in the world. Although tantalite is the dominant ore mineral, more than ten other tantalum-bearing phases have been reported. The tantalum-rich pyrochlore, microlite, has been identified in mill concentrates at the Greenbushes mine, however its paragenesis is not well documented. In the present petrographic investigation of different zones within the Greenbushes pegmatite, microlite was discovered within a fine grained assemblage of quartz, albite and fluorapatite in the border zone near the footwall contact of the pegmatite. It occurs as equant, anhedral to subhedral grains that are generally less that 0.5 mm in diameter. The grains are pale yellow in plane polarized light and sometimes contain small inclusions of a high birefringence mineral. Optical and backscattered electron images (BSEI) indicate that most individual grains are essentially homogeneous in composition and texture. Raman spectra obtained from Greenbushes microlite closely matches that of stannomicrolite, but electron microprobe results reveal significant concentrations of antimony in addition to tin. Microlite occurs in intensely sheared and recrystallized pegmatite; however, individual grains show no sign of deformation or alteration. We suggest that microlite precipitation is coeval with late deformation and the remobilization of tantalum within the pegmatite. The occurrence of microlite and abundant apatite in the border zone is attributed in part to chemical exchange between the pegmatite and the calcium-rich metasedimentary host rocks.

Correlation of thermo-tectonic and metallogenic events in the Avalon and Meguma terranes of Nova Scotia with the use of $^{40}Ar/^{39}Ar$ and Re-Os geochronometry

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The geological evolution of the Avalon-Meguma composite terrane is punctuated with numerous thermo-tectonic events, including widespread magmatism and deformation (e.g., Acadian and Alleghanian orogenies). Associated with these regional events is fluid flow, localized in the case of magmatism, but more widespread for regional deformation. Herein are presented new geochronological data ($^{40}Ar/^{39}Ar$, Re-Os) from mineralized areas in this region that constrains the timing of related magmatic-tectonic events. Results are summarized, progressing from east to west geographically. (1) A Re-Os age for molybdenite from the Coxheath Cu-Au-Mo porphyry deposit, Cape Breton, indicates an age of 626 ± 3 Ma, which compares to 620 Ma $^{40}Ar/^{39}Ar$ ages for the host rock. The new Re-Os age, along with the nature of mineralization, confirms this as a rare example of a Precambrian porphyry system. (2) The terrane bounding Cobequid - Chedabucto Fault System has been the locus of episodic deformation, magmatism, fluid flow, and mineralization. The age of hydrothermal activity is constrained at two localities, Copper Lake (Cu-Au) and Mt. Thom (Cu-Ni-Co). At the former, concordant ages for hydrothermal muscovite ($^{40}Ar/^{39}Ar$, 327 ± 1.3 Ma) and pyrite (Re-Os, 323 ± 8 Ma) were obtained, which agree with $^{40}Ar/^{39}Ar$ whole-rock ages for two hydrothermally altered granites (335 ± 5 Ma). (3) Whole-rock slates from gold districts near Halifax were dated with $^{40}Ar/^{39}Ar$. Samples in and distal from bedding-concordant quartz veins yielded plateau ages of ca. 375 Ma, thus younger than the age for regional deformation. That the ages overlap both vein Au formation (Re-Os arsenopyrite = 380 Ma) and 380 Ma granitic plutonism suggest that large thermal anomalies related to vein formation may reflect an underlying heat source (i.e., granites). (4) Mineralization at the East Kemptville Sn deposit is constrained at 376 ± 1 Ma (Re-Os molybdenite); however, the age for reactivation of fault zones controlling ore are unconstrained. Dating of euhedral sanidine from banded zeolite-sulphide fault-fill yielded a 230 Ma $^{40}Ar/^{39}Ar$ plateau age. This age may equate to Triassic faulting and sedimentation in the Fundy Basin. (5) Dating of both molybdenite (Re-Os) and hydrothermal muscovite ($^{40}Ar/^{39}Ar$) in the Clayton Hill pluton give essentially concordant ages of 363 ± 1.3 Ma and 361 ± 2.3 Ma, respectively. These new data provide evidence for a previously unknown metallogenic event in the Meguma terrane, possibly associated with A-type magmatism. (6) Re-Os dating of molydenite from richly-mineralized greisen boulders from the Plymouth area, which initiated the tin rush in SW Nova Scotia in the 1970s, gave an age of 374 ± 2 Ma, similar to the age for mineralization at East Kemptville. This material is, therefore, not related to the nearby 357 Ma Wedgeport pluton.

Winter ice and sediment budgets in upper Fundy

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Extensive winter ice develops routinely in the extremities of the Bay of Fundy: Minas Basin / Cobequid Bay and Cumberland Basin. Much research has been carried out on estuarine ice formation, both in Fundy and elsewhere and these processes are fairly well understood. The relation between winter ice and the estuarine sediment budget, however, is an intelligent guess at best. Winter ice affects marshes both verti-

cally and laterally. Supratidal marshes are inundated by high tide only at extreme spring tides, at most about 100 hours per year in years with sufficiently high tides. Typically, half of these inundations take place in (late) winter. Large ice cakes may be floated on top of supratidal marshes (just landward from tidal creeks) and remain stranded there, because flood currents continue to flow landwards for about 30 minutes after the time of high water. The sediment concentration of ice cakes may vary from 0 to 23% by weight and appears to consist mostly of silt-sized and finer material, but its variation within ice cakes as well as geographically is unknown and nearly impossible to predict. Research elsewhere suggests that coastal marsh accretion accelerated after colder winters and that amounts of ice-rafted debris equaled amounts of summer sediment accretion. Hence the hypothesis that winter ice contributes significantly to tidal marsh accretion. Erosion of tidal marshes by winter ice seems to occur mostly in a lateral sense, i.e. on the banks of tidal creeks and channels. However, the creation of vertical ice walls along tidal creeks also has a stabilizing effect. This process too, has never been quantified.

As much as 60–85% of original tidal marshlands have been locked away behind dykes, a process that affected the storage capacity of the estuary as documented elsewhere. Tidal marshes are important primary organic matter producers, contributing significantly to the food chain. Questions regarding the mutual effects between winter ice and the construction of tidal turbines are not part of the Strategic Environmental Assessment (SEA), presently carried out under auspices of the Nova Scotia Government, thus suggesting that this is a solvable engineering issue. Thus, the extent to which winter ice contributes to the health of the few remaining salt marshes and the extent to which tidal turbines may interfere with ice formation, ice circulation and sediment budget of a fragile environment remains a risky unknown.

A research agenda for Fundy: results from the 2006 'Fundy Session' at the Atlantic Geoscience Society Colloquium

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During the 2006 AGS Colloquium, we convened a session on "Sedimentation in the Greater Bay of Fundy". The aim of this session was to define a research agenda, an exercise that had not been carried out for a long time and which we deemed necessary because of: a) global change implications, b) renewed interest in tidal power generation, c) changing views on coastal zone management practices. These were the most important topics of the agenda: (1) map the entire Bay floor using multibeam bathymetry, paying special attention to mussel reefs and large sand and gravel bedforms; (2) establish the timing of origin of the big sand waves on the bottom of the Bay; (3) establish a sediment budget, paying special attention to the different contributions of bedload, suspended load, organic and inorganic matter; (4) improve understanding of sea level rise over the last 10,000 years; (5) establish the proportions of organic and non-organic material in the sediment column; (6) establish a sediment monitoring system in the upper Bay prior to removing the Petitcodiac causeway; (7) quantify the role of winter ice as a source of sediment and in relation to marsh ecology; (8) quantify the effects of (increased) wave activity on exposed marsh cliffs; (9) compile detailed high-resolution LiDAR surveys of marshes and mudflats; (10) integrate modern and historical bathymetric data with historical aerial photography and HR satellite imagery; (11) expand monitoring of dredge spoil disposal sites, as at Saint John (NB), to elsewhere; (12) address bottom fishing and its effects on benthic communities and sediment erosion. The 2008 session has been convened to document progress and revisit the agenda in the light of recent (political) developments.

Radial growth of trees from northeastern to southeastern Labrador

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Prior to the Mount Allison Dendrochronology (MAD Lab) sampling in the summer of 2007, little tree ring work was conducted in Labrador, with the most studies coming from the eastern coast and from one species. Given this, the information is still quite spotty, as the cost of transportation and limited tree availability has limited a systematic sampling across the landscape. Over this backdrop, the MAD Lab initiated a more region-wide study breaking Labrador into three zones (east, west, and north). Within each zone a consistent grid was used that will link the entire region together, while at the same time highlight the major zones of homogenous tree cover currently found. This talk will illustrate some of the early results of areas in southeastern Labrador, while at the same time discuss some of the difficulties in sampling the more northern locations. Three species will be discussed (white spruce (*Picea glauca*), black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*)). Preliminary results from chronologies of black spruce and balsam fir developed from the southeastern region will be compared to the other chronologies in adjacent

areas in Labrador, highlighting some of the similarities and differences in growing conditions that are already being seen.

Climate change: An atmospheric perspective

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Climate change is currently dominated by anthropogenic global warming induced by the burning of fossil fuels. Natural causes of climate change will likely be only a minor contributor in the 21st century. The anthropogenic increase of atmospheric greenhouse gases such as carbon dioxide, methane and nitrous oxide is enhancing the downward long wave infrared radiation at the Earth's surface resulting in higher temperatures. Much of the total warming is a result of the positive feedback associated with increasing atmospheric water vapour, itself a very strong greenhouse gas, which accompanies the higher temperatures. Large uncertainties still exist in quantifying a number of other feedbacks such as clouds, ocean circulation, surface albedo and vegetation. As a result climate models used in the latest IPCC Fourth Assessment predict that a doubling of carbon dioxide equivalent will increase the equilibrium global averaged surface temperature in the range from 2.0 to 4.5 C with 3.0 C being most likely. Very significant regional climate change, including more frequent floods, droughts and heat waves, are predicted if atmospheric carbon dioxide continues to increase without strong mitigation efforts.

The search for life on Mars: the importance of Mars-like minerals on Earth to astrobiology

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In recent years, orbital and surface missions have provided a wealth of information on the Red Planet. In particular, the mineralogical composition of surface materials has helped to unravel the geological and climatic history of Mars. The ongoing accumulation of information and knowledge about Martian mineralogy, geochemical processes and climate history is helping to define search strategies for future missions that will specifically seek out traces of past life or evidence of existing life – two of the primary goals of astrobiology. This talk will give an overview of the importance of studying Mars-like minerals on Earth as an important step to addressing whether life ever existed on Mars.

Spectroscopic data from *Mars Global Surveyor* and *Mars Express*, as well as from the Mars Exploration Rovers show that *Ca-Mg-Fe-sulphates* are abundant and diverse at various locations. The fact that these sulphates almost exclusively require liquid water to form means they are of interest to astrobiologists. The presence of the ferric sulphate jarosite within sedimentary rocks at *Meridiani Planum* has received particular attention because this mineral only forms at relatively low pH in Earth systems. Therefore, its presence suggests that the aqueous solutions that deposited or altered these rocks were acidic. This could potentially have important implications for the development of life on Mars or for the preservation of biosignatures of early Martian life. However, jarosite has recently been discovered within carbonate sediments on Devon Island in the Canadian High Arctic. This finding shows that jarosite can form in a well-buffered environment and likely only requires localized or transient acidic conditions in order to form.

Various Ca-Mg-Fe-phyllosilicates (or clay minerals) have also been identified in some of the oldest terranes exposed at the Martian surface. Their presence suggests an early active hydrologic system, and the formation of these abundant and widespread clays would have required the presence of persistent liquid water over extended periods of time, as phyllosilicates generally form from extended periods of water-rock interaction at near circum-neutral pH. These deposits may therefore represent some of the best places to search for past habitable environments and traces of relict life on Mars. Clays are known to bind and trap organic molecules. They may also be formed by microorganisms, in some case preserving physical traces of such processes. Their catalytic properties have also been implicated in prebiotic chemistry on Earth – and perhaps Mars. However, very little work has been done on biosignature formation and preservation in clay-rich systems. It is therefore imperative that the formation and preservation of microbial biosignatures in clay minerals is studied in more detailed using analog systems on Earth in anticipation of future Mars missions.

Newly-recognized lowstands of the Laurentian Great Lakes signal their sensitivity to changed climate

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Today the Great Lakes are collectively ranked as North America's largest freshwater reservoir. Their five basins support a total population of >33 million persons, and host well-developed activities and facilities for shipping, industry, power production, fishing, recreation, and municipalities. Their monthly mean levels have varied little more than ± 1 m during 150 years of instrumental measurement, and thus appear relatively stable. Together, the lakes contain 23,000 km^3 of water, and their watersheds add about 1 % of this volume annually, derived from precipitation and runoff. Overflow from this positive water balance sustains major rivers and shipping canals between lakes, and discharges to the St. Lawrence River. In a similar way, geologists and paleo-hydrologists have always considered the

paleo-Great Lakes to have been overflowing bodies of water since their formation during retreat of the last (Laurentide) ice sheet. This paradigm of continuous abundant water supply is shown to be false by recent findings of early Holocene lowstands, indicated by submerged tree stumps, beaches, and spillways, buried erosion surfaces, infilled river valleys, and a new analysis of differential glacio-isostatic uplift.

Comparison of the early Holocene lake level, based on the original elevations of all dated lake-level indicators, with the uplift history of possible outlets, revealed an episode of low water level tens of meters below outlets about 7,900 ^{14}C (8,800 cal) BP, possibly a few centuries long. Lakes without outflow can only be explained by a dry climate in which water losses by evaporation exceeded water additions by precipitation and runoff.

The discovery that the Great Lakes entered a phase of negative water balance in a dry climate with low water levels below outlets, and hence without connecting rivers, signals the sensitivity of these lakes to climate change, and that significant reductions in lake level relative to current societal usage should be expected as climate in the Great Lakes Basin warms in future. Modeling and prediction of future levels requires confident knowledge of the sensitivity of the Great Lakes hydrology to climate change. An opportunity to add to this knowledge is possible by further research and quantification of this new phase of early Holocene climate and closed lakes.

Sources of magnetic and gravity anomalies on the Scotian Shelf southeast of Cape Breton Island, Nova Scotia, and onshore-offshore geological correlations using geophysical modeling

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The Scatarie Ridge Magnetic Anomalies (SRMA) form a prominent northeast-trending belt, 100 km long by 25 km wide, on the Scotian Shelf southeast of Cape Breton Island. The area is inferred to be part of the Mira terrane, a component of the Avalonia realm of the northern Appalachian orogen. The magnetic anomalies range from 300 nT to 600 nT with the centres reaching highs of 1000 nT. Associated with the magnetic anomalies are positive gravity anomalies that range from 10 to 30 mGal. This study used forward-modeling software to model magnetic and gravity data to investigate possible sources of the SRMA. The interpretations are constrained by physical property data measured in samples collected from onshore areas, and by multichannel seismic lines collected by PetroCanada and the Geological Survey of Canada Frontier Geoscience Project (Lithoprobe East). Using the second derivative magnetic map, the SRMA has been resolved into a linear anomaly trending east-northeast and two large magnetic aureoles located north of the central part of the SRMA. Forward potential field models indicate that the southern margin of the linear anomaly is the northern margin of the Orpheus Graben. A south-dipping fault separates rocks of the Meguma terrane to the south from rocks of the Avalon terrane to the north of the graben. The Meguma terrane is modeled as one unit with average density of 2750 kg/m^3 and average magnetic susceptibility of 2x10^{-3} SI. The offshore Avalon terrane has been modeled as five geological units based on differences in magnetic susceptibility and density, in the range of 10x10^{-3} to 20x10^{-3} SI and 2600 to 2700 kg/m^3, respectively. Upper crustal units beneath the Avalon terrane offshore have higher susceptibility and lower density than units beneath the onshore Mira terrane, suggesting that the offshore area is a different part of Avalonia, perhaps equivalent to the Antigonish Highlands or the eastern part of Avalon terrane in Newfoundland. The source of the large linear anomaly is interpreted to be a belt of mafic volcanic rocks at a depth of 6–15 km in the offshore Avalon terrane. The large magnetic aureoles have associated gravity anomalies indicating that they are caused by granite plutons and magnetic rocks in the surrounding contact metamorphic aureoles. In the Gabarus Bay area, similar magnetic aureoles are associated with the Devonian Deep Cove granite and other intrusions. Two granitic bodies south of the Orpheus Graben in the Meguma terrane have densities and magnetic susceptibilities similar to Devonian plutons in the adjacent onshore part of the Meguma terrane.

Thermal structure and chemical composition of the Archean mantle and origin of mantle "plumes": Insights from ca. 2.73 Ga komatiite and basalt, Nunavut, Canada

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Geochemical studies of komatiite- and basalt-dominated volcanic successions within late Archean supracrustal belts have the potential to yield important insights into the thermal structure and chemical composition of the early Earth's mantle, as well as the dynamics of mantle melting. The high eruption temperatures and degrees of melting that are required to explain the first-order geochemical features displayed by the vast majority of late Archean komatiite, namely their high-MgO contents and pronounced depletion in incompatible elements, have been used to argue that these magmas must have an origin related to mantle plumes. Unfortunately, the near universal acceptance of a mantle plume origin for komatiite is used as an argument (circular) for the existence of plumes, and geochemical observations are routinely interpreted in terms

of the modern plume paradigm. The underlying assumptions of the paradigm are seldom questioned or why, if they exist, potential plumes in the modern mantle might be similar to those in the Archean. Currently, no consensus exists on the nature or very existence of modern or ancient mantle plumes and their relationship with respect to the ambient mantle, a situation that requires remediation. This study presents geochemical data from a unique and exceptionally well-preserved ca. 2.73 Ga volcanic succession, dominated by large volumes of chemically diverse komatiite and basalt recently discovered in the Canadian Arctic. This succession constitutes the basal sequence to a vast network of co-genetic clastic-dominated supracrustal belts (~1400 km long and ~400 km wide) formed between ca. 2.73–2.69 Ga. Modeling the geochemical data with constraints from high- and low-pressure peridotite melting experiments has yielded the following conclusions: (1) high-MgO komatiite magmas were derived from thermally anomalous mantle, which was ~150°C hotter than the ambient mantle; (2) the ambient ca. 2.7 Ga mantle was ~200°C hotter than the modern mantle; (3) ambient and thermally anomalous mantle are the same composition and both are similar to the modern depleted upper mantle; (4) Archean mantle plumes are discrete "parcels" of thermally anomalous mantle; (5) primary magmas within the late Archean were komatiitic not basaltic; (6) plumes have an origin within the upper mantle; and (7) the source of thermal energy required to heat the upper mantle may ultimately have originated from the core.

Impacts of climate change to the water resources of Cape Breton Island, Nova Scotia

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Predicted changes in climatic conditions could alter the annual snow pack which accumulates in the Cape Breton Highlands and cause earlier timing of the spring freshet. If the warmer temperatures result in more rainfall and less snow accumulation, less snow would be available for the spring melt. This meltwater affects many aspects of the surface and ground water conditions later into the year. Mid- to high-latitude rivers have been modeled to respond to the expected increase in temperature due to climate change, in general, these trials have resulted in slightly lower average flow and earlier spring maximum flows. This modeling has been performed for major river systems and the implications would vary for smaller watersheds, also depending on the particular climatic changes that occur within each specific watershed area. Watersheds which are not snow dominated may not see much average annual change, however, the highlands are dominated by a snowbelt region and could have significant alterations to the river systems in that area. Geological setting also appears to be an important consideration in this region, particularly due to its influence on baseflow recession.

Mineralogical investigations at Canadian Analogue Research Network (CARN) sites using a portable Raman spectrometer

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Presently, the search for life on Mars has focussed on minerals formed by chemical precipitation. Miniaturized Raman spectrometers have been proposed for future rover missions to Mars, such as the European Space Agency (ESA)'s ExoMars rover to be launched in 2013. A 10-week internship was dedicated to assisting a Canadian Space Agency project investigating the use of Raman spectroscopy on geological samples: carbonate and iron-oxides/iron-sulphate precipitates, for its potential applications on a Mars rover or lander. The off-the-shelf portable Raman spectrometer was tested at analogue sites in the central Yukon Territory and from the Haughton Impact Crater, Devon Island, Canada.

The Raman spectrometer utilizes a 120 mW laser with a wavelength of 785 nm. The instrument can detect Raman spectrum within the range of 100–2000 cm^{-1} at resolution of detection of 8 cm^{-1}. Preliminary assessments revealed that the instrument was able to conclusively identify carbonate (calcite and dolomite) and sulphate (gypsum) minerals. However, spectra from carbonate samples that had a high percentage of organic material (~5%) proved to be inconclusive: fluorescence from this organic material is thought to have caused interference with the Raman spectra.

With relatively minor upgrades, including a small, rugged computer, attachment stage, and fitted cover, the portable Raman spectrometer system used in this study could be functional in a field environment. However, to be more effective, this system would also benefit from a wider selection of standards in the library database and more effective matching criteria.

A Holocene sedimentary record of the Labrador Current

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The climate of the Atlantic Provinces is influenced by the Gulf Stream and Labrador Current. As temperature rises in response to increased CO_2 output, the increased melting from Greenland may cause a strengthening of the Labrador Current, which could result in regional cooling.

In this study, one marine sediment core from Karlsefni Trough on the Labrador Shelf is analyzed for its Holocene sedimentological record of the Labrador Current in order to determine how the strength of the current has varied in the Holocene. This core was analyzed using the Geological Survey of Canada Atlantic facilities at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

Grain size data were obtained from Coulter Laser analyses and percent $CaCO_3$ was obtained using a LECO carbon determinator. Using the signature of ice-rafted detritus (IRD) and the percent $CaCO_3$, the sediment supply to the area was inferred. An age model of the core was determined using carbon-14 dating of mollusk shells and foraminifera.

The Karlsefni Trough core was found to be older than 8.9 ka. Based on the high percent $CaCO_3$, the source of the sediment in the cores before 6.3 ka was inferred to be Canadian Arctic proglacial sediment. After 6.3 ka the $CaCO_3$ drops off and is inferred to be only terrigenous sediment from ice-rafting and reworking of bank sediment. Using the carbon-14 dates, IRD, percent sand, color, and percent $CaCO_3$ the core was interpreted to contain marker beds for both the Lake Agassiz and Foxe Basin Deglaciation events.

The sortable-silt proxy for current strength in the Coulter Laser grain-size data shows a trend from almost unsorted at the base of the core to very well sorted around 7.8 ka with a slight dip around 6.9 ka and a return to maximum strength in the upper part of the core, estimated at 4.4 ka, before gradually declining to the present.

A strong sorting signal can be caused either by reworking of the adjacent bank sediment or a very strong Labrador Current. If there were a large sediment input from the bank, the IRD would be diluted. This is not the case, since IRD increases from around 5.4 ka to the present time. Therefore, the sortable-silt proxy appears to represent variations in the strength of the Labrador Current. Further work is needed to identify what past changes in climate and particularly precipitation on land correlates with increased late Holocene strength of the Labrador Current. Such an understanding may help predict future changes in the Labrador Current as a result of global warming, which could have economic, social, and environmental impacts on the Atlantic Provinces.

In-situ LA-MC-ICPMS Sm-Nd dating using REE-enriched accessory minerals

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Whereas Sm-Nd isochron ages have conventionally been obtained using combinations of dissolved and purified whole rock and major-mineral aliquots analyzed by TIMS, the recent development of precise and accurate LA-MC-ICPMS Sm-Nd analyses of REE-enriched accessory minerals provides a potentially rapid method to date high-temperature magmatic and metamorphic crystallization events. Monazite, allanite, titanite, and apatite, which together comprise the bulk of the LREE budget of most crustal rocks, have all been successfully analyzed for Sm-Nd using LA-MC-ICPMS at spatial resolutions raging from 16 µm (monazite) to 150 µm (apatite). For these laser crater sizes, precision better than 50 ppm (2σ) can typically be achieved on $^{143}Nd/^{144}Nd$. This technique was originally developed to combine in-situ SHRIMP U-Pb ages and Sm-Nd systematics to investigate isotopic inheritance at the grain scale. However, the technique can also be used to obtain relatively precise Sm-Nd isochron ages independent of external calibrations, matrix corrections, or time-consuming isotope dilution. By analyzing a range of (presumed) cogenetic LREE-enriched accessory minerals from the same rock to obtain a range of Sm/Nd, a sufficient number of data points can be collected in a single analytical session to define a statistically robust isochron age. In the example presented here, a fresh granite sampled from the Morila Mine, Mali, was dated at 2093 ± 6 Ma (1σ) based on an upper intercept of near-concordant SHRIMP U-Pb data for oscillatory zoned zircon. Allanite and apatite separated from the same rock were analyzed for Sm-Nd using LA-MC-ICPMS. The range of $^{147}Sm/^{144}Nd$ both between allanite (~0.07) and apatite (up to 0.16) and within each group of analyses provides a sufficient spread of Sm/Nd to calculate a reasonably precise Sm-Nd isochron age of 2097 ± 36 Ma (1σ). This demonstrated precision and accuracy combined with the ability to target accessory minerals in thin section (unknowns and standards can be mounted separately), can, therefore, be exploited as a geochronological and Sm-Nd isotope tracer tool to help guide interpretations for the origin and evolution of Proterozoic and older rocks.

The Tail of the Bank Mud: a deposit originating from Agassiz –driven outburst floods?

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Along the Labrador and northeastern Newfoundland continental margins we recognize distinct Holocene sediment layers rich in detrital carbonate (DC) that likely originated through entrained glacial sediment eroded from Paleozoic limestone and dolomite bedrock flooring Hudson Bay and Strait, and transported in plumes and ice rafts by catastrophic discharges from glacial lakes in both the inner and outer branches of the Labrador Current. Radiocarbon dating shows that two DC layers on the northern Northeast Newfoundland Shelf correlate to glacial Lake Agassiz outbursts and retreat of the Noble Inlet ice advance, respectively. Foraminiferal faunas indicate the layers are associated with reduced-salinity waters. DC layers in a recently re-examined core from southern NENS suggest that outburst floodwaters likely continued traveling southward in the Labrador Current toward Grand Bank, where on the southern margin of the Bank an enigmatic deposit of sandy mud has long been known. The Tail of the Bank Mud consists of silty and clayey sand, the deposit is up to 30 km wide, and extends 200 km along the edge in present-day water depths of 55 to 120 m. The Mud rests unconformably on an erosional surface formed by the last marine transgression, which was submerged here after 10 ka. Recognition of outburst floods issuing from Hudson Strait into the Labrador Current raises a possibility that suspended plumes and ice-rafted sediment carried by these floods may have been a source for the Mud, and that mixing of early Holocene marine and floodwater could explain its known lower-salinity fauna. This is supported by new analysis of two cores that reveals two DC layers with the same foraminiferal fauna as found in DC layers farther north that are correlated to the Holocene lake outburst floods. The recognition of Holocene-aged DC layers and oxygen isotope evidence in Scotian Slope cores also indicates that outburst reduced-salinity waters had been transported south of Grand Bank at this time.

We hypothesize that icebergs and outburst waters flowed over and around the Grand Bank and were transported over the shelf edge into the northern zone of the Gulf Stream. Warmer water temperatures and decreased current velocity in the deeper water facilitated deposition on the Tail of the Bank. Some of the reduced-salinity waters may have been carried by the Gulf Stream and North Atlantic Drift to the Nordic Seas, where they could have decreased thermohaline circulation, and contributed to a cold event.

Geotourism in Saint John, New Brunswick

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Geotourism definitions range from the global view of "Tourism that sustains or enhances the geographical character of a place—its environment, heritage, aesthetics, culture, and the well-being of its residents" to a more focused perspective where "Geotourism is tourism surrounding geological attractions and destinations". Geotourism, based on the observation and understanding of geology, is a growing part of the tourism market. While geotourism is not new, the development of the European Geoparks Network and the UNESCO Geopark program are providing models for engaging the public in the appreciation of geology that link sustainable economic develop with the preservation and interpretation of geology. We think of geotourism destinations as sites with dramatic landscapes and obvious interpretive and geological impact, but there are other opportunities to incorporate less obvious geological stories into the tourism and public realm. With support from the Community–University Research Alliances (CURA-SSHRC) we have been exploring geotourism opportunities in the Saint John region. Interest has come in part from the tourism industry, seeking to enhance a product that includes exploitation of cultural and natural attractions in a market that strives to provide unique experiences for visitors. In Saint John, boat tours of the Reversing Falls have added the geological story of the gorge to their traditional interpretation of the tides. Kayak tour guides are seeking information about geology to enhance their stories of the natural and cultural landscape. Trail designers are looking for information to develop interpretive signs along walkways. Tour operators working the cruise ship market have considered tours of geological sites for ship passengers. Our strategy for enhancing geotourism includes research and development of human interest stories. Viewing the 'study of geology' as important as the science reminds us that geoscience is part of society. This region has promoted its shipbuilding heritage and stories of owners, builders and sailors. The same cannot be said of its geoscience heritage and the people who explored and interpreted the rocks. Nevertheless geoheritage stories captivate the public. The Pennsylvanian geology of west Saint John has puzzled geologists for 150 years. Synthesizing the science into a 30-minute tour can be difficult. But who is not intrigued by the visit of a colourful character like Marie Stopes (both a paleobotanist and a pioneer in the sexual revolution) to Saint John in 1911, and her efforts to reconcile a bitter debate about the age of the rocks at "Fern Ledges"?

Development of a background soil chemistry/toxicology database for the Atlantic Region and the North American Soil Geochemical Landscapes Project (NASGLP)

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The need for baseline soil geochemical data to effectively assess and manage natural resources and the risk of environmental hazards is well recognized. One particular application of such data is to compliment the ecological and human health risk assessment processes. While other jurisdictions have established background soil data, at present, there is limited data on the background soil chemistry for the Atlantic Region. Environment Canada-Atlantic (EC-Atlantic), in partnership with other stakeholders, has undertaken the development of a background soil conditions for the region. In addition to standard chemical analyses, the sampling protocols also include subjecting a portion of the soils to several soil toxicity tests which provides a biological aspect to the chemical data interpretation. Samples have been collected throughout the Atlantic Region over the past 4 years and the resulting data is being collated in a GIS-based database. A key purpose of this research is provide risk assessors with additional data in which to incorporate into their risk calculations, further strengthening the scientific validity of the risk assessment process.

The North American Soil Geochemical Landscapes Project (NASGLP) is a tri-national initiative between US, Canada and Mexico designed to understand the amount and origin of variation in soil geochemistry and to establish a consistent methodology for determining these characteristics. For Canada, this project is being lead by Natural Resources Canada with in-kind support being provided by EC-Atlantic, Health Canada, Agriculture Canada and several provincial departments of natural resources. EC-Atlantic has partnered with NASGLP in order to exchange protocols and data, allow comparisons between the sampling protocols at each site (discrete sample vs. composite samples, horizon-based sampling vs. integrated 0–30 cm sampling, etc.) and optimize sampling efforts between the two projects. NASGLP sampling occurred in between June and September 2007 resulting in the collection of approximately 175 samples from Nova Scotia and New Brunswick. These samples are to be analyzed for metals, polycyclic aromatic hydrocarbons (PAHs), total organic carbon, pH, and grain size. In addition, bulk soil samples were collected at 30 sites for the purposes of toxicological testing. Chemical and toxicological results are pending.

Did Laurentide Ice Sheet floodwater change the history of European civilization?

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In a recent (November 2007) paper, it was reported that a 1.4 m increase in sea level rise accompanied the collapse of the Laurentide Ice Sheet, and the resulting discharge of floodwater from 8.4–8.2 cal ka BP drowned a subaerially exposed Black Sea shelf with seawater. The consequence of this hypothetical catastrophic flooding was that early Neolithic farmers had to flee from the region to higher ground in Europe and Russia, thus ending cultural development in the Pontic region for several millennia. In contrast, our paleoenvironmental data collected from sediment cores on the SW Black Sea Shelf and the Marmara Sea show that the Black Sea was already connected to the World's Oceans by 9.5 cal ka BP, and central shelf was flooded by brackish water to a depth of ca. 20 m by 8.6 cal ka BP or earlier. Our data show a slow two-step reconnection of the Black and Mediterranean seas in the early Holocene, at which time the climate was relatively warm and wet, not cold and dry as required for drawdown and isolation of a Black Sea lake. Our palynological data also show that there is no evidence for either a catastrophic flood around 8.4–8.2 cal ka BP, or for sustained agriculture near the Black Sea before the Bronze Age, ca. 6 cal Ka BP. Furthermore, our paleoenvironmental reconstruction is consistent with the available archaeological evidence showing a steady early Holocene migration of agricultural societies into the Mediterranean and Europe westwards from centers in the Middle East.

Geochemistry and Sm-Nd isotopic signature of the 0.76 ga Burin Group: a compositional equivalent of the basement for late Neoproterozoic Avalonian magmatism?

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The ca. 760 Ma Burin Group occurs in a 60 km long northeasterly-trending belt on the Burin Peninsula of southeastern Newfoundland and consists of low grade massive and pillowed basalts, abundant dykes and sills, with minor mafic pyroclastic rocks and limestone. The Burin Group preserves the oldest known magmatic event in the Avalon terrane, but its tectonic evolution and its relationship to the voluminous 635–570 Ma arc-related magmatism that typifies Avalonia is uncertain. Geochemical analyses confirm that the basalts are predominantly low-K tholeiites. They are characterized by high LIL/HFS, and display depletion to slight enrichment in LREE. Sm-Nd isotopic data reveal that most basalts have juvenile compositions, with εNd values similar to contemporaneous depleted mantle, indicating that high LIL/HFS was probably due to coeval subduction which contaminated the mantle source. Other basalts have lower εNd values, and the negative correlation of εNd with La/Sm, together with a positive correlation of εNd with $^{147}Sm/^{144}Nd$ suggest that their isotopic signatures have been modified by a Mesoproterozoic or older crust or sub-continental lithospheric mantle into which Burin Group mafic volcanics were emplaced. The isotopic signature of the Burin mafic rocks is similar to that inferred for the source of the main phase of Avalonian magmatism. These data, together with paleocontinental reconstructions for ca. 760 Ma, suggest that the Burin Group is a local representative of an ensimatic arcs within the peri-Rodinian ocean, possibly as a far-field response to the breakup of Rodinia. Vestiges of these arcs were accreted to the northern Gondwanan margin at about 650 Ma, and then recycled by subduction beneath that margin during the main ca. 635–570 Ma Avalonian event. Although its low metamorphic grade precludes it being the basement from which Avalonian magmas were extracted, the Burin Group may be representative of the geochemical and isotopic composition of that basement.

Geological mapping in northwestern Bhutan using ASTER remote sensing data

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A klippe of low-grade metasediments is exposed in northwestern Bhutan, the base of which forms the erosional remnant of the southern-most extent of the South Tibetan Detachment (STD) system. This detachment is an orogen-wide normal-sense shear zone that forms the upper boundary of the Greater Himalayan Sequence (GHS), the exposed metamorphic core of the Himalaya. Field mapping in this region of Bhutan is hindered by many factors such as access, terrain, expense and climate. Thus, many geological boundaries are inadequately mapped and constrained. Due to high elevation, lack of vegetation and good exposure this area is well-suited for mapping using remote sensing data. Here we examine the use of ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) remote sensing data for geological mapping of a critical area of the Bhutan Himalaya. The main lithologies mapped using ASTER are: gneiss, leucogranite, metapelite, metacarbonate and shale. The first two belong to the footwall block (i.e. GHS) and the other three units to the hanging wall block of the STD. A structural analysis of the field data from the area is used to help constrain remote sensing mapping and construct geological cross-sections of the study area. This study has improved the geological map of a largely inaccessible, yet geologically significant region of the Himalaya and highlights the effectiveness of using remote sensing data as a geological mapping tool.

Hydrocarbon potential of the eastern Shelburne sub-basin and surrounding areas from petroleum systems modelling constrained by well log information, seismic images, and analogue models

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Recent petroleum exploration on the Scotian margin has yielded poor results as new wells drilled into the shallow-water shelf and along the deep-water continental slope struck no economic hydrocarbon deposits. This lack of recent exploration success shows that a better understanding of the Scotian margin's geological complexity and structural evolution is required for future successful exploration. In an attempt to broaden our knowledge of the Scotian margin, I have compared analogue modelling results with seismic data from the eastern Shelburne sub-basin and surrounding regions, and have created a petroleum systems model of the area using PetroMod software. The goal of this project was two fold: (1) Interpret and correlate available seismic data with available well data from the targeted area for petroleum systems modelling, as well as for comparison with existing analogue models; (2) Create a petroleum systems model constraining possible hydrocarbon reservoirs, also to be used in determining regions for future heat flow measurements in the Scotian Basin.

Three 2D Seismic lines from the GXT NovaSPAN survey and one 2D Lithoprobe line were interpreted, depicting stratigraphic boundaries and outlines of all salt structures present. A 3D analogue model with a symmetric rift graben basement structure and thick salt fill (~2 km when scaled) representing a possible Late Triassic configuration in the Scotian Basin was structurally analyzed and retrodeformed. Salt structures identified in the analogue model were compared to those in the seismic images. Structural restorations of the analogue model through time constrained the evolution of the salt deformation structures and provided insight on the formation mechanism of salt structures within the Scotian Basin. The simplified analogue model setup of the Scotian Basin developed many salt structures similar to those seen in seismic images. The 2D

seismic lines all intersect forming a four sided grid, and the interpretations of these lines were used to create 3D surfaces as the initial constraint for petroleum systems modeling. The retrodeformation of the analogue model was used to provide constraints for the evolution of salt structures in the petroleum systems model, and well data from the region was used to provide stratigraphic and sedimentological constraints in the model. The model is used to interpret the hydrocarbon potential of the region, and to demonstrate in 3D the locations and evolution of salt diapirs. The model also produces surface heat flow estimates and is used to interpret the affects of salt diapirs on heat flow. The model will ultimately be used in order to define potential regions for future heat flow measurements within the Scotian Basin.

Dendrochronological Analysis of Four Conifers in Western Labrador

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To date, little dendrochronological research has been conducted in western Labrador and therefore limited analysis of past tree growth patterns exists for this area. A study was undertaken to address this gap in knowledge this past summer. This paper will look at some of the first results coming from an inter-species comparison of the radial growth rates of four species from this region.

Balsam fir (*Abies balsamea* (L.) Mill.), white spruce (*Picea glauca*), black spruce (*Picea mariana*) and tamarack larch (*Larix laricina*) are this region's dominant coniferous species, and all four were sampled at sites along a north-south latitudinal transect (55N 62W to 52N 62W). Each chronology was analyzed using standard dendrochronological procedures, with cross-dating results indicating that there is a link between all sites and between species. Each species seems to be acting in a similar nature across the spatial gradient and so we suggest that the dominant factor that links these growing environments on a regional scale across the grid is climate.

Earth science outreach in Canada: Cottage industry or national program?

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Science outreach in Canada has gone through many phases. In the late 19th Century, science was of great interest to educated people. However in the early 20th century science became more exclusive and public accessibility declined. By the mid 20th century there was peer sneer in the science community for those who undertook outreach activities. This attitude has been dissipating slowly since the 1970s and now most earth science organizations support outreach, but do not fund it well. During the modern period of re-development of earth science outreach, programs have grown through locally based organizations and individuals. The programs are analogous to cottage industries, which are characterized by small scale production of high quality, hand-made products with limited production and only local distribution. The level of earth science outreach has increased dramatically over the past 35 years. Thousands of teachers have taken EdGEO workshops. Many have perused geoscape posters and brochures, and watched television programs to learn more about earth sciences. Many have visited museums, science centres, parks and geoheritage sites or attended public lectures to learn about earth science. Increasingly, we develop projects that involve the whole community from scientific, cultural and economic viewpoints; a wonderful example is the Community Mapping Program conducted in N.W.T. But the fact remains that few Canadians understand the significance of earth science for their everyday lives. They fail to understand where all their stuff comes from and they remain largely unaware of Earth processes that affect them. Based mainly on volunteer effort, the Canadian geoscience community is trying to reverse this situation. Most programs originate locally and are completed at low cost. This local approach means that many excellent products are not widely available because of a lack of national distribution. Experience is not well shared and efforts are not coordinated nationally. There is no funded, active national inventory of resources for Earth science outreach. Is geoscience outreach to remain a cottage industry forever or can it aspire to operating nationally? These are questions we must ask of the main institutions: geological surveys, societies, universities, science centres and resource industries. People need to know about the Earth to be responsible citizens of the planet, yet earth science is barely taught in schools. If our profession is to rejuvenate and gain influence in society, we have to attract new people. Therefore, young people have to be aware of it. These requirements argue for a national approach to earth science outreach. The International Year of Planet Earth affords an opportunity to leave a national legacy of earth science outreach and we need to embrace it strongly and make it work.

Distribution, form, and origin of precious metals related to the Boomerang and Domino volcanogenic massive sulfide deposits, Tulks belt, central Newfoundland

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The Boomerang and Domino volcanogenic massive sulfide (VMS) deposits are hosted within felsic pyroclastic rocks of the Victoria Lake Supergroup located in central Newfoundland's Tulks belt. The Tulks belt is a Late Cambrian to Middle

Ordovician bimodal volcanic arc and back-arc basin assemblage. Numerous other prospective VMS deposits occur in this belt, e.g., Tulks Hill, Tulks East, Bobby's Pond, Daniel's Pond, Jack's Pond, and Curve Pond. Indicated mineral resources for the Boomerang deposit were recently calculated to be 1.36 million tonnes grading 7.09% Zn, 3.00% Pb, 0.51% Cu, 110.4 g/t Ag, and 1.66 g/t Au at a 1% Zn cut-off grade with similar inferred grades calculated for the nearby Domino deposit, and other deposits with this belt. The Boomerang and Domino massive sulfides commonly occur as lenses hosted within fine to sandy ash tuffs of dacitic composition with rare lapilli clasts and intervals of graphitic argillite in the hangingwall. In hand sample, sulfide banding is evident as thin layers rich in sphalerite ranging from nearly massive units to laminated fine-grained sphalerite and galena in association with pyrite, locally with irregular-shaped chalcopyrite forming pressure shadows, up to 5 cm in size. In general, the sulfide assemblage consists of intergrown equigranular, subhedral sphalerite, galena, and pyrite with lesser amounts of chalcopyrite, tetrahedrite, and arsenopyrite. Pyrite constitutes over 40% of the total sulfide content at the Boomerang and Domino deposit as primary fine grained, euhedral porphyroblasts within the sulfide assemblage, but is also brecciated to form porphyroclasts. Generally, coarse-grained pyrite and arsenopyrite are intergrown, reflecting recrystallization as a result of regional deformation. Tetrahedrite commonly occurs as interlocking grains, inclusions, and along grain boundaries of the other sulfides. EPMA reveals Ag as a solid solution component within tetrahedrite, with minimal Ag within galena.

Multi-element ICP-ES analysis of precious metal-enriched massive sulfides (n = 156) of the Boomerang deposit show positive Spearman Rank correlations between Au and Ag (respectively) with As ($r` = 0.91$ and $r` = 0.81$), Cd ($r` = 0.53$ and $r` = 0.73$), Cu ($r` = 0.66$ and $r` = 0.82$), Fe ($r` = 0.57$ and $r` = 0.45$), Hg ($r` = 0.70$ and $r` = 0.73$), Pb ($r` = 0.79$ and $r` = 0.96$), Sb ($r` = 0.84$ and $r` = 0.84$), and Zn ($r` = 0.59$ and $r` = 0.79$); Au and Ag are strongly correlated ($r` = 0.86$). These precious metal and whole-rock element associations reflect cryptic mineralogical relationships throughout this deposit, i.e., Au is associated with arsenian phases and Ag is associated with tetrahedrite- and galena-rich assemblages.

Laser ablation ICP-MS results from selected samples (n = 8) reveal elemental abundance variations from core to rim, complimenting earlier EPMA results. Arsenopyrite rims are enriched in precious metals, averaging 228 ppm Au and 25 ppm Ag with Co richer cores. Precious metal enrichment is evident in the cores of pyrite porphyroclasts, averaging 13 ppm Au and 382 ppm Ag with Co, Ni, and Hg concentrated in the rims.

Preliminary investigation of a major high-strain zone in the Caledonian Highlands, southern New Brunswick

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The Caledonian Highlands consist mainly of volcanic, sedimentary, and plutonic rocks formed in a continental margin magmatic arc complex in combination with later extensional tectonic events over a span of at least 70 million years in the late Neoproterozoic. The southern and eastern parts of the highlands are dominated by the Broad River Group, an assemblage of ca. 620 Ma rocks, including intermediate and felsic tuff, chloritic phyllite, and arkosic sandstone and conglomerate. Plutonic rocks of inferred ca. 620 Ma age occur in spatial association with the Broad River Group, and show a wide range in composition from gabbro and diorite to tonalite, granodiorite, and granite. The ca. 560–550 Ma Coldbrook Group forms most of the western part of the highlands, but also extends into the eastern part, where it is inferred to originally have had an unconformable relationship with the underlying Broad River Group. Typical Coldbrook Group rocks include intermediate to felsic lapilli tuff, dacitic to rhyolitic flows and plugs, laminated tuffaceous siltstone, amygdaloidal basalt flows, and coarse clastic sedimentary rocks. Circa 560–550 Ma plutons are widespread throughout the central and western parts of the Caledonian Highlands intruded into the lower units of the Coldbrook Group. Most consist of syenogranite with less abundant diorite and gabbro.

A major high-strain zone up to 5 km in width can be traced for at least 70 km diagonally across the highlands from at least the Big Salmon River area in the southwest to the Caledonia Mountain area in the northeast. In this zone, both the Broad River Group and associated plutons and the Coldbrook Group contain similar structural elements, related to a largely shared deformation history. Some of this history is apparent also in the 560–550 Ma plutonic rocks. A pervasive foliation (S_1) lies parallel to bedding (S_0), and although evidently composite ($S_{0\text{-}1}$) in the Broad River Group, this fabric is very heterogeneous in the younger Coldbrook Group, where low strain enclaves are widespread.

No folds have been seen of an F_1 generation, and no reversals of facing or vergence are apparent. A mineral lineation (L_{1m}) is locally prominent. The plutonic rocks have early fabrics, including a foliation (S_1) producing augen-gneiss with a prominent L-tectonite (L_{1m}). S_1 also includes a schistosity associated with the growth of white mica and breakdown of feldspar. Geometry suggests that S_1 in the granites is related to $S_{0\text{-}1}$ in the supracrustal rocks, and L_{1m} in both units shares a common orienta-

tion. S_1 and $S_{0\text{-}1}$ are crenulated by a strong second cleavage (S_2) axial planar to folds (F_2), the large-scale expression of which is an asymmetric synform containing a belt of Coldbrook Group rocks lying between Stuart Mountain and Point Wolfe River. Kinematic indicators suggest an overall top-to-the-southeast motion along thrusts that stack units of Broad River Group, Coldbrook Group, and plutonic rocks. Fabric development in the plutonic rocks implies a history of exhumation beginning under hot, anhydrous conditions, followed by hydration during retrogression as plutonic rocks were tectonically emplaced into this crustal stack. The youngest deformation features are brittle fractures filled with pseudotachylite. The age of these tectonic events is not yet well constrained, but could be as young as Carboniferous.

The Maritime Soil Project: a New Brunswick perspective

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The North American Soil Geochemical Landscape Project (NASGLP) was born out of the need for geochemical background data for health and environmental reasons and was initiated by the geological surveys of Canada, the USA, and Mexico. The New Brunswick and Nova Scotia Geological Surveys, together with Environment Canada Atlantic (ECA), proposed to make the Maritimes a showcase of the NASGLP with sampling to be started and completed in 2007. The Tri-National survey will be linked to the National Forest Inventory (a Natural Resources Canada initiative). The final database will be accessible via the National Land and Water Information Service which is presently managed by Agriculture and Agri-food Canada (AAFC).

In an effort to ensure quality control and consistency in field methodologies, a field training session was organized in the Fredericton area in early June. Staff from AAFC, the United States Geological Survey, NBDNR, the Geological Survey of Canada (GSC), and ECA participated; the first Maritime Soil Project (MSP) sites were sampled. In total, 116 sites were sampled in New Brunswick; at each site, 19 samples were collected for 7 different agencies (including Health Canada, Environment Canada, GSC, NRCanForestry, ECAtlantic, USDHS, and NBDNR's Geological Surveys Branch). Analytical results are pending and will be tied in to existing databases. To facilitate this, an additional (till) sample was collected at each site. The soil types in New Brunswick are mainly podsols (100 out of 116 sites) with a lesser amount of luvisols (4) and brunisols (6), and locally gleysols (6). Although most soils were developed in till, a few were formed in other parent materials such as (glacio-)fluvial, glacio-lacustrine, and colluvium.

Health Canada's Radiation Protection Bureau requested that a soil Radon survey be included in the project and the GSC supported this request with a ground radiometric and soil permeability survey as well as on-the-job training. It was found that most areas of New Brunswick show moderate to high risk potential (by EPA and Health Canada standards) for radon. A local follow-up study in the Fredericton area showed that outdoor and indoor radon measurements do not correlate well. This study and a similar study in the Ottawa area indicate that indoor radon risk is more directly related to type and age of the dwelling.

Also, composite samples were collected from all sites for analysis of eco-toxicological compounds at Environment Canada's Moncton laboratory. The resulting database will testify to some of the visionary work during the initial stages of the project. Further evaluation of field procedures, "add-on" modules that were relatively simple to incorporate in a Maritime context, and archived sample material for future use, form part of the heritage of the MSP.

Preliminary results from multibeam bathymetry and LiDAR surveys in 2007 of the Bay of Fundy, Canada

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In 2006, the Geological Survey of Canada (GSC), in conjunction with Canadian Hydrographic Service (CHS) and several universities, commenced a three year program to map the Bay of Fundy on the east coast of Canada. The Bay of Fundy has the largest recorded tides in the world, with a maximum range of about 17 metres at the head of the bay. Tidal current velocities that exceed 4.5 m/s in restricted narrow passages at various points in the bay could be harnessed for electrical power generation. To date about 10,000 km² of multibeam bathymetry have been collected in the bay. Sub-bottom profiler data were collected simultaneously to provide information on the character and thickness of the sediments on the seafloor. Additional bathymetry and sub-bottom profiler data will be collected in 2008. CHS will use the data for improved navigation charts and GSC will integrate information from geophysical surveys, seafloor samples, photographs, and video transects to produce

surficial geology and benthic habitat maps. The resulting 1: 50,000-scale maps will be released as part of a new Canadian national marine map series. Current meter and suspended sediment sensor data and time lapse photographs will be used to provide information on seafloor properties, nearbed hydrodynamics and sediment transport processes. These data, in conjunction with the improved bathymetry data, will be used to assess the accuracy of tide and current prediction models. The broad intertidal zone in the Bay of Fundy presents a challenge to collection of marine geophysical and bathymetry data. Traditionally, this area has not been surveyed due to the significant time requirements and inherent danger involved in operating vessels in coastal areas that dry between tides. However, these large drying areas were surveyed using airborne terrestrial laser (LiDAR), providing an opportunity to generate a continuous map of the marine, intertidal and terrestrial areas. The data were collected during an extreme low tide to provide detailed elevation measurements of the inter-tidal areas. Multibeam bathymetry data will be collected during high tides to provide a seamless digital elevation model across the intertidal zone. The presentation will focus on the status of the project after the first two years of data collection, challenges and future plans of the project as well as a summary of the most recent data collection and interpretation from the project.

Background concentrations of arsenic and mercury in soils from the Montague and Goldenville gold districts, Nova Scotia

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Recent studies of 15 historical gold districts in Nova Scotia have identified several areas where exposure to mine wastes may represent a potential risk to human health. Arsenopyrite (FeAsS) occurs naturally in the ore and surrounding bedrock in these gold deposits, and was concentrated in the tailings during historical milling operations. The concentration of arsenic (As) in tailings at these sites is generally two to four orders of magnitude higher than the 12 mg/kg Canadian Soil Quality Guideline for As in residential and parkland soils. Two sites, Montague and Goldenville, are of particular concern, as the tailings are located close to residential properties and are occasionally used for racing off-road vehicles. Environmental Site Assessments are ongoing at both of these sites to clarify the spatial extent of mine tailings, and to investigate the fate of windblown tailings dusts. Delineation of the area impacted by tailings requires an understanding of the naturally occurring concentrations of As and mercury (Hg) in soils overlying the variably mineralized bedrock within these gold districts. In 2007, Natural Resources Canada collected samples of the top 0–5 cm of surface soil (the Public Health layer) from 46 sites near Montague, and 39 sites near Goldenville. Samples of individual soil horizons (H, Ae, B, and C) were also collected from 10 sites in Montague, and 6 sites in Goldenville, to evaluate the vertical distribution of elements in the soil profile. All samples were air dried, sieved to various grain size fractions (< 2 mm, < 150 µm, < 63 µm), and digested and analyzed for metal(loids) and organic carbon using protocols commonly employed during environmental assessments (e.g. EPA Method 3050B). Preliminary results from these surveys show that the concentrations of As and Hg in all soil horizons are generally higher down-ice (south) of the ore zones in both districts, reflecting glacial erosion and transport of mineralized bedrock containing arsenopyrite and other sulfides. Analysis of the top 0-5 cm of soils shows the following ranges in As and Hg concentrations (< 2 mm, HNO_3-H_2O_2 digestion): Montague: As, 2–273 mg/kg (median 40 mg/kg); Hg, 72–490 µg/kg (median 164 µg/kg); Goldenville: As, 2–140 mg/kg (median 13 mg/kg); Hg, 60–312 µg/kg (median 123 µg/kg). In general, the concentrations of As are highest in the B and C horizon soils, whereas Hg concentrations are highest in the organic-rich humus (H) layer. Data for As and Hg in soils from Montague are in close agreement with results from previous soil surveys in 9 gold districts conducted by the Nova Scotia Department of Natural Resources in 2003–2005. However, the concentrations of both As and Hg are significantly lower in most soil horizons at Goldenville. Results from this study will be used by the Nova Scotia Historic Gold Mines Advisory Committee to assess the distribution of tailings at these sites, and to help guide risk-management decisions.

Expanding on radial growth forecasting: Future responses of tree species of the Acadian forest to climate change

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As the climate begins to warm optimal conditions for various tree species will undergo geographical shifts. Over the long-term, the ranges of particular species will respond through slow migrations to the new optimal climatic zones. In the short-term, trees currently or soon to be rooted will be forced to endure the altered climatic regimes in their current positions. The features of the future climate that will drive or limit their radial growth rates will, in some cases, cause deviations from past environments. Some species will lose their competitive advantage while others may gain the ability to become dominant.

This ongoing project is in the process of forecasting radial growth response to future climates using past tree growth data, past weather data and projected coupled global climate model data. The radial growth models being produced will provide a

means to identify the most at risk species and the most potentially robust tree types. Outcomes will help determine new sustainability goals in both conservation and resource use areas.

Results of the projected species forecasts indicate that white pine will not be greatly affected by increases in temperature. Eastern hemlock should increase its growth rate by up to 60% by the year 2100 as the growing season lengthens. Eastern white cedar reacts poorly to hotter drier July conditions and it should decrease its growth rate by as much as 75% by the year 2100. Meanwhile red and black spruces appear to hold remain stable or increase their growth rates slightly. What is not known exactly is if the potential for an increase in insect activity will limit their success.

Anthropogenic climate change: a geological perspective

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Earth scientists are well known as a group of scientific stakeholders unusually sceptical of the importance of anthropogenic climate change. This presentation will examine reasons for this scepticism and the positive role that Earth scientists can play in the debate about the consequences of atmospheric greenhouse gasses. The scepticism arises from ignorance, bloody-mindedness, a Lyellian aversion to catastrophism, our training in the use of multiple working hypotheses, and our knowledge of a geologic record that shows constant change. Numerous processes act on different time scales to cause climate change. The geologic record confirms the atmospheric science predictions that abundant atmospheric carbon dioxide is correlated with times of warmer temperatures. Previous high carbon dioxide or high methane events, such as the Paleocene-Eocene Thermal Maximum and later Quaternary interglacials, provide partial analogues for current high greenhouse-gas abundance. The rate of increase in greenhouse gas abundance was likely less rapid in these past events than is now observed, making disequilibrium conditions more severe during the present event. Current changes in climate trends are those predicted by modelling greenhouse gasses together with solar variability and volcanic activity.

Earth scientists provide an important perspective on the consequences of change due to global warming. The geologic record suggests that the two more catastrophic consequences of the current event, if left unchecked, could be massive methane release from permafrost areas and melting of the Greenland and/or West Antarctic ice sheets. In the geological record, the former led to spectacular extinction, whereas the latter would incorporate many densely populated urban areas into a transgressive systems tract. Not every response to human abuse of the environment can be ascribed to global warming: for example, in Bangladesh, it is flood-control structures on the coast and rivers, not rising eustatic sea level, that pose the most immediate threat to millions of people.

Many geologists were initially resistant to the concepts of plate tectonics, invented by geophysicists, just as they have been to anthropogenic global warming, invented by atmospheric scientists. Analogous to the state of plate tectonics in the early 1970s, it is becoming increasingly untenable for geologists to argue that forcing mechanisms other than anthropogenic carbon dioxide are the principal cause of current climate trends. As a profession, we must play a more positive and influential role in the scientific debates on the nature of future climate change and its implications. The medical profession provides a useful analogue for the professional behaviour of individual earth scientists in providing a balanced assessment to policy makers and the public. As geologists, we understand the consequences of population explosions and rapid environmental changes, and we should urge the application of the precautionary principle.

Geological vignettes from York Redoubt, National Historic Site

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York Redoubt, one of the fortifications that made up Halifax's harbour defences, has stood guard atop a bedrock ridge since 1793. A National Historic Site, administered by Parks Canada, it offers panoramic views of the harbour while providing a glimpse into the region's military history.

The site provides a wonderful introduction to the geology of the region. It sits astride a contact between the two major rock units found in southwest Nova Scotia, the metamorphosed sedimentary rocks of the Cambrian Meguma Group and Devonian granitoid rocks of the South Mountain Batholith. As the two rock types look very different, this contact can be mapped quite easily by neophytes as they wander through the historic terrain. Last November, one of the authors took a group of Young Field Naturalists (and their parents) to do exactly that, with all not only surviving, but enjoying the experience.

In the process of mapping, students had to find their location on an air photo while mapping the different rock types. They also observed variability within the rock units, all the while opening their eyes to the usually "invisible" rocks beneath their feet. Some of the interesting vignettes that can be recounted include: large plagioclase and quartz crystals in the granite; enormous glacial boulders; cubic "holes" left behind from the weathering of pyrite in slate; quartz banding and veins in the metasediments near the contact; and even "stalactites" made out of Portland cement, leached out by water percolating through the concrete structures built during WWII for the operation of the anti-submarine net. And of course, there is the overarching story of the region's glacial history, carving

out the harbour and creating a landscape which made the city so impervious to attack from the sea.

Following the walkabout, students were able to apply their newly-gained understanding by continuing their mapping during the car trip down Purcell's Cove Road as they passed from one rock type to another and back again all the way to the Armdale Rotary. After mapping the contact, participants compared their map to a published one (the AGS Geological Highway Map of Nova Scotia), giving them an appreciation for the astounding amount of work done by geologists who have preceded us. In this International Year of Planet Earth we have an opportunity to re-discover the Earth beneath our feet. This field trip serves as an example of similar outings wherever we might live. All that is necessary is for us to open our eyes to the diverse geological vignettes all around us waiting to be told.

Hydrogeological and geological inferences from core, well-logs, drill-stem tests, and 3D seismic data in the Sussex region of the Moncton sub-basin, New Brunswick, Canada

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The Lower Carboniferous Mabou Group represents a packet of continental red beds comprised of siltstone, sandstone, sandy shale, polymictic conglomerate, and coal in some places. These rocks overlie the salts of the Windsor Group evaporate, within which potash is mined at Penobsquis, New Brunswick. Aquifers within the Mabou Group present an inflow hazard to any potash mine in the Moncton sub-basin, and, in fact, the PotashCorp mine at Penobsquis has been dealing with a brine inflow into mine workings since 1998. Currently the inflow, while chronic, is manageable and has not had an impact on either potash or salt mining. However, recognising the potential consequences of such inflows, a program of investigating the hydrogeology of the Mabou siltstones was undertaken as part of a recent exploration program, when potash was discovered in the Picadilly region just south of the Penobsquis mine. A preliminary hydrogeological model for the siltstone in this region was created using well-log data (to gain basic rock-type and porosity information) and drill-stem formation testing (to confirm porosity inferences and establish formation permeability). The most useful borehole measurement was the "FMI" (Schlumberger Formation Micro-Imager) well-log, which was used to map fracture orientations (i.e. strike & dip), and to infer whether fractures were open (fluid-filled) or sealed (gypsum-filled). Core was used to confirm there results. Borehole data were extrapolated using high resolution 3D seismic. The end result is a 3D model of the Mabou Group siltstone aquifer in the Penobsquis / Picadilly area. This study shows the Mabou siltstone to be "tight" (i.e. low porosity and permeability) where it overlies the main zone of Picadilly potash mineralization.

Salt-related growth fault history and structural inversion in the Penobscot area, western Abenaki Subbasin, offshore Nova Scotia

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Earlier work in the western Abenaki Subbasin has established that the salt structures experienced two main phases of activity, one in the Jurassic-Early Cretaceous, the other in the Upper Cretaceous-Cenozoic, with a period of reduced activity in the "mid" Cretaceous (Aptian-Cenomanian). Although not the site of major salt structures, the fault systems in the Penobscot area are clearly linked to salt withdrawal to the north and south. Using recently publicly-released 3D seismic, this study examines the timing, magnitude, and location of growth fault displacement at Penobscot to gain a better understanding of salt movement in the area.

The amount of detail in the growth fault history is determined primarily by the number of seismic horizons that can be mapped reliably in the vicinity of the faults. This determines the number of time steps. Approximately 10 horizons were mapped in this study, stratigraphically ranging from the Upper Jurassic to Cenozoic. Two main, en echelon faults cross the Penobscot area. Numerous secondary faults complicate the structure, including a polygonal fault level at and just above the top of the Wyandot Formation. Corrections for time:depth relationships and folding in the vicinity of the faults are necessary to properly assess the growth history.

Early results of this work demonstrate that: 1) two main phases of fault motion are confirmed; 2) significant fault growth continued into the post-Eocene; 3) faults persist to within 150 metres of the modern sea floor; 4) there is evidence for fault inversion sometime in the Early Cretaceous (exact timing is yet to be determined). Whether the fault inversion is due to local salt tectonism or to broader tectonic events is unknown, but this study identifies the need for other studies in the region to better constrain the possibility of widespread structural inversion at this time.

Tri-national Soil Survey: Start of a North American geochemical data base

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The need for soil geochemical data for assessing human health and environmental hazard risks is well recognized. However, at present there is no common understanding

of soil geochemical background variation and its origin for those agencies dealing with human health and environmental risk assessment and management. The North American Soil Geochemical Landscapes Project - a tri-national initiative between United States, Canada, and Mexico – was designed to (1) develop a continental-scale framework for generating soil geochemistry and relevant biological and organic compound data; and (2) provide soil geochemical data that are available and useful for a wide range of applications and disciplines. This project is the first multi-national multi-agency collaboration of its kind starting with common focus and protocols.

The project is based on low-density sample collection (40 km spacing) over a spatially balanced grid with a total of 13, 212 sites over North America, including over 6200 samples across Canada. There is a core set of project protocols and also additional ones to meet the needs of users in each province and country. These include standardized sampling of the 0-5 cm "human health" layer, and the A-, B- and C-horizons and analysis of the < 2mm and < 0.063 mm fractions for selected trace, minor, and major elements (including Hg, Pb, As, and Cd) and limited organic components.

In the summer of 2007 a series of mini-surveys were undertaken to progress towards national geochemical coverage. A major initiative has been in the Maritimes where approximately 200 sample sites including 115 in New Brunswick, 55 in Nova Scotia and 10 in Prince Edward Island were taken. Samples in NB and NS were taken by the Ministry of Natural Resources. Similarly the USGS has covered a number of the New England states as well as a transect across Alaska. Mexico has started sampling and over 200 samples were taken.

In addition to the core set of parameters, a set of "add on" parameters will be assessed to determine if they should be added to the core protocols. The major component was analyzing for soil radon with the intention of creating maps of the potential of soil radon risk. This work includes ground based measures as well as airborne radiometric data. Results from the summer's work will be available by the spring of 2009.

Geology and architecture of deformation associated with the Scottie Creek fault, western Yukon

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The northwestern Canadian Cordillera is a complex assemblage of tectonic terranes defined on the basis of age, lithologies and metamorphic history. Within southwestern Yukon, the relationships of terrane boundaries remain ambiguous. The Scottie Creek fault and its associated shear zone marks the boundary between the newly defined Mirror Creek Formation and Triassic gabbro and Snowcap metasedimentary assemblage of the Yukon-Tanana terrane. Previously, the Mirror Creek Formation had been assigned to the Windy-McKinley terrane. The objectives of this study were to establish the detailed architecture across the shear zone, characterize the lithostratigraphic relationships of units and examine the kinematics of deformation. The methodology comprised detailed structural and lithological mapping in conjunction with microtextural analysis. Two primary exposures were studied, the northernmost being part of the Mirror Creek formation and the southernmost consisting of Triassic gabbros. The northern exposure consists mostly of quartz-muscovite schist, carbonate schist, quartzite and a mixed metasedimentary unit. The southern exposure is highly altered with two main lithologies, a chlorite schist and a fuchsite schist, plus a marble that does not seem to be depositionally related to the latter units. The deformation geometry is fairly consistent in both outcrops. F_1 and F_2 folding generations are nearly coaxial to each other and trend northwest-southeast. S_1 and S_2 commonly cannot be distinguished from each other on the regional scale and form a composite foliation. Transposition through isoclinal folding occurs for both generations. F_1 and F_2 fold axes form a small circle around the F_3 axis, which has a general orientation of 22°-211° and is defined by crenulations as well as open folds. S_3 foliation is rare, and where found is a discrete, spaced cleavage. Microstructural work shows development of complex tectonometamorphic fabrics that correlate with the macroscopic field observations.

Post-glacial tsunami hazard for eastern North America: real or imagined?

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Few tsunamis have been documented along the coasts of eastern Canada (5900BC(?), 1755, 1864, 1848, 1914, 1929, 2004) and the U.S. (5900BC(?), 1755(?), 1926(?), mid-1930s, mid-1960s, 2004). Known large marine or near coastal earthquakes are limited to 1886, 1929 and 1933. Thus need we be concerned about tsunamis as a potential coastal hazard?

Very clear post glacial faults (pgfs) have been documented in Fennscandia with lengths of 50 km and throws up to 10 m; such faults would have had magnitudes > 8.0 – even up to 9. It is believed that pgfs occur in rapidly deglaciating areas where zones of differential crustal strain can build up to trigger a seismic release. If such pgfs are known in the Fennoscandian shield is there any reason why they might not occur in the Greenland or Canadian Shield during or soon after deglaciation? However in Canada until recently no pgfs have been identified. The Dec. 25, 1989 Lac Turquoise 6.3 magnitude earthquake in the Ungava area of N. Quebec broke the surface of the shield for 8.5 km with reverse throws up to 1.8 m. This appears to be a modest pgf. In north central Manitoba the pre-historic Holy Grail Fault is at least 20 km long and forms a very evident curvilinear fault scarp of at least 5 m height in

Lake Agassiz varved clays. This pgf appears to have occurred beneath glacial Lake Agassiz raising the possibility that it was tsunamigenic and that Manitoba experienced Canada's first known tsunami! If pgfs can occur beneath a glacial lake can they occur below the ocean and cause tsunamis? Marginal marine channels are common off most glaciated coasts. These linear topographic lows are eroded by seaward-flowing continental ice sheets along the contacts between the onshore crystalline cratonic shield rocks and the offshore younger fringing sedimentary strata. Such marginal channels are known all around Canada's glaciated coasts, off Greenland and off Norway and may represent up to 100 m of glacially eroded rock giving rise to additional differential crustal strain during deglaciation. Alan Grant at the GSCAtlantic mapped apparent pgf fault scarps in the offshore Labrador Trough which is a pronounced marginal channel. These pgfs will have been tsunamigenic. The tsunamigenic Storegga Slide of 7900 y BP off NE Norway has moved ~20,000 cu km of continental slope sediment; no cause for the slide is known but to postulate an offshore, or coastal, pgf is a very reasonable suggestion. This then leaves us with the question of 'where might future pgfs occur indeglaciated areas in view of possible climate change or climate variability?' The coasts of Svalbard, Greenland, Baffin Island, Devon Is. and perhaps N. Labrador may all be the source of submarine pgfs that may be tsunamigenic or which may shake loose significant volumes of ocean floor, or continental slope sediments, to cause significant landslide tsunamis. In either case such events could threaten both the coasts of eastern N. America and parts of western Europe.

Nova Scotia case studies of radon soil gas distribution and mobility

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Radon is a radioactive noble gas that is formed by the decay of radium, which in turn is a product of the decay of uranium. All soils have radon present, and the concentration of this gas is dependant on the nature of the underlying bedrock, composition of the soil, permeability and porosity of the soil, and the organic content of the soil. In Nova Scotia there are numerous radon soil gas anomalies. The areas of high radon soil gas at Three Mile Plains near Windsor are related to uranium enrichment in the Horton Group sandstones and shales, whereas the radon soil gas anomaly at Reeves Road near New Ross is related to saprolites developed on the granites. In the Reeves Road occurrence a strong disequilibrium occurs, with radium concentrations greatly exceeding the uranium content of the weathered granite horizon, indicating that uranium has been mobilized out of the horizon and radium remains. Radon mobility within soil horizons in Nova Scotia can also be linked to groundwater movement. The concentration of radon in the atmosphere is very low and, therefore, radon-rich groundwater will lose radon by volatilization. The saturated zone of a soil, therefore, usually has higher radon content than the unsaturated zone.

Synergy between terrestrial and space technologies: auto-synchronized 3D-laser imaging and electromagnetic induction sounding

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Technological development for terrestrial and space applications is often closely interrelated. In one scenario, a proven terrestrial technology or scientific instrument is ported to space. Inversely, technologies developed for the rigors of space can find new uses in challenging terrestrial environments. This presentation will focus on two versatile Canadian technologies adapted to both terrestrial and space applications: auto-synchronized 3D-laser imaging and electromagnetic induction sounding.

The principle of auto-synchronized 3D-laser imaging originated at the National Research Council in Ottawa and was later adapted for space by Neptec Design Group of Kanata, Ontario. Neptec's Laser Camera System (LCS) projects an infrared laser beam on a target with rotating mirrors, and focuses the reflected light onto a linear detector array to obtain 3 spatial coordinates and intensity (X, Y, Z, I). The system is currently used during shuttle missions on low-earth orbit to inspect the orbiter's tiles for potential damage following liftoff. In an interesting twist, the system has recently found new terrestrial applications: non-intrusive measurement of the volume of rare and fragile meteorites, and fracture mapping in an underground mining environment.

Canada is a world leader in electromagnetic geophysical techniques, which have been credited with numerous mineral deposit discoveries since World War II. In electromagnetic induction, a transmitter outputs a time-variant, primary magnetic field which generates electrical currents in the subsurface. These currents, in turn, induce a secondary magnetic field which is recorded at the receiver. The Electromagnetic Induction Sounder (EMIS) is a compact instrument based on this principle. Hosted in a one-metre long tube, the instrument measures the electrical conductivity and magnetic susceptibility in the few first metres of the subsurface, e.g. for the characterization of agricultural soils and ice wedges in arctic polygons. The EMIS is of interest to the space community because of potential use to detect brine pockets in the near-subsurface of Mars.

Chemical and Sm-Nd isotopic constraints on the provenance and tectonic setting of late Neoproterozoic and Cambrian sedimentary and metasedimentary rocks in Avalonia of southern New Brunswick

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Neoproterozoic though Cambrian clastic sedimentary and/or metasedimentary rocks occur in the Hammondvale Metamorphic Suite (> ca. 620 to <680 Ma) and Broad River (ca. 620 Ma), Coldbrook (ca. 560–542 Ma) and Saint John (ca. 540–490 Ma) groups in the Avalonian Caledonia terrane of southern New Brunswick. The petrographic, major and trace element chemical, and Nd isotopic compositions of the sedimentary rocks provide constraints on the provenance and tectonic setting of these units and hence on the tectonic evolution of this typical part of Avalonia.

Nd isotopic and whole-rock chemical data show that the Hammondvale Metamorphic Suite and metasedimentary rocks of the Broad River Group have negative ε_{Nd} values, were derived from recycled sedimentary and mafic igneous sources, and were deposited in intra-arc basins as part of the ca. 620 volcanic-arc complex. In contrast, sedimentary rocks of the Coldbrook Group show generally positive ε_{Nd} values and likely were derived from Avalonian felsic to intermediate igneous sources and deposited in rift basins associated with 560–550 Ma arc extension. Samples from the overlying Saint John Group have felsic to mafic igneous sources, but are characterized by negative ε_{Nd} values and likely were deposited as part of a newly forming passive margin sequence.

Many metasedimentary and sedimentary samples from the Hammondvale Metamorphic Suite, Broad River Group, and Saint John Group fall outside the normal Nd isotopic range for Avalonian igneous rocks, whereas Coldbrook Group samples fall mainly in the typical Avalonian igneous Nd isotopic range, suggesting a substantially larger Avalonian crustal component in their evolution. Based on their mostly positive ε_{Nd} values, the sedimentary units in the Coldbrook Group were most likely derived from associated volcanic units as well as the older Broad River Group igneous units. The more negative ε_{Nd} values for samples from the Hammondvale Metamorphic Suite and Broad River Group indicate a large, isotopically mature source from more interior locations in Gondwana. Based on overlapping detrital muscovite ages and similar Nd isotopic values, the lower Saint John Group units were derived from the Hammondvale Metamorphic Suite, whereas the middle to upper units, which have more evolved Nd isotopic values, appear to require a source outside of the Caledonia terrane.

Phosphate deposits in Cambrian rocks of Avalonia in the Saint John area, New Brunswick

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Unusual black sandstone beds of Cambrian age (~530 to 511 Ma) occur in the upper part of the Glen Falls Formation and the lower part of the overlying Hanford Brook Formation of the Saint John Group in the Saint John area of southern New Brunswick. The dark color of these beds has been attributed to phosphatic minerals and iron chlorite. The ubiquitous presence of phosphorous, an essential nutrient for life, is important as these rocks formed during the time of the "Cambrian Explosion" in the early evolution of life. This project focuses on mineralogy, origin, and depositional environment of the black sandstones, as well as their disputed stratigraphic relationships with overlying and underlying rocks, and the phosphorous cycling that took place during deposition. The study will investigate also the correlation between the evolution of life as recorded in the Saint John Group and the appearance of phosphorite.

Phosphorite is defined as a marine sedimentary rock with equal to or greater than 18% P_2O_5. The sedimentary phosphate mineral is francolite. The origin of phosphorite involves phosphorous in particulate organic matter being transferred to sediment, followed by diagenetic degradation and dissolved inorganic phosphorous being released from the organic matter to sedimentary pore waters, causing the precipitation of francolite. This process produces phosphorite hardgrounds, as well as individual grains or concretions that become reworked, forming concentrated phosphorite beds. The phosphorite that occurs in the Glen Falls and Hanford Brook formations was likely linked to sea-level rise at the Precambrian-Cambrian boundary and iron-redox cycling. These events allowed more phosphorous to be available for life forms.

Fifty-two samples were collected from outcrops in and around the Saint John area and stratigraphic sections were logged for each location. The stratigraphic sections have been compared for lateral and stratigraphic variations. Interpretations of seven lithofacies described in these outcrops suggest deposition was in a tidal barrier island environment to mid-to-distal shelf environment. Thin sections of samples have been cut and examined using both petrographic and scanning electron microscopy to aid in determining paragenesis. Results confirm that francolite occurs as firmgrounds, intraclasts, and coated grains. SEM-EDS was used to determine the chemical composition of the phosphorites. Five samples were sent to the Queen's Facility for Isotopic Research where stable isotope compositions for carbon ($\delta^{13}C$) are being determined by ICP-MS; these data will aid in the interpretation of depositional conditions.

$^{40}Ar/^{39}Ar$ dating of three shear-zone hosted gold occurrences, northern New Brunswick

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Gold mineralization at the Elmtree, Middle River and Tetagouche Falls deposits is focused in ductile to brittle fault zones where hydrothermal fluids have overprinted Ordovician to Silurian host rocks. The gold occurs in sulfides as submicroscopic inclusions or lattice constituents of auriferous arsenopyrite-pyrrhotite ± (arsenian) pyrite ± chalcopyrite contained within quartz-carbonate veins or disseminated in the adjacent wall rocks. Sericite alteration (proximal) is intimately associated with Au mineralization in all three deposits. Other types of alteration including carbonatization, chloritization, and silicification (jasperoid formation) are more distal.

Six whole rock powders of drill-core samples from the sericitic alteration associated with each deposit were submitted for $^{40}Ar/^{39}Ar$ step heating to evaluate the timing of mineralization. Both Tetagouche Falls samples (n=2) yielded plateau ages of 420 ± 2 Ma (Ludlow) and 436 ± 3 Ma (Llandovery). The Middle River sample (n=1) gave a proper plateau age of 434 ±3 Ma (Llandovery). The Elmtree samples (n=3) did not give a plateau, but yielded ages ranging between 430 and 420 ± 4 Ma (Llandovery-Ludlow). For all samples the K/Ca and K/Cl ratios are not well correlated with age, suggesting a difference in the chemical composition of sericite between the low-temperature and high-temperature steps, later thermal overprinting, or the influence of other K-bearing phases.

Although the dataset is limited, two $^{40}Ar/^{39}Ar$ age plateaus are interpreted: one ≥ 430 Ma and the other circa 420 Ma. The older age is interpreted to reflect peak metamorphism (ca. 442–430 Ma) in the Brunswick subduction complex resulting from closure of the Tetagouche–Exploits back-arc basin. The age of 420 Ma is interpreted to reflect the timing of hydrothermal sericite formation coincident with Au mineralization, and is supported by the observation that mineralization extends into Wenlock-Ludlow sedimentary rocks at Elmtree.

The 420 Ma age of mineralization is significant in terms of regional tectono-stratigraphy as it is coeval with exhumation of the Brunswick subduction complex during the Wenlock (ca 428–418 Ma) and manifested by conglomerates containing erosional detritus from this complex. Exhumation occurred during oblique convergence of the Miramichi Zone (Ganderia) with Laurentia and was accompanied by strike-slip movement along major faults, i.e. Rocky Brook-Millstream and Elmtree faults, which acted as conduits for mineralizing fluids. Locally, mafic dykes that are altered and mineralized cut the Wenlock conglomerates and farther west in the Chaleurs Bay Synclinorium, there are mafic lavas that are coeval with these conglomerates. The 420 Ma age is clearly older than the major felsic intrusions in the area, i.e., Antinouri Lake Granite ≈ 372 Ma and Nicholas Dénys Granodiorite ≈381 Ma, meaning that Au mineralization is not linked to felsic plutonism.

Spatial and temporal evolution of the Rockeskyllerkopf volcanic centre, west Eifel volcanic field, Germany

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The Rockeskyllerkopf volcanic center (RVC) is part of the Quaternary West Eifel Volcanic Field. As a first step towards understanding the dynamics of the plumbing system, we have studied the volcanological evolution of the RVC and examined the evolution of the magmas and their source. The RVC comprises three distinct but overlapping centers that evolved over an extended period of time from distinct mantle sources. The oldest center, the SE Lammersdorf Center (SEL), was dominantly phreatomagmatic and formed a tuff ring. The earliest eruptions developed from pulses of magma transported rapidly from the mantle source; the lack of mantle xenoliths and more evolved geochemical signatures in the later SEL deposits indicate significant fractionation and possible development of a magma chamber. Phlogopite from the second eruptive event yields an $^{40}Ar/^{39}Ar$ age of 480 ± 50 ka. A phlogopite megacryst gave an isochron age of 643 ± 11 ka, implying an earlier phase of intrusion at depth, the products of which were subsequently entrained by the migrating SEL magmas. The second and dominant center, the Rockeskyllerkopf Center (RKK), lies to the SW and forms an elongate edifice parallel to one of the regional fault orientations. This center also comprises three distinct units; a lower spatter unit with overlapping cones aligned along a fissure, followed by well-bedded airfall deposits that are in turn overlain by another sequence of spatter, the later of which are closely associated with a dyke. Eruptions were more magmatic than those of the SEL center. This episode was followed by a significant hiatus during which weathering led to local soil development. The soil is overlain by an ash flow tuff deposited during the vent-clearing event that marked the onset of the last eruptive episode the Franzosichebuche (FB) center. This dominantly strombolian episode produced a small cinder cone. The final eruptions produced clastogenic lava flows, the distribution of which was controlled by local paleotopography. The lavas of the RVC are clinopyroxene and olivine phyric leucitites and nephelinites. Magma compositions reveal evidence for limited fractionation of clinopyroxene and

olivine in various proportions, generally consistent with the observed phenocryst assemblages. Major and trace element signatures indicate distinct sources for all three centers implying a combination of variable degrees of partial melting and vertical and lateral heterogeneity in the source region.

2007 deep-water marine seismic acquisition to define the Canadian Extended Continental Shelf under Article 76 of the United Nations Convention on the Law of the Sea

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The United Nations Convention on the Law of the Sea (UNCLOS) establishes under international law the concept of the 200 nautical mile exclusive economic zone (EEZ) allowing coastal states to exercise jurisdiction for the purposes of exploration, exploitation, conservation, and management of natural resources of the water column, seabed, and subsoil. Beyond the EEZ, there is also provision, under Article 76, for coastal states to define an Extended Continental Shelf (ECS) within which they may exercise jurisdiction over resources of the seabed and subsoil. Canada ratified the UNCLOS in November 2003 and has ten years from that date to submit a claim for an ECS to the UN Commission on the Limits of the Continental Shelf. The government allocated $70 million to the Department of Fisheries and Oceans and to Natural Resources Canada in September 2004 to acquire and compile all the necessary data and, with Foreign Affairs and International Trade Canada, to prepare the claim.

The Canadian claim will be based on existing and newly-acquired geophysical datasets including single- and multi-beam bathymetry, spot soundings, gravity, magnetics, and seismic reflection and refraction surveys. During the 2007 field season, 9800 km of seismic data were successfully acquired over continental slope, rise, and abyssal plain regions of the Atlantic and western Arctic margins of Canada. In the eastern Arctic, heavy ice conditions thwarted attempts to collect seismic data along the Canadian margin even though two icebreakers were used and one of them is considered to be the most powerful in the world.

The new datasets acquired specifically for the UNCLOS project are confidential until the Canadian claim is accepted by the UN. However, selected examples and important scientific results will be published as the data are analysed. Also, collaborations are being fostered with researchers in universities and other government departments to minimize costs and to take advantage of logistical opportunities to acquire complementary datasets. This poster presents an overview of the datasets that were acquired in 2007.

The Lower Devonian North Pole Stream Pluton: A strongly peraluminous granitic complex hosting a polymetallic vein-type uranium deposit, New Brunswick, Canada

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The North Pole Stream Pluton (NPSP) underlies an area of about 500 km² between Trousers Lake and Big Bald Mountain in north-central New Brunswick. Magmatic fractionation produced four, probable, comagmatic differentiates namely: biotite granite (oldest phase); biotite-muscovite granite; muscovite granite; and quartz-feldspar porphyry (QFP) granite that crosscuts all other phases of the pluton.

Existing petrochemical data for the NPSP suggest that the muscovite granite is the most highly evolved phase in that it has A/CNK = 1.3–1.4, a P/Ca higher than apatite, has low ∑REE (8.4 ppm), Zr/Hf (16.8), Nb/Ta (5.9), and Th/U (0.04), and is enriched in Rb (542.3 ppm), Sn (30.7 ppm), Nb (51.8 ppm), Ta (8.8 ppm), and U (28.5 ppm). The fractional crystallization of monazite, xenotime, zircon, and apatite in the muscovite granite produced extreme depletions in HFSE's and the REE's, and chondrite-normalized REE patterns with low LREEs/HREEs and a slight discontinuity between Nd and Sm.

Other phases of the pluton are far less fractionated and represent a continuous differentiation series that becomes increasingly more perphosphorus and uranium-specialized with decreasing age. The excess P is located primarily in K-feldspar, is enriched in the rims compared to the core of the grains, and increases in concentration with decreasing age of the host-granitoid. Ba and Cs have a similar relationship in K-feldspar; however, their concentrations decrease with increasing degree of fractionation.

A number of radiometric ages have been reported from the NPSP. A sample of biotite granite obtained from approximately one half kilometre south of the study area has yielded a U-Pb monazite age of 417 ± 1 Ma, and has been interpreted as the emplacement age of the NPSP. A ten-point whole-rock isochron from the biotite to the east of the map area gave an age of 387 ± 7 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.703. A muscovite K-Ar age of 414 ± 5 Ma and a Rb-Sr age of 381±4 Ma have been reported from one sample of muscovite granite and, from another sample, Rb-Sr ages of 425 ± 4 Ma and 397 ± 4 Ma have been obtained from muscovite and biotite respectively. Recent CHIME dating of quartz-hosted monazite inclusions in the muscovite granite has yielded an age date of 421 ± 6 Ma, implying the monazite inclusions pre-date the muscovite granite and are inherited from an earlier phase in the crystallization history.

The Long Lake polymetallic vein-type uranium deposit is located near the southwest end of the NPSP. The mineralization occurs in hydrothermally altered, and highly brecciated, northwesterly trending fractures that follow the regional structural trend and are parallel to the orientation of QFP dykes. The parallel orientation and the proximity of the veins to the QFP dykes imply a cogenetic relationship between the youngest phase of the NPSP and the uraniferous veins.

What is climate change? Engaging the public in a critical discussion

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During the past 18 months, the author has presented a talk entitled "Weather, Climate Change and Global Warming, what Al Gore didn't tell you!" to high school classes and service groups throughout Nova Scotia. Weather, as distinguished from climate, consists of the short-term (minutes to months) variations of the atmosphere. Climate change refers to the "… statistically significant change in measurements of either the mean state or variability of the climate for a specific place or region over decades to centuries". Alternatively, climate change has also been referred to in the press "as the process by which human emissions of greenhouse gases are believed to be causing changes in the Earth's climate system". Audience feedback during the author's presentations has shown that there is much confusion over what constitutes climate change and how to place local and regional climate variability in the context of global warming.

The author will discuss how his presentations resulted in a lively discussion of the differences in atmospheric phenomena and how an understanding of the differences might better inform the public's critical assessment of climate change policy and potential adaptation and mitigation strategies. As well, the author will discuss the reaction of the audience to the contention that pollution of the planet may be a more significant problem than global warming.

Partial digestions in soil geochemical exploration: How buffering, adsorption, and mineral stabilities influence data processing and interpretation

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In the 1990s, many commercial geochemical laboratories introduced ostensibly new, proprietary partial digestions for the analysis of soil samples from mineral exploration programs. These digestions were designed to solubilize specific components of soil samples (*e.g.,* those components transported from depth through exotic overburden to the surface) so that high geochemical contrast allowed reliable recognition of transported element anomalies. Unfortunately, the reception these proprietary digestions received from geoscientists has been highly variable: some geoscientists 'believe' in their worth as effective exploration tools, whereas others pan them as 'snake oil'. Furthermore, the performance level of these techniques has generally been disappointing, partly because no exploration technique is infallible, and partly because proper data interpretation is virtually impossible when the reagent chemistry used to solubilize a sample is unknown.

Factors that typically must be considered when evaluating what component of a soil sample has been put into solution, and thus providing insight into how to interpret geochemical anomalies, are: (*i*) the geochemical behavior of the pathfinder element, (*ii*) the stability and adsorptive behavior/characteristics of the mineral in/on which it resides, (*iii*) the equilibrium *pH* and *pe* of the soil in deionized water, (*iv*) the *pH* and *pe* of the reagent before and after digestion, (*v*) the presence of buffers in the reagent, (*vi*) the behavior of exchangeable ions in the reagent, and (*vii*) the presence of ligands in the reagent. Obviously, last four factors are not known when using a proprietary leach, but need to be to properly data process and interpret the cause of a soil geochemical anomaly.

For example, if Zn is adsorbed onto the surfaces of poorly crystalline Fe-oxy-hydroxides (*e.g*., ferrihydroxide, goethite and hematite) in a soil, and a weak solubilizing reagent (say, $MgCl_2$) merely causes cation exchange of Mg^{+2} for the adsorbed Zn^{+2}, then two factors could control the Zn concentration in the resulting solution: the amount of Fe-oxy-hydroxide in the soil, and the amount of soluble Zn available for adsorption to the soil (a factor probably related to the presence of mineralization). More Fe-oxy-hydroxide could produce a Zn anomaly merely because more adsorption of Zn could take place. Consequently, dividing the Zn concentration by the amount of readily soluble Fe would remove (standardize) these variations, leaving the variations caused by differing amounts of soluble Zn available for adsorption. However, if Pb occurs in clastically dispersed galena grains, and an oxidizing agent (say, nitric acid) oxidizes the sulphide, breaking down galena and liberating Pb, then examining the Pb concentration as an individual variable represents an appropriate data processing and interpretive strategy. Obviously, understanding the mineralogical and geochemical properties of soil samples and the behavior of partial digestion reagents are both required to identify the appropriate manner in which to evaluate and interpret geochemical soil anomalies.

Physical evidence of a late-glacial (Younger Dryas?) impact event in southwestern Nova Scotia

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An oval structure in southwestern Nova Scotia measuring 350 × 420 m has been identified as a possible Late-Glacial age impact crater. Evidence for an impact origin is based on integrated analysis of geomorphic, magnetic, petrographic, ground penetrating radar and stratigraphic data. A magnetic survey of the site indicates that the regional linear magnetic pattern in granitic rock is interrupted and distorted within the raised crystalline crater rim, due either to shock remagnetization or reorientation of broken blocks. Probable shock-metamorphic features in rim rocks, not present in unaltered rocks outside the structure, include common single and multiple sets of closely spaced (~4–15 μm) planar microstructures in quartz and feldspar, kink-banded feldspar and biotite, reduced mineral birefringence, rare diaplectic feldspar and rare melt veinlets with flow textures. Fresh grain comminution, grain mosaicism and other lattice distortion features are pervasive.

Ground penetrating radar shows that the crater has a depressed inner floor that is sharply ringed by a 10-m-high buried scarp. Heterogeneous material under the floor, interpreted as ejecta fallback or slumpback deposits, is overlain by stratified and faulted lacustrine sediment. A Late-Glacial age is inferred through similarities in sedimentation rates to nearby bogs with well-constrained ages and the lack of any evidence of ice-sheet reworking and associated glacial deposits. Strata within the structure appear to be wedge-shaped, indicating post-glacial differential subsidence and compaction. In addition to the main crater, a cluster of arcuate, rimmed scarps 1 km north of the structure may record additional smaller impact sites, suggesting the impactor fragmented upon entry into the atmosphere producing a crater field. The oval shape of the main crater may also indicate an oblique impact or impact doublet. Continuing research focuses on identifying ejecta material in lake sediments from southwestern Nova Scotia in order to elucidate any potential link to Late-Glacial environmental change.

Investigating flood risk in an ungauged watershed using LiDAR, GIS and HEC TOOLS

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This study was initiated because there is a concern over the predication and recurrence of significant flooding in the town of Oxford, Nova Scotia. The Oxford watershed is ungauged and modelling parameters required for HEC-HMS were derived based on the analogous, gauged, River John watershed. Voronoi polygons were used to distribute precipitation within the watersheds and Soil Conservation Society curve numbers were calculated using LandSat ETM and imagery and soil drainage data. Base flow was calculated using a ratio to peak of 0.11 and recession constant of 0.87. The constant rate of infiltration is 0.074 m/hr. Recurrence intervals calculated for the Oxford watershed show that the September 1999 flood was a 1 in 23 year event and that 10, 25 and 100 year floods have flows of 156 m^3/s, 197 m^3/s and 258 m^3/s respectively. Using these flows, inundation was calculated and flood risk maps were produced using HEC-RAS. This study has developed new and repeatable techniques for simulating flooding events in rural Nova Scotia by using LiDAR intensity and height data as an indicator of friction and selecting and analogous basin for use in the HEC-HMS modelling system. Sensitivity analysis shows that SCS curve number is by far the most important factor in watershed modelling and variations by 10% result in recurrence interval peak flows of between 8% and 10%.

500 million years of episodic anorthosite/leucogabbro – granodiorite/monzogranite (ALG) magmatism in the Archean Yilgarn craton

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The Narryer Gneiss Complex (NGC) of Western Australia is one of largest intact blocks of early-middle Archean rocks (3.7–3.2 Ga) preserved on Earth. New laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS) U-Pb zircon geochronology and whole rock geochemistry of twenty-five NGC orthogneisses suggest that the terrane formed largely from episodic, bimodal

anorthosite/leucogabbro–granodiorite/monzogranite (ALG) magmatism. Trondhjemite-tonalite-granodiorite (TTG) and dioritic magmatism, common in many Archean terranes elsewhere, is rare in the NGC. ALG suites represent a newly-defined, distinctive magmatic association for the Archean, similar in some respects to Mesoproterozoic Anorthosite-Mangerite-Charnockite-(Rapakivi) Granite (AMCG) suites.

The gneiss samples were collected from north of the Jack Hills and northwest of Mount Dugel. LA-ICP-MS U-Pb zircon ages cluster at 3720 Ma, 3680 Ma, 3620 Ma, 3490 Ma, 3320 Ma, and 3260 Ma. Each of the age populations includes granodiorite/monzogranite gneisses, and all except the two youngest populations consist of anorthosite/leucogabbro gneisses. The granite gneisses have remarkably similar bulk compositions, independent of age: they are all moderately peraluminous (alumina saturation indices of 1.05 to 1.1) potassic granodiorites and monzogranites, quite unlike their more well-known Archean, sodic TTG counterparts. Formation of the ALG magmatic association is not easily reconciled with convergent plate tectonic processes (subduction). Its existence suggests that a major mechanism of mantle heat loss before 3.2 Ga was by episodic, but long-lived, within-plate magmatism in intra-continental rifts or at hot spots.

Petrographic, chemostratigraphic, and alteration analysis through the deformed volcanosedimentary sequence hosting the Boomerang massive sulfide deposits, Tulks belt, central Newfoundland

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A detailed study of 8 drill holes through the Cambrian to mid-Ordovician rocks of the Tulks volcanic belt that hosts the 1.3 Mt Boomerang massive sulfide deposit in central Newfoundland is an attempt to unravel the complicated host stratigraphy and enhance correlations in this belt. The deposit strikes at approximately 225° and dips 80° to the NW. Rock types include various felsic, intermediate, and mafic pyroclastic rocks (ash tuffs, lapilli tuffs, and agglomerates), mafic to intermediate dykes and sills, and sedimentary rocks (greywacke, grey siltstone, graphitic argillites, and carbonaceous phyllites).

The hanging wall tuffs are composed of approximately 50% fine grained quartz with rare quartz and feldspar phenoclasts (10%), 30% fine-grained muscovite with minor sericite, and rare carbonate and sulfides; dominantly pyrite with very rare base metals and rare accessory minerals. The footwall tuffs differ with increased fine-grained muscovite and sericite up to 50% with 30% fine-grained quartz and increased base metals including sphalerite with less chalcopyrite and galena.

Immobile elements and their ratios prove very useful in stratigraphic interpretation. Four populations of dykes and sills have been identified, ranging from basaltic andesite to rhyolitic dacite, based on element abundances and ratios including (Winchester and Floyd inverse ratio numbers in italics) TiO_2/Zr (213.1, 98.97, 51.04, 83.79) (*0.0048, 0.010, 0.020, 0.013*), Y/Nb (10.6, 5.51, 4.30, 10.1)(*0.098, 0.20, 0.24, 0.10*), TiO_2/1000 (9.45, 13.1, 9.28, 7.10), Y+Nb (20.5, 29.3, 35.8, 29.6), Zr/Y (2.43, 5.49. 6.40, 3.14, Zr (45.56, 136.1, 182.4, 83.79), V (399.9, 232.5, 108.3, 45.29), Y (18.6, 24.4, 29.0, 26.8), Nb (1.81, 4.92, 6.75, 2.76), Rb (7.00, 18.8, 28.9, 14.94), and Th (2.00, 3.75, 6.25, 2.74). The footwall and hanging wall tuffs are geochemically very similar shown by element ratio averages of (Winchester and Floyd inverse ratio numbers in italics) TiO_2/Zr (HW=77.22, *0.026*, FW=85.20, *0.018*), Al_2O_3/Zr (HW=2062.51, *0.0007*, FW=2432.66, *0.0005*), Zr/Y (HW=3.98, FW=4.12), TiO_2/Y (HW=244.23, *0.006*, FW=280.34, *0.004*), Al_2O_3/Y (HW=6995.25, *0.00018*, FW=8717.30, *0.00013*), TiO_2/Al_2O_3 (HW=343.17, FW=328.22), Th/Nb (HW=1.20, FW=1.03), and Zr/Th (HW=3.98, *0.033*,FW=4.12, *0.034*) and range from basaltic andesite to rhyolitic dacite.

Towards the ore horizon deformation increases in intensity with two directions of foliation which are enhanced by increased sericite. The alteration system and stockwork zone are recognizable by: (1) increased Fe-rich chlorite and disseminated and veined sulfides in the hanging wall; and (2) intense sericite alteration with increased disseminated and veined base-metal sulfides in the footwall. This is consistent with the fact that $Al_2O_3/(Al_2O_3 + K_2O + Na_2O)$ increases with proximity to the ore horizon.

Monazite as a provenance indicator for the Lower Cretaceous reservoir sandstones, Scotian Basin

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Electron microprobe geochronology on detrital monazite grains was determined to understand the provenance of sediment supplied to the Lower Cretaceous deltas of the Scotian Basin, to interpret distribution of river mouth facies and to understand variability in diagenesis and hence reservoir quality. Previous work demonstrated the use of detrital monazite in the fluvial facies of the Lower Cretaceous (Chaswood Formation).

197 detrital monazite grains from 13 wells and different stratigraphic levels of the Lower Cretaceous of the Scotian Basin have been dated by electron microprobe and groups of monazites of similar age have been characterised by backscattered electron imagery and REE chemistry. After removing analyses showing errors greater than 20% (resulting from interference of Y and Th in Pb peaks, and Th in U peaks) and single analyses that were extreme outliers, ages from 651 analyses

were interpreted. Based on their REE abundance, monazites were classified into 4 types (A–D). Moreover, X-ray maps were made from selected grains and histograms and cumulative probability plots were produced for each well.

Detrital monazite from western Scotian Basin (Naskapi N-30) yielded Carboniferous ages. In the central Scotian Basin (Alma K-85, Thebaud C-74, I-93 and 3, Glenelg E58 and E58A, Venture 1, 3 and 4) Devonian and Silurian–Devonian ages are the dominant populations in both the Logan Canyon and Missisauga formations, and a small peak at 500 Ma is found at Venture. Proterozoic ages, present throughout the central part of the basin, are the second largest population. In the eastern Scotian Basin, Mesoproterozoic ages dominate in the Peskowesk A-99 well, whereas in the Tantallon M-41 the majority of the ages are Silurian–Devonian. Based on REE patterns, there is a clear discrimination between the western Scotian Basin (Naskapi N-30), where types C and D predominate, and the central and eastern part of the Basin where type A and B type patterns are more abundant.

Variation in detrital monazite age and composition suggest that several rivers transported sediment from multiple bedrock sources. At least one river supplied material to the western part of the Scotian Basin, as indicated by the Carboniferous ages and the distinctive dominant REE patterns. In the eastern part of the basin (Peskowesk A-99) the dominant ages are Proterozoic and type C REE patterns are absent, indicating that this part of the Scotian Basin was fed by a different river relative to the one(s) that supplied material to the central part of the basin.

Geochemical identification of clastic sediment provenance from known sources of similar geology: the Cretaceous Scotian Basin, offshore eastern Canada

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This study tests the effectiveness of a geochemical approach in identifying provenance in a basin where different sources do not show strongly contrasting geology. Petrological studies indicate that at least three distinct rivers, draining reactivated horsts of the Appalachian orogen, supplied sediment to the Lower Cretaceous deltaic sandstones and mudrocks in the offshore Scotian Basin. 95 samples mostly from conventional core were analyzed for 44 major and trace elements. The data were first screened for variability unrelated to provenance, including changes in elemental abundance due to weathering and diagenesis, and the effects of grain size and sorting on element variation. The effect of hydraulic sorting was distinguished from the effects of concentration of ultrastable heavy minerals from polycyclic sources. Multivariate statistical analysis by principal component analysis (PCA) was used to test the hypothesis of three discrete sources suggested by the petrologic model. Major element PCA on sandstones discriminated the sources but results from trace element PCA required further investigation using element biplots to understand their significance. Only a few elements were found to be diagnostic of different sources, namely K, Rb, Sr, U, Th, Nb and Ti, with the latter two of value only for sandstones. These are all elements that are abundant in the granites of the Appalachians. Most published geochemical discrimination diagrams did a poor job of distinguishing the three petrographically recognized sources. In other basins with quite different hinterland geology, other elements are known to be of value in discriminating provenance. Thus it is unlikely that a globally applicable set of elemental discriminants can identify terrigenous sediment sources. Rather, systematic investigation is needed that evaluates processes such as diagenesis and sorting and then tests geographic and stratigraphic variability in bulk geochemistry, informed by at least semi-quantitative petrographic data.

Dendroclimatic response of alpine treeline species in central Labrador: a multi-species perspective

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This study presents the first black spruce, balsam fir and larch tree ring width chronologies from Labrador. It uses a multi-species perspective to study the radial growth response of alpine treeline species in the Mealy Mountains to local and regional climate variables using bootstrapped correlation analysis. The radial growth response of black and white spruce trees is positively sensitive to growing season air temperatures and sea surface temperatures (SSTs) in the vicinity of the Grand Banks. Moisture originating from warm SSTs in the adjacent Labrador Sea appears to affect moisture-sensitive white spruce and balsam fir trees negatively in the Mealy Mountains.

Comparative analysis of 4 tree-ring time series indicates that periods of larch sawfly outbreaks have occurred in the Mealy Mountains and that these events exert a significant amount of influence on the radial growth of larch trees in the Mealy Mountains. These inferred periods of insect infestations coincide with others reported in Quebec.

Growing season (June-September) temperature is reconstructed for the Mealy Mountains using merged spruce tree ring width chronologies (1847–2004). The reconstruction is in accordance with other reconstructions at regional and hemispheric scales. The sensitivity of spruce trees to local temperature and precipitation is unstable throughout the period

of instrumental record due to moisture effects. Further, spruce trees in the Mealy Mountains show evidence of divergence from air temperatures over the last several decades.

Unravelling the sources of the thick Miocene pyroclastic flows, Kos (Greece)

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Kos is one of several localities (Samos, Patmos, Bodrum) in the southeast Aegean Sea with Upper Miocene volcanic rocks. The stratigraphic succession of flows, ignimbrites and interbedded sediments were studied in the field in order to better understand the age, distribution, source and tectonic setting of Upper Miocene volcanic rocks of Kos. Previous radiometric dating shows that the age of the volcanism is about 10 Ma.

In northern Kos, thin andesite flows and dacite domes are overlain by thin pyroclastic rocks near Profitis Ilias and at Tripa; north of Ag. Fokas, a thin pyroclastic succession includes lahars. In southern Kos, pyroclastic successions totalling 80 m in thickness are interbedded with Miocene clastic sediments and marls at Ag. Fokas and Ag. Stefanos.

At Ag. Stefanos, the lowest volcanic rocks are volcaniclastic conglomerates deposited from channelised hyperconcentrated flows, overlain by an ignimbrite rich in limestone clasts. This is overlain by 50–60 m of marls and clastic sediments, a 10–20 m thick ignimbrite succession, a further 80 m of marls and clastic sediments, and finally 60 m of ignimbrite, possibly in three major eruptive cycles with upward increase in abundance and size of lithic clasts. At Ag. Fokas, 80 m of ignimbrites overlie thin airfall tuff over marls and are interrupted by two thin intervals of sediment, one marl and the other sandstone. In both localities, interbedded sediments appear to be of fluvial or lacustrine origin.

Paleocurrent indicators in ignimbrites suggest that the Ag. Stefanos section was derived from a source to the southeast and Ag. Fokas from a source to the south, most probably from a Miocene precursor of the modern volcanic centre of Nisyros–Yali. Lithic clasts in the ignimbrites were divided into groups on the basis of petrography and geochemistry, to attempt correlations between Ag. Stefanos and Ag. Fokas and to assess their affinity to the minor andesite-dacite volcanism at Prof. Ilias and Tripa. Preliminary results suggest correlations between the upper Ag. Stefanos ignimbrite and that at Ag. Fokas north. Other ignimbrites appear to be petrographically distinct. Clasts similar to lavas at Prof. Ilias are common in several ignimbrites.

Upper Miocene volcanism was synchronous with emplacement of the Dikeos monzonite during E-W strike-slip faulting. This faulting created local transtensional or transpressional deformation, leading to uplift and unroofing of the monzonite, the overthrusting emplacement of alpine basement onto the monzonite, and creation of the Late Miocene basins in which thick successions of ignimbrite were deposited subaerially or in shallow lakes. The flows at Prof. Ilias and Tripa may be related to the faulted northern margin of a southern Kos basin within which the thick ignimbrites accumulated. The thickest ignimbrites were derived from a stratovolcano located near the present island of Nisyros.

Geology and mineral occurrences of the Faribault Brook area, Cape Breton Island, Nova Scotia

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The Cheticamp area of western Cape Breton Island is located in the Aspy terrane, part of the Ganderia realm of the northern Appalachian orogen. Equivalent parts of Ganderia in Newfoundland and New Brunswick are well known for their mainly volcanic-hosted metallic mineral deposits, and hence the Cheticamp area potentially has similar deposits. Mineral occurrences (Zn, Cu, Pb, Fe, As, Au) around Faribault Brook east of Cheticamp have been exploration targets since the 1890s, and are hosted by rocks generally assigned to the Ordovician-Silurian Jumping Brook Metamorphic Suite (JBMS). Subsequent geochronological work in the 1990s in the area showed that at least some of the metasedimentary and metavolcanic rocks of the JBMS could be Late Neoproterozoic, and similar in age to the ca. 550 Ma Cheticamp Pluton. However, no new mapping or petrological studies had been undertaken since then to assess the significance of these new age data.

During the summer of 2007, an area of ~180 km² that included all of the known mineral occurrences in the Faribault Brook area was mapped at a scale of 1:20 000, and geophysical data were incorporated in constructing a revised geological map of the area. Recent trenches not available to earlier workers were examined, as well as all available drill core from the area in the core storage facility at Stellarton. Mineralization was observed in mafic and felsic metavolcanic units, as well as in associated metasedimentary rocks. Unit names follow as much as possible those established by earlier workers, and include the Faribault Brook metavolcanic unit, Dauphinee Brook schist, Barren Brook schist, George Brook amphibolite, and Corney Brook schist. The Faribault Brook metavolcanic unit is mainly mafic flows with less abundant felsic flows and mafic tuff. The George Brook amphibolite appears to represent higher grade metavolcanic rocks. The Dauphinee Brook schist is fine-grained and pelitic, whereas the Barren Brook schist is coarser grained and has a higher quartz content. The Corney Brook schist is

higher grade and includes metasedimentary and meta-igneous units; it may be similar to or part of the Pleasant Bay Complex. The contact between the Dauphinee Brook schist of the Jumping Brook metamorphic suite and the Cheticamp Pluton is intrusive, at least in part, rather than a nonconformity or fault as suggested in some earlier interpretations, based on recently exposed outcrop. Hence at least part of the Jumping Brook Metamorphic Suite is older than ca. 550 Ma. However, felsic porphyry that hosts mineralization at some locations (e.g., Galena Mine) is Silurian based on published U-Pb (zircon) ages. Similar lithology is observed at the Mountain Top Adit where is seems to be extrusive rather than intrusive as at the Galena Mine occurrence.

Barium as a possible indicator of biogenic methane generation

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Biogenic gas resources associated with an influx of fresh subglacial water during the late Pleistocene and early Holocene are known to exist in various sedimentary basins in North America. It is suspected that the Western Canada Sedimentary Basin (WCSB) may contain natural gas of this origin but there have not been any detailed studies on this possibility aside from a significant body of research examining the hydrodynamics of the basin during the last glaciation. In this study, the possibility of biogenic gas generation in the Winnipeg Formation is examined through an analysis of groundwater from that formation. The presence of low sulfate and elevated barium concentrations in the Winnipeg Formation of southeastern Manitoba indicates that redox conditions necessary for the production of methane may have been present. Geochemical models created using PHREEQ C corroborate this concept. This indicates that barium might be a good indicator of areas with natural gas potential and this is also supported by data available for the Michigan Basin.

Geological factors affecting surface water chemistry in southwestern Nova Scotia

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In southwestern Nova Scotia, some lakes have been adversely affected by acid rain, causing a reduction of pH and stress to fish habitat. The effects of this acidification have been heavily studied in terms of ecology and water chemistry, and have been extensively monitored and modelled. Previous studies have generally ignored the effects of geology, however, considering the bedrock as 'un-buffering' granites, metasediments and slates. Although bedrock geology may have a more significant control on water chemistry than previously considered, this study focuses on the role of glacial sediment cover on the buffering capacity of lakes in southwestern Nova Scotia.

Southwestern Nova Scotia has been affected by numerous glacial events including the Escuminac Phase, when an ice divide located to the north over the Magdalen Shelf resulted in glacial advance to the south over the region. This phase produced tills and drumlins composed of distally derived material that may have higher calcium carbonate content than locally derived materials. Because of the region's complex history of multiple ice-flow phases, this calcium carbonate is not equally distributed. Understanding its dispersal and relationship to water chemistry is critical for modelling responses to acid rain.

To establish a link between glacial sediment and lake chemistry, the authors compare a Department of Natural Resources archive of over 3000 lake sediment geochemistry samples collected in the late 1970s to water chemistry from Environment Canada's database of monitoring lakes (n=74), which has operated continuously since the 1970s. In lakes where both the sediment geochemistry and water chemistry were measured, there is a negative correlation between calcium concentrations in the sediment and the acidity of the water: lakes with higher concentrations of Ca in their sediments have less acidic water. A map of Ca concentrations from the more extensive lake sediment database reveals that lakes with enough Ca in the sediment to buffer the lake pH tend to occur within drumlin fields. This is confirmed at the scale of local catchments, where if the upper topographic elevation is above the occurrence of drumlins a corresponding low Ca concentration is observed. Conversely, in the lower elevations of the catchments, if they lie within a drumlin field, higher Ca concentrations are measured in the sediment.

Ice-flow and deglacial chronology, Foxe Peninsula, southwest Baffin Island, Nunavut

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The Foxe Peninsula lies north of the former Hudson Strait ice stream and along the southern margin of the Foxe Dome of the Laurentide Ice Sheet, placing the peninsula in a salient location to record glaciologically significant events such as marine incursion in Hudson Strait and Foxe Basin. Field data collected in 2006, as part of the Southwest Baffin Integrated Geoscience Project (SWBIG), have led to an improved model of ice flow and deglaciation in the area, based on ice-flow indicators, marine-limit features, distribution of erratics, till geochemistry and radiocarbon dating.

At full glacial conditions, ice flowed toward the east in Hudson Strait. In the eastern portion of the peninsula, ice

flow was predominantly to the southwest, flowing from the Amadjuak Ice Divide. The western sector experienced more changes in ice flow, where the potentially full ice configuration flow was toward the southeast, possibly from the Foxe Divide, radiating from the Foxe Dome. Later, flow in the western sector shifted southward, as an apparently greater control was exerted from the Amadjuak Divide.

Ice likely evacuated from the Hudson Strait relatively rapidly, initiating deglaciation of the Foxe Peninsula. This resulted in the highest and oldest glaciomarine features observed on the peninsula: ice contact deltas at 180 m with related radiocarbon ages of *ca.* 8.1 ^{14}C ka BP (9.0 cal ka BP). As deglaciation progressed, a re-advance formed large moraines (the 'Foxe moraines') on the western part of the peninsula. Elevated calcium in till samples, numerous carbonate erratics, and shell fragments that predate the last glaciation on the peninsula north of the Foxe moraines (i.e. ice proximal side) indicate a source for the material offshore and suggest higher ice sheet velocities and greater transport distances for this phase of ice flow compared to the rest of the study area. An age for this phase is bracketed by radiocarbon ages and marine limit observations distal to the moraine of *ca.*7.7 ^{14}C ka BP (8.0 cal ka BP) at 150 m, compared to the age of marine limit proximal to the moraine some 700 years later at 132 m. Between the western and eastern sectors is a lowland area, where the presence of De Geer moraines suggests a grounded ice margin that retreated northwards. This marine incursion may relate to the collapse of the Foxe Dome, disintegration of the Amadjuak Divide, and ultimately formation of the Amadjuak Dome centred over Amadjuak Lake in the eastern sector. This resulted in a shift of ice-flow direction in the north of the eastern sector by more than 90 degrees, to flow to the northwest. In the eastern sector, marine limit elevations decline with more recent deglaciation in a gradual northward pattern with no re-advance detected, and in comparison to the western sector are younger by almost a thousand years.

A tale of two estuaries: Comparison of anthropogenic impacts on the contemporary evolution of the Avon and Petitcodiac River systems, Bay of Fundy

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Both the Avon and Petitcodiac River estuaries have had a long history of modification by human activities ranging from dyking by the Acadians to causeway construction in the late 1960s. This presentation examines the spatial variability and temporal in the intertidal morphodynamics of both estuaries and compares the resilience of each system to the influence of tidal barrier construction. Contemporary bathymetric surveys were compared with historical surveys from the 1960s/70s as well as an 1858 British Admiralty bathymetric chart. These data were modeled and observed changes supported by orthorectified aerial photography and satellite imagery using ArcGIS 9.2.

Both rivers demonstrated very rapid sedimentation during the final stages of the construction and rapid infilling during the first year after the causeway was completed. In the case of the Windsor causeway, this accumulation took place in the vicinity of a pre-existing sand bar. At both sites, there was a significant decrease in intertidal cross sectional area within the first km downstream of the causeway. The greatest decrease was measured on the Petitcodiac (90%) whereas between a 54 to 75% decrease was measured at Windsor from 1970 to 2006 as a layer of sediment between 5.8 to 6.5 m deep accumulated downstream of the causeway. Once sufficiently consolidated, these mudflats were rapidly colonized by *spartina alterniflora*. Beyond this point, approximately 3 km downstream of the causeway on the Avon River, there was no significant decrease in cross sectional area. The minor changes recorded could not be directly attributed to the causeway, but rather were likely associated with shifts in the main tidal channel as the St. Croix River joined the Avon. In addition, seasonal cycles of changes in bed elevation by as much as 2 m were measured, which exceed differences recorded between 1858–1969 and 2005/2006. For the remaining 11 km downstream, after the entrance of the Kennetcook River, negligible changes in intertidal cross sectional area were recorded since 1858. Any changes in bed elevation can be linked to changes in the position of major intertidal sand bodies. Any areas of sedimentation along the shoreline have been compensated by either deepening of the main tidal channel or bank erosion along the opposite shore. In the Petitcodiac River, however, the bed elevation rose by 2 m and continues to infill 16 km downstream of the causeway. It is hypothesized that the resilience of the Avon system to the construction of the causeway is mostly attributed to its sandier sediment and associated sediment dynamics, position of the causeway within the broader estuary, and hydrology.

The Halifax Experimental Pollen and Spore Monitoring and Forecast Program: publicizing 6-year results and trends

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The Saint Mary's University-Environment Canada Experimental Pollen and Spore Monitoring Program began operating in Nova Scotia in 2000. Airborne pollen and spore levels have been recorded daily throughout the flowering season at various locations, based on land use and population density. Previously sites have included include Halifax, Beaverbank or Wellington, and Noel Shore (urban, suburban and rural settings, respectively). In 2006 samplers were stationed in Halifax, Kentville, and Sydney, allowing monitoring over greater geographical and climatic ranges. Annual variation in the pollen records appear to be due to biannual reproductive behaviour, local weather conditions, latitudinal differences, and prevailing climatic conditions.

Pollen forecasts are made based on the species trapped, the densities calculated, and the predicted weather. Pollen and spores are potentially allergenic to sensitive individuals, and the forecasts publicize when activity and medication modification may be advisable, helping reduce the demands on the health-care system. Forecasts were updated for Halifax each afternoon Monday to Friday and were available to the public electronically via a hyperlink found at Environment Canada's Halifax weather forecast website. It was also available for Halifax on an automated voice message system.

Long-term monitoring may reveal early indications of vegetation responses and increased health risks from anthropogenic atmospheric contamination and global warming. Seasonal pollen calendar composites can aid in interpreting the taphonomic changes that occur in the processes of deposition and preservation of Holocene pollen records, and the vegetation patterns and climates responsible for producing these records.

LiDAR collection and processing in the coastal Bay of Fundy region and Cobequid-Chedabucto fault system, Nova Scotia.

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Light Detection and Ranging (LiDAR) is a technology that can be used both from an airborne or terrestrial platform to precisely measure range information. Since 2000, researchers at the Applied Geomatics Research Group at COGS have been involved with using airborne LiDAR data to construct high-resolution surface models and more recently using terrestrial based LiDAR to image cliffed shoreline exposures that are not well resolved with airborne technology. In collaboration with the Geological Survey of Canada, part of the costal region of the Bay of Fundy has been surveyed with airborne LiDAR, including Joggins and the Parsborro area. Airborne and terrestrial data have been merged to capture the deformation in the Carboniferous rocks along the Walton-Cambridge Cove area. A recent survey has been conducted along the northern boundary of the Cobequid-Chedabucto fault system between Eden and Guysborough. The usual ground point spacing of these small scale surveys are on the order of 0.5 to 1 m and the data volumes are on the order of several gigabytes. Once a survey has been flown the processing steps include: 1. process the trajectory of the aircraft and relate the laser ranges to the aircraft position; 2. export each flightline as binary LAS files (LiDAR standard format); 3. LiDAR point cloud is analyzed to determine ground and non-ground points; 4. points are imported into a GIS for validation and analysis; 5. two types of surface models are constructed: Digital Surface Model (DSM) using all the points and a Digital Elevation Model (DEM) using only the classified ground points. These surface models are then used to derive other parameters such as shaded relief models and surface profiles. Ground points at the top of cliffed shorelines and other abrupt natural vertical structures are often incorrectly classified by most standard algorithms and must be dealt with differently than other variable terrain. This presentation will review airborne and terrestrial LiDAR and the associated workflow and potential pitfalls (abrupt terrain changes) and present examples of recently completed surveys of areas of geolscience interest.

Defining the stratigraphy of the Meguma Supergroup in southern Nova Scotia: where do we go from here?

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In 1998, the Nova Scotia Department of Natural Resources began a major bedrock mapping initiative in the Meguma Group of southern Nova Scotia to produce a series of 1:50 000-scale geological bedrock maps. As a result of mapping, combined with follow-up geological studies, a redefinition of its stratigraphy is now justified.

As previously proposed, the lower metasandstone-dominated Goldenville Formation and upper slate-dominated Halifax Formation should be formally elevated to 'group' status. Mapping has demonstrated that both formations can themselves be subdivided into formations and members. Thus, the Meguma Group will be elevated to a 'supergroup'. The Meguma Supergroup can be divided into two distinct stratigraphic packages separated by the Chebogue Point shear zone (CPSZ). In the Digby-Yarmouth area (west and northwest of the CPSZ), the lower part of the Goldenville Group is the metasandstone-dominated Church Point Formation, whereas the upper part consists of metasiltstone of the Bloomfield Formation. Units in the overlying slate-rich Halifax Group are the Acacia Brook Formation and overlying Bear River Formation.

East of the CPSZ in the Pubnico-Chester area the lowest unit in the Goldenville Group is a metasandstone/slate package termed the Moses Lake Formation. The Moses Lake Formation is overlain by the metasandstone-dominated Green Harbour Formation, which is similar in appearance to the Church Point

Formation. The middle part of the Goldenville Group consists of metasandstone/metasiltstone assigned to the Government Point Formation. No equivalent unit is recognized in the Digby-Yarmouth area. The upper part consists of Mn-rich metasiltstone of the Moshers Island Formation. Although this unit appears to be the stratigraphic equivalent to the Bloomfield Formation, no Mn-rich beds have been found west of the CPSZ. Units in the overlying slate-rich Halifax Group include the Cunard and overlying Feltzen formations.

The Church Point Formation of the Goldenville Group contains a metasiltstone unit (High Head Member) with a distinctive trace fossil assemblage characteristic of the boundary between the Neoproterozoic and Phanerozoic, suggesting that the Goldenville Group below this member extends into the Neoproterozoic. The upper part of the Government Point Formation has yielded early Middle Cambrian trilobite fossils of Acado-Baltic affinity. The upper part of the Bear River and Feltzen formations locally contains the Early Ordovician graptolite *Rhabdinopora flabelliformis*, suggesting that the underlying Acacia Brook, Cunard, Bloomfield, and Moshers Island formations are Middle to Late Cambrian, and that a significant unconformity exists between the Halifax Group and the overlying late Ordovician–Early Silurian White Rock Formation. A revised minimum thickness for the Meguma Group is 10 km.

One of the most significant obstacles to formalizing the proposed stratigraphy in the Meguma Supergroup is gaining acceptance of the new subdivisions among geologists. Hence, establishment of a joint working group is proposed to reach consensus on the proposed divisions and avoid confusion in the geological literature.

The Quaternary erosional and depositional history of the Black Point area, Saint John, New Brunswick, based on seismic sub-bottom profiles

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High-resolution seismic sub-bottom profiles from the region offshore of Saint John Harbour facilitate the first investigation of coastal marine Quaternary units in the area. The data were obtained from a region 7 km W-E, and 10 km N-S encompassing an ocean disposal site located near Black Point in the approaches to Saint John harbour. Sediments dredged from shipping channels in Saint John harbour are disposed of at this site. One sub-bottom profile extends north of the main study area into the mouth of the Saint John River, and another profile extends 21 km south of Partridge Island. A total of 41, mostly N-S oriented lines, were interpreted. The nominal line spacing was 150 m in the central region, and 320 to 750 m in the eastern and western extremities of the study area.

Stratigraphic assignments are based on comparisons with the ground-truthed geological units present off the Scotian Shelf and include bedrock, till, Emerald Silt facies A, Emerald Silt facies B and LaHave Clay. Some differences were noted from the Scotian Shelf region including the presence of a single layer of non-interdigitating till, which becomes discontinuous to the north. Several sedimentary packages restricted to the northern region of the study area are related to the local outflow of the Saint John River or local seabed currents (e.g., the Mispec dune field). To the north, the LaHave Clay also appears to undergo a facies change, as more typical laminar bedding is replaced by cross-bedded units, which may reflect higher nearshore currents, or the influence of the Saint John River.

Several areally-extensive unconformities are defined, revealed by reflector truncation, including two within the Emerald Silt facies B unit, and one at the base of the LaHave Clay. The Mispec dune field, in the east of the study area, lies unconformably on older units. South of the dune field, the seafloor appears to have changed from being predominantly depositional during glacial times to one which is now dominated by erosion. Recent erosion has exposed Emerald Silt facies B on the seabed.

Lower Silurian subduction-related volcanic rocks in the Chaleurs Group, northern New Brunswick, Canada

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Volcanic rocks are hosted by Lower Silurian rocks of the Chaleurs Group at two locations in northern New Brunswick. At Quinn Point, minor mafic to intermediate volcanic rocks occur in the Weir Formation, and at Pointe Rochette, a thin bed of felsic tuff has been identified at the top of the Clemville Formation. These rocks are interpreted as the first evidence in New Brunswick of magmatism associated with Late Ordovician-Silurian northwest-directed subduction of the Tetagouche-Exploits back-arc basin. At Quinn Point, volcanic rocks include a thick flow of massive basalt, and mainly andesitic cobbles and boulders in overlying conglomerate beds. The basalts have low (evolved) Mg#s, despite high Cr and Ni values and abundant pseudomorphed olivine phenocrysts, implying replacement of Mg by Ca during olivine alteration. The *in situ* flow and the conglomerate clasts are chemically alike, and display volcanic-arc affinities on diagrams used to infer tectonic setting. The volcanic rocks were emplaced in the fore-arc region, probably reflecting local step-back of the

magmatic axis due to accretion of continental back-arc ribbons. Chemical characteristics such as depleted HREE, high La/Yb, high Al_2O_3 and slight positive Eu anomalies suggest that the parent magma may have been generated from partial melting of the subducting slab, namely young, warm Tetagouche-Exploits back-arc oceanic crust. Subduction of young back-arc crust in general was probably largely responsible for the relatively low volume of Early Silurian arc magmatic rocks in the northern Appalachians. At Pointe Rochette, fine-grained vitroclastic felsic tuff has a rhyodacitic composition and displays extensive alkali and large-ion-lithophile mobility, with depletion in K, Rb, Ba and Cs. Elevated Th and U, and depleted high-field-strength elements (Nb, Hf, Zr), are consistent with a subduction-influenced setting, although REE abundances are low and the REE profile is relatively flat and unfractionated. A U-Pb (zircon) age of 429.2 ± 0.5 Ma was obtained from the tuff, consistent with the late Llandovery to early Wenlock fossil-indicated age of the overlying La Vieille Formation. Although not altered to bentonite, the age of the tuff suggests an affiliation with one of many Early Silurian subduction-related K-bentonites documented in northwestern Europe and eastern North America, e.g., at Arisaig in Nova Scotia.

Distinguishing between geogenic and anthropogenic sources of arsenic in soils in the North Brookfield Gold District, Nova Scotia

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Soils in the North Brookfield Gold District, Nova Scotia are enriched in arsenic (As) both naturally, associated with local gold mineralization in bedrock, and anthropogenically, due to the processing of gold ore. The focus of this research is on soils surrounding the abandoned, publicly-accessible North Brookfield Gold Mine which operated from 1887–1936, and produced approximately 43,000 troy ounces of gold from 105,000 tonnes of crushed rock. At present, the North Brookfield district is a popular recreational site with off-road vehicle enthusiasts, who have constructed ramps and jumps using the historical mine tailings. North Brookfield is a unique site because it is the only Nova Scotia Gold mine that, in the early years of operation (from 1897 to 1903), combined roasting and chlorination in the extraction of gold from the arsenopyrite (FeAsS)-bearing ore. Roasting of the gold ore decomposed the arsenopyrite to iron oxides, releasing sulphur dioxide (SO_2) and arsenic trioxide (As_2O_3) from the stacks to the surrounding area. Arsenic trioxide is a very soluble and potentially mobile form of arsenic and understanding its fate in the environment is important for assessing the potential risks associated with human exposure to these soils. In 2007, 10 shallow soil cores (40–60 cm long) were taken with the objective of developing and applying methods of distinguishing between geogenic and anthropogenic sources of As in North Brookfield soils. Samples were taken within 1 km upwind and downwind of the approximate location of the historic roasting stacks. Results from bulk aqua-regia soil digestions and ICP-AES analysis show that the average As concentrations for all sub-samples was 300 ppm (median= 38 ppm), exceeding the Canadian Soil Quality Guideline of 12 ppm (residential and parkland soils). Five sub-samples from two locations stand out, with As concentrations in the top 10 cm ranging from 350 to 4300 ppm. These samples were taken within 100 m of the furnaces and chlorination house. The high As sub-samples were magnetically separated, then magnetic materials and residuals were made into thin sections. Roaster-derived Fe-oxides, natural Fe-Ti oxides and primary sulphides were identified in the sections, along with an as yet unidentified brown mass. Synchrotron-based microanalytical techniques were then used to identify nanocrystalline As-bearing phases and results indicated that As was associated with all of the above phases. Preliminary examination of XANES (X-ray absorption near-edge spectroscopy) data shows that the As was predominately As^{5+} with typically 10% As^{3+}, however one sample of the weakly reflective brown mass had significant As^{3+}. Work to-date suggests that anthropogenically derived As is associated with the brown mass, while natural As-bearing materials such as the weathering products of arsenopyrite were also observed. Future work on soils from the area will include sequential selective extractions on high-As samples, as well as scanning electron microscopy and electron microprobe analysis.

Petrology and tectonic significance of coronitic mafic granulites, Southampton Island, Nunavut

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Southampton Island, south-central Nunavut, occupies the "Dorset corridor", the enigmatic boundary region between the Trans-Hudson Orogen and the western Churchill Province. The eastern part of the island is underlain largely by granulite and upper amphibolite facies metagranitoid rocks, with local supracrustal enclaves. Mineral assemblages, textures, and P-T estimates in mafic enclaves from the eastern part of the island shed light on first-order aspects of the regional tectonometamorphic history. Most samples contain the granulite facies assemblage grt-opx-cpx-plag-hbl, with spectacular coronitic textures developed around garnet porphyroblasts. Three suites of texturally heterogeneous granulites each preserve three textural domains, interpreted to represent three points on the

P-T path. Near-peak metamorphic conditions, 850–900°C and 0.9–1.0 GPa, are preserved by cpx-opx-plag inclusions in garnet. Symplectites of opx-plag-spl-mag around garnets indicate near-isothermal decompression from 0.8 to 0.7 GPa at 800–850°C. Matrix plag-cpx-opx-hbl represents a re-equilibrated assemblage, yielding a P-T estimate at 500–600°C and 0.5–0.6 GPa. The P-T path derived from these estimates contrasts with those obtained from lithologically similar units in the western Churchill Province, suggesting that the rocks of Southampton Island share tectonic affinities with the Baffin-Ungava segment of the Trans-Hudson Orogen.

Geochemistry of the bauxitic-lateritic occurrences in the Deh-Dasht area, Zagros, Iran: exploration guidelines

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This study is focused on the bauxitic-lateritic paleo-horizons in the Deh-Dasht area 250 km east of Ahvaz city, Iran, located within the Zagros fold belt. The bauxite horizon developed on strata of the Cretaceous Sarvak and Ilam Formations. Most occurrences are related to the exposure of the paleo-horizons in the eroded limbs and cores of major anticlines, and have a predominantly NW-SE elongation, parallel to the main structural trend of the Zagros. The age of folding and faulting is Oligocene-Miocene, which were followed by erosion, exposing the bauxite horizon.

Boehmite, Gibbsite and Diaspore are the main Al-bearing minerals in the Zagros bauxitic paleo-horizon. The bauxitic stratum in the study area can be divided into three main parts: 1) Argillite- argillaceous bauxite (Lower layer), 2) Bauxite zone (e.g., red and white bauxite; Middle layer) and 3) Ferruginous Limestone (Upper layer). Geochemically, the Zagros bauxitic horizon contains mainly Al_2O_3 (19–62 wt. %), Fe_2O_3 (3–38wt. %), SiO_2 (10–35 wt. %) and TiO_2 (0.28–3.0 wt. %). In general, Ti, Al, and the trace elements V, Cr, Zr, Nb, Y, and Th get enriched through all parts of the bauxite sequences with respect to the unweathered protolith. The highest value of Ba and Sr are observed in the Sarvak Formation's bauxitic limestones and marly limestones. The high values of Ca, Mg and Si in some yellow bauxite and red bauxite samples can be explained by the presence of kaolinite in the bauxite. The enrichment of V, LREE, Th, Nb, Co, Cr, Ni and Zr is interpreted to reflect the concentration of these elements in the Fe oxides and Ti-bearing minerals.

Geological and structural investigations in combination with remote sensing techniques are found to be useful in exploration of new bauxite-bearing districts in the Zagros. The Crosta technique, a multivariate statistical technique that uses multi-spectral image channel data, has been used in this project to help in the discrimination of economic bauxitic-lateritic occurrences. Ground truthing reveals that the bauxitic-lateritic occurrences outlined by the Crosta technique coincide well with the studied areas and the favorable geochemical characteristics determined. Detailed geology and estimation of ore reserve of these occurrences require a systematic sampling and drilling program.

Mineralogy of a lead-barite occurrence in Kap Henson, Northumberland Island, Greenland

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During a traverse part of the Canadian-German Nares Strait Geocruise 2001 expedition, we came across "vuggy" diabase, a cavity ridden upper part of a regionally extensive diabase sill, with irregular cavities (1–20 cm) and irregular veins (0.5 to 10 cm) partially filled with calcite, barite, minor quartz and sulphides, mainly galena, in crystals up to 2 cm. The locality is at Lat. 77° 22.087' N/Long. 71° 30.568', at 265 m.a.s.l. in Kap Henson of deserted Northumberland Island. The altered and sparsely mineralized rock is exposed in an area of 250 m in an E-W direction, by 35 m NS. Alteration has corroded the phaneritic quartz diorite, and locally the rock is intensely altered and can be dug out with a knife. The permeability for the veining was provided by extensional fractures and the upper contact of the brittle (Proterozoic) sill with grey shales of the (Proterozoic) Dundas Group. Transmitted and reflected light microscopy and electron probe microanalysis indicate that the host rock is a fine grained quartz diabase with pyroxene, amphibole, biotite, plagioclase (sericitized), K-feldspar and minor quartz. Magmatic titanomagnetite is very abundant and pyrite and chalcopyrite occur in accessory amounts; euhedral apatite is conspicuous as relatively large inclusions within the major minerals. The rock is affected to various degrees by alteration dominated by sericitization and chloritization. The main hypogene vein sulphide is galena, with lesser amounts of chalcopyrite, and minor pyrite and rare sphalerite. Calcite and barite (one earlier generation clear, euhedral; one later cloudy, brownish) and minor quartz are the gangue minerals, and the veins are crustified, having formed by open-space filling. Quartz occurs as doubly terminated bipyramids in calcite and barite (early), and in granular veinlets (late). All barite is rich in two-phase (liquid-gas) fluid inclusions, and barite II contains traces of solidified petroleum. Two-phase fluid inclusions homogenize (median Th) as a liquid at 158 °C (calcite) and 165 °C (barite) respectively. There is no evidence of boiling of the fluids. Ice-melting temperatures (Tm,ice) of -35 °C (calcite) and 0 °C (barite) suggest the involvement of two distinct fluids, one Na-Ca-Mg, probably basinal brines, and the other dilute meteoric water. Hydrocarbons may have played a chemical role in sulphide precipitation. Hydrothermal alteration has produced calcite, epidote and chlorite. Incipient weathering

has produced covellite, chalcocite, goethite and trace malachite as alteration products of chalcopyrite and/or pyrite. The age of mineralization is clearly post-Proterozoic intrusion and post brittle fracturing. Apatite fission track data indicate that the rocks now at the surface at Kap Henson cooled below ca. 100 ºC in the Triassic, hence the age of base metal deposition is constrained between post-Proterozoic and Triassic. Hot basinal fluids, as well as penetrating meteoric fluids were involved; hence it is possible that mineralization took place during basin inversion.