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ABSTRACTS

2002 Colloquium & Annual General Meeting

ANTIGONISH, NOVA SCOTIA

The 2002 Colloquium and Annual General Meeting was held at the Greenway Claymore Inn, Antigonish, Nova Scotia, on February 8 and 9, 2002. On behalf of the Society, we thank Colloquium Chairman Brendan Murphy and his organizing committee (Alan Anderson, Jennifer Dorrington, Millie Dunbar, Tony Evans, Jonathan Ferrier, Erica Gillis, Rebecca Hert, Matthieu LaPointe, Tom Martel, Gary McLearn, Cindy Murphy, Tara Oicle, Michael Parkhill, David Risk, Dave Shepherd, Ian Spooner, Peter Wallace) for providing an excellent meeting. We also wish to acknowledge support of the corporate sponsors: PCS-Potash, New Brunswick Division; Corridor Resources Inc.; and Nimbus Publishing Ltd.

In the following pages, we are pleased to publish the abstracts of oral presentations and posters from the Colloquium, which focused on Current Research in the Atlantic Provinces.

THE EDITORS

Inferences on glacial flow from till geochemistry and clast dispersal: Rollingdam area, New Brunswick

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A total of 267 till samples were collected in the Rollingdam area of southwestern New Brunswick, and analyzed for patterns of glacial dispersal. The concentrations of 37 base metals, trace, and rare earth elements and 18 clast lithologies, are used to define the dominant glacial transport direction in an area of complex ice-flow history. Examination of bedrock striae, flutes, and drumlins indicates that rapid stagnation of the late Wisconsinan ice sheet was preceded by at least four directions of glacial flow. These data indicate that the main (regional) south-southeastward flow direction was preceded by at least two (and possibly three) events. Glaciation was initiated by eastward-flowing ice emanating from northern Maine and followed by southwestward-moving ice likely due to growth of New Brunswick ice to the northeast of the study area. The major erosional and depositional events were accomplished by southeastward-flowing ice and this was followed by extensive meltwater activity during deglaciation.

Clast trains from known outcrops are traceable southeastward over distances greater than 36 km, while distinctive elongated geochemical trains are lost within a distance of 10 km due to homogenization of the till matrix and possibly winnowing by glacial meltwater. Most geochemical anomalies were found to form small, less than 5 km wide, bullseye-shaped patterns. In this area of New Brunswick, rapid glacier wasting and meltwater activity has likely affected the geochemical content of the till matrix. These results demonstrate that for drift prospecting exercises in areas of glacier mass-wasting, transport path and source unit are more clearly delineated by shape and size of till clast dispersal patterns, than by analysis of matrix geochemistry.

Petrology and age of the Lower Coverdale high-Ti, -P, and -V gabbro-anorthosite complex and associated granite, Moncton area, New Brunswick

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The Lower Coverdale gabbro-anorthosite complex is the apparent cause of a large positive aeromagnetic anomaly that covers an area of approximately 35 km^2 in the Lower Coverdale area southwest of the City of Moncton. The complex is not known to crop out at surface, but was intersected in a petroleum exploration well drilled in the area in 1919. Subsequent drilling, mainly by Noranda Mining and Exploration Inc., intersected gabbroic rocks at depths of 100–200 m below Carboniferous sedimentary rocks. For the present study, approximately 3700 m of core from the gabbro-anorthosite body were examined and sampled in five Noranda drill holes. Additional samples had been obtained previously from cuttings in older wells. Geochemical data reported in previous studies were combined with additional analyses of samples collected in the present study.

As revealed by the drill core, the complex consists of interlayered coarse-grained anorthosite and gabbro, both intruded by abundant finer grained gabbroic dykes. Much of the core shows extensive alteration but microprobe analyses of fresh samples revealed that the plagioclase in both anorthositic and gabbroic rocks has a fairly uniform andesine composition. In contrast, later diabase dykes contain labradorite. Relict igneous pyroxene of hypersthene composition was observed in rare gabbroic samples, whereas the later diabase dykes contain augite. Ilmenite and apatite are abundant accessory phases, and associated with high Ti, V, and P values in whole-rock analyses.

The deepest drill hole encountered highly altered coarse-grained quartz monzodiorite at a depth of 1196 m. These homogeneous rocks continue to the bottom of the hole at 1206 m. The quartz monzodiorite is mineralogically and chemically similar to rocks in the Gaytons quarry located 20 km east of Lower Coverdale. U-Pb zircon ages of ca. 390 Ma (Middle Devonian) have been obtained for both the quartz monzodiorite in the core and from the Gaytons quarry. Rare felsic dykes in the complex appear to be related to the quartz monzodiorite based on mineralogy and texture. We speculate that the extreme alteration in the gabbro-anorthosite may have been related to intrusion of this H_2O- and F-rich granite.

The Lower Coverdale complex is located in the Brookville terrane of southern New Brunswick. Although the gabbro-anorthosite has not been directly dated, similar rocks in the Stewarton Complex west of Sussex are Silurian or younger based on an intrusive contact with Silurian host rocks. Combined with the ca. 390 Ma from the closely associated Gaytons granite, a Devonian age is suggested for the Lower Coverdale complex.

Transient character of the South Tibetan Detachment: microtectonic documentation from the Bhutan Himalaya

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The Greater Himalayan Sequence (GHS) of the Bhutan Himalaya is a complex, highly deformed unit of gneiss and migmatite that has been intruded by leucogranite. Several shear zones play a major role in the deformation of the GHS; from south to north these are the Main Central Thrust (MCT), the out-of-sequence Kakhtang thrust, and the South Tibetan

Detachment (STD). The Bhutan Himalaya differs from the rest of the Himalayas by the presence of low-grade sedimentary rocks on top of the GHS. These sediments are found in cores of several synclines. The metamorphic facies present in the GHS range from upper greenschist in the south, increasing upward to upper amphibolite-granulite facies in the north, indicating an inversion of the metamorphic sequence. In the uppermost part of the GHS the metamorphic sequence is again right way up, as the metamorphic grade decreases rapidly across the STD and disappears in the hanging wall rocks within a hundred metres of the contact.

The aim of this study is the structural analysis of a contact between GHS rocks and sedimentary rocks found in a syncline in central Bhutan. Field observations indicate that a ductile shear zone soles the sediments. Oriented thin sections of rocks that form this shear zone were analyzed under optical microscope for their kinematic indicators. These data were used to determine the sense of shear and the geometry of strain (whether simple or pure shear) within the shear zone. The kinematic data were compiled with published geological maps and new field observations using GIS software.

The map shows the inferred movements in the study area. Because the shear zone at the bottom of the sediments contains top-to-the-north shear sense indicators, the sedimentary units were interpreted as a klippe, i.e. as erosional remnants of the STD. Accordingly, it is proposed that the STD in the Bhutan Himalaya extended further to the south than its today's trace at the border with Tibet. In addition, microtectonic studies indicate that the north-directed shearing along the STD was preceded by a south-directed shearing. These observations have major implications in interpretation of tectonics of the Himalayas during the Miocene when the STD was active as a ductile shear zone, and when leucogranite was emplaced and then deformed along the STD. This new interpretation of the STD helps to explain the intrusion mechanism of the leucogranite units and their relationship to the inverted metamorphic sequence.

Humus as a sampling medium for mineral prospecting in glaciated areas: an example from the Popelogan Lake area of northeastern New Brunswick

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A total of 109 samples were collected from both humus and till overlying Cu-Mo skarn occurrences in the Popelogan Lake area of northeastern New Brunswick. Till matrix and humus samples were analyzed for a total of 39 different base metals, trace, and rare earth elements. These data were compared by statistical correlation for samples taken from till and humus at the same sites and plotted on maps to compare with a larger study of regional till geochemistry and till clast dispersal.

Silver, Cd, Hg, Mn, Pb, and Zn were the only elements that demonstrated significantly higher mean concentrations in the humus samples, relative to samples from the underlying till. This is attributed to the greater capacity of humus to adsorb cations and/or form complexes with some elements, relative to the clay size-fraction of the till matrix. Humus element concentrations were not consistently correlative with maximum or minimum concentrations found in the underlying till. Concentration patterns plotted on areal maps for Ag, Cd, Hg, Mn, Pb, and Zn in humus were larger than those exhibited by the dispersal patterns for till matrix analysis. While forming a larger exploration target than that recognized by the till analysis, the humus elemental concentration patterns did not delineate a point source similar to the typical elongated or fan-shaped dispersal patterns commonly found using till geochemistry or till clast concentrations.

As humus has the ability to concentrate elements from the underlying substrate it can be a suitable sample material when conducting reconnaissance surveys to delineate areas for further exploration. However, as a third derivative sediment (bedrock to till to groundwater and vegetation), humus dose not always reflect directly the underlying mineralized source, nor does it give a reliable indication of ice-flow direction. It is likely that humus analysis is of most benefit to mineral exploration when used as a preliminary stage of assessment, preceding routine till clast and geochemical sampling.

Delineating river-bottom recharge to the Fredericton Aquifer by seismic and electrical imaging

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The sand and gravel aquifer supplying water to the City of Fredericton, New Brunswick, in the Saint John River valley is one of many river valley aquifers that serve cities and towns in Atlantic Canada and world-wide. It has recently been selected for a multi-disciplinary study of water quality and supply in alluvial aquifers that are recharged by infiltration from rivers above and fractured bedrock below. Delineation of the river-bottom recharge zone for Fredericton's well field is a project priority as knowledge of the infiltration pathways is required in order to site piezometers for hydrogeological and hydrogeochemical studies.

Infiltration of river water into the Fredericton aquifer occurs where elevated portions of the sand and gravel unit, widely believed to be parts of a buried esker, protrude through an overlying clay/silt layer to the floor of the Saint John River. We report on the promising and complementary results obtained using

seismic and electrical imaging for detection of these zones during the spring and fall of 2001.

Over 30 line-km of high resolution, single-channel seismic reflection profiles and side-scan sonar data were collected on the Saint John River using real-time kinematic GPS for navigation. Equipment was deployed from UNB's 40-foot research vessel, the Mary-O, in water as shallow as 1.5 metres. Data quality seemed to be dependent on river bottom type but in most areas the 'Seistec' seismic profiling system with its boomer source and special line-in-cone hydrophone receiver generated excellent broadband records showing reflection events with dominant frequencies of approximately 2.5 kHz at depths as great as approximately 50 m. The edges of inferred recharge zones are identified as boundaries where reflectors present within the clay/silt layer suddenly terminate and are draped on the sides of an interpreted esker.

Shallow electromagnetic (EM31) and resistivity imaging data collected along the shoreline have helped to constrain interpretation of the seismic data and have yielded a detailed cross-section through the recharge zone opposite the Fredericton well field. Areas of high resistivity, where sand extends to the surface, are bounded by areas of much lower resistivity where clay is present. There is evidence of isolated clay pods within the recharge zone - presumably remnants of clay that filled depressions in the esker as it was buried. The presence of these pods has important implications for design of the planned piezometric monitoring array, and an electromagnetic survey is planned for the summer of 2002 to determine their extent and morphology under the river.

Building the scientific case for World Heritage designation of Joggins

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The long-celebrated cliff section at Joggins, Nova Scotia, has the potential to become Maritime Canada's first natural World Heritage Site, but the case presented must be skilfully argued. Site management, infrastructure development, and community involvement are the concern of a broad-based Steering Committee to which the Scientific Sub-Committee reports. The importance of these issues notwithstanding, UNESCO describes scientific justification as "the most crucial aspect of the whole nomination dossier". The sub-committee must present irrefutable evidence that Joggins represents a natural site of "outstanding universal value" representing a major stage in the history of life, specifically, the Pennsylvanian 'Coal Age' wetlands of Euramerica. The case being developed builds upon the following pillars: (1) the site itself: a dramatic yet accessible cliff section hewn and replenished by the world's highest tides ; (2) the fossil record: vertebrate, invertebrate, and floral records satisfying requirements of biodiversity, evolutionary innovation, community, and uniqueness; (3) the sedimentary record: the world's best exposed succession of Carboniferous coal measures, providing context to the fossil record; (4) the history of science: formative in such canons as Lyell's Principles of Geology and Darwin's Origin of Species.

Complementing these are: cultural history: site of coal mining since the early 17th C, grindstone quarries of the 18th and 19th C; significance to ongoing research and education: still the site of innovative research and discovery and field trips by scientific groups, universities, and schools; historical recognition: international field trip destination since the mid 19th C and the first field project of the Geological Survey Canada in 1842; international interest: sought out by recent visitors from over 44 countries worldwide even before inscription, subject of international research, Joggins specimens in world museum collections. Although not part of the Carboniferous story, Joggins also exposes a classic multiple till section recording Quaternary glaciations.

Individual projects, some of which fulfill specific edicts of UNESCO, address compilation of the floral and faunal record, type specimens, and collections housed in world museums, an atlas of specimens and features, a scientific bibliography, and numerous journal manuscripts in preparation. Chief among these projects is a comparative study to confirm Joggins' worth amongst contemporary world sites. Recently successful cases for the Devonian site at Miguasha, Gaspé, and the Mesozoic section of the Dorset Coast, UK, provide useful comparisons in developing the case for Joggins.

Fixation of sulphur during framboidal pyrite development in a petroleum reservoir in Cretaceous volcanics in the Andes: implications for Cu metallogenesis

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El Soldado, Chile, is a giant strata-bound copper deposit hosted in Lower Cretaceous basalts and rhyolite. Previous work suggested that copper was concentrated preferentially where hydrothermal copper-rich solutions replaced pre-existing, low-temperature, diagenetic pyrite, which is generally associated with bitumen (solidified petroleum). This model implies that the mineralizing hydrothermal phase did not supply sulphur to the system; sulphur would have been inherited from the diagenetic sulphides. Doubt remains on whether some deep zones with massive crystalline pyrite veins, and massive chalcopyrite, bornite, and chalcocite

ores, could represent a net input of sulphur from hydrothermal, magmatically-derived sources. To answer this question, massive sulphide assemblages are being studied by microscope, microprobe, and sulphur isotope analysis.

All new samples studied so far show petrographic evidence of pre-existing diagenetic pyrite, including deep massive pyrite veins and massive-crystalline copper-rich ores. Diagenetic pyrite is characterized by framboidal structures of ca. 16μm diameter or smaller. Framboids consist of microcrysts of pyrite, <2 μm in size, organized in spheroidal aggregates. In this deposit, the framboids developed mostly within liquid petroleum, now solid bitumen. Although controversial, the general consensus is that framboids may grow with bacterial involvement, and that their spheroidal shape is determined by colloidal-scale magnetic and electric properties of their precursor iron monosulphides. A range of stages of development of massive crystalline aggregates is observed in the samples: individual microcrysts, framboids, framboid clusters, recrystallized megacryst overgrowths, and banded concentric zones.

If there was an influx of homogenized, magmatic-related sulphur one would expect that the $\delta^{34}S$ would be close to zero ‰. However, available sulphur isotope data to date show a wide variation in $\delta^{34}S$ values, thus supporting low-temperature fractionation, which is compatible with the wholesale fixation of sulphide sulphur with the aid of sulphur-reducing bacteria in a degrading petroleum reservoir at a few kilometres depth in the crust, at temperatures within or below the oil window. The incursion of sulphate- and iron-rich meteoric or basinal fluids may have provided the raw materials; reduction of sulphur produced H_2S, which combined with iron in solution and formed iron monosulphides in framboidal aggregates within mobilized petroleum. Thermal metamorphism led to recrystallisation and consolidation of original framboids into crystalline pyrite aggregates.

A compilation and preliminary assessment of groundwater hydrogeochemical data from Carboniferous bedrock aquifers

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Fractured conglomerate, sandstone and siltstone aquifers within the Maritimes Basin are an important source of potable groundwater in the Maritime Provinces. Despite the importance of this resource, little is known about the hydrogeological and hydrogeochemical controls on water quantity and quality in these aquifer systems. The Maritime Ground Water Initiative (MGWI) is a new research program lead by the GSC that was designed to gain a greater understanding of the geologic setting, the hydraulic properties, and the hydrogeochemistry of the Carboniferous bedrock aquifers. The initial activities related to the hydrogeochemical aspect of the MGWI are discussed in this paper. Historic hydrogeochemical data from domestic and municipal wells dating from 1982 to the present, and covering an area of roughly 25,000 km^2 in southeastern New Brunswick, are being compiled from sources that include the NB Department of the Environment and Local Government, regional health districts, school boards, and municipalities. The database is being assessed to identify geochemical trends and anomalies that result from natural characteristics of the geologic and hydrologic setting, or from anthropogenic activities. These geochemical features of interest will be the focus of future, more detailed investigations.

Geology of the Orangedale salt deposit, central Cape Breton

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Several salt deposits have recently been defined in south-central Cape Breton Island. Three wells in the vicinity of Orangedale, central Cape Breton, intersect the regionally extensive Viséan Windsor Group, host strata for the Orangedale salt deposit and neighbouring deposits.

Regional composite stratigraphy of the area was constructed from data using the Malagawatch and McIntyre Lake salt deposits. The Lower Windsor Group consists of the Macumber Limestone, an overlying anhydrite succession, and a thick salt unit containing the 'A' potash horizon. The Middle Windsor Group is dominated by salt which is interbedded with anhydrite and thin limestone units, and includes the 'B' potash horizon and the regionally distinctive 'triplet marker'. Non-marine strata comprise the primary lithologies seen in the uppermost Middle Windsor Group and throughout the Upper Windsor Group strata. The base of the Upper Windsor Group is placed at the base of the distinctive Herbert River Limestone.

Orangedale deposit cores provide a record which represents most of the regional composite section with the exception of the lowest part of the Windsor Group and the upper parts of the Upper Windsor Group. Although detailed Windsor Group stratigraphy can be readily demonstrated in each of the three Orangedale wells, structural complexity is a marked feature of the deposit.

Strata at Orangedale are folded and overturned resulting in northeast-southwest to north-south trending inclined horizontal folds. Scale of folding is best represented in hole Noranda-225-4 which drilled into 268 m of lower Middle Windsor Group and Lower Windsor Group strata before intersecting overturned Lower Windsor salt. Further downhole, but up-section, the drill encountered Middle Windsor dolomite, anhydritic dolomite, and 240 m of overturned Middle Windsor Group salt. Hole Noranda-

225-5A penetrated five fold axes, in which the Middle Windsor 'triplet marker' horizon repeated six times and 'B' potash horizon three times.

Overall, the deposit has relatively good economic potential for salt resources. The potash may be of lesser economic potential due to the structural complexity of the deposit. A more complete understanding of the geology of the Windsor Group in the Orangedale area is crucial to future exploration and development activities.

Life and times of some Late Cretaceous-Early Tertiary polar forests from northwest Ellesmere Island, Arctic Canada

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During the Mesozoic to Early Cenozoic, greenhouse climate phase forests grew well within the polar circle. These unique polar forest ecosystems flourished in a warm, high-latitude environment where trees were subjected to months of unbroken winter darkness followed by continuous daylight in the summer and elevated atmospheric CO_2 levels. Analysis of these polar forests is important because they provide a long-term context for the response of modern boreal forest ecosystems to future global climate change; as one scientist succinctly put it, "the past is the key to the future".

In this paper, new Late Cretaceous to Early Tertiary fossil plant sites are described from Emma Fjord and Phillips Inlet, NW Ellesmere Island (paleolatitude of ~78°N). The fossil sites occur in the Campanian/Maastrichtian to Danian Hansen Point Volcanics of the Eureka Sound Group, Sverdrup Basin. This stratigraphic unit is interpreted as originating in a volcanically disturbed, alluvial plain/peat mire setting close to the margins of the paleo-Arctic Ocean. Moderately diverse assemblages of megaflora (wood and foliage) and palynoflora occur. Thin section studies of anatomical features in five silicified and calcified fossil wood specimens indicate the presence of three conifer families in this high-latitude environment, the Taxodiaceae, Pinaceae, and Cupressaceae. Foliage assemblages are dominantly composed of taxodiaceous conifers together with cupressaceous conifers, gingkos, angiosperms, and ferns. Taxodiaceous conifers were probably the main source plants for the common amber remains at the two sites. Biometric analysis of tree trunks suggests that the forest canopy was in the order of 15–25 m high. Growth ring studies indicate a cool temperate climate with high year-to-year variability. Traumatic rings indicate the occurrence of sharp frosts towards the end of the growing season. Abundant charcoal remains suggest that these polar forests were frequently disturbed by wildfire, perhaps related to local volcanism.

Mercury in till and bedrock, Kejimkujik National Park, Nova Scotia

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Loons in Kejimkujik National Park have the highest levels of mercury (Hg) concentration in blood of any loon population in North America. For the past several years, a multi-disciplinary team of research scientists has been attempting to identify the potential Hg source(s) and process(es) responsible for the anomalous Hg levels. One component of this research involves the collection and geochemical analysis of till and bedrock samples in order to quantify the geogenic contribution of Hg from glacial sediments and bedrock sources. Health Canada provided funding for the project through the Toxic Substance Research Initiative (TSRI).

A total of 39 C horizon till samples were collected at 100 to 200 m intervals from three NW–SE transects that cross the inferred contact between the Halifax and Goldenville formations immediately south of the park boundary. Samples were collected from depths ranging from 70 to 120 cm. Geochemical results for the <63 microns size fraction were determined by Cetac CV-AA and indicate Hg ranges from a minimum of 6.6 ppb to a maximum of 158.5 ppb (mean = 44 ppb).

Nine bedrock samples of slate and meta-sandstone were collected along the same transects. Geochemical results for the <105 microns size fraction of the bedrock samples also were determined by Cetac CV-AA with Hg values ranging from 0.2 to 3.4 ppb (mean = 2.5 ppb). Strict QA/QC protocols were followed in the collection, preparation, and analysis of all samples.

Within the study area, results from bedrock mapping indicate that the actual contact between the Halifax and Goldenville formations is located north of the contact indicated on the most recent published geological map. This interpretation is supported by a detailed (12.5 m) ground magnetometer survey along the same transects that suggests placement of the contact 500 to 1000 m further to the north. This is significant because a previous study has suggested a spatial correlation between Hg in soil gas and the contact between the Halifax and Goldenville formations. Proper identification and placement of the contact is imperative for the interpretation of the Hg content of the <63 microns till geochemistry.

Gravity and seismic interpretations for some Maritime Carboniferous basins: implications for Upper Carboniferous basin development

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A recent interpretation of a coincident gravity and seismic profile across the Carboniferous Moncton Sedimentary Basin has provided some insight into the nature of the Berry Mills Fault. A model of the gravity data shows that a triangle or wedge shaped block initially interpreted as salt on the basis of seismic reflection data, is actually composed of rock with a density contrast similar to that of the Horton Group. The rocks in question occur above reflections interpreted as basal Windsor Group, and yet below reflections interpreted as interbedded evaporite and clastic rocks at the top of the Windsor Group (Clover Hill Formation). The block may be depositional (alluvial fan) or structural (triangle zone/tectonic wedge); however, we favour a structural interpretation.

Similar geological structures are observed in the Antigonish-Mabou, Cumberland, and Sackville subbasins. In each of these areas, triangular-shaped bodies appear to be wedged between basal Windsor Group rocks (limestone and anhydrite) and younger Windsor evaporites. In the Mull River area, well data support a thrust fault or triangle zone interpretation. Similar relationships are observed in the Cumberland Subbasin at the northern edge of the Cobequid Highlands, although thrust faulting cannot be demonstrated. In the Sackville Subbasin, a seismic profile acquired in 1999 clearly shows Horton Group rocks thrust over the Windsor Group, and yet underlie a Windsor salt pillow at the same time, demonstrating a structural origin.

The observed structures occur at the margins of Upper Carboniferous basins and are associated with large vertical displacements across presumed strike-slip faults. Seismic and gravity data suggest that a significant component of dip slip movement occurred on these faults, in some cases up to several kilometres of shortening reminiscent of tectonic wedging or triangle zone development. Some Upper Carboniferous basins in eastern Canada may be examples of foreland basin style subsidence within a convergent wrench system.

Paleoenvironmental analysis of the Lower Cretaceous (Aptian-Albian) sediments of the Musquodoboit and Shubenacadie basins, Nova Scotia

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The unconsolidated sand and clay deposits of the Shubenacadie and Musquodoboit basins have been documented in detailed studies since the 1950s. General mapping projects from as early as the 1900s have postulated that the deposits are of Cretaceous age. More recently they have been found to be of late Early Cretaceous (Aptian–Albian) age. Previous workers have hypothesized a non-marine depositional environment, but marine foraminifera have also been reported, suggesting the possibility of marine pulses. The present study has found freshwater protists such as the dinoflagellate *Nyktericysta* sp., zygnematacean (algal) cysts *Lecaniella foveata*, *Lecaniella irregularis*, *Ovoidites grandis*, *Ovoidites parvus*, and *Ovoidites spriggii* and other protists such as *Schizocystia rugosa*, *Schizospora reticulatus*, and *Botryococcus* sp. A variety of trilete spores, gymnosperm pollen grains, and angiosperm pollen grains have also been found. The palynomorphs tend to occur in assemblages dominated by one or more fossil types. For example, assemblages dominated by freshwater protists represent an environment of shallow, slow moving fresh water, while the assemblages dominated by trilete spores and pollen represent terrestrial deposits where little or no standing water was present. All of the assemblages found in the present study support a non-marine depositional environment.

A Jurassic hallucination? Wooded oases in the Phanerozoic's largest desert, Utah

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The Lower Jurassic Navajo Sandstone Formation represents the deposits of the largest sandy desert known in the entire Phanerozoic record. Thick strata containing gigantic desert dune forms extend across the states of Arizona, Utah, New Mexico, and Colorado in a continuous belt, 500 km long by 300 km wide. Until recently the Navajo desert was considered an extremely arid, inhospitable region at the heart of the Pangean supercontinent. However, fieldwork last summer has greatly altered our understanding of the paleoenvironment and biota of this region. In this paper I document the occurrence of large silicified conifer trunks rooted in discontinuous limestone beds that locally occur between the dune deposits at multiple horizons near Moab, SE Utah. Limestone beds appear to have originated from mineralized spring-seeps. Associated fossil trees represent the remains of ephemeral wooded oases that periodically developed in the desert.

Abundant trackways indicate that this was a very biologically rich environment frequented by a large range of animals including dinosaurs and mammals. Estimates based on tree growth rate suggest oasis communities bloomed for about 50–100 years before the desert sands encroached once again.

Recent vertebrate fossil discoveries from the (Hettangian) McCoy Brook Formation

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Researchers working for the Fundy Geological Museum (Parrsboro, NS) have recently collected new fossil vertebrate specimens from the Early Jurassic McCoy Brook Formation. Of particular significance is the fossilized skeletal material attributed to early lizard, crocodilian, and dinosaurian taxa. The discoveries demonstrate the benefit of regular, systematic monitoring of important fossil-producing coastal exposures.

A bone bed in the eolian/fluvial sandstone of the McCoy Brook Formation at Wasson Bluff has produced fossil skeletal material from at least four prosauropod dinosaurs. The four specimens vary in size, quality of preservation and completeness. The most recently collected specimen includes the first prosauropod skull material recovered from the McCoy Brook deposits, very important for identification to the genus level.

Other significant vertebrate fossil discoveries have been made within the intertidal exposures at Wasson Bluff. A nearly complete specimen of the sphendontian lizard *Clevosaurus*, including three articulated feet, as well as an articulated skull of the early crocodilian *Protosuchus micmac* have been recently collected. An erosion study was designed and carried out on these intertidal outcrops to determine the rate of surface erosion caused from the enormous tidal action along the beach. The results suggest a mean vertical erosion rate of 1.5 cm per year. Given this rate of erosion, regular (monthly) prospecting of the intertidal deposits continues to be an appropriate research strategy.

The Last Billion Years – past, present, and future

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Conceived in the mid-1990s, the book The Last Billion Years – A Geological History of the Maritime Provinces of Canada was finally born in July 2001. The book, under the authorship of the Atlantic Geoscience Society and jointly published by AGS and Nimbus, represents a collaborative effort involving over 50 geologists and artists. It tells the story of rocks, fossils, plate tectonics, and changing climates in the Maritimes for a general audience. Hundreds of images – watercolours, pencil sketches, photographs, schematic diagrams, and maps were collected or commissioned for the project. The text went through many rewrites based on thorough reviews by geologists and non-geologists in order to provide an accurate, informative, and reader-friendly narrative. The success of The Last Billion Years has surprised even its most ardent proponents: the initial print run of 2,100 copies sold out in 5 weeks and the first reprinting of 2,000 copies was practically sold out by the end of 2001; the book was on the Nova Scotia non-fiction best-seller list for several weeks; and it elicited very positive reviews from national and regional newspapers. AGS can be justly proud of its truly collective product, which has brought Maritimes geology within reach of non-specialists in a way that has probably not been achieved since Sir J.W. Dawson's Acadian Geology in the nineteenth century. Lest it be thought that the AGS Book Committee is resting on its laurels, talk of further spin-offs (there is already a talk series based on the book) and a second edition of The Last Billion Years is already in the air.

Mineralogy and potential recovery of rutile (TiO^2) as a by-product in porphyry copper deposits

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Rutile is a common accessory phase in altered porphyry copper ores (up to 1 wt. % of the host rock), yet it is generally lost to tailings, despite its relatively high price. Ti metal (sponge) is about 5 times the price of Cu, and high-grade rutile concentrate for pigment is comparable in price to copper-sulphide concentrate. This pilot study assesses the feasibility of rutile recovery from ores going through the mill of large mining operations. As a first step, ores and heavy mineral concentrates from Chuquicamata, Chile were analyzed using microscopy, electron probe microanalysis, and various mineral separation techniques.

Rutile commonly forms by alteration of sphene (titanite), titanomagnetite, or biotite. In the potassic alteration zone of Chuquicamata, rutile occurs as individual grains surrounding biotite or pseudomorphing sphene, in habits that could lead to easy liberation. In the quartz-sericite alteration zone rutile is intergrown with pyrite, thus decreasing the likelihood of effective separation.

Electron microprobe analysis reveals that rutile is zoned with respect to varying amounts of trace elements such as Nb (up to 2.7 wt. %) and Ta (up to 0.21 wt. %), which are potential by-products. This geochemical characterization could facilitate the use of refractory rutile in geochemical exploration for porphyry copper deposits. The U and Th content detected in rutile suggest it is datable by U/Pb methods. Image analysis in the microprobe allows determining the relative abundance of rutile in polished grain mounts of heavy mineral concentrates, which can be satisfactorily compared with microscope point-counting data. It also gives sizes and aspect ratios of grains, and permits useful imaging of degree of liberation.

Statistically, there is a high positive correlation r between rutile and chalcopyrite, rutile and bornite, and a consistently high negative correlation between rutile and pyrite. This behaviour mimics a high positive correlation between Ti and Cu in the least overprinted potassic alteration zone (Cu/Ti ~15/1; r = 0.82). Geochemically, the element Ti behaved as immobile element during alteration. A high negative correlation between Ti and Cu observed in the quartz-sericite alteration zone, suggests a fresh input of Cu into a constant reservoir of Ti during this hydrothermal event.

The results suggest that full liberation of rutile would require excessively fine milling (to ca. 10 μm) making it uneconomic, but partial recovery may be possible. Alternatively, rutile could be recovered from dry tailings using a combination of gravity and electrostatic methods to separate it from sulphides and silicates.

A synthesis of Carboniferous stratigraphy – Cape Breton Island, Nova Scotia, with new data from southwestern Cape Breton Island

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Recent geological mapping at 1:50,000 scale in southwestern Cape Breton Island documents a Carboniferous succession extending from the latest Devonian (Fisset Brook Formation) to the youngest Namurian (upper Port Hood Formation). New subdivisions of the Horton Group have been mapped successfully, with lateral extent documented as far westerly as the Antigonish Highland block. The overlying Windsor Group is represented by very saline facies which extend in the subsurface upwards into the overlying Mabou Group. The latter, conformable with the Windsor Group, comprises a lower grey-shale interval, overlain by fine-grained redbeds. The Mabou Group is overlain unconformably by the lower part of the Port Hood Formation characterized by thick, multi-storied sandstone channel bodies interbedded with fine-grained redbeds. The upper part of the Port Hood Formation is represented by coal measures comprising grey mudrock interbedded with sandstone, with minor red siltstone and shale.

The preserved Carboniferous succession in southwestern Cape Breton Island is quite comparable with that of western Cape Breton Island although some differences in detail are apparent in Horton Group subdivisions. Comparing the succession of southwestern Cape Breton Island with that of the Loch Lomond half-graben and the Sydney Basin to the east and northeast reveals significant differences in the rock record. In the latter areas, Westphalian coal measures are well-represented, laterally extensive (Sydney) and historically of considerable economic importance. In the Sydney Basin, however, these coal measures lie unconformably on strata of the Mabou Group and the Port Hood Formation is apparently missing from the record. In the Loch Lomond setting, strata equivalent to the Port Hood Formation are well-represented, passing upwards into Westphalian coal measures correlative with those of the Sydney Basin.

The presence of Port Hood Formation strata in western and southwestern Cape Breton Island, as well as in the Loch Lomond half-graben, attests to its former broad distribution, and suggests that it may have been deposited in the Sydney Basin as well, albeit subsequently removed beneath the unconformity at the base of the Westphalian coal measures. The Westphalian coal measures can be extended by inference through southwestern Cape Breton Island in a reconstructed stratigraphic succession, thereby connecting the Sydney Basin, the Loch Lomond half-graben, and western Cape Breton Island. Major differences in regional stratigraphic architecture reflect mainly differing preservation of the rock record. Those rock units which are preserved in each of the areas considered here, are quite comparable in lithofacies and in biofacies (biostratigraphic age) and attest to the regional scale of the depositional systems which characterize the southern portions of the Maritimes Basin.

Bioturbation influences dolomitization patterns in carbonate rocks

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The 'dolomite problem' is normally addressed with models that reflect larger-scale processes that describe the relationship between the supply and transport of Mg, and geochemical conditions that are amenable to the precipitation of dolomite. However, heterogeneities in the substrate, made by bioturbating infauna, may play a more important role in dolomitization than has been previously considered. The concentration of organic material in burrows locally increases permeability and porosity, supports microbial populations whose byproducts mediate dolomitization, and provides a source of organic acids that compound with metal ions and act as chelating agents.

Burrow-facilitated dolomitization is evident in the Ordovician Tyndall Limestone (Red River Group, Selkirk Formation). The diagenetic fabrics present are attributed to dolomitizing fluids that both developed in, and flowed through burrow networks. Petrographic analysis suggests that two phases of dolomite precipitation are present: the first consists of a fine-grained, fabric-destructive cement that probably accompanied early burial; the second is a fine- to medium-grained, locally sucrosic dolomite that is interpreted to have precipitated during later burial. Isotopic analysis supports the proposed paragenetic history. An apparent linking of the stable isotopes ^{13}C and ^{18}O strongly suggests that the matrix (micritic cement) precipitated during very early diagenesis and was derived from sea-water. The initial phase of

dolomitization is potentially microbially mediated, as evidenced by the enrichment of $\delta^{13}C$. This was probably due to fermentation occurring within the burrow microenvironment. Isotopic values for ensuing dolomite reflect the mixing of ground water and resorbed early dolomite.

Stratigraphy, sedimentology, and depositional setting of the Lower Cretaceous Chaswood Formation in the West Indian Road pit, Nova Scotia

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On the Scotian Shelf, Lower Cretaceous deltaic sandstone reservoirs (Mississauga and Logan Canyon formations) are being exploited for gas and explored for oil. Studies of offshore wells are limited by the restricted availability of samples other than cuttings. Correlative strata on land, the accessible age-equivalent Chaswood Formation, more readily provide information about the source of the sands, the regional paleogeography, and structural history.

The Barremian to Aptian Chaswood Formation is characterized by the alternation of clay and sand units. The fining- upward sequences, the presence of armoured clay balls within the sands and the development of oxisols in the clays strongly suggest a fluvial environment. The occurrence of lignite in some clay units suggests lacustrine or fresh water marsh sedimentation. However, marine fossils (rhizopod assemblages) found in the lowermost clay units indicate the possibility of a marginal marine environment. Consequently, the Chaswood Formation may have been deposited during one or more phases of marine transgression followed by fluvial progradation.

The West Indian Road silica sand pit is the largest exposure of the Chaswood Formation. The deposit is enclosed in a fault-bounded basin within the Carboniferous Windsor Group sedimentary rocks. Two dominant oblique fault systems have N–S and NW–SE orientations. The basal unit, a thick dark lignitic grey clay, lies unconformably on the bedrock. It is overlain by more than 20 m of sand and gravel intercalated with two major clay markers. Faults show evidence of syn-sedimentary movement, with at least two internal angular unconformities within the pit. Both the stratigraphy and the sedimentology of the pit show evidence of a braided fluvial environment of deposition characterized by several fining-upward sequences from gravel lags to sandy beds to vertical accretion-related clay units and a predominance of trough cross-bedded sand and gravel.

Cosmogenic nuclide insights on the interaction between local ice caps and Laurentide Ice in northern Labrador

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Terrestrial cosmogenic nuclides (TCN) are produced in minerals exposed to cosmic radiation and are used to determine erosion rates, ages of landform surfaces, and burial histories. The TCN facility being constructed at Dalhousie will prepare samples for ^{10}Be and ^{26}Al dating. We report TCN exposure data used to test a hypothesis suggesting that local thin ice caps played a significant role in the glaciation of the Ungava Peninsula and northern coastal Labrador. Glacial geomorphology, soils mineralogy and chemistry, and cosmogenic ^{10}Be and ^{26}Al are combined to show that: (1) glacial erosion rates are extremely low on small plateaux and summits; (2) glacial erosion rates are high in areas documented by warm-based ice features; (3) the Labrador weathering zones designated in the type locality are likely a product of differential erosion due to variations in glacier basal thermal regime. Exposure ages ranging from 11 ± 1 to 250 ± 9 kyr characterize the bedrock tor-like features that have been sampled. Evidence for deglaciation from a Younger Dryas advance is apparent at multiple sites. There is growing evidence to suggest that the ice caps have controlled or even redirected concurrent Laurentide Ice Sheet (LIS) flow. Exposure ages on felsenmeer summits are consistent with higher abundances of gibbsite found in summit soils relative to soils in tills and valley floors. The field and isotope data lead us to envision a thinner, less extensive last-glacial-maximum-Labradorean LIS than is currently visualized.

Update on the Eastern Shore Compilation Project, Nova Scotia

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A wealth of information resides in Nova Scotia Department of Natural Resources (NSDNR) databases, private research files, and in internal company reports on numerous gold districts located along Nova Scotia's Eastern Shore. The first documented gold discovery was in 1858. By 1861, several gold-bearing areas were officially declared gold districts and gold had been discovered in many other localities throughout the Eastern Shore. E.R. Faribault and H. Fletcher produced geological maps early in the 19th century, and W. Malcolm compiled a classic memoir on the gold districts, published in 1929. Subsequently, substantial work

has been done by mineral exploration companies, prospectors, and university and government geoscientists.

NSDNR initiated the Eastern Shore Compilation Project in 1998 to (i) compile pre-existing geoscientific information on the gold districts and surrounding areas, (ii) incorporate relevant information on digital base maps with attached databases, and (iii) write site-specific deposit reports, which include reviews of deposit geology and provide interpretive models. Some work (e.g. geochemistry) is undertaken collaboratively with the Geological Survey of Canada (GSC). Work has involved the easternmost portion of the study area (Guysborough to Country Harbour) and current work is centred on Musquodoboit Harbour. This involves numerous gold districts including Country Harbour, Wine Harbour, Forest Hills, Mooseland, and Tangier.

Work has primarily involved digitizing Faribault and Fletcher's work, and correcting and referencing this work onto digital base maps. Geological information from other available sources was also incorporated. Initial work done with AutoCAD® and Fieldlog® was consolidated in ArcView® with NSDNR information, principally the mineral occurrence and drillhole databases with corrected drillhole locations. Individual gold districts recently digitized by NSDNR's GIS section, cross-sections, mine maps, and geophysics are incorporated; some of these are 'hotlinked' to other digital files, including photographs. Database information includes geochemistry, petrography, selected metal analyses, and isotopic data. Additionally, Malcolm's memoir has been reworked digitally, complete with original photographs, and will be released by the GSC on CD-Rom.

The project area is underlain by metasedimentary rocks of the Goldenville and Halifax formations, with Goldenville rocks forming anticlines and Halifax rocks lying in syncline troughs. Folding and structures, particularly in the gold districts, are complex. The more important geological features include domed anticlines and numerous local and regional faults, generally trending northwest. Local faulting, found in all districts, is related mainly to late-stage doming of anticlines. Wine Harbour is highlighted in the talk, where gold was discovered in interbedded veins, mined from 1862–1939, and produced 42,346.5 troy ounces.

The St. Francis Xavier University Environmental Earth Science Research Laboratory: current research and research facilities

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We review current research conducted at the Environmental Earth Science Research Laboratory at St. Francis Xavier University. This working group produces internationally recognized multidisciplinary earth sciences research and provides original graduate and undergraduate research opportunities. Using qualitative and quantitative chemical, physical, and biological approaches to study environmental processes, the group is currently working on projects in the following areas: nitrogen cycling including the use of nitrogen isotopes as tracers of nitrate removal processes and pollution sources in watersheds; physical controls on carbon dioxide production in soil profiles; energy balance at the Earth's surface; paleoclimatic reconstructions from geothermal data, and global heat flux and energy balance histories at the Earth's surface. Lab members currently maintain and gather data from four air/underground climate observatories and trace gas flux research sites. New analytical laboratory facilities permit a range of analyses and data is processed in the modern UNIX computing facilities. The working group currently includes one M.Sc. student (Dave Risk), undergraduate research assistants (Shari Hayne and Amy Myette), and undergraduate thesis students Scott Rayner and Danielle Goulard. This poster will provide details of our research sites, analytical equipment, an overview of current research, and the current opportunities for graduate students (i.e. Fellowships) available in this group. More details are available at: http://envscilab.stfx.ca/envirolab/envsciences.html.

Geophysical investigation of salt tectonics and deeper structure in the eastern Magdalen Basin

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Investigation of salt structures in the eastern Magdalen Basin has revealed an area of intense salt tectonism, above a fault-bounded sub-salt high. The basin contains up to 18 km of Paleozoic sedimentary rocks resting on the crystalline basement of the Acadian orogeny. Carboniferous rocks, although regionally exhibiting minor deformation, are intensely deformed to the southeast of the Magdalen Islands, as a result of faulting and tectonism of evaporites of the Viséan Windsor Group. Clusters of short wavelength magnetic lineations, associated with gravity anomaly lows, coincide with the salt structures and define NNE- and ENE-trending linear belts. These enclose rhomboidal zones of very low amplitude magnetic anomalies. Seismic profiles show the lineations to be related to zones of deformation and diapir collapse near the margins of salt structures. Euler deconvolution models indicate shallow (< 400 m) fault or contact-type magnetic sources, interpreted to result from mineralization associated with alteration in salt-impregnated, iron-rich sedimentary rocks, brecciated during salt activity. Measurements on mine samples confirm the presence of higher susceptibility carnallite-rich veins with salt units. Deeper sources (< 1 km) within and at margins of salt, are related to faulting and linked to the deeper structure. The base event, the deepest regionally mappable seismic reflection (2–5 s. TWTT, ~ 5–11 km), is associated with an unconformity at the base of the Windsor Group, sampled at the Cap Rouge well.

Salt structures and associated features are influenced by faults and related topography of the base event.

Structural trends in the eastern Magdalen Basin are consistent with a dextral transpressive regime associated with the Cobequid-Chedabucto fault zone and related faults. Motion on this fault produced WNW compression and ENE dextral motion in the eastern Magdalen Basin from the Late Viséan to Westphalian D. Thrusting of the base event to the ENE and WSW, and dextral motion on ENE trending faults bounding the southern edges of rhomboidal blocks were integral in forming the pattern of salt deformation observed in the present basin.

Geology of the Dufferin gold deposit, Port Dufferin, Nova Scotia

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The Dufferin gold deposit occurs in the hinge zone of the Crown Reserve Anticline (CRA), a minor fold on the south limb of the Salmon River Anticline, and represents the faulted extension of the 'old' Dufferin mine, which operated in the late 1800s and early1900s. The CRA is a tight, steeply inclined chevron fold in the Goldenville Formation, and in the mine area stratigraphy consists of thickly bedded metasandstone with minor slate. The hinge zone generally defines a flat arch approximately 10 m across. The deposit consists mainly of stacked "saddle-reef" veins, occurring within slate beds at fairly regular intervals. Diamond-drilling has identified up to thirteen individual or groups of saddle reefs to a depth of 400 m, and a strike extension of 700 m has been defined for the upper two saddle reefs. Three northwest-trending, oblique faults with east-side-down, sinistral displacement offset the veins approximately 10 m.

Vein types at Dufferin include saddle reefs in the fold hinge, bedding-concordant veins (leg reefs) extending down fold limbs, and discordant veins. Saddle reef veins are defined by thick (up to 4 m) bedding-concordant veins of massive, commonly vuggy quartz in the hinge zone. Laminated quartz veins locally occur at the margins of the saddle reef veins and are cross-cut by massive quartz of the saddle veins. Bedding-concordant, en echelon shear veins (EESV) occur adjacent to saddle reef veins and, locally, the internal structure of saddle veins resembles amalgamated EESV separated by thin septa of wall rock. This suggests saddle reef formation may reflect a combination of extension related to bedding-parallel shear and hinge zone dilatency. Saddle reef geometry is strongly asymmetric, with thick north limbs thinning near the fold hinge This asymmetry may reflect hinge migration, or an asymmetric fold geometry; the inferred geometry implies a relatively short north limb.

Leg reef veins, the down-limb extension of saddle reefs, include laminated bedding-concordant veins and EESV arrays within slate horizons. Laminated veins are typically 5–8 cm thick and consist of dark banded quartz; movement striae on internal laminae support a shear origin. EESV consist of massive, locally vuggy quartz, are strongly sigmoidal (pegged in sandstone and rotated within the slate intervals), record significant reverse, dip-slip bedding-parallel shear, are locally boudinaged (at high shear strains), and include multiple generations of veins which record progressive vein formation during shearing. Fold-related bedding-parallel shear is also recorded by movement horizons at most slate-sandstone boundaries.

Discordant veins are common and are related to the saddle reef veins. They commonly merge with and taper away from saddle reef or related leg reef veins. The observed vein array is consistent with syn-folding vein emplacement along structures related to flexural folding and chevron fold development, characterized by bedding-parallel shear and hinge zone dilatency.

Carbonate and sulphide minerals (abundant arsenopyrite and minor pyrite, galena, and sphalerite) are common as accessory phases within veins and occur with wall rock. Of note is an apparent positive correlation of visible gold and galena. Gold was observed in all vein types.

Decompressional reaction textures in the southeast Long Range Inlier, Newfoundland: products of thermal metamorphism adjacent to the Taylor Brook Gabbro Complex?

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High-grade metamorphic terranes typically record aspects of their tectonic history subsequent to regional metamorphism. The rocks in many such terranes commonly preserve arrested mineral reaction features, such as corona structures, indicating that high-grade metamorphism was superseded either by near-isobaric cooling or near-isothermal decompression. However, in the Proterozoic Long Range Inlier of western Newfoundland, these corona structures are spatially associated with a mafic intrusion, the Silurian Taylor Brook Gabbro Complex (TBGC).

Reaction textures and corona structures, which include pressure-sensitive assemblages (e.g., coronal pyroxene on garnet in metabasite), have been identified in gneissic rocks near (within a few km) the TBGC. These types of coronal assemblages are generally interpreted to indicate near-isothermal decompression following regional metamorphism, which in the inlier occurred at ca. 1.03 – 1.10 Ga. However, since they appear to be absent elsewhere in the inlier, there is reason to believe that they are products of contact metamorphism within the thermal aureole of the intrusion. Furthermore, one-dimensional thermal modeling calculations yield results consistent with paleotemperatures determined for the coronal assemblages in samples collected at various distances from the TBGC. We therefore conclude that the coronas formed during cooling of the TBGC, so that there is a ca. 0.7 Ga difference (i.e., mid-Proterozoic versus Silurian) between the age of the regional metamorphic mineral assemblages, as represented by the mineral cores of the corona structures, and the coronas

themselves. Investigation of coronal structures within the aureole of the TBGC therefore adds an additional point to the P-T-t curve for the Long Range Inlier.

Nares Strait expedition: collaborative research to solve a geological controversy

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A multi-disciplinary experiment in Nares Strait, the waterway between North Greenland and Ellesmere Island, was organized under the auspices of the Canadian-German Bilateral Agreement in Science and Technology and run in August and early September of 2001. The German Federal Institute for Geosciences and Natural Resources (BGR) and the Geological Survey of Canada (GSC) were the principal participants with critical support from Danish and other Canadian agencies. Heavy ice conditions in Nares Strait necessitated the use of Canada's most powerful ice-breaker, the CCGS Louis S. St-Laurent.

The primary rationale for the experiment was to collect information to solve a long-standing controversy on the origins of the Nares Strait. The debate revolves around three hypotheses: 1) the strait is a major strike-slip fault; 2) plate motion has been taken up first by strike-slip along the strait followed by compression in a broad zone on Ellesmere Island; and 3) the strait is not a tectonic boundary and the geology can be correlated across it. This controversy has resulted from an apparent incompatibility between the onshore geology surrounding Nares Strait and plate tectonic models describing the opening of the North Atlantic and resulting motions of Greenland. The strength of this expedition was the ability to integrate targeted onshore geological fieldwork with regional geophysical measurements to extend interpretations offshore.

The major marine geophysical component of the cruise was the acquisition of three types of seismic data: 1) high resolution reflection for imaging 100 m below the seafloor, 2) multi-channel reflection for penetration to 5 km, and 3) refraction to map large-scale structures from 0–40 km in depth. Aeromagnetic data were acquired by towing a sensor from a helicopter. This style of surveying allows for direct correlation of magnetic rock samples collected onshore with offshore areas. A total of 9000 km of aeromagnetic data were collected.

Nares Strait is a unique laboratory for studying continental translation and compression because the amount and timing of the deformation are quantitatively constrained by plate reconstructions. The preliminary analyses of the data are consistent with the hypothesis that strike-slip motion was followed by compression.

A return to the southern Grand Banks; a seismic review of the Bandol No.1 well

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After a 14 year hiatus, drilling resumed on the southern Grand Banks of Newfoundland with the spudding of the Bandol No.1 well in the summer of 2001. This test, although now abandoned, is significant because it shows that there are still industry expectations that this area will deliver a commercial petroleum discovery. More importantly, this well represents a break from previous southern Grand Bank exploration strategies that have focused largely on salt structures as locales for potential hydrocarbon traps. This approach started in 1966 with the Tors Cove D-52 test, 315 km to the southeast and ended by 1974 with 24 wells drilled in the South Whale Subbasin and Whale Basin. One additional test, Narwhal F-99, was drilled in deeper water on the continental slope in 1987. While the prospectivity of the Mesozoic section as a potential reservoir was established, only a minor gas show at Tors Cove and a small oil show from the adjacent Heron H-73 were encountered. With only this very limited past drilling in such a large region lying between the huge finds in the Scotian and Jeanne d'Arc basins there remains the tantalizing prospect of a future discovery.

This presentation will show the seismic expression of the drilling target compared to previous exploratory targets in the area. The structural feature tested by this well was previously noted in 1992 on seismic data acquired for the Geological Survey of Canada (GSC). The seismic interpretation here can be shown to be similar to the known geology of the easternmost Scotian Basin and is tied through to wells there and in the South Whale Subbasin. The well to seismic correlation was done with Hampson Russell's STRATA seismic inversion software, which provided a wavelet extraction from the seismic and sonic log data for precise well ties. The STRATA software also enabled a seismic inversion that gave some insights into the nature of the probable geology encountered in this yet unreleased well.

Revised geology of the New River Belt and proposed correlations in southern New Brunswick

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Cambrian rocks in southern New Brunswick are exposed in four fault-bounded belts, referred to as the St. Croix, New River, Brookville, and Caledonia belts, from west to east respectively. The New River Belt is separated from the Brookville and Caledonia belts to the east by Late Ordovician to Early Silurian arc-related volcanic rocks of the Kingston Group and from the St. Croix Belt to the west by Early Silurian to Early Devonian

rocks of the Mascarene Group. Previous mapping indicated that Cambrian and older rocks in the southwestern part of the New River Belt, although comparable to those in the Brookville Belt, were distinct from coeval rocks in the Caledonia Belt (Avalon Zone *sensu stricto*). These distinctions were thought to apply to the entire New River Belt; consequently the Avalonian affinity of the belt was questioned.

Recent mapping in the northeastern part of the New River Belt has shown, however, that there are significant lithological changes across the Robin Hood Lake Fault that bisects the belt into southwestern (Pocologan River and Beaver Harbour) and northeastern (Long Reach) segments. In the Long Reach segment the presence of ca. 625 Ma compositionally-expanded granitoid rocks, ca. 555 Ma bimodal volcanic rocks and Cambrian marine sedimentary strata directly correlative to the Saint John Group indicates a correlation with the Caledonia Belt.

Middle Cambrian volcanic rocks at Beaver Harbour in the southwestern part of the New River Belt distinguish this area from the Caledonia Belt. Nonetheless, their correlation with volcanic rocks found locally throughout the Avalonian cover sequence demonstrates that at least this segment of the southwestern New River Belt is also part of the Avalon Zone. Although Early Cambrian volcanic and sedimentary rocks in the Pocologan River area appear to have no correlatives in the Avalon Zone in the Maritime region, it is noteworthy that this volcanic activity is broadly contemporaneous with a major sequence boundary in the Avalonian cover sequence. This could imply an association between the Pocologan River area and Avalon, perhaps as geographically isolated regions of the same continent that were subsequently juxtaposed by strike-slip faulting. If correct, a possible correlation between late Early to (?) Middle Cambrian quartzose sedimentary strata in the Pocologan River area and Middle Cambrian rocks in the St. Croix Belt evokes an earlier interpretation of the St. Croix Belt and Avalonian cover sequence as basin and shelf equivalents.

The granitoid units of Cape Breton Island, Nova Scotia: a catalogue of background information to aid assessment of their potential as building and/or dimension stones

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Canada has great potential for all types of stone resources (e.g., granite, sandstone, marble, and slate). However, granite has exclusively become Canada's most internationally sought after building and dimension stone because of its beauty and durability. The quarrying and fabrication of Nova Scotian granite dates back to the mid-1700s. Since then, over 75 quarries have periodically produced stone, mostly granite, over the past 150 years.

Granitoid rocks of many varieties and ages are abundant in Cape Breton Island. This abundance, as well as the strategic location of Cape Breton Island for shipping, should encourage future production. In order to provide background information for the assessment of the potential of granitoid rocks in Cape Breton Island for use as building and/or dimension stone, a compilation has been undertaken, using as its base the extensive collection at Acadia University of granitoid samples representing essentially all granitoid units in Cape Breton Island. The purpose of the study is to document useful information about the granitoid units across Cape Breton Island in a readily accessible format. Such an inventory will perhaps assist future users in investigating the suitability of these rocks for building stone/dimension stone purposes.

Background information on the past and present use of Cape Breton Island granite reveals that certain characteristics make them potentially useful for building/dimension stone purposes. Attractive colour, grain texture and pattern, and surface finish of the stone are normal requirements. Before quarrying, granite is also commonly tested for specific weight, absorption, compressive strength, transverse strength, and resistance to abrasion. These characteristics help determine the durability of the granite and its capacity to resist weathering agents and human impact.

This study is being done as a Special Project course at Acadia University. It will include a short written report on the usage of Cape Breton granite as building and /or decorative stone and an investigation through a literature/website survey to obtain the characteristics of granite that make them potentially useful for this purpose. Secondly, an appropriate catalogue format is being designed to effectively organize and present the relevant information, such as location, accessibility, size, and appearance of the rock. The final product will be a Cape Breton granite catalogue in both paper and electronic versions. The inventory will include a colour digital image of a representative sample from each unit.

Modelling of Horton Group (Devonian–Carboniferous) paleolakes, southern New Brunswick – are we still out of our depth?

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A variety of lithofacies are present in strata assigned to the Horton Group in southern New Brunswick, including: alluvial fan, sheetflood, fluvio-deltaic, algal swamp, shoreface, carbonate mudflat, shallow lacustrine, evaporitic lake, and offshore lake. The general lithofacies model projects a humid tropical intermontane setting with alluvial fans and fluvio-deltaics enclosing lacustrine strata in at least two structurally discrete subbasins. Most earlier authors have noted that lake area and depth fluctuated due to numerous lake transgressions and regressions. Some authors additionally have envisioned the lake evolving from a predominantly closed lake to an open lake with time, or that relatively deep lakes (10's of metres) are thought to have persisted in the southeast with more transient lakes elsewhere.

Ongoing analysis of recently available data, and comparison

with other modern and ancient lake basins, broadly confirms the existing model. In the Hillsborough area, core, wireline, and seismic data suggest high relief lacustrine delta systems periodically prograded from the NNE toward the Albert Mines depocentre where the oil shales accumulated. Preservation of 'highstand' delta-top deposits in the Dawson Settlement Member support the contention that deep, possibly open lake conditions were the norm relatively early in Horton times. In the Sussex area, similar delta-top facies from outcrop suggest infilling toward the northeast.

The Mira – Bras d'Or terrane boundary in Cape Breton Island, Nova Scotia: potential field and petrophysical investigations applied to tectonic analysis in the northern Appalachian orogen

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The regional geology of south-central Cape Breton Island is interpreted to consist of two terranes or tectonostratigraphic zones correlative throughout the northern Appalachians. The Mira and Bras d'Or terranes have been locally defined based on stratigraphy, age, metamorphic grade, plutonism, and lithogeochemistry. However, the spatial continuity of the Mira and Bras d'Or terranes, in particular the boundary location and geometry, is for the most part equivocal. This is due in large part to the presence of water cover and/or extensive Devonian and Carboniferous sedimentary sequences.

Previous tectonic studies have utilized various geophysical methods (e.g., seismic and/or potential fields) to identify subsurface features associated with terranes or tectonostratigraphic boundaries. The present study has compiled qualitative, semi-quantitative, and quantitative potential field and petrophysical data for the Avalon and Gander terranes in Newfoundland in addition to generating an extensive corresponding data set for southern Cape Breton Island. This information is used to assess the internal character of the Avalonian Mira and Ganderian Bras d'Or terranes and evaluate the nature of the boundary between these two terranes through south-central Cape Breton Island.

Magnetic and gravity data have been processed to extract long wavelength features associated with shallow (<5 km) crustal sources, and petrophysical data is correlated to mapped geological units in the study area. The results confirm the presence of significant geophysical breaks related to an interpreted terrane contact and other geophysical phenomena interpreted to reflect the structural complexity of the Mira – Bras d'Or terrane boundary. In several areas, the mapped units associated with the terrane boundary appear to have limited depth extent interpreted from 2-D potential field modelling. Preliminary interpretations suggest that these phenomena could be locally explained by positive flower structures whereby the terrane boundary lies beneath a wedge of strata comprised of both Mira and Bras d'Or terrane rocks.

The Jurassic North Mountain Basalts, Nova Scotia: more than just simple flood basalts

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The 201 Ma North Mountain Basalt (NMB) is a sequence of continental tholeiitic basalts erupted within a continental rift (Fundy Basin) that has been subdivided into lower, middle, and upper flow units (LFU, MFU, UFU, respectively). Petrographically the basalts are medium- to fine-grained with ophitic textures and are variably vitrophyric (≤30 %). Results of ongoing investigations of the features of the NMB are summarized below followed by inferences regarding their nature and origin.

1. The LFU (≤190 to ≤40 m) is a medium- to coarse-grained, massive, columnar jointed basalt of dominantly holocrystalline texture with minor vitrophyre. The top few metres are often amygdaloidal and mafic pegmatites locally occur with felsic layers (≤2–3 cm). Rarely spectacular Neptunian dykes (≤20–30 cm) are controlled by columnar jointing. Although the LFU forms a prominent valley wall along the Annapolis Valley, this topographic feature diminishes westwards.

2. The MFU contains numerous (4–16), variably thick (≤1 to ≤25 m) flows with a laterally variable composite thickness (150 to 10 m) that decreases westwards. The basalts are fine- to medium-grained and contain abundant, variably textured mesostasis (≤30–40%). The MFU is characterized by a systematic zonation of zeolites occluding primary vugs. Minor amounts of massive, fine-grained, homogeneous, red inter-flow sediment occurs as thin (cm scale) beds, and discordant vein networks or dykes; zeolites cross-cut and locally replace the dyke rock.

3. The UFU (≤160 m) consists of at least two or more flows and is similar to the LFU. It is a massive, columnar jointed basalt with a medium- to coarse-grained texture and contains abundant vitrophyre (≤30%). Segregation pipes of 3–5 cm to 1 m occur locally and a pervasive early silica alteration along columnar joints postdates pipe formation. The distribution of the UFU is poorly constrained with the greatest exposure at the west end and the bottom part only observed along the length of the valley coast line; it is not exposed along the north side of the Fundy Basin.

4. Silica veins overlap zeolite formation and occur in the MFU and UFU. The veins form en echelon arrays, occupy brittle structures, are massive to finely laminated, and colour varies (clear, cloudy white, green, red). There is a change in orientation from N–S to NE from Long Island to Scots Bay.

5. Disconformably overlying weathered flows of the MFU are red-brown sediments of the Scots Bay and McCoy Brook formations.

The above observations indicate: (1) deposition of NMB in a sub-basin of variable thickness, (2) extraction of MFU from a different magma source or one that changed post LFU; (3) sinistral movement along E–W bounding faults, (4) rapid deposition and minor inter-flow exposure to weathering, (5) formation of zeolites from circulating hydrothermal fluids post volcanism.

Drag folding in the northeastern Thor-Odin culmination, Monashee complex, British Columbia

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Kinematics of regional flow are inferred from the geometry of large scale folds, based on 1:5000 structural mapping in the northeastern Monashee complex. The Monashee complex is located in the Omineca Belt of the southern Canadian cordillera.

Three major folds are found in the study area. These are the Begbie anticline, Mulvehill syncline, and Tilley anticline, listed from north to south. Based on map-scale overprinting relationships, the Begbie anticline is interpreted as an F2 fold, overprinted by the Tilley anticline and Mulvehill syncline, both F3 structures. The asymmetry and style of the north-northeast verging Tilley anticline suggests that this fold developed as a drag fold in response to a non-coaxial flow.

The model presented here suggests that the early-formed F1 and F2 folds are also drag folds that have undergone progressive tightening and reorientation toward the flow direction, while simultaneously being refolded by F3 folds developing parallel to the vorticity axis of a non-coaxial shear. Thus, F1 through F3 folding is not a series of discrete tectonic events, but a continuum of deformation.

The consistent pattern of south-southwest trending folds overprinted by east-west trending folds, and lack of large scale sheath folds suggests that non-coaxial flow was not a simple monoclinic deformation, but rather a bulk triclinic and/or non-steady flow, that consistently favoured anticlockwise rotation of linear markers.

The implication of this model is that only those "late" folds (F3) that have recently initiated parallel to the vorticity axis, or those completely transposed "early" (F1 and F2) folds in equilibrium with the shear direction, have meaningful orientations for interpreting regional kinematics. Most folds will have an orientation intermediate between the vorticity axis and the shear direction.

Manganese (Mn) in the geologic environment, central Nova Scotia

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In the environment, manganese (Mn) occurs naturally as well as from anthropogenic sources including emissions from industry (steel industry, manufacture of batteries), combustion of gasoline, and certain pesticides. High concentrations of some Mn species may be toxic to flora and fauna. In the human population, elevated Mn in municipal water supplies is considered a nuisance resulting in the staining of clothes and water fixtures. In some cases where Mn is a problem, expensive water treatment facilities are required. For example, the City of Fredericton, New Brunswick required a 3.5 million dollar treatment system in order to maintain Mn concentrations at less than or equal to 0.05 mg/L as specified in the Guidelines for Canadian Drinking Water Quality.

The formation of secondary Mn oxide and hydroxide minerals is a very important control for the cycling of some toxic, heavy metals through the surface environment. Some heavy metals are easily adsorbed onto the surface of the secondary Mn minerals. However, the formation of secondary Mn minerals, the adsorption process, and the general cycling of Mn in the environment is not completely understood. Many variables drive these processes, including oxidizing/reducing conditions, the availability of oxygen, and pH of co-existing aqueous solutions.

This study involves an examination of Mn in the environment in central Nova Scotia. The study was initiated in order to: 1) examine the occurrence of manganese mineralization within the two contrasting geological environments, 2) develop a GIS database of Mn concentrations in water, lake sediments, and bedrock, 3) investigate if there is a correlation between Mn in the surface environment and Mn occurrences in bedrock. In the longer-term, the ultimate goal is to understand better the source, transport, and fate of Mn through the environment.

In the study area, sedimentary rocks within the Carboniferous Basin, and metasedimentary rocks of the Cambro-Ordovician Meguma Supergroup are both known to host Mn mineralization. X-ray diffraction indicates that pyrolusite is the main Mn phase in the areas examined in the sedimentary rocks of the Carboniferous Basin. In the Meguma Supergroup, Mn-rich garnet, ilmenite, and in some areas, Mn-rich carbonate minerals occur. In the Carboniferous Basin, preliminary results indicate at least some positive correlation between Mn in surface waters and Mn mineralization in the host bedrock.

MapTool: a new software program for managing field data

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Traditionally, field observations are recorded in a standard field notebook at an outcrop. These data are distilled by the geoscientist and the basic features are plotted on a base map. Information that can be garnered by users of the map is typically limited to location, group-formation-unit, structural measurements, and perhaps type of mineralization. Few maps contain outcrop data relating to intensity and type of alteration and mineralization, specific rock-type, development and overprinting relationships of structural fabrics, colour, magnetic characteristics, or bed thickness, yet this information was probably recorded in the mapper's fieldbook. When remapping of an area is required, there is an enormous amount of effort expended recording data that has

already been recorded, simply because the original observations (fieldbook) are rarely available. This duplication of effort is inefficient at best, especially in light of the recent advances in digital data capture and management, which have helped to transform the ways in which geological data can now be recorded, spatially referenced, managed, and distributed. By storing field observations in a universally accessible digital database, the geological mapper becomes a data conduit rather than a data repository.

MapTool is a program, developed jointly by the New Brunswick Geological Surveys Branch and CARIS, to aid in the digital capture, display, management, and distribution of geological field data. A desktop version and a Pocket-PC version, which can be used in the field, have been developed. Through a series of simple on-screen forms, geologists can record their field observations into a relational database and link them to outcrop symbols on a digital base map. The outcrop symbols are geo-referenced using data retrieved from a handheld GPS receiver. By periodically uploading field data through the course of a mapping project, map preparation and interpretation can be significantly expedited. The result is a geological map with an underlying relational database of field observations that can be distributed to users. As MapTool stores its data in Microsoft Access, it can be exported, if necessary, to other popular database formats (e.g., Oracle, dBase), and linked to digital maps in other GIS programs.

Central Scotian slope stability: the role of gas hydrates

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Gas hydrates are ice-like solids in which large quantities of methane are trapped in a solid phase as a result of suitable pressure and temperature conditions in the presence of an excess supply of methane gas. They are a potential fuel source, possible greenhouse gas contributor, and a geohazard concern due to their potential effect on slope stability. Gas hydrates may cause sediment failures by releasing methane gas when they dissociate (melt) resulting in an increase *in situ* sediment pore pressures. The purpose of this study is to search for the presence of gas in an area of known sediment instability on the continental slope east of Nova Scotia (Verrill Canyon area) using a geophysical approach. This area displays several sediment failures, between 15 and 12 ka. Geotechnical infinite slope stability analysis has shown that the area is inherently statically stable and that excess pore pressures were necessary to effect failure. Increased pore pressure probably resulted from one or more of: ground accelerations due to earthquakes or isostatic readjustments following glaciation, shallow gas charging, dissociation of gas hydrates, or rapid sedimentation during glaciation / deglaciation. Dissociation of gas hydrate is one of the proposed potential mechanisms. A drop in sea level or increase in bottom water temperatures (as during glaciation / deglaciation) may cause dissociation of gas hydrate, which would free methane and water, causing an increase in pore pressure. The presence of failures and pockmarks near the theoretical minimum stable depth (500 metres below sea level) is indirect evidence of gas hydrate existence. Hydrates in some locations can be detected on seismic reflection profiles by the presence of a BSR (a bottom simulating reflector, which corresponds to the bottom of the hydrate layer), or by using wide angle seismics (such as an ocean bottom seismometer, or OBS) to detect an unusually high velocity. Examination of 14 high resolution single channel reflection lines has not revealed any BSRs. An OBS was deployed where gas hydrates are most likely to be present (850 metres below sea level). A velocity model was produced from the OBS data, which displays no anomalous velocities. Therefore it is proposed that if gas hydrate is present, concentrations are too low to be detected by the seismic methods employed.

High resolution palynological records from the southeastern Canadian seaboard: Holocene paleoceanographic and paleoclimatic history

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Palynological records were used to reconstruct Holocene paleoceanographic and paleoclimatic conditions along the eastern Canadian seaboard. Cores from La Have Basin, St. Anne's Basin, and Bay of Islands provide a resolution of about 100 years and have multiple radiocarbon ages. Proxy data from dinoflagellate cysts were used to reconstruct sea surface conditions by means of paleobioclimatic transfer functions. Ocean-atmosphere interactions were determined by onshore-offshore correlation of marine and terrestrial pollen records from Nova Scotia and Newfoundland.

Records from the Scotian Shelf show a south to north progression of oceanic events. An early Holocene sea surface temperature (SST) maximum, 3 to 5°C warmer than today's average, occurs from 10.5 to 8.5 ka in La Have Basin, and 7.5 to 6 ka in St. Anne's Basin. Salinity was also higher than today. The warm conditions were followed by an interval of SST 1–2°C cooler than today. In most basins, sea surface conditions during the latest half of the Holocene were characterized by frequent oscillations of SST (1–2°C below and above today's average) and salinity. A second warm SST interval was reconstructed in St. Anne's Basin between 4 and 2.5 ka. Evidence for a major late Holocene cooling is weak.

In Bay of Islands, SSTs were lower by 3°C during the early Holocene. The Holocene SST maximum between 8.5 and 7 ka, was characterized by SST up to 5°C warmer than today's February average (1°C in August). After the SST maximum (7–4 ka), the sea surface conditions were similar to the past century, except for

cooler summer SST (by 3°C). Between 4 and 1 ka, February SST were up to 5°C higher than today. Cooler SSTs were reconstructed 1000 years ago.

Pollen records from the same shelf basins and from Bay of Islands showed that the warming of the land was delayed by 2000 years on average relative to the ocean. Increased proportions of spruce and a decline of pine indicate a cooling during the last 2000 to 3000 years.

Mechanisms of lithification of lunar breccias

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Most lunar rocks studied to date are breccias of one form or another. The nature of the "glue" that bonds the fragments together and the processes by which an unconsolidated material becomes a non-porous, highly coherent breccia are poorly understood. Previous work on lunar impact melt rocks has investigated the relationships between the melt and cooler clasts. Textural studies have also been made on coarser grained breccias and melt rocks, which modeled temperatures, chemical changes and lithification as a result of shock. Fine-grained friable lunar breccias have also been studied using a scanning electron microscope to determine mechanisms of lithification. This study complements previous studies in that a range of lunar breccias, from impact melt to the very friable feldspathic breccia, have been examined from the Apollo missions 15, 16, and 17. In addition, samples of howardite and diogenite meteorites were used for comparison. Laboratory synthesized breccias were used as a control for shock conditions.

There appears to be a strong link between the friability of a lunar breccia, the porosity and the amount of intergranular melt. As the amount of intergranular melt increases, the sample becomes more coherent and the porosity decreases. Since the intergranular melt is generated by the energy released by an impact event, there must be a correlation between the friability of the rock and its distance from the impact or its source energy of lithification. This is complicated by the fact that on the moon, and other planetary bodies, it is likely that many impact events have affected the same rock. However, a sample should record the largest, closest and most recent event more strongly than other distant weaker, older events. It is thereby proposed that one can model the relative distance from the point of impact through the textural examination of a sample on the basis of intergranular melt, porosity, and friability.

Regional implications of the structural geology and tectonics at Chignecto Bay, Nova Scotia

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The Minas fault zone, a Paleozoic Appalachian terrane boundary, is an excellent example of a long lived zone of intense deformation of low metamorphic grade and significant displacement. Current interpretations indicate dominant dextral transpression during the Acadian orogeny as Meguma docked against the Avalon terrane. This transpressive fault zone was later reactivated and acted as the locus for the opening of the Fundy and Minas basins during the initial fragmentation of Pangea in the Triassic.

Chignecto Bay offers excellent along and across strike exposure of the Minas fault zone; from this a detailed tectonic history can be obtained. The principal rock unit is the Greville River Formation, the distal facies of a single alluvial fan-fluviatile-lacustrine unit of the Late Devonian–Early Carboniferous Horton Group. Four folding episodes have been identified; first generation folds are tight and isoclinal, second generation folds are open and recumbent, third generation folds are upright, NW vergent with shallow fold axis. Transposition is a dominant deformation mechanism. The final folding episode produced large-scale warps with dextral vergence which have an axial plane oblique to the fault trace. This sequence of folding suggests that there has been a progression in regional tectonics from early contractional deformation across the fault zone to one of dextral shear along the fault.

Early Mesozoic NW transtensional reactivation of the fault zone produced the Minas and Fundy basins which are filled by the Fundy Group syn-rift sedimentary deposits and basalts. Adjacent to the fault is a zone of intense deformation in which transtensional displacement is localized. This area is dominated by sinistral and normal faulting resulting in calcite veining and brittle microstructures.

The Wolfville Formation is in fault contact with the Greville River Formation and is characterized by normal and sinistral strike slip faults. This is anticipated in a transtensional regime. Fold orientations are consistent with dextral displacement, which may be a late stage response of the now passive Fundy and Minas basins to the continued spreading offshore as the Atlantic opens.

The relative westerly position of Chignecto with respect to the direction of collision between Avalon and Meguma produces an east–west variation in deformation intensity and styles. This can account for some of the differences in the structures observed at Chignecto and Greville Bay. Chignecto Bay offers insight into the early folding history of the Greville River Formation, which contrasts with the exposure at Greville Bay where cyclical transposition has obliterated the early folding sequence. Clearly Chignecto offers the opportunity to increase our knowledge of the tectonic evolution of the Minas and Fundy basins.

Ultramafic rocks in an arc environment: Neoproterozoic magmatism in the Avalon terrane, Antigonish Highlands, Nova Scotia

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Typical continental arc magmas are calc-alkaline and range from andesitic to felsic compositions. The ca. 610 Ma Neoproterozoic Greendale Complex, in the Antigonish Highlands, Nova Scotia, is a local example of regional arc-related magmatism that typifies the Avalon terrane. The dominant rocks of the complex exhibit calc-alkaline trends and have continental arc magmatic affinities that range from andesitic to felsic in composition. However, they also contain an important ultramafic component that is atypical of Neoproterozoic Avalonian magmatism. Petrographic examination and microprobe analyses of the ultramafic rocks within the Greendale Complex show that they contain tschermakitic hornblende (magnesiohastingsite) which poikilitically encloses olivine, hypersthene, clinopyroxene (augite, endiopside, diopside), and chromite. Minor minerals include interstitial plagioclase and phlogopite (<5%) as well as late magnetite-apatite veins. The mafic minerals have high magnesium numbers (56–80) that are typical of ultramafic rock compositions. The Greendale Complex was emplaced during the final stages of coeval dextral motion between the Hollow and Greendale faults associated with subduction along the northeastern margin of Gondwana. Geochemical analyses, phase equilibria, and field relationships indicate a two-stage process for emplacement of the ultramafic rocks. Early crystallizing mafic minerals (olivine and pyroxene) probably formed as cumulus minerals in a basaltic parental magma chamber at depth. Large, poikilitic hornblende crystals are believed to have formed after this magma (and entrained mafic minerals) was injected into a shallower water-rich environment near the roof of the Greendale Complex. This process would account for large poikilitic hornblende crystals that enclose the early mafic minerals.

The origin of magma within the Greendale Complex is related to Neoproterozoic intra-arc rifting. The range of rock compositions within the Greendale Complex, including the ultramafic component offers insights into Neoproterozoic tectonic processes which contributed to the formation of the Avalon terrane in Atlantic Canada.

Cryptic erosion on the Upper Cretaceous Wyandot Formation, Sable Island area, Scotian Shelf

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The Upper Cretaceous Wyandot Formation is a widespread, predominantly chalk unit found on the Scotian Margin and Grand Banks. A distinctive stratigraphic unit, it produces a strong regional seismic marker and is a proven gas reservoir. From previous studies, the Wyandot Formation is known to vary in thickness from 20 to over 300 metres on the Scotian Margin, and age determinations have varied from Santonian–Campanian to Coniacian–Maastrichtian.

Detailed study of wireline logs and industry seismic reflection data reveals that in many areas north, southwest, and west of Sable Island, the upper portion of the Wyandot Formation is truncated by erosion, in some cases reducing the formation to less than half its original thickness. A seismic isochron map of Wyandot horizons accurately predicts the thickness variations seen in the wells of the area. Previously published age control and new biostratigraphy implies that the unconformity developed within the mid-Campanian to earliest Maastrichtian. The erosional truncation explains much of the variation in age determinations for the top of the Wyandot Formation. There is a strong correlation between the area of erosive thinning and "bumpy" discontinuous reflections noted by previous workers. However, there is evidence for significant erosion even in some areas where the "top Wyandot" seismic horizon is smooth and continuous. Additional factors, such as draping by overlying Maastrichtian clinoform units, may explain the different seismic character of the erosion surface.

The presence of an extensive erosion surface so close to the shelf edge, near the Sable Subbasin depocentre, and on top of a deep shelfal marine unit, is surprising. Significant tectonic uplift, due to regional crustal tilting or salt deformation, may be necessary to account for its occurrence. In the North Sea Central Graben, major hydrocarbon fields are found in areas of 'resedimented' chalk that was eroded from the basin margins. An understanding of chalk erosion on the Scotian Margin might lead to analogous plays on the Scotian Slope.

Beach mining, nearshore dredging, coastal erosion, and sedimentation in the McNabs Island area of Nova Scotia

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The McNabs Island area, situated at the eastern side of the entrance to Halifax Harbour, consists of several drumlins formed in the Wisconsinan-age Lawrencetown and Hartlen tills. Bluffs in these drumlins exposed to the open Atlantic Ocean are actively eroding at rates up to 6 m/a, supplying sand and gravel sediment which builds local beaches. Beach growth is supplemented by sediment transported landwards by storm wave action under the effects of long-term sea-level rise.

This area has been subject to significant anthropogenic disturbance with the commercial, defensive and urban development of Halifax. The earliest known written record of exploitation of coastal geologic resources suggests mining for shipping ballast occurred *circa* 1849. Other beach mining and dredging activities were conducted to build and maintain military infrastructure on McNabs Island between the late 1800s and 1950s and at

CFB Shearwater beginning in 1918, to rebuild parts of Halifax destroyed in the 1917 Halifax Explosion, and for the construction of the Halifax Container Terminal completed in 1970. Also, nearshore anti-submarine defences consisting of single rows of closely spaced wooden pilings with interstrung cables were constructed at two shallow harbour entrances (Eastern Passage and Drake's Gut) in the area during the Second World War.

Coastal change resulting from these disturbances (and from the natural forcing of change by storms and continuing sea-level rise) are documented using a combination of historical charts dating from 1759, aerial photography since 1935, Canadian Hydrographic Service (CHS) field sheets and other single-beam echosounding surveys since 1959, and precision single-beam and sweep multibeam echosoundings collected in 1998 and 1999.

Analyses of these sources reveal that beach mining caused the overwash and destruction of Barrie Beach, Noonan's Beach, and Doyle Beach, and acceleration of coastal erosion in adjacent areas. Sediment liberated from the beach deposits by overwash was transported landward and deposited at the anti-submarine defences forming new beach deposits. These were later exploited by nearshore dredging with little impact on coastal stability, likely because of continuing landward transport of sediment.

These results demonstrate the reasons for change of some beaches in the McNabs Island area and allow quantitative estimates of nearshore sediment mobility. In a broader context, these analyses may also, with continued monitoring, provide insight into the relative contributions of eroding bluffs versus overwashing barriers in contributing beach-forming sediment to the local sediment budget.

The impacts of coastal storms on the north shore of Prince Edward Island

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Long-term sea-level rise off the north shore of Prince Edward Island (PEI) has averaged 0.3 m/century over the past 6000 years and analysis of tide gauge records for Charlottetown and North Rustico, PEI, indicate mean relative sea-level rise of 0.32 m/century since 1911. This rate is projected to increase to 0.7 ± 0.4 m/century over the coming 100 years.

In response to sea-level rise, coastal retreat has averaged >50 m/century over 6000 years, resulting in the submergence of fluvial channels and estuarine and coastal facies. Sand is transported landward to multidecadal to century-scale storage in coastal dune and flood-tidal delta sinks leaving the shoreface, nearshore multiple bar complex, and beaches sand-limited.

Storms supply the energy required for driving coastal retreat and individual large storms can cause local rapid erosion. We document the impacts of two recent severe storms affecting the North Shore of PEI in October 2000 and November 2001 and consider these in context with a catalogue of potentially damaging storms developed using a 90 year record of storm surge occurrences, a 48 year record of wind speeds and directions, a 42 year wave hindcast, and sea-ice charts for 28 winters.

Photogrammetric rectification of digital aerial photography (1935–1990) and shore-zone surveys (1989–2001) show large spatial and temporal variance in coastal recession rates which is partly a function of backshore materials. Retreat of till/sandstone cliffs at <1 m/yr shows no statistically significant decadal variance whereas other sites with dunes have variably retreated up to 3 m/yr and accreted up to 4 m/yr.

Multidecadal healing of former washover and inlet channels in the early airphoto record may reflect recovery from widespread washover predating the 1935 photography that was possibly initiated by intense storms or a succession of storms in the late 19th century. Several sites show local acceleration after 1980 and again after 2000 in response to storms. In general, however, temporal variance in retreat rates is poorly correlated with the storm record. This may be partly due to variable sediment supply altering the morphodynamic response of shorelines to storms, suppression of storm waves by sea ice, and may also reflect the importance of storm clustering on scales of weeks to years in determining erosion vulnerability. The projected increase in the rate of sea-level rise and decrease in ice cover in the southern Gulf imply a potentially significant increase in the coastal erosion hazard on the north shore of PEI.

Research on mercury contamination of an aqueous system in New Brunswick, Canada: a hydrologic and hydrogeochemical approach

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Mercury contamination of Canadian aquatic ecosystems has become an important issue as a number of freshwater fish species have been reported to bear mercury levels of concern to human health. Gossan Creek, a first-order stream in the Upsalquitch River watershed in northern New Brunswick carries elevated concentrations of Hg as a result of leaching from a gold-mine tailings disposal site. Hydrological and hydrogeochemical methods are being used to investigate the transport paths, speciation, and attenuation mechanisms of Hg in this groundwater-surface water flow system.

Shallow depth (1 to 2 m) piezometers have been installed in the area between the tailings pile and the head of Gossan Creek for systematic sampling of groundwater. Major anions and major cations were analyzed by Ion Chromatography and ICP-OES respectively. Oxidation, purge and trap, and CVAFS method was used to ana-

lyze Hg concentration in water. ICP-MS equipped with a dynamic reaction cell was used for trace metal analysis. Our study indicates that the tailings pile acts as a point source of mercury into the aqueous system. A contaminated groundwater plume originates from the base of the tailings pile and flows toward the headwaters of Gossan Creek. The discharge area of the plume has been delineated using chloride concentrations, a conservative solute in the groundwater. Further studies of geochemical and biogeochemical processes that occur at the shallow groundwater/soil/atmosphere interface will be focussed at this discharge zone.

The headwaters of the stream system contain high concentrations of total dissolved Hg (up to 60 μg/L) and other elements like Cu, Zn, Mn, Ni, Co, As, Al, and Fe. The mass flux variations of total dissolved mercury (0.45μm; HgT) along the stream system have been calculated based on stream discharge measurements and HgT concentrations in water samples. More than 99% of the mass flux of the HgT is attenuated in the first 3 to 4 km from the source. Delineation of the Hg sinks and the attenuation mechanisms will be the focus of the future research.

A sequence stratigraphic interpretation of the McCully Reservoir sandstones

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The McCully Field lies within the Albert Formation of the Moncton Basin near Sussex, New Brunswick. These strata are interpreted within a sequence stratigraphic framework in order to anticipate hydrocarbon reservoir quality and distribution. While sequence stratigraphic analysis is more commonly applied to marine deposition, strata deposited within lacustrine environments should show similar patterns. Both show fluctuations in their sea- or lake-level that influence accommodation space, although the causes and the periodicity of the fluctuations may differ.

The Albert Formation may be considered a large order sequence or supersequence that is common to most lake systems and results from the basinal interplay between accommodation space and sediment input. This gives rise to three principal basin-centre members. The (lowest) Dawson Settlement Member consists of fluvial sediments that gradually become deltaic upward as accommodation outpaced sediment input. The overlying lacustrine Frederick Brook Member was deposited during maximum accommodation and contains highly organic condensed zones and (presumably) the maximum flooding surface. The upper Hiram Brook Member resulted from the progradation of delta systems that filled the accommodation space as sediment input outpaced accommodation.

New drilling in the McCully Field in the Hiram Brook Member allows the preliminary identification of sequences. The base of each sequence contains fluvial sandstone (LST) that fines upward into shale (TST). The strata fine upward until they reach the maximum flooding surface (base of the HST) that is interpreted as the organic-rich, high gamma peak from wireline logs. The strata gradually coarsen upward as the progradational system tract of the HST moves into the area. The progradational system tract is composed of smaller parasequences representing individual prograding deltas.

The thickest, coarsest grained, most productive (to date), and most laterally extensive reservoir sandstone is the fluvial sandstone of the LST. The "McCully A Sand" sits unconformably above the Frederick Brook Member shale, is medium- to coarse-grained, and appears to extend from the west of Sussex to the McCully Field (a distance of 14 km). It may represent a forced regression. The best production from overlying sandstone comes from thicker sandstone packages that are also good candidates for LST deposits. Parasequence sandstone units are thinner, finer-grained and more difficult to correlate between wells, but are numerous and may contribute significant reserves to the McCully Field.

Stratigraphy and paleoecology of the Sydney Mines Formation at Morien Bay, Nova Scotia

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Coastal exposures of the Sydney Mines Formation (Westphalian D) at Morien Bay consist of fluvial, restricted marine, and possibly lacustrine strata, with economic coals. Measured 75–150 m stratigraphic sections at Schooner Pond, Long Beach, and Port Morien include the Emery to Harbour seam interval and record stacked high-frequency sequences approximately 10–30 m thick. The dominant facies association comprises grey sandstone and shale and associated hydromorphic paleosols. The second major facies association includes calcareous paleosols as well as red shale and red and grey paleosols.

Repetition of wetland and dryland facies, representing regressive and transgressive cycles, is observed in all sections and allows for a sequence stratigraphic framework to be applied. Marine flooding surfaces are represented by thick coals and faunal concentrate limestone/shale. Sequence boundaries can be identified by the presence of calcretes and red mudstones. Grey, wetland facies are well represented within the Transgressive and Highstand Systems Tracts. Red and grey dryland facies are represented in the topmost Highstand to Lowstand Systems Tracts. The Falling Stage Systems Tract may also be represented here in some valley fills within highstand deposits.

Forested horizons of calamitacean and lepidodendrid trees standing in their growth position are observed at many levels, with large stigmarian rooting systems. Most horizons were found in grey siltstone and sandstone with small distributary-type channels, implying poorly drained or wetland associations. Abundant compression flora of *Neuropteris*, *Alethopteris*, *Pecopteris*, and *Cordaites* are recorded throughout all sections, mainly in wetland facies but also as rarer litter identified in red beds of the Highstand through Lowstand Systems Tracts. A well-preserved tetrapod trackway was discovered at Long Beach, just below the

Phalen Seam. Located within a shallow gully in a multi-story dryland channel body deposit, this ~3 m long trackway preserves 18 footprints generated in a soft, wet substrate. Rainprints, rill marks, and windblown sand suggest dryland conditions. A smaller set of tetrapod trackways was found higher in the section as well as two separate *Arthropleura* trackways.

Monitoring bioremediation after oil spills, old and new, using marsh foraminiferans as indicators

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Salt marshes of Nova Scotia are highly susceptible to marine oil spills. Removal of oil by natural processes is slow in low-energy environments, allowing oil to remain unaltered for many years. Marsh foraminiferans, microfossils sensitive to various environmental stresses, can indicate oil pollution and are useful to monitor bioremediation. Petpeswick Inlet, Nova Scotia, a two year-old experimental spill site, and Black Duck Cove, Chedabucto Bay, Nova Scotia, a 32 year-old spill site, have similar foraminiferal assemblages. At Petpeswick Inlet are 18 plots treated with one of the following: a controlled plot with nutrients (not oiled), a controlled plot without nutrients (not oiled), a plot with natural attenuation (oiled), a plot with nutrient enrichment (oiled), a plot with nutrient enrichment and cut plants (oiled), and a plot with nutrient enrichment and agricultural disking (oiled). Results continue to show deformation in the species *Miliamina fusca* in oil plots with no change in the control plot. Cores examined from Black Duck Cove indicate that *Miliamina fusca* is the dominant species with deformation present. The two areas provide present-day and post-spill scenarios that show how foraminiferans may be used to detect the duration needed for bioremediation within a marsh environment.

A deglacial foraminiferal assemblage (or DFA) sequence: meltwater / Heinrich event proxy on the shelf and slope

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During analysis of foraminiferans in Late Wisconsinan to modern sediments at locations on eastern Canada's continental shelf, sharp, shorted-lived increases in the percent occurrence of two species groups, *Cassidulina-Islandiella* and *Stainforthia*, termed a DFA sequence, appeared consistently in the early post-glacial record. These two groups live in modern environments, and have recently been the focus of intensive studies. *Islandiella helenae* reaches maximum occurrence in water depths of 70–140 m, and salinities of 32‰ to 33.5‰; and *Stainforthia* sp. can quickly recolonize in hyposaline (<32 ‰) waters. Applying the adage "the present is the key to the past" it is believed that the short-lived increases in percent occurrence were a direct response to a drop in ocean-water salinity, caused by an influx of meltwater. Examination of foraminiferans immediately above, through, and below Heinrich (H) / detrital carbonate (DC) layers in sediment cores from upper-slope environments also reveals the presence and variation in percent occurrence of the *Cassidulina-Islandiella* and *Stainforthia* species groups. Here the signal is more subtle; its magnitude is less, and it appears in a very thin layer, revealed only by very careful and precise sampling. Thus this DFA sequence is a meltwater proxy on the shelf and upper slope, and in sediments without apparent H / DC layers.

Instrumental in recognizing this DFA sequence is the careful and consistent identification of the "species" within the species groups. It has only been since 1976 that *Islandiella helenae*, a meltwater indicator on the shelf, and *I. norcrossi*, a meltwater indicator on the upper slope, have been recognized as separate and distinct from *Cassidulina latacamerata* (= *C. teretis*), a slope species reaching its maximum occurrence during glacial intervals. If these three species are lumped, the percent occurrence of the group appears constant throughout glacial, late-glacial, and post-glacial sediments. Care must also be taken to distinguish *Stainforthia fusiformis*, present throughout some post-glacial sediments, from *S. rotundata* and *S. pauciloculata*, peaking during periods of highest meltwater influx.

The relative magnitude of a foraminiferal meltwater signal in upper-slope and shelf sediments should give an estimate of ice extent, meltwater volume, and pathways. Age constraint on these faunas will provide a first-order estimate on the timing and rates of local ice retreat. The stratigraphic relationship of this sequence to recognizable H / DC layers indicates the synchroneity of local and global meltwater influxes.

Buckminsterfullerene, and the search for fullerenes in carbonaceous substances associated with the Oklo natural nuclear fission reactors

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Buckminsterfullerene (C_{60}), a soccer ball-shaped molecule of 60 carbon atoms, is a new form of carbon first synthesized in 1985. Fullerenes, including C_{60}, have potentially important industrial applications including manufacture of molecule-size electronic devices. C_{60} remains difficult to purify once synthesized and consequently commands a high price. Nowhere in nature has it

been found to be concentrated. The first report of a natural occurrence was in 1992 from shungite, found as inclusions in diabase, in the Lake Onega region of Karelian, Russia. Shungite is a highly carbonaceous metasedimentary rock similar in appearance to meta-anthracite and to solid bitumen. C_{60} has since been reported in meteorites, in soot at the K/T boundary, in carbonaceous tuff from Sudbury's Onaping Formation impact breccia, in fulgurites, and in sediments at the Permian/Triassic boundary. Our search for fullerenes at Oklo, Republic of Gabon, was prompted by the presence of "onion skin-like" structures in a sample of Oklo carbonaceous substances, as revealed by transmission electron microscopy. Initially our focus was the carbonaceous substances associated with the 2 Ga-old natural nuclear fission reactors of Oklo. Analytical techniques employed include infra-red spectroscopy, laser desorption, laser desorption post ionization (TOF), and high resolution electron impact mass spectroscopy. Without exception, the results of this work have proven negative. We find no indications of the presence of fullerenes in Oklo carbonaceous substances. If, as initially hypothesized, C_{60} was produced during the sustained nuclear fission at Oklo, then it either is present below the detection limit (ca. 1ppm) or it has been destabilized, possibly due to the high hydrogen fluence that prevailed during criticality. Assessment of this possibility is difficult because the stability of C_{60} is not well understood. Among our intended natural fullerene-bearing standards we confirm the presence of C_{60} in the "Black Tuff" from Sudbury's Onaping Formation, and the presence of C_{60} in one sample of Karelian shungite. We view as highly unlikely reports that C_{60} formed in the carbonaceous sediments of Karelia as a result of regional metamorphism; more likely the fullerenes are a consequence of the intrusion of basalt into sedimentary rocks highly enriched in reduced carbon.

Metamorphism and structure of the White Rock Formation in the Yarmouth area, Nova Scotia

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The White Rock Formation (WRF) of the Meguma terrane forms a belt of mostly mafic metavolcanic and shallow-marine metasedimentary rocks in the Yarmouth area of Nova Scotia. The WRF, together with the adjacent comagmatic Brenton Pluton, formed during the latest Ordovician to earliest Silurian in a within-plate tectonic setting. Acadian (Devonian) deformation in the Meguma terrane is manifested in NE-trending, upright, regional-scale folds with a well-developed axial-planar cleavage. In the Yarmouth area, a regional synclinal structure is suggested by the presence of Cambrian-Ordovician Halifax Formation either side of the WRF and by magnetic anomaly maps. However, younging directions on the coastal section consistently face southeast and no clear stratigraphic repetition is apparent. The contacts of the WRF with the Halifax Formation lie within broad Alleghenian shear zones. Original contact relations are unclear.

Low-pressure metamorphism accompanied Acadian deformation elsewhere in the Meguma terrane; however, mineral assemblages preserved in the WRF of the Yarmouth area suggest metamorphism under moderate-pressure conditions. Metamorphic grade ranges from upper greenschist to lower amphibolite facies in the WRF. Staurolite-bearing pelites are widely developed in the southeastern part of the area and are locally present within the Cranberry Point Shear Zone. Those in the southeast preserve common staurolite-garnet-biotite assemblages, whereas staurolite appears in association with oligoclase porphyroblasts in the northwest. Peak-metamorphic porphyroblasts overgrow the main regional schistosity (S1) and the well-developed, gently southwest-plunging stretching lineation (L1) throughout the area. Textures in staurolite-oligoclase porphyroblastic pelite within the Cranberry Point Shear Zone indicate peak metamorphism was synchronous with localized crenulation of S1 around steep axes. Peak-metamorphic porphyroblasts pre-date a transposition fabric developed in bounding Alleghenian shear zones. Bounding shear zones juxtapose amphibolite facies rocks of the WRF against greenschist facies Halifax Formation. These shear zones have therefore accommodated significant post-peak-metamorphic displacement and may represent major crustal structures.

The role of offset dykes in complex crater formation; the Sudbury example

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The 1.85 Ga Sudbury Structure of Ontario is now widely accepted to be a 200–250 km multi-ring impact basin. The structure consists of the 27 x 60 km Sudbury Igneous Complex (SIC), which is a differentiated impact melt sheet, and the Whitewater Group, which is composed of fallback and overlying sedimentary rocks, as well as various impact breccias in the footwall.

The so-called offset dykes consist of melt-breccia dykes that emanate from the SIC. They can occur as radial, concentric or discontinuous dykes. Quartz Diorite is the local term for the rocks of the offset dykes, but most are granodioritic to monzodioritic in composition. There are ten known offset dykes: five radial dykes (Copper Cliff, Worthington, Whistle-Parkin, Ministic, and Foy), three concentric (South Range Breccia Belt, Manchester, and Hess), and two discontinuous (Creighton and Maclennan). The radial offset dykes are generally linked to the Main Mass by means of a funnel-shaped embayment, which typically contains abundant sulphides associated with the Sublayer unit.

The offset dykes contain a variety of different rock types. These include Quartz Diorite (QD), containing little or no inclusions, Inclusion-bearing Quartz Diorite (IQD), Radial Breccia, Mafic Sulphide Bearing Breccia (MSBB), Sudbury Breccia, and Sublayer.

Field relationships between the various rock units are variable. In general, the Sublayer is restricted to the embayment areas of radial offsets but is also found as discontinuous lenses around the SIC. Radial dykes differ between the North Range and the South Range of the Sudbury Structure. North Range radial dykes consist of IQD, QD, Radial Breccia, and MSBB, whereas South Range radial dykes consist of IQD and QD only. Relationships between these rock units indicate a multi-stage emplacement mechanism. Rock types in concentric dykes consist of QD, IQD, and Sudbury Breccia.

Radial and concentric offset dykes record all three stages of Complex crater formation. The contact/compression stage of impact crater formation is responsible for creating the radial and concentric cracks, which are later exploited during the crater excavation stage as inclusion-rich breccias forcefully injected into radial cracks. Modification stage processes generate the Sudbury Breccia in concentric dykes and allow for the injection of melt from the overlying melt sheet into both the radial and concentric dykes.

The missing record of subduction in ancient orogens: consideration of modern analogues

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The record of subduction in ancient orogens is commonly interpreted by its style of magmatism, sedimentation, deformation, and metamorphism. However, in the circum-Pacific, about 10% of modern subduction zones are sub-horizontal. The Andean margin, for example, has several flat-slab segments, up to 500 km wide, that are each correlated with subduction of anomalously warm oceanic crust, represented by oceanic plateaux. Mesozoic–Cenozoic orogens, such as the Late Cretaceous–Eocene Laramide orogeny, have been ascribed to flat-slab subduction. These orogens are characterized by an absence of magmatism, widespread deformation, and thick-skinned tectonics up to 1000 km inboard of the plate margin, characteristics that are difficult to assess in ancient orogens. The origin of the flat-slab subduction is controversial, and several mechanisms may be responsible. In previous studies, we attributed the generation of the flat slab subduction associated with the Laramide orogeny to the overriding of an elongate swell and oceanic plateau associated with the ancestral Yellowstone hotspot. Reconstructions in a hot spot reference frame indicate that the Yellowstone hot spot was located beneath the oceanic Kula or Farallon plate until about 50 Ma. Evidence for the existence of the plume beneath the oceanic plate prior to this time is derived from 70–50 Ma accreted terranes such as the Crescent mafic complexes of western Canada. These terranes have geochemical and paleomagnetic data compatible with an origin as seamounts above the Yellowstone plume. Reconstructions indicate that the Crescent seamount was emplaced into oceanic crust that was 20–30 million years old and buoyancy flux calculations yield a value comparable to modern hotspots. Therefore a plume at the same paleolatitude as Yellowstone and with comparable or even greater vigour was responsible for generation of these seamounts. Such a plume would have generated a swell up to 2400 km in length and an oceanic plateau that would have been subducted as North America drifted westward in a hotspot reference frame.

Assuming the present distribution of hotspots and underlying plumes is representative of the past, then overriding of plumes and their buoyant swells at convergent margins should be common in the geologic record. This orogenic activity profoundly changes the geometry of subduction zones, and hence the style of orogenic activity, and may provide a unified interpretation for a number of individually enigmatic events associated with the Acadian orogeny in Atlantic Canada.

Alpine glaciation in Nova Scotia and Newfoundland: Who'd a thought?

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Alpine glacial features have long been known to exist in the highlands of Cape Breton Island and western Newfoundland; however, little is known of their age or mode of formation. A study of these features underway will attempt to address some of the issues noted below. In Gros Morne National Park, lateral moraines, rock glaciers, cirque tarns, and cirque moraines have been noted in guidebooks and regional maps. Preliminary investigations in 2001 indicated that these features are more complex than previously thought. In the Trout River Gorge an irregular bench previously mapped as a lateral moraine modified by rock glacierization may not be. The clasts at the level of the alleged moraine are angular, unstriated, and entirely or almost entirely of local lithologies; it is at least as plausible that all the debris lining the valley side is derived from rockfall on the higher slopes, reworked in places by rock glacierization. Lobate forms, most prominent below the Punchbowl cirque moraine and in the Penman's Brook drainage, have been described variously as rock glaciers and gelifluction lobes in guidebook articles. The features are probably fossil valley-wall rock glaciers possibly fed by snow/ debris avalanches more snow-rich in early Spring and more debris-

rich into the Summer. Depressions behind terminal ridges suggest that rock glacierization was not entirely due to interstitial ice. The Punchbowl Cirque moraine has generated much interest and has been variously suggested to be Little Ice Age (LIA), Neoglacial, or "?Late Wisconsinan" in age. Headwall weathering and thickness of colluvium suggest a pre-LIA age. A pre-LIA Neoglacial age is conceivable, but Neoglacial moraines apparently do not occur in isolation from LIA moraines in the closest alpine area in which such moraines have been mapped, the Torngat Mountains of Labrador. The moraine could be latest Pleistocene in age, but that interpretation conflicts with other interpretations that ice extended to the coast at about that time. This moraine is a good candidate for cosmogenic dating.

Cirques, tarns, and cirque moraines have been previously identified in the Codroy Valley, southwestern Newfoundland; however, their age is not well established. In the Cape Breton Highlands, Nova Scotia, cirques are also common and have been described as late Wisconsinan in age. The headwalls of these cirques have been deeply incised by stream erosion, unlike late Wisconsinan cirques in western mountain ranges, which may indicate that the cirques are older than previously thought. This study demonstrates that further work, including lake coring, is required to better understand these features and place them in context with existing models of regional glaciation.

Compositional variation in Fe-Ti-Nb-Ta oxides, South Mountain Batholith, Nova Scotia

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The South Mountain Batholith (~372 Ma) is a large, differentiated, peraluminous, granitic intrusion in southwestern Nova Scotia. Iron-titanium oxide minerals are rare in the batholith, but all polished thin sections prepared from thirty whole-rock samples covering the entire compositional range of the batholith contain oxide minerals. The two principal oxide minerals are: ilmenite-pyrophanite solid solution, occurring as prismatic, or blocky 0.05–0.90 mm grains in biotite, as well as larger, massive discrete grains along grain boundaries; and Nb-Ta rutile, occurring as massive, or blocky to acicular 0.03–0.70 mm grains in biotite. These textural relations suggest that the oxide minerals are primary magmatic. The ilmenite-pyrophanite solid solutions overall contain 3–23% MnO, with much of the compositional range occurring within single samples. The ilmenite cores have lower manganese contents (5–11% MnO) than the rims (7–14% MnO). The rutile grains consist of two types: (i) high Nb_2O_5 (up to 15 wt. %) with Nb_2O_5 / Ta_2O_5 ~ 4; and (ii) low Nb_2O_5 (less than 4 wt. %) with Nb_2O_5 / Ta_2O_5 << 4. The high Nb_2O_5 grains are mostly isolated grains, whereas the low Nb_2O_5 grains are more common as elongate grains parallel to cleavage in biotite. Normally, niobium and tantalum are incompatible elements with similar ionic radii, and charge (+5), which cause them to act together in the melt, but these two elements clearly fractionate strongly at the mineralogical level.

Biologically mediated reductive dissolution of Mn oxide in river-recharged aquifers: groundwater geochemistry results from laboratory investigations

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The City of Fredericton obtains all of its drinking water from the Fredericton Aquifer, a glacio-fluvial deposit located in the Saint John River Valley in the downtown area of the city. Pumping began from a single production well in 1955, and currently there are eight wells installed in the aquifer. Manganese (Mn) concentrations in some of the production wells have increased over the years to levels above the Canadian drinking water guideline, prompting the construction of a Mn treatment plant in 1989. The Saint John River and the Fredericton Aquifer are hydraulically connected and it is hypothesized that Mn oxides in the aquifer undergo reductive dissolution due to the influx of dissolved organic carbon (DOC) with infiltrating river water. The reductive dissolution of Mn oxides may also cause trace metals, commonly associated with oxides, to be released into the drinking water. This study focuses on the Mn-oxide reduction zone that may develop in aquifer systems that become anaerobic. Laboratory sand columns were constructed to provide an estimate of Mn reductive dissolution rates for Fredericton Aquifer sand, and to identify the geochemical processes that occur as a result of Mn-oxide reduction. The columns were filled with a mixture of silica sand and Mn oxide from the Fredericton Aquifer. One column was inoculated with microorganisms from Saint John River sediment, and a second control column was not inoculated. For a period of 250 days, a continuous flux of DOC-containing water (CH3COOH) was passed through the columns under anaerobic conditions. Results from the column experiments indicate that Mn(II) concentrations in the groundwater can be expected to increase (to a range of 3 to 4 mg/L) as a result of microbiologically mediated reactions involving DOC. Also, the data indicate that cation exchange reactions are an important control on Mn and other cation concentrations in the groundwater system. Based on the laboratory experiments, the influx of DOC with infiltrating water causes an initial increase in the aqueous Mn(II) concentration that results from the combined effects of reductive dissolution of Mn oxide and cation exchange reactions. This is followed by an asymptotic decline to a lower but still elevated Mn(II) concentration that is limited by the rate of the microbial Mn-oxide reduction reactions.

Metamorphism, microstructure, and 40Ar/39Ar thermochronology of the Humboldt Bay High Strain Zone, Wabigoon Subprovince, Lake Nipigon, Ontario

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The Humboldt Bay High Strain Zone (HBHSZ) is a shear zone in the Onaman-Tashota Belt, a granite-greenstone belt of the Wabigoon Subprovince of the Archean Superior Province. The HBHSZ represents a boundary within the Onaman-Tashota Belt, separating domains with different tectonic histories. In order to constrain the age of metamorphism and deformation on this boundary, an $^{40}Ar/^{39}Ar$ study utilizing step-heating techniques on 10 samples of hornblende from the HBHSZ is presented. Important relationships seen at both macroscopic and microscopic scales include (1) rocks of the shear zone have undergone polymetamorphism, (2) an earlier phase of actinolitic amphibole (greenschist facies) is replaced in areas by a later phase of hornblendic amphibole (amphibolite facies), (3) zones of high strain correlate with rocks with a larger amount of hornblende, and (4) zones of lower strain correlate with rocks with a larger amount of porphyroclastic actinolite, surrounded by significant amounts of hornblende. $^{40}Ar/^{39}Ar$ spectra from these porphyroclastic samples show disturbed spectra, with step ages ranging from 2600 – 2710 Ma. Samples showing the highest degree of strain yield flat spectra which plateau at an approximate age of 2680 Ma. This age is taken to represent the age of the last major deformation along the HBHSZ. The initial data suggest that this late deformation along the HBHSZ is syn-plutonic with respect to the adjacent North Wind pluton.

Delineation of hydrocarbon contaminant plumes in a shallow unconfined aquifer at a central Alberta compressor station

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The objective of this study was to delineate the full extent of hydrocarbon contaminant plumes and discuss possible migration in a shallow unconfined aquifer at a Central Alberta compressor station. Data sets were obtained through soil gas surveying, borehole drilling, subsequent monitoring well installation, groundwater sampling, recovery testing, and slug testing.

Soil surveying of volatile vapour diffusion, using a portable photoionization detector, revealed that contamination likely existed at this site. Direct delineation of the plumes was attempted using groundwater sampling and aquifer property testing.

Once monitoring wells were installed in the desired locations, groundwater samples were analyzed for dissolved, light and heavy end, hydrocarbons as well as other indicator parameters. It was determined that there was free phase light and heavy end and dissolved phase light and heavy end hydrocarbon contamination of the soil and shallow groundwater. Free phase contamination extended approximately 50 m off-site and dissolved phase contamination extended greater than 125 m off-site. Using groundwater chemistry data and aquifer property test results, the contamination was divided into three separate free phase plumes and one dissolved phase plume. Using historical site data, groundwater chemistry data, and the physical locations of the plumes several probable sources of contamination were identified, including an on-site underground storage tank, an on-site dehydrator, an on-site compressor, and an off-site buried pipeline. Alternatively, however more unlikely, a lens could be channelling free phase and dissolved phase contamination, which would exclude the off-site buried pipeline as a source of contamination.

Data sets from two separate recovery and slug tests were used to estimate aquifer flow characteristics. Hydraulic conductivity and transmissivity of the unconfined aquifer was estimated using the slug and recovery test data. Estimates were indicative of a fractured sandstone aquifer. Using an estimate of porosity, a measured hydraulic gradient, and the estimate of hydraulic conductivity, linear groundwater velocity was calculated. The calculated velocity was determined to be moderate and representative of regional groundwater flow. Estimated and calculated aquifer flow characteristic data suggest that contaminant migration is in progress. Therefore, a remediation program should be implemented. To conclude that there are in fact four separate sources, and to fully enclose the dissolved phase plume, installation of additional monitoring wells may be required.

Physical processes controlling soil respiration: results from four sites in eastern Nova Scotia

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Soil respiration is a critical determinant of landscape carbon balance, and global atmospheric carbon concentrations. Variations in soil temperature and moisture patterns are important physical processes controlling soil respiration that need to be better understood. Relationships between soil respiration and physical controls are typically addressed using only surface flux data though other more intensive methods also exist that permit more rigorous interpretation of soil respiration processes. Here we use a combination of subsurface CO_2 concentrations, surface CO_2 fluxes, and detailed physical monitoring of the subsurface environment to examine physical controls on soil CO_2 production at four climate observatories in Nova Scotia. Results indicate that subsurface CO_2 production is more strongly correlated to the subsurface thermal environment than is surface CO_2 flux. Soil moisture was also found to have an important influence on subsurface CO_2 production, particularly as a control on soil profile gas diffusivity. Non-diffusive profile CO_2 transport appears to be

important at these sites, resulting in a de-coupling of summertime surface fluxes from subsurface processes and violating assumptions that surface CO_2 emissions are the result solely of diffusion. These results have implications for the study and modelling of soil respiration across a broad range of terrestrial environments.

The pressure and temperature conditions, and timing of glass formation in mantle-derived xenoliths from Baarley, West Eifel, Germany: the case for amphibole breakdown, lava infiltration, and mineral-melt reaction

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Mantle-derived xenoliths from Baarley in the Quaternary West Eifel volcanic field contain 6 distinct varieties of glass in veins, selvages, and pools. 1) Silica-undersaturated glass that forms jackets around, and veins within, the xenoliths. This glass is compositionally similar to groundmass glass in the host basanite. 2) Silica-undersaturated alkaline glass associated with amphibole in peridotites. This glass locally contains corroded primary spinel and phlogopite. 3) Silica-undersaturated glass in partly to completely broken down amphibole grains in clinopyroxenites. 4) Silica-undersaturated to silica-saturated, potassic glass in microlite-rich fringes around phlogopite grains in peridotite. 5) Silica-undersaturated potassic glass in glimmerite xenoliths. 6) Silica-rich glass around partly dissolved orthopyroxene crystals in peridotites.

Clinopyroxene - melt thermobarometry shows that Cr-diopside - type 2 glass pairs in harzburgite formed at 1.4 to 1.1 GPa and ~ 1250 °C whereas Cr-diopside - type 2 glass pairs in wehrlite formed at 0.9 to 0.7 GPa and 1120 – 1200 °C. This bimodal distribution in pressure and temperature suggests that harzburgite xenoliths may have been entrained at greater depth than wehrlite xenoliths.

Glass in the Baarley xenoliths has three different origins: infiltration of an early host melt different in composition from the erupted host basanite; partial melting of amphibole; reaction of either of these melts with xenolith minerals. The composition of type 1 glass suggests that jackets are accumulations of relatively evolved host magma. Mass balance modelling of the type 2 glass and its microlites indicates that it results from breakdown of disseminated amphibole and reaction of the melt with the surrounding xenolith minerals. Type 3 glass in clinopyroxenite xenoliths is the result of breakdown of amphibole at low pressure. Type 4 and 5 glass formed by reaction between phlogopite and type 2 melt or jacket melt. Type 6 glass associated with orthopyroxene is due to the incongruent dissolution of orthopyroxene by any of the above-mentioned melts.

Compositional gradients in xenolith olivine adjacent to type 2 glass pools and jacket glass can be modelled as Fe-Mg interdiffusion profiles that indicate melt - olivine contact times between 0.5 and 58 days. Together with the clinopyroxene - melt thermobarometry calculations these data suggest that the glass (melt) formed over a short time due to decompression melting of amphibole and infiltration of evolved host melt. None of the glass in these xenoliths can be directly related to metasomatism or any other process that occurred *in situ* in the mantle.

The Klinkit Formation: stratigraphy, geochemistry, and paleogeographic reconstruction of an arc system offshore from the Paleozoic Pacific margin of the North American craton

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The Canadian Cordillera is known to be a collage of oceanic and arc terranes that were accreted to the western margin of the North American craton during the Mesozoic. Upper Paleozoic magmatic sequences are an important part of these terranes. However, the understanding of the tectonomagmatic evolution of these terranes is limited, in part due to incomplete knowledge of the stratigraphy and geochemical composition of these sequences. An understanding of the geological and geochemical evolution of these sequences is essential for paleogeographic reconstruction, as well as for comparison and correlation of the various time-correlative magmatic suites in northern British Columbia and southern Yukon.

The Mississippian to Permian Klinkit Formation in northern British Columbia and southern Yukon, straddles several inboard terranes, both exotic and pericratonic, of the northern Canadian Cordillera. This well-preserved volcanic sequence provides a rare opportunity to document a pre-accretion volcanic system on the Paleozoic Pacific margin, prior to its destruction in the formation of the Cordillera.

The Klinkit Formation conformably overlies a prominent reef and debris-flow carbonate of Bashkirian age (Late Carboniferous-Pennsylvanian) and also deep-water sedimentary rocks. The Klinkit Formation is informally subdivided into: (1) the volcaniclastic unit, a >250 m thick dominantly volcanic pile with interbedded sediments, overlain by (2) the thin Bigfoot unit, a mixed volcanic and sedimentary sequence which contains upward increasing sandstone and dark argillite. These sequences are megaturbidites typical of a subaqueous, below-wave-base depositional setting. The Klinkit rocks are unconformably overlain by the Triassic Teh succession composed of clastic sediments of continental affinity.

The Klinkit volcanic rocks are calc-alkaline with characteristics of a mature island-arc suite including (La/Yb)n ~ 2.8– 4.7, negative Nb and Ti anomalies on the mantle-normalized trace element plots and positive åNd values. The Klinkit Formation is interpreted as the distal facies of an arc system.

The Klinkit Formation is similar in composition and age to several Paleozoic arc successions of the exotic Quesnel terrane (e.g., the Lay Range Assemblage of the Harper Ranch Subterrane, northern central British Columbia; Boswell-Semenoff Hills, central Yukon), and of the pericratonic Yukon-Tanana terrane (Little Salmon succession, central Yukon).

The volcanic suites in the present assemblage of distinct pericratonic and exotic terranes in the northern Canadian Cordillera could provide the magmatic link to indicate that a large Paleozoic arc system was structurally dismembered prior to its emplacement on the western margin of the North American craton.

Sangamonian interglacial sea-levels of + 20 m in Maritime Canada

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A well-defined wave-cut rock platform overlain by organic paleosols and several tills implies that relative sea-level (RSL) in eastern Canada during the last interglacial was between 4 and 6 m above mean sea-level (MSL). But was it much higher? Sections exposed during a severe winter storm on the southwest coast of Cape Breton show the lower platform, overlain by openwork gravel, two distinct peat layers, then a well-sorted, parallel-laminated sand to +12 m, and finally two till units. The peat layers, contain large logs and can be traced laterally for 500 m, dipping seaward below the high water mark. The interglacial sand unit can be traced along much of the northern coast of mainland Nova Scotia and attains an elevation of +20 m. Optically-stimulated luminescence (OSL) dating of the Cape George Sand, gave an age of 115 ± 10 ka. The lateral extent, sorting, age, and sedimentology of the sand imply a marine origin, and the overlying till contains a reworked interglacial molluscan fauna including *Mercenaria* and *Ostrea*.

Correlative sections at Castle Bay along the Bras D'Or Lakes in Cape Breton reveal an organic silt unit with marine diatom floras underlying till at an elevation of >18 m. A stratigraphy identical to the Nova Scotia sections is found in Quebec, with interglacial peat, well-sorted sand deposits containing *Ostrea virginica* and an erosional rock platform at elevations of +13 to +20 m. At Salmon River in southern Nova Scotia, a massive sand unit containing an interglacial marine molluscan fauna indicates a paleo-sea level between +16 and +31 m. The anomalous elevations of pre-Late Wisconsinan marine sections were variously explained by Mid-Wisconsinan glacio-isostatic subsidence, neotectonics, salt tectonics, and glaciotectonics.

Each of these local explanations has serious flaws, so the logical synthesis is that interglacial sea-levels were much higher than previously thought. Pollen studies suggest that the highest RSL occurred during a cooler climate interval after the thermal maximum (~125 ka;), verified by the single OSL date on the Cape George sand and amino acid racemization (AAR) and electron spin resonance (ESR) dating of shell faunas. The stratigraphic record also suggests an RSL oscillation with an early rise to ~4 m (rock bench), RSL fall (peat layer), and then subsequent RSL rise (Cape George-Salmon River sands) to ~20 m. This RSL record suggests the combined effects of climate change and slower forebulge collapse following the Illinoian glaciation although such a magnitude of forebulge subsidence is not predicted by current models.

Deposits of earthenware clay in southwest Cape Breton: origin and economic potential

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There are abundant surface clay deposits in the lowlands of southwest Cape Breton with potential for use as low temperature ceramic products. Ice-dammed lakes formed at the end of the last glaciation when a large glacier in the Gulf of St. Lawrence dammed up meltwater sourced in highlands that rim the Gulf. Coastal plain basins were filled with fine-grained, turbid sediment from eroding till deposits washed in by slope runoff and glacier melt in the highlands. Some of the glaciolacustrine facies found in these basins are unusually fine-grained and massive. They lack graded beds and coarse silt and sand strata that often characterize glacial lake sediments (varves) and have a low percentage of dropstones. The implication is that active glaciers were not directly calving into these bodies of water, but dammed the basin outlets at lower elevations. The age of the youngest of these ice-dammed lakes has been bracketed by an organic paleosol underlying lake clay at several localities dated around 11,200–10,800 ^{14}C yrs B.P. and regional basal lake sediment accumulation ages of around 10,000 yrs B.P. The last of these ephemeral ice-dammed lakes formed when a glacier in the Gulf of St. Lawrence re-advanced during the Younger Dryas period (11–10 ka), a brief but intense cold period at the end of the last glaciation.

These clay deposits are widespread, fine-grained, and homogenous. Utilization of clay as a resource material for ceramics and structural clays depends on a range of properties unique for each industry. A common denominator for all industrial clay uses is a large-volume source of moderately uniform clay that has a low shrinkage/swelling percentage, consistent firing colour, relatively low firing temperature, and good strength after firing. The initial firing tests show that clays are of the earthenware type, and meet the requirements of many low temperature ceramic products. They have excellent plasticity and good strength after firing. It appears from the initial testing, that the Cape Breton deposits are very similar to the glaciolacustrine Lantz clay of central Nova Scotia, which is currently mined for structural (brick-tile) and pottery use. More testing will be required to fully evaluate

these clays, and a joint program to evaluate Cape Breton clays is being initiated with the Nova Scotia College of Art and Design. The project is funded through the Targeted Geoscience Initiative (TGI), aimed at stimulating resource development in Cape Breton by improving the geoscience knowledge base relating to both the Carboniferous bedrock and the overlying Mesozoic and Cenozoic sediments in the area.

The Harvey-Hopewell Fault, New Brunswick

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The Harvey-Hopewell Fault of southeastern New Brunswick is a major break that has an on-land northeasterly strike-length of 90 kilometres. Previous workers traced the fault southwest of the Petitcodiac River where it is seen to juxtapose the northwestern side of the Carboniferous Cumberland Subbasin against the mainly Proterozoic Caledonia Uplift. Published documents have described only the late Carboniferous movement on the fault as either northwest-directed thrusting or sinistral transcurrence. Recent studies have succeeded in following the continuation of the fault to the northeast from the Petitcodiac River to Port Elgin, where it marks the northwestern margin of the Carboniferous Sackville Subbasin with the older crystalline rocks of the Westmorland Uplift.

In the Early Carboniferous, during Windsor Group and Mabou Group time, the Harvey-Hopewell Fault acted as a down-to-the-southeast extensional or growth fault accommodating the deposition of about 2 kilometres of Windsor-Mabou section in the Cumberland and Sackville subbasins. Late Carboniferous (post-Boss Point Formation) inversion of the Cumberland and Sackville subbasins was accomplished by northwest-directed reverse displacement on the Harvey-Hopewell Fault. Comparison of clast compositions in Mabou Group conglomerates with adjacent crystalline rocks in the Caledonia Uplift source area suggests little transcurrent offset on the fault. The parallel and subsidiary Dennis Beach Fault shows Mesozoic extension implying that the Harvey-Hopewell system was reactivated during the break-up of Pangea.

Stratigraphy and structure of the Horton Group in the Lochaber-Mulgrave area, Nova Scotia

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During the summer of 2001, extensive mapping was done in the Lochaber-Mulgrave area of northern mainland Nova Scotia as part of an on-going study of stratigraphy and structure in this complex area, bounded by the Glenroy Fault on the north, the Strait of Canso on the east, the Roman Valley Fault on the south, and pre-Carboniferous rocks of the Antigonish Highlands on the west. Sedimentary rocks in the area are now assigned to the Early Devonian Knoydart Formation, Early Carboniferous Horton and Windsor groups, and Late Carboniferous Mabou Group. The Horton Group underlies most of the map area, and has been divided into four formations (from oldest to youngest): (i) Clam Harbour River Formation (Englands Lake and Goose Harbour Lake members), (ii) Tracadie Road Formation (Halfmoon Lake and Lincolnville members), (iii) Caledonia Mills Formation, and (iv) Steep Creek Formation. The fluviatile Englands Lake Member consists of fine- to coarse-grained sandstone and polymictic conglomerate, and maroon to green-grey siltstone. The overlying, lacustrine-deposited Goose Harbour Lake Member consists of poorly- to well-laminated green-grey siltstone and shale with interbedded dolomite. The fluviatile Halfmoon Lake Member consists of polymictic conglomerate, pebble sandstone, and quartz arenite with minor interlayered dark grey siltstone. The overlying, lacustrine-deposited Lincolnville Member consists of dark grey laminated siltstone and shale interlayered with minor quartz arenite. Rare *Lepidodendropsis* plant fossils of Tournaisian age are found in the fine-grained sandstone and shale beds. The overlying Caledonia Mills Formation consists of red to light grey, massive to well-laminated siltstone and sandstone and is interpreted to have been deposited in an arid fluvial environment. The Steep Creek Formation unconformably overlies the Goose Harbour Lake and Lincolnville members and consists of polymictic conglomerate, fine-grained to pebble sandstone, and maroon to dark grey siltstone. All of these units are lithologically similar to those assigned to the Horton Group in the St. Marys Basin. The sedimentary provenance may be confirmed through $^{40}Ar/^{39}Ar$ dating of detrital muscovite grains in the Horton Group sedimentary units.

In comparison to the Horton Group in other areas, the rocks in the Lochaber-Mulgrave area are highly deformed. In addition, most of the area has undergone low-grade regional metamorphism, and cleavage is well developed as a result of accompanying deformation. The western part of the region has open to tight, upright to overturned, northeast-trending folds with well-developed axial planar cleavage. The eastern part has tight to close, upright, north-south-trending folds with moderately developed axial planar cleavage. Folded axial plane traces and scattered cleavage orientations indicate the region has undergone polyphase deformation. The structural complexity in the Lochaber-Mulgrave area may be related to interaction between the Avalon and Meguma terranes during their juxtaposition along the Cobequid-Chedabucto fault system.

An assessment of landslide potential in Cape Breton Highlands National Park: a GIS approach

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Landslides are common in Nova Scotia, particularly within the highly incised river valleys of the Cape Breton Highlands (CBH) and occur as complex slides, slumps, debris flows, and skinflows. These landslides have resulted in the modification of habitat and may pose considerable risk as both industrial and recreational use of this region intensifies. Research in the CBH focuses on a) investigating the morphology of these slides and the temporal and spatial constraints on their formation and b) constructing a GIS to assess the risk potential of other sites within the CBH.

Thin-skinned landslides most commonly occur on south-facing slopes that exceed 34° at the interface between bedrock and the overlying colluvium. These landslides are complex events, which begin as thin translational slides that evolve quickly into debris flows. Failure has previously been attributed to the presence of steep slopes in incised valleys where colluvium directly overlies bedrock. We note that specific hydrological and stratigraphic conditions may be instrumental in the initiation of slope failure. In our investigations, highly compacted, impermeable clay-rich lodgement till was exposed on the slide scar and continues to act as both a barrier to surface water drainage and a conduit for groundwater flow. The colluvium/till boundary is the primary glide plane during initial failure. The activation zone was bounded by bedrock exhibiting low primary porosity in which occasional fracture associated seeps and springs were noted. We surmise that redirected surface and ground water accumulated at the colluvium/till interface within the activation zone producing an effective glide plane for initial translational movement.

Preliminary results from image analysis indicate that areas of both abnormally stressed vegetation and exposed bedrock are associated with known landslide sites. Site observations, vector and raster datasets, including Landsat TM and Radarsat satellite imagery, and aerial photographs of the region will be integrated to produce a landslide risk assessment Geographic Information System (GIS) database for the region. This GIS database will enable more specific and detailed analysis and advanced statistical modelling of landslides for the purpose of creating a landslide hazard prediction model that will be applied to other sites in eastern Canada to help influence present and future land-use applications.

The comparison of LIDAR and traditional elevation data for watershed modelling

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Digital Elevation Models (DEM) are becoming a standard dataset used in many geological applications in recent times. The use of DEMs in environmental geology in the areas of watershed modelling and geomorphology are the focus of the research discussed here. Watersheds are important physical regions that define the catchment of all water flowing into a stream outlet. The watershed or catchment area can be used to assess variations of sediment concentrations, water quality, and water quantity of a stream. Watershed modelling, among other things, involves the use of a DEM to automatically define watershed boundaries, flow direction, and flow accumulation. High resolution DEMs are able to replace stereo airphoto interpretation in some geomorphological investigations. Traditional elevation data derived from photogrammetry are available for the Province of Nova Scotia at a horizontal spacing of 70 m with a vertical accuracy of ± 2.5 m. These data have been used to construct DEMs with a 20 m grid spacing and have been used to automatically build watershed boundaries. A new technology, Light Detection and Ranging (LIDAR), has been acquired in the central Annapolis Valley region with a horizontal spacing of 2–3 m and a vertical accuracy of 15 cm. The LIDAR data has been gridded to a DEM with a 2 m grid spacing using a variety of techniques. Image data ranging from airborne spectral, to satellite optical and radar data are also available for the study area and will be used to derive other modelling parameters related to surface run-off such as land cover, land use, and leaf area index. Other parameters such as geology and soil properties will be incorporated into the GIS database. An example application to compare this new technology to traditional data is planned that will include a variety of topographical index measurements as well as watershed modelling of rainfall run-off events and water quality prediction.

Preliminary bedrock geology of the Tusket (20P/13) map sheet, southwestern Nova Scotia

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Geological bedrock mapping (1:10 000 scale) related to the Southwest Nova Scotia Mapping Project continued through the summer of 2001 on the Tusket map sheet (20P/13), in southwestern Nova Scotia. The oldest stratified units in the map area are the

Cambrian to Early Ordovician Goldenville and overlying Halifax formations of the Meguma Group. The Goldenville Formation occurs in the western part of the map area and consists of grey, thick-bedded, featureless metasandstone that locally contains numerous "vugs" of weathered-out calc-silicate nodules. Black sulphide-rich spotted slate is locally interlayered with the metasandstone. The Halifax Formation consists of grey spotted slate, although textural and lithological features vary depending on metamorphic conditions. As metamorphic grade increases, the Halifax Formation is characterized by the development of porphyroblastic staurolite and andalusite granofels and schist. Around the western and northern margins of the Barrington Passage Pluton the Halifax Formation consists of garnet-sillimanite granofels and schist, whereas on the eastern side the formation is migmatitic in character. The contact with the Goldenville Formation is not exposed.

The latest Ordovician to Early Silurian White Rock Formation outcrops in the northwestern margin of the map area. Here it is composed mainly of amphibolite interlayered with staurolite-biotite schist and quartzite. It is separated from the Meguma Group by the Cheboque Point shear zone.

The ca. 375 Ma Barrington Passage Pluton intrudes rocks of the Meguma Group in the eastern part of the map area and consists of medium-grained, locally well-foliated biotite tonalite gradational to quartz diorite. Dykes of pegmatite and biotite-muscovite granite are common. The northern margin of the pluton has an irregular outline due to the abundance of garnet-sillimanite granofels and schist xenoliths. This area probably represents the roof of the pluton whereas the migmatitic rocks on the east presumably represent deeper depths.

Units in the Meguma Group have been folded into regional, north-trending F1 folds in the southern part of the map area and northeast-trending F1 folds in the north, with an axial planar cleavage during the Devonian Acadian orogeny. Deformation was accompanied by greenschist- to amphibolite-facies metamorphism that resulted in an eastward increase in metamorphic grade from biotite zone in the west to garnet-sillimanite assemblages in the east. The presence of a locally prominent steep to moderately north- and northeast-plunging mineral lineation defined by elongate andalusite and sillimanite in the granofels and quartz rods in the tonalite suggests that the pluton in this area may be syntectonic with respect to regional deformation and metamorphism.

The Late Carboniferous Wedgeport Pluton intrudes metasandstone of the Goldenville Formation in the southern part of the map area. It consists of a medium-grained, biotite-bearing monzogranite. Olivine-bearing diabase and lamprophyric dykes are rare, but intrude both the Wedgeport Pluton and adjacent Goldenville Formation.

Structural geology and tectonics of the Albert Mines-Taylor Village area, Moncton subbasin, southeast New Brunswick

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Current onshore petroleum exploration in southeast New Brunswick is focussing on an area straddling the Petitcodiac River around Albert Mines in the west and Taylor Village in the east. This area is structurally very complex and has been affected by a number of fault sets with long histories of movement and reactivation. A knowledge of timing of initiation, timing of reactivation and sense of the various phases of movement is clearly critical for local exploration efforts. This study is intended to provide better constraints on the structural and tectonic evolution of this area through detailed structural analysis of well-exposed localities and interpretation of previously available maps, core logs, and seismic reflection profiles. The study mainly concentrates on rocks of the Albert and Weldon formations of the Tournaisian-age Horton Group.

Recent interpretations of the tectonic evolution of the Moncton subbasin have emphasized the role of dextral transtension on northeast-trending fault zones followed by dextral transpression and basin inversion. However, detailed field observations and study of published geological maps of the area reveals that some northeast-trending faults exhibit sinistral movement, especially in the southern part of the study area. In the south of the area Windsor Group (Viséan) rocks show net sinistral displacements, while in the north they show net dextral displacements. Faults associated with the Boudreau fault zone near Boudreau Village show asymmetric folds, steps on slickensided surfaces, and drag folds indicative of sinistral movement. Conglomerates of the Hopewell Cape Formation (Mabou Group, Namurian) at Dennis Beach contain asymmetric clasts and drag folds indicating sinistral movement on the Dennis Beach fault, suggesting that sinistral movement in southeast New Brunswick may be post-Namurian in age. Northeast-trending faults are cut by a set of east-trending normal faults.

Thus a tectonic model for the study area is proposed where dextral movement on northeast-trending faults continues until after Windsor Group deposition. Northeast-trending faults in the south of the area are then reactivated as sinistral-transpressional structures, probably in post-Mabou times. Northeast-trending structures are then cut by east-trending normal faults which may be related to Mesozoic rifting and formation of the Atlantic Ocean. Local petroleum exploration should take into account the possibility of sinistral offsets of source and reservoir rocks, especially in the southern part of the study area.

A novel 3D seismic survey, Shoal Point, Newfoundland: new data, new interpretation

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The Port-au-Port Peninsula in western Newfoundland has been a recent focus for petroleum exploration. The exploration effort has targeted the Lower Palaeozoic carbonate succession of the St. George's Group both on the peninsula and in the immediate offshore. The drilling targets have been mostly related to structures in the thrust slices of the carbonate platform, and especially in the complex triangle zone. The most recent exploration well, K-39 (PanCanadian and partners), drilled on Shoal Point tested a structure under Shoal Bay. The well was guided by limited seismic data as acquisition was difficult in the shallow water immediately surrounding the Point. This paper describes a research project to develop 3D acquisition methods suitable for the transition zone in the area. The interpretation of these data gives rise to a new understanding of the structural detail and tectonic evolution of the region. This new interpretation assists in explaining the negative result of the K-39 well and identifies a structure that is worthy of further investigation.

The acquisition of exploration seismic data in the transition zone is a difficult challenge. Conventional marine seismic methods using large vessels and many streamers are not logistically feasible. Similarly, land methods using vibrators or explosives cannot be employed in the marine setting. Compounding this challenge is the fact that the shoreline is often a zone of geological complexity that requires 3D seismic coverage for proper exploration. Furthermore, the shallow, near-shore environment is the most environmentally sensitive region and any approach to data acquisition must be designed for minimal environmental impact. The survey at Shoal Point met these challenges and produced an excellent 3D seismic image that agrees with industry 2D seismic data in the bay, but provides extended coverage.

The processing of the 3D data did not follow a conventional processing strategy as most of the traces were for large source-receiver offsets, making conventional normal moveout correction (NMO) and velocity analysis impossible. Nonetheless, a binning strategy was developed that employed 25 m by 50 m bins, led to a mean fold of over 20, and produced good 3D images of the subsurface.

The interpretation of these data has shown that the K-39 well was probably drilled below the target structure. The interpretation has led to a greatly increased knowledge of the detail of the geology in the immediate Shoal Point area and to a better understanding of the tectonic evolution of both the Cambro-Ordovician platform and the allochthons of western Newfoundland.

The petrology of the Lake George granodiorite stock, New Brunswick: implications for crystallization conditions, volatile exsolution, and W-Mo-Au-Sb mineralization

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The Lake George Sb vein deposit is spatially and temporally associated with W-Mo-Au mineralization that is genetically related to a Middle Devonian granodiorite stock at depth. The fine- to medium-grained porphyritic granodiorite consists of quartz, plagioclase, orthoclase, biotite, and trace hornblende with minor titanite, zircon, apatite, ilmenite, magnetite, and pyrite. Detailed mineral compositions (EMPA) are employed to evaluate P, T, and fugacity conditions for magmatic-hydrothermal activity related to the granodiorite, based on various geothermobarometric calibrations.

Normally zoned plagioclase phenocrysts are oligoclase on average (An_{58} to An_{20}), which is typically higher than those in the groundmass. K-feldspar phenocrysts and those in the groundmass have similar compositions (orthoclase; $Or_{93}Ab_{6.7}An_{1.9}$). Two-feldspar geothermometry yields temperatures lower than 500˚C, reflecting subsolidus recrystallisation. Early hornblende phenocrysts were followed by simultaneous crystallization of biotite and plagioclase, subsequently by quartz and orthoclase. Biotite has relatively consistent high Ti and Al contents, and average Fe/(Fe+Mg) ratios of 0.54 ± 0.10. However, calculated halogen fugacity ratios of log(fHF/fHCl) in equilibrating magmatic volatiles have a large range from -2 to 0 units at 400˚C, corresponding to a significant variation of log(XF/XCl) ratios in biotite, revealing that the halogens in biotite re-equilibrated with various Cl-rich magmatic fluids. Those fluids emanated from the granodiorite as it cooled at depth. Low calculated $Fe^{3+}/(Fe^{2+}Fe^{3+})$ ratios in both amphibole (ave. 0.07) and biotite (ave. 0.06), the presence of ilmenite as predominant Fe-Ti oxide, and low magnetic susceptibility (ave. 6 x 10-5 SI), indicate reducing conditions of the magma, as well as associated magmatic fluids.

The calcic hornblende in the granodiorite has Σ(Ca+Na) in M4 ≥ 1.0 with Na < 0.5, Si/(Si+Al+Ti) > 0.775, average Fe/(Fe+Mg) of 0.53 ± 0.06, and moderate Al2O3 (<10 wt.%) and TiO2 (<2 wt.%) contents. Al-in-amphibole geobarometry yields crystallization pressures ranging from 3 to 5 kb; this is obviously higher than that of the final emplacement depth of the stock (<2 kb), based qualitatively on texture and Ab-Or-Q-H2O phase equilibria. This pressure discrepancy is interpreted as early amphibole crystallization prior to the final emplacement of the stock, implying the magma became water-saturated during ascent. According to amphibole-plagioclase geothermometry, temperatures calculated for co-genetic amphibole and plagioclase of five granodiorite sam-

ples indicate they crystallized between 729 – 772°C, which is near the wet granodiorite solidus (3 to 5 kb). However, the calculated apatite saturation temperatures (848 – 911°C), based on P content, infers much higher original supersolidus temperatures.

Fission track thermogeochronology in the lands surrounding the Nares Strait, Canadian Arctic Archipelago and Greenland: a field report

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The timing of uplift and exhumation of the lands bordering the Nares Strait are being studied using the apatite fission track (AFT) dating technique. Under certain conditions AFT allows one to date the last time rocks cooled through a temperature of ca. 100°C, equivalent to exhumation from a depth of ca. 3–4 km in the crust. The analysis of confined fission track lengths in the dated apatite crystals allows modelling of time-temperature histories between temperatures of 125 and 70°C (overlapping with the *oil window*) for rocks now at the surface. The sampling strategy, in suitable rocks on both sides of Baffin Bay, Kane Basin, and Nares Strait, was intended to allow us to address specific questions concerning the uplift/exhumation related to extension and rifting in Baffin Bay-Labrador Sea, compressional tectonics of the Eurekan Orogeny, and to better understand the tectonic and thermal history of Tertiary clastic sediments in the region, with implications for petroleum exploration. During August and September 2001, ca. 80 samples were collected with the help of helicopters based on the Coast Guard icebreaker Louis S. St. Laurent, funded mainly by the Geological Surveys of Germany (BGR) and Canada (GSC) as a component of the project entitled Nares Strait Geo-Cruise 2001.

On the basis of the appearance of carbonaceous matter in many of the Tertiary clastic units in Ellesmere Island, and reports of the presence of sub-bituminous and high-volatile bituminous coal in the Judge Daly and Bache Peninsula, we expect to find that fission track data will indicate that some clastic units have been heated to temperatures within the oil window. The permeable Tertiary clastic units would make excellent reservoirs. Coaly and organic rich strata are potentially good source rocks for hydrocarbons. It is possible that significant hydrocarbons (mainly gas) may have accumulated within these Cenozoic units if they have been buried by thrust stacking, in particular because many of the thrust faults are rooted in impervious evaporites. Depending on our expected results, and based on our previous AFT work in Ellesmere Island, we may recommend that future hydrocarbon exploration in northeastern Ellesmere Island should focus on sub-thrust plays to test potential structural traps at depth.