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ABSTRACTS

2004 Colloquium & Annual General Meeting

MONCTON, NEW BRUNSWICK

The 2004 Colloquium & Annual General Meeting was held at the Delta Beausejour Hotel, Moncton, New Brunswick, on January 30 and 31, 2004. On behalf of the society, we thank Colloquium Chairperson Susan Johnson and her organizing committee (Alan Anderson, Cameron Bartsch, Robin Black, Lori Cook, Russell Hiebert, Ken Howells, Dave Keighley, Maurice Mazerolle, Tansy O'Connor-Parsons, Michael Parkhill, Brian Roulston, Erin Smith, Ian Spooner, Peter Wallace, and Reg Wilson) for providing an excellent meeting. We also wish to acknowledge support of the corporate sponsors: PCS-Potash, New Brunswick Division; McGregor GeoScience Limited; Mineralogical Association of Canada; Corridor Resources Inc.; and the Dean of Science, St. Francis Xavier University.

In the following pages, we are pleased to publish the abstracts of oral presentations and posters from the Colloquium, which included The First J. Ewart Blanchard Special Session on Geophysics; sessions on Environmental Geology, Hydrocarbon Geology, and Current Research in the Atlantic Provinces; an Ion Microprobe Workshop; and a tour of the PCS Potash Mine.

THE EDITORS

Contrasting behaviour of acid-generating rock of the Meguma Supergroup in fresh and salt water

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Acid rock drainage is a well-known problem associated with the Meguma Supergroup in the Halifax region of Nova Scotia, Canada. Finding the ideal site for waste rock disposal is not always easy, and it has been proposed that dumping waste acid generating materials into salt water of the Bedford Basin is a possible solution. This study focuses on the survival and geomicrobiological interactions of *Acidithiobacillus ferrooxidans*, and the behaviour of the Halifax slates and the Goldenville-Halifax transition zone (GHT) in fresh and saline waters. Samples collected from both the Halifax slates and GHT were crushed and divided into <0.5 mm, 1 mm, and 4.75 mm size fractions. Five grams of each size fraction from the Halifax slates, and 5 grams of each size sample from the GHT, were covered by 50 ml of fresh water. An additional set of samples of both Halifax slates and the GHT were covered by 50 ml salt water from the Bedford Basin.

Data collected over a period of 5 weeks indicate that for all size fractions, and for both the fresh and salt water samples, an initial dramatic drop of pH is followed by a levelling off in pH, producing an exponential curve of pH vs. time. This trend is evident for the Halifax slates with an initial average fresh water pH of 5.6 (range 5.3–6.1), and an average final pH of 3.2 (range 3.1–3.5). The salt water samples of Halifax slates have an average initial pH of 6.71 (range 6.3–7.0), and an average final pH of 4.03 (range 3.6–5.5). The trend of the GHT data is similar; however, the salt water pH drop is not as dramatic as the drop in pH of the fresh water. The average initial pH of GHT fresh water samples is 7.1 (range 6.9–7.4), and an average final pH of 4.7 (range 3.8–5.5). The GHT salt water average initial pH is 7.23 (range 7.1–7.4), and the average final pH is 6.31 (range 5.4–7.0). Implications from this study show that although the pH change is somewhat less in salt water, the drop is not insignificant, and indicates the continuing oxidization of sulphide minerals. Care should be taken when disposing of waste acid rock in any aquatic environment.

Petrological studies of mafic pegmatites in the Jurassic North Mountain Basalt, Nova Scotia: a record of extreme fractionation in the late-stage evolution of continental tholeiite

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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%). The LFU is $190 m thick and massive in nature with well-developed colonnade and entablature fracture patterns. However, two exceptions are noted, namely the presence of a thin ($1–3 m) amygdaloidal zone delineating the upper contact with the overlying MFU and rare, locally developed pegmatite sheets in the upper part of the flow. This study focuses on two pegmatite localities, namely Mount Pleasant and Beamans Mountain that outcrop near Digby. These areas were previously exploited for aggregate, the resultant excavations having provided exceptional exposure of the pegmatite sheets. The two areas were examined in detail and mapped onto digitally generated photos with subsequent sampling for petrography, and mineral and whole- rock geochemistry. We note the following textural and mineralogical features of the pegmatites, which are appropriately named given the presence of abundant, coarse (i.e., $10–15 cm) pyroxene crystals: (1) the contacts are welded with the host basalt and chilling is apparent; (2) the sheets are $3 m thick, but cm-scale lenses occur, and bifurcation is common; (3) internal zonation occurs, as defined by textural variation and different proportions of pyroxene, plagioclase, and an aphanitic beige matrix; locally, pyroxenite occurs; (4) skeletal pyroxene is a prominent feature, often with comb and radial textures; (5) thin ($1–2 cm), flat veins/dykes of aphanitic, beige felsite (i.e., granophyre in thin section) cut the pegmatites and locally they are miarolitic and globules of red-brown (rhyolitic?) glass; (6) the pegmatites are dominated by coarse, normally zoned pyroxene that show prominent Fe enrichment with Fe/(Fe+Mg) to 0.8 and plagioclase (An_{40-70}) that may contain 0.5–1% wt. % FeO. Late phosphorus enrichment is manifested by abundant apatite euhedral in the granophyre and felsic glass.

Our observations indicate the pegmatites represent filling of flat to undulating dilatant zones within crystallized basalt by a mobilized, possibly filter-pressed, evolved melt generated via fractionation from a precursor basaltic magma. The heterogenetic nature of the pegmatite, locally Fe-rich pyroxenite, and presence of globules of rhyolite suggest that liquid immiscibility, documented elsewhere in the NMB, in addition to fractional crystallization, may have occurred within the basaltic magma.

Sensitivity of intertidal and shallow marine environments to climate change: a case study at the Morton Environmental Centre, Heckmans Island, Nova Scotia

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The Morton Environmental Centre, Heckmans Island, is a 40 ha field research station located near Lunenburg, Nova Scotia, that has 1.6 kilometres of coastline that can be characterized as a shallow marine environment. The effects of climate variability, in particular ocean water temperature fluctuations, rising sea levels, and the impacts of increased storminess (all proposed future climate scenarios) are not well known for shallow marine environments. This study evaluates the sensitivity of the shallow marine environment at the Morton Centre to various climate scenarios.

Physical characteristics of the nearshore marine environment were surveyed to determine: relative temperature, current activity, bathymetry, bottom substrate flora and sedimentology. The intertidal zone was characterized using longitudinal surveys to determine slope, percolation, and sediment type. Preliminary results of this survey indicate much variability in substrate composition and biological communities, that together influence sediment cohesion and susceptibility to movement. The complex nature of sediment distribution may be influenced by storm activity and seiche length, but is also influenced by tidal currents which were found to be quite strong at select sites. The intertidal zone is also variable with zones of intense erosion and deposition located in close proximity.

Future climate change scenarios predict increased and anomalous storm activity and rising sea level which, given survey results, could dramatically alter intertidal and nearshore morphology, sediment distribution and type in both of these zones. This in turn is projected to have a significant impact on ecology in this environment. The sensitivity model developed in this study will be used to develop management strategies for the site and has the potential to be transportable to other similar environments.

Learning from our legacy: high soil lead levels in St. John's, Newfoundland

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A pilot study to investigate the metal content of urban soils in St. John's, Newfoundland, was carried out in the summer of 2003. The study was prompted by results of a geochemical analysis of sediments in urban lakes in St. John's that indicated historically high levels of lead and other toxic metals. Although lead levels in the sediments had declined over the last several decades, primarily due to the removal of lead from gasoline, the possibility that urban soils had accumulated a reservoir of toxic metals remained untested. Our results are preliminary, and further sampling and analyses are required to adequately delineate patterns and sources; however, interim results provide some preliminary indication of the controls on soil lead in St. John's. The results from 260 samples range between 17 and 7048 ppm, with a median value of 203 ppm. Background levels were measured between 18 and 43 ppm, with a mean of 26 ppm.

A total of 140 samples or 60% exceed the guideline of 140 ppm for soil-lead recommended by the Canadian Council of Ministers of the Environment (CCME). The urban land use most clearly affected by high soil lead is residential property, mostly yards and gardens associated with older houses (median value was 744 ppm and 89% of samples exceeded the CCME guideline), although open spaces and school property also had elevated levels (median values of 248 and 123 ppm, respectively). Lead-based paint and coal-ash residue likely are major sources in residential settings, whereas leaded gasoline also may contribute to high values found close to major roads. Examination of the geographic distribution of soil lead clearly indicates a concentration around the urban core of St. John's. Sampling of older residential properties from outside the core, however, yields soil lead values as high, or higher than those in the core, suggesting that the main control on soil lead values is age of construction, rather than proximity to the downtown. Values exceeding CCME guidelines were commonly found for other elements also, including notably arsenic, barium, chromium, copper, and zinc.

St. John's is an old city, with a long history of coal burning and vehicular traffic and a tradition of painted clapboard houses. The legacy of these activities appears to be high soil lead levels (and other elements) which may have implications for human health. How many other communities in eastern Canada share a similar legacy?

New perspective for the post-Taconian Gaspé Belt of northern New Brunswick: hydrocarbon potential from new organic matter data

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In the course of the Appalachian Forelands and Platform NATMAP project, a regional investigation of organic matter maturation was conducted in northern New Brunswick in the areas covered by new provincial mapping. Prior to this study, little information was available on the thermal evolution of the post-Taconian successions.

The surface maturation data reveal, for the first time, a wide area in northernmost New Brunswick that lies well within the oil window, with a surrounding envelope within the condensate zone. This area is known as the Squaw Cap block. Fewer samples west of the Sellarsville Fault and east of the McKenzie Gulch Fault indicate that these latter areas are significantly more thermally mature (dry gas to sterile zone).

Maturity values increase down-section. Samples at the top of the sedimentary pile (Devonian Val d'Amour and Campbellton formations) can be locally immature (Ro less than 0.4%) and those near the base (Upper Ordovician Grog Brook Group) could locally reach the lower limit of the dry gas zone (Ro up to 4.9%). However, this simple scenario is locally complicated by local thermal events. In the Squaw Cap block, samples from the base of the succession (Upper Ordovician Boland Brook Formation) can still locally be in the oil window (Ro as low as 1.05%) whereas the overlying White Head Formation (Upper Ordovician to Lower Silurian) lies at the limit of the immature – oil window (Ro between 0.6 and 0.65%).

Detailed petrography of the samples has revealed that a significant number of the Upper Ordovician samples of the Boland Brook Formation in the Squaw Cap block are very rich in zooclasts and liptinite. From a purely descriptive framework, these samples could well be described as potential hydrocarbon source rocks. The Boland Brook Formation is known to extend to the west (the carbonaceous shale of the Ritchie Brook Member) and to the southern Gaspé (Garin Formation). Timewise, these Upper Ordovician units are coeval with the widespread black shales of the Macasty, Utica and Ruisseau Isabelle units that are all considered good hydrocarbon source rocks in the adjacent St. Lawrence Platform and Appalachians.

As part of the new TGI 2 project in New Brunswick, additional samples were collected in the autumn of 2003 in northern New Brunswick. Rock Eval analyses are in progress to precisely evaluate the potential for hydrocarbon source rock, and the study of potential reservoir units will be initiated next summer.

Dr. J. E. Blanchard, Director, Geophysics Division (1949 – 1966), Nova Scotia Research Foundation

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Dr. I.E. Blanchard joined the recently established Nova Scotia Research Foundation (NSRF) in 1949. He served as Director of the Geophysics Division until 1966 when he became Vice President of NSRF. As Director he was responsible for creating the Geophysics Division with expertise in various geophysical survey methods applicable to the needs of the mining and exploration industry in Nova Scotia.

His practical and theoretical investigations helped establish the limitations of the various techniques when applied to areas with heavy glacial drift cover. By proper choice of exploration method, including gravity, resistivity, and seismic surveys, significant new information was obtained on the presence of thick sedimentary basins, and salt structures which attracted the interest of mineral exploration groups outside the province. Eventually new industry resulted.

In conjunction with other Federal and Provincial agencies his group developed new knowledge of the crust underlying the Province, and the stress factors involved in the Springhill "bumps". When the need developed, he introduced in new equipment including the hammer seismograph, boomer and sparker continuous seismic profiling, and a slim hole gamma logging probe.

His numerous publications on applied geophysics, together with papers delivered at national and international conferences helped publicize the Province and its mineral potential. His expertise was recognized by his appointment to national and provincial geoscience advisory committees. He was a member of the Royal Society of Canada.

Pre-Mesozoic geology of Grand Manan Island, New Brunswick

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Recent bedrock mapping and geochronological studies have led to a better understanding of stratigraphic relationships among complexly faulted Paleozoic and older rocks on Grand Manan Island, New Brunswick, although correlation with terranes on the mainland remain problematic. During 2003, additional mapping and petrological studies as part of the M.Sc. thesis project of the first author, as well as new U-Pb (zircon) age determinations, have resulted in further clarification of relationships.

The Thoroughfare Formation, which consists of recrystallized black shale and grey siltstone interbedded with white, maroon, and orange quartzite, is faulted against mafic to felsic flows and tuff, maroon to green mudstone, and banded iron formation of the Ingalls Head Formation. A U-Pb age of 618 ± 3 Ma from rhyolitic tuff in the Ingalls Head Formation suggests that the unit may be related to the slightly younger (611 ± 3 Ma) Three Islands Granite that underlies small islands to the south of Grand Manan Island. The Three Islands Granite contains large blocks of marble (Kent Island Formation). The Kent Island and Thoroughfare formations are interpreted to be the oldest units exposed on Grand Manan Island, and to be overlain by the Ingalls Head Formation.

Intermediate to felsic volcanic rocks, siltstone, arkose, and pebble-cobble conglomerate of the Great Duck Island Formation are interpreted to be younger than the Ingalls Head Formation; a U-Pb age of ca. 547 Ma from a granitic unit in the Great Duck Island Formation provides a minimum age. The Great Duck Formation is in fault contact with the presumably overlying Flagg Cove Formation, which consists of black shale and dark grey siltstone interbedded with grey quartzite and minor conglomerate. The Stanley Brook Granite (U-Pb age ca. 535 Ma) intruded the Flagg Cove Formation, and similar granite intruded the Great Duck Island Formation on Long Island, providing a further age constraint on both units. The Great Duck Island Formation is in fault contact with the Priest Cove Formation, which consists of volcaniclastic rocks. Dacitic crystal tuff in the Priest Cove Formation yielded a U-Pb age of 539 ± 4.9 Ma, contradicting a younger age previously suggested on the basis of a poorly documented fossil occurrence. The Priest Cove Formation is interpreted to be a lateral facies equivalent of volcanic flows and breccias of the Ross Island Formation as exposed on Ross and White Head islands southeast of Grand Manan Island. The Ingalls Head and Thoroughfare formations are everywhere in fault contact with the Priest Cove and Ross Island formations.

Volcaniclastic rocks and wacke in the Red Point area in southern Grand Manan Island and subaerial mafic to felsic volcanic and coarse- to fine-grained arkosic rocks on offshore islands are considered to be younger than all of the above units because of their less deformed character, but relations are not known because contacts are faulted or unexposed. Similarly, the relationship of volcanic flows and breccias that form the northern tip of Grand Manan Island to the other units is not known; a felsic porphyry dike with a previously reported U-Pb age of ca. 396 Ma provides a minimum age for these rocks. Gabbroic bodies of uncertain age occur in association with several units on Grand Manan Island; their petrologic features may provide additional constraints on unit correlation.

Fold mechanisms in the shallow crust: an example from the Siluro-Devonian Arisaig Group, Antigonish Highlands, Nova Scotia

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The Silurian-early Devonian Arisaig Group, consisting mainly of shale and fine-grained sandstone, was deformed in the middle Devonian into regional NE- to NNE-trending folds, an event traditionally attributed to the Acadian orogeny. These strata are unconformably overlain by interbedded basalt and red clastic rocks of the McArras Brook Formation. The Arisaig Group affords a chance to study fold mechanisms in the shallow crust related to the Acadian orogeny. The observed structural features are indicative of classical complementary fold-fault regimes with evidence of coeval compressional and extensional tectonic features. Outcrop-scale fold propagation is associated with ramp-flat thrust fault geometry and local extension is recorded by a set of conjugate normal faults. Many of the outcrop-scale folds have sheared limbs and show evidence of a complex progressive deformation. The rare occurrence of slickensides along bedding planes indicates that flexural slip mechanisms are not dominant.

Although a synoptic plot of structural data suggest a complicated folding pattern, stereoplots of bedding data around individual folds reveals a more simple geometry, one that is dominated by conical folds rather than classically cylindrical folds (i.e. the axis of rotation does not lie in the bedding plane). The axial plane, fold and conical axes orientations show high variability, further suggesting a complex progressive deformational history. Taken together, the data suggest that outcrop-scale structural features in the Arisaig Group are much more complex than regional geometries would indicate. The data indicate that fold mechanisms in the shallow crust during the Acadian orogeny are related to coeval fault movements in underlying strata, yielding geometries possibly imposed by the coeval dextral strike slip movement along the Hollow Fault.

A seismic reflection profile across the Petitcodiac River tidal flats at Moncton (Riverview), New Brunswick: a buried channel or "seismic artifact"?

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A 900 m shallow seismic reflection profile was shot across the tidal flats at Riverview, New Brunswick, over a three-day period in mid-August, 2001, as part of the Maritimes Groundwater Initiative (MGWI) program. The main objective of the seismic profile was to investigate the near-surface stratigraphy and shape of the buried bedrock valley.

A Buffalo Gun firing 12-gauge blank shells in 1 m deep holes was used as the seismic source. A common midpoint (CMP) data set was acquired by firing shots every 3 m into a spread of 36 vertical 28 Hz geophones spaced at 3 m intervals. Successive shots were fired between the first 13 geophones, after which the geophones behind the last shot were "leapfrogged" to the end of the spread and the whole shooting sequence repeated. This asymmetrical survey procedure allowed geophone traces to be collected into CMP gathers varying between 12 and 24 fold.

Seismic refraction analyses indicated bedrock depths of approximately 10 m near the south valley wall, and 35 m at the north end of the line near the Petitcodiac River. Bedrock depths in the central part of the line appear to be greater than 35 m, as no clear bedrock refractions could be identified there, given the relatively short seismic reflection spread length.

For seismic reflection processing, a total of 344 shot records were processed using a VISTA™ processing software package. Although some records showed reflections between times of 50 to 90 milliseconds, no consistent reflectors were identified at earlier times from units within the overburden. Data processing challenges included the relatively low frequency (<100 Hz) content of the data (attributed to the effects of biogenic gas in the sediments) and bands of linear coherent noise which obscured many of the shot records. The CMP section produced after refraction static corrections, band pass filtering and R-T filtering, shows a pattern of flat lying intermittent bedrock reflectors, which is interrupted in the central part of the line by a 250 m long zone where reflectors appear to be "pushed down" by longer near surface travel times. A refraction tomography interpretation of first arrival times offers some support for the idea that this zone may represent a buried channel. There is, however, uncertainty associated with this interpretation given the limitations imposed by the short length of the seismic reflection spread and by lateral variations in seismic velocity related to variations in shallow gas content.

Sedimentology and stratigraphy of Pennsylvanian red beds near Joggins, Nova Scotia: the proposed Lower Cove Formation with redefinition of the Joggins Formation

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The section of Carboniferous strata exposed along the eastern shore of Chignecto Bay has long been considered the classic section of the Pennsylvanian 'coal measures'. The seminal work that defined the stratigraphy of these strata is that of Sir William Logan, who undertook the meticulous bed-by-bed measurement of the section as the first project of the newly formed Geological Survey of Canada. In this poster, we present in detail for the first time since that work, a continuous sedimentological log of the 619 m-thick red bed section of low relief that intervenes between underlying prominent, thick sandstone bodies of the Boss Point Formation and the cliff section of the Joggins coal measures. The strata, which correspond almost precisely with Logan's Division V, are exposed in the wave-cut platform and bluffs in a two kilometre long section at Lower Cove north and south of Little River.

The section of red beds illustrated herein provides a clear basis for the division and redefinition of stratigraphic units in this classic section, in particular the stratigraphic relationship of the Boss Point and Joggins formations and coeval units exposed across the Bay in New Brunswick. The Lower Cove red beds are currently included in the Joggins Formation but are lithologically distinct from overlying strata that comprise the Joggins coal measures (Division IV of Logan) and from the underlying Boss Point Formation (Division VI of Logan). Furthermore, the Lower Cove red beds, as quintessential dryland deposits, are key to understanding the evolution of the landscape, setting the stage for the wetland and seasonal dryland environments recorded in the succeeding classic Joggins section.

Trace element geochemistry of moose teeth apatite and possible links with increased incidence of incisorform fracture in Cape Breton Highlands moose

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Ungulates in the wild are normally free from periodontal disease. Yet, moose (*Alces alces andersoni*) in the Cape Breton Highlands (CBH) of Nova Scotia have displayed an increased incidence of incisorform macro- and micro-fractures, which may have an effect on moose longevity. This condition appears to be rare, as it has only been formally documented in the literature in Alaskan moose (*Alces alces gigas*) and somewhat differently (tooth wear rather than breakage) in Manitoban moose (*Alces alces andersoni*), and remains unexplained.

We have selected suites of broken and healthy teeth from the CBH and compared them with moose teeth from Shelburne County, Nova Scotia, where no incidence of broken incisorform teeth has been documented. Fracture patterns in teeth, and especially tooth enamel (hydroxy-apatite) were studied under the petrographic microscope and the electron microprobe. Enamel was carefully separated and 15 representative samples were analyzed chemically by inductively coupled plasma mass spectrometry (ICP-MS).

Samples from the problematic CBH area are significantly depleted in Ba, Sr, Zn, Co, and Ga in comparison with those of the control area, and some of these deficiencies have been associated with dental disease in animals elsewhere. Samples from the CBH were divided arbitrarily into two groups: A) those collected north of the CBH National Park, and B) those collected south of the Park. In each case, they were separated with respect of their perceived low, medium, and high degree of fracturing.

Within the CBH the results are not always consistent. A) North of the Park increased degree of fracturing correlates positively with contents of Cd, Mn, Nb, Rb, Sr, Y, Zr, Sn, and Bi, and negatively with Al, Cu, Ti, Zn, Mg, As, Th, and U., B) South of the Park increased degree of fracturing correlates positively with Ba, Mn, Sr, Mg, Se, As, Y, Th, and U, and negatively with Al, Cr, Cu, Ga, and Sn. Undoubtedly the number of samples is so far insufficient to draw useful conclusions, yet these are the first data available for moose teeth in the region, and raise interesting questions.

The results are being analyzed spatially with respect to geographic, geological and geochemical databases, and considered in terms of natural and anthropogenic factors, such as acidic precipitation, chemicals used to control budworm infestation, and vehicle pollution, among others.

Tracing the source of a low profile iceberg with ice rafted debris in the Nares Strait area between Canada and Greenland

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One of the dangers to navigation in northern waters is the presence of icebergs loaded with ice-rafted debris (IRD). Neutrally buoyant icebergs, floating slightly above or below the water line, can go undetected by radar due to their characteristic low profile and rock cover. On August 17, 2001, during the Canadian-German Nares Strait Geo-Cruise Expedition, a near neutral-buoyancy rock-loaded iceberg was encountered (Kane Basin, Lat. 80°N; Long. 69°W). The large, roughly 90 by 70 m, iceberg had a significantly low profile, floating only 5 to 15 m above sea level. The coverage of dark debris gave no contrast with the dark sea, and the submerged nature of the iceberg made it otherwise invisible to radar. The ice surface was covered with boulders, gravel sand and silt. Blocks were generally less than 1 m, with one impressive limestone block (2 × 2 × 3 m).

Samples collected by boarding the iceberg revealed predominantly unfoliated, angular, fossiliferous, and petroliferous sedimentary rock and scarce rounded gneiss and granitoid fragments. Their characteristics match those of Cambrian, Ordovician and Silurian strata mapped in valley outcrops of the enormous Petermann and Humboldt glacier, NW Greenland (Cape Webster, Cape Storm, and/or Goose Fiord formations). Similarities also exist in Dobbin Bay, Richardson Bay, and Rawlings Bay tidewater glaciers on Ellesmere Island (Allen Bay Formation) but the glaciers are small in comparison and rocks there have been affected by Eurekan deformation.

To ascertain the source of the debris, petrographic, mineralogical (XRD), and organic maturation analyses of petroliferous rocks are being conducted. Archival air photographs and recent satellite image of some representative glaciers help determine whether the iceberg sediment load is the consequence of landslide activity as well as what the possible path and fate of the iceberg was, on the basis of ocean current patterns. It is important to know whether this activity is on the increase as a result of climate change, because low profile, rock-loaded icebergs pose a threat to exploration and shipping in the north Atlantic.

Three-dimensional glacial stratigraphy: a tool for aquifer characterization of glacial valley-fills

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Most of New Brunswick's major river valleys are host to glacial valley-fills demonstrating the characteristic advance and retreat sequences associated with the Wisconsinan Glaciation across North America. Advance sequences are generally characterized by lacustrine, marine, or aeolian sediments of intermixed sands and silts deposited in a proglacial environment, overlain by coarsening-upward glaciofluvial sediments of well-sorted stratified sand and gravel with rounded clasts; in turn overlain by, ice contact deposits of poorly-sorted sand and gravel with occasional lenses of till, underlying over-consolidated basal till of mixed lithologies and grain sizes. The overlying retreat sequence is characterized as the inverse of the advance sequence and is overlain by glaciolacustrine or glaciomarine silts and clays in most of New Brunswick. Post-glacial sediments deposited during the Holocene in fluvial and aeolian environments are commonly found at surface.

The false assumption of lateral continuity of valley-fill deposits can lead to oversimplifications of glacial stratigraphy and to the false conclusion that the aquifer is confined at depth. Often, vertical pathways are recognized only after the aquifer has been contaminated from conflicting land-uses. However, the stratigraphic relationships and continuity of units can be better assessed spatially, through the use of computer-assisted three-dimensional stratigraphic mapping programs. Advances in computer technology now allow for the rapid processing of large multidisciplinary datasets necessary for the three-dimensional visualization of complex stratigraphic units. By entering existing well logs and borehole data into modelling programs such as RockWorks™, geologists, engineers, government agencies and other environmental professionals can add a third dimension to the more common one and two-dimensional mapping techniques currently utilized. This visualization technique leads to a better understanding of complex glacial stratigraphy and the potential environmental concerns associated with land-use practices in glaciated regions, particularly as they pertain to water-supply aquifers associated with valley-fills. The three- dimensional glacial stratigraphy of Fredericton, New Brunswick, is presented here as an example of the relevance and applicability of this visualization technique for aquifer delineation and wellfleld protection.

Geomorphological processes and the formation of the lower Saint John River, New Brunswick, leading to Holocene occupation

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Deglaciation of New Brunswick resulted in flooding of the Saint John River valley, marine incursion, and formation of a large inland lake informally referred to here as de-glacial Grand Lake. Examination of topography and existing drill-core data from drill sites within the lower Saint John River valley, may be used to reconstruct a deglacial geomorphic history for the Grand Lake area. This model is compared with 21 known archaeological sites, dating 400 to 6000 BP, indicating the spatial and temporal distribution of known archaeological sites relative to post-glacial evolution of the Saint John River valley.

Present evidence from surrounding provinces and states, indicates that precontact occupation of the Maritimes occurred around 10 000 BP; however, no sites dating older than 6000 BP have been found in New Brunswick. It is not yet clear if the delineation of post glacial water bodies and lake levels will suggest that occupation of the area may have been hampered by residual ice masses and meltwater drainage systems.

The delineation of ancient drainage pathways and associated occupational patterns aids in the prediction of where newly discovered and potentially older archaeological sites may be found within the region. The ability to predict areas with a high probability for buried archaeological sites can represent a major cost-saving to engineering projects and provide a focus for new archaeological research.

Lithofacies, detrital petrology, and diagenesis of the Chaswood Formation: a detailed examination of borehole RR-97-23

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The mid-Cretaceous Chaswood Formation of central Nova Scotia is a fluvial sand-clay succession that is the proximal equivalent of offshore deltaic reservoir rocks of the Scotian Basin. Borehole RR-97-23 provides a 130 m long section that penetrates all three members of the Chaswood Formation and has thus been studied in detail using a variety of analytical techniques. The rocks have been grouped into five main facies associations: light grey clays, dark grey clays, silty clays and muddy sands, sorted sands and gravels, and paleosols. Facies transitions in the coarser facies are related to deposition in and near fluvial channels; in the mudrocks, the transitions indicate a progression from the dark grey clay association (swamps and floodplain soils) to mottled paleosols (well-drained soils following syn-depositional uplift), with the light grey clay association forming from early diagenetic oxidation and alteration of the dark grey clay association.

The bulk mineralogy of 176 sand and mudrock samples was determined by X-ray diffraction. Principal minerals in the mudrocks are illite/muscovite, kaolinite, vermiculite, and quartz, with rutile, hematite, and goethite in the paleosol association and siderite and pyrite in the dark grey clay association. In the sandstones, translucent heavy minerals comprise stable and unstable assemblages, indicating the potential for both proximal immature sources and more distal and/or polycyclic sources. Ilmenite is the most common opaque heavy mineral and is variably altered to rutile; detrital rutile, magnetite, and titano-magnetite are also present. The earliest phase of sandstone cementation, occurring under reducing conditions in swamps and ponds, produced siderite nodules and framboidal pyrite, both of which were later corroded and oxidized during development of paleosols. Kaolinite is an early cement, occurring as a coating on quartz grains and as well- crystallized, pore-filling booklets. Later illite and barite cements indicate a source of abundant K and Ba in formation waters.

The sediment delivered to the Chaswood Formation is equivalent to that deposited in the Logan Canyon Formation offshore, where deltaic sandstones are now reservoirs for important gas fields. Although part of the same sedimentary system, the Chaswood Formation experienced subaerial, rather than marine, early diagenetic processes and considerably less burial. The Chaswood Formation does, however, provide insight into the early stages of diagenesis and may therefore be used for comparative purposes in order to better understand the processes that lead to the development of good reservoir rocks.

A petrochemical analysis of the Little Falls Member of the Nepisiguit Falls Formation, Bathurst Mining Camp, northern New Brunswick

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The major, trace, and rare-earth element composition of 17 samples of felsic tuffaceous rocks from two cliff sections near Little Falls, New Brunswick, was determined. Felsic tuffaceous rocks at Little Falls, located 1.4 km below Tetagouche Falls on the Tetagouche River, have been divided into two units, a lower lithic tuff and an upper crystal tuff, based on their petrography and chemistry. The lithic tuff unit is characterized by greenish grey, medium- to fine-grained, bedded, ash tuff with pumice and shale rip up clasts. Thicker sections of this unit contain rare, angular quartz grains. The crystal tuff unit is characterized by a medium grey, coarse-grained tuff, with thick sections characterized by abundant (75%) rhyolitic clasts and angular quartz phenoclasts. These rocks are exposed in two cliff sections that constitute the reference section for the Little Falls Member of the Nepisiguit Falls Formation, part of the Ordovician Tetagouche Group.

In the lower lithic (n = 15) and upper crystal (n = 2) tuff, the SiO_2 contents range from 66 to 78 wt. %, with one particular sample enriched in Mn (7.2 wt. %) and Fe (4.6 wt. %). Zr/TiO_2 versus Nb/Y plots show both units have signatures typical of the average Nepisiguit Falls Formation. Using these trace-element discriminants, the lithic tuff plots in the rhyodacite field, whereas the crystal tuff plots in dacitic field consistent with TiO_2 abundance and SiO_2 contents. The lithic tuff shares similar average Zr/Ti values (0.075) to average Nepisiguit Falls Formation tuff (0.079), whereas the crystal tuff Zr/Ti values (0.03) are lower. However, REE profiles of lithic tuff exhibit higher heavy REE signatures than average Nepisiguit Falls rocks in the type area, indicating that this came from a different volcanic system.

REE plots of the lithic tuff show a pronounced negative Eu/Eu* in both the lithic tuff (0.40) and upper crystal tuff unit (0.48). The Ce/Ce* values for lower crystal tuff unit are slightly positive (1.03 – 1.07), the lower crystal tuff unit has a negative value (0.4), and the upper crystal tuff unit has positive value (1.4). The lower part of the crystal tuff unit has Fe and Mn enrichment, and a pronounced negative Ce anomaly indicating that it has experienced mixing with a distal exhalite, which is possibly correlative to the Brunswick Horizon.

Optimization of a 3-axis induction magnetometer for airborne time domain electromagnetic geophysical surveys

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Geophysical surveys using transient electromagnetic methods are used extensively in the exploration for massive sulphides and ground water, and for locating contaminant plumes. When large areas must be explored economically, an airborne survey is usually favoured. The design of a survey system must include a very sensitive receiver with large dynamic range and with minimum noise. Typically, the receiver system is made of a set of three orthogonal conventional induction magnetometers (CIM).

The design and optimization of induction magnetometers for airborne time domain electromagnetic is not simple. The signal-to-noise ratio, overall weight, maximum dimensions, and bandwidth must all be taken into account during the design and optimization process. The concept of an orthogonal induction magnetometer array (OIMA) is presented in this work. A three component array is built of light weight elemental induction magnetometers (EIMs) to replace the three orthogonal CIMs. The OIMA provides significant signal-to-noise ratio and bandwidth improvements over prior art.

New information on the early Jurassic prosauropod dinosaurs of Nova Scotia

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The early Jurassic McCoy Brook Formation fluvial and aeolian sandstones can now be recognized as the richest site in North America for prosauropod dinosaurs. Articulated and semi-articulated specimens have been found throughout much of the exposure; however, at least four specimens have been recovered from a small bone bed rich in skeletal material. Recent fieldwork demonstrates that less than one quarter of the bone horizon has been collected, suggesting many more specimens remain to be collected. The bone bed contains articulated skeletons of various sizes and likely represents a mass burial event.

The prosauropod dinosaurs of the McCoy Brook Formation have previously been attributed to the Connecticut Valley prosauropod genus *Ammosaurus*, based on size and morphology of the femora. However, recent preparation of specimens collected during the summer of 2000 show that the pelvis and cervical vertebrae do not resemble *Ammosaurus* or *Anchisaurus*. Therefore, the Nova Scotia specimens at least represent a new taxon occurrence for North America, although the specimens may yet prove to be a new prosauropod taxon. Furthermore, recent preparation of a very small specimen (est. femur length 10 cm), also likely a prosauropod, suggests nesting sites may be found with continued collection activities. Preparation of all specimens is ongoing at the Fundy Geological Museum.

Reports of recent field work, stratigraphy, bone histology, and specimen descriptions will be presented to demonstrate the progress made on the study of these important specimens and directions of future work. This work has been generously supported by research grants from The Jurassic Foundation, Nova Scotia Museum, NSERC Post-Graduate Scholarship, NSERC Systematics Supplement, and NSERC grant #A5056.

Electron microprobe study and chemical dating of Paleoproterozoic metamorphic monazites

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Metamorphic grade in the metapelite of the Paleoproterozoic Longstaff Bluff Formation, Trans-Hudson Orogen, ranges from upper greenschist to granulite facies. An electron microprobe study of monazite was carried out on grains of various grades and textural settings. Major element and trace element contents and mapping were used to investigate the effects of progressive metamorphism on monazite. Major element analyses were used to document chemical variation with metamorphic grade and mineral assemblage. Monazite Y content increases from low grade to high grade with a significant jump at the sillimanite isograd. This may result from consumption of xenotime, an important Y-sink, at higher metamorphic grade. The U and Th contents also increase with higher metamorphic grade. There is a corresponding decrease in total REE content due to substitutions for U, Th, and Y. Trace element (Pb, U, Th, and Y) analyses combined with chemical maps allow calculations of chemical ages (the CHIME method). Calculation of the error is based on counting statistics. Errors on spot ages vary from 2 to 5% at the 2-sigma level, depending on the Pb and U content of the grains. Multiple analyses within a single grain can reduce the statistical error to - 1%. CHIME results from the Longstaff Bluff Formation yield ages ranging from 1760 to 1890 Ma, with main clusters at -1800 Ma, -1830 Ma, and -1850 Ma, and minor clusters at -1760 Ma and -1910 Ma. The main clusters agree well with TIMS analysis of monazites from the same area. The minor clusters have not yet been correlated with known ages. The younger cluster may represent small monazite grains not normally recovered during mineral separation for TIMS work. The significance of the older cluster is still unclear. The main age clusters are found in monazites of all metamorphic grades. Older ages are more present in higher grade monazites and the -1910 Ma age is only found in the highest grade monazites. The -1760 Ma is restricted to the lower grade samples.

Ice-contact volcanism in southwest Iceland: analysis of hyaloclastite flow deposits using remote sensing, stratigraphy, and geochemistry

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Ice-contact volcanism, and specifically subglacial volcanism, can provide information about paleo-environments such as the extent and thickness of former glaciers and ice sheets. In southwest Iceland, approximately 30 km southeast of Reykjavik on the Reykjanes Peninsula, the regions of Northern Bláfjöll, Vífilsfell, and Arnarþúfur contain structures associated with Pleistocene ice-contact volcanism. This study combines remote sensing classification of multispectral satellite imagery, field observations, and geochemical analysis to determine the relationship between these features. Remote sensing classification of SPOT 5 imagery using Geographic Information Systems (GIS) generates 22 discrete spectral signatures of which 15 are significant (cumulative proportion 94.67%). Determination of significant clusters and their spatial distribution facilitates subsequent field investigations. Ground-truthing of Northern Bláfjöll reveals a flat-topped volcano with steep sides that consist of basal pillow lavas, pillow-breccia, altered hyaloclastite (palagonite), flow-foot breccia, welded scoria, and superincumbent subaerial lava flows. Vífilsfell directly overlies Northern Bláfjöll and encompasses a conical mound of palagonite with isolated welded scoria, volcanic bombs, dykes with pillowed surfaces, and peripheral slump deposits. Arnarþúfur comprises a series of linearly oriented discrete mounds with rhythmically layered fine-grained palagonite and clast supported beds that include varying proportions of armoured lapilli. Beds typically contain flow indicators such as climbing ripples, cross-beds, and flutes. Electron microprobe analysis of major element concentrations in volcanic glass reveals that Northern Bláfjöll, Vífilsfell, and Arnarþúfur have indistinguishable olivine normative tholeiite compositions. Northern Bláfjöll is a tuya that emerged from a deep englacial melt-water lake with a surrounding ice- thickness exceeding 400 m, according to the passage zone elevation above the surrounding plain. Vífilsfell is a subglacial mound that formed beneath thin-ice conditions with episodic melt-water drainage during its emplacement. Arnarþúfur is an ice-confined hyaloclastite flow deposit that combines characteristics of pyroclastic density currents, turbidites, and eskers. Stratigraphic relationships suggest that Arnarþúfur formed in association with the Vífilsfell eruption as a result of gravity-controlled mobilization of unconsolidated volcaniclastic material into an ice-confined melt-water drainage system. The chemical homogeneity of Northern Bláfjöll, Vífilsfell, and Arnarþúfur suggest a common magma source and rapid emplacement of the volcanic edifice relative to the evolution of the melt.

Cooperative geological mapping strategies across Canada

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“Cooperative Geological Mapping Strategies Across Canada” (CGMS) is a 10 year vision statement by the National Geological Surveys Committee (NGSC), endorsed by all of Canada’s Mines Ministers in 2000, that focused on the continuing need for reliable geoscience knowledge relating to mineral and energy resources, compatible with the Intergovernmental Geoscience Accord. It identified geoscience knowledge as a key competitive advantage, essential to maintaining Canada as a pre-eminent global destination for exploration investment.

The Geological Survey of Canada (GSC, Earth Sciences Sector, Natural Resources Canada) has launched the two year COGMAPS project to formulate and communicate the federal component of a 10-year implementation plan for CGMS, to be co-authored by the NGSC in consultation with industrial and academic partners.

CGMS must contribute to issues and priorities identified by governments. Federal government priorities where public geoscience is a tool that can contribute directly to public good include: improving the quality of life of Canadians; strong and safe communities; sustainable development of natural resources; development of the north; clean environment; aboriginal people; and communicating with Canadians.

At the provincial and territorial level similar priorities are: Employment; Prosperous and safe communities; Sustainable economic development, especially in resource-producing regions; Competitiveness of provincial/territorial resource sectors; and Aboriginal People.

This poster highlights examples of the public good derived from public geoscience projects undertaken over the past decade through various programs in the Atlantic Provinces, and specifically New Brunswick, Newfoundland, and Nova Scotia. A vital ingredient for all of these successful projects has been the high degree of co-operation among stakeholders, especially between provincial/territorial and federal governments. The goal of CGMS is to build on this success in the next decade.

Petrology of the Mechanic Settlement Pluton, southern New Brunswick, and potential for platinum group element mineralization

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The Mechanic Settlement Pluton, located on the northern margin of the Caledonian Highlands of southern New Brunswick, is a relatively undeformed late Neoproterozoic layered mafic intrusion. It contains at least seven lithologies: plagioclase-bearing lherzolite, olivine gabbronorite, gabbronorite, troctolite, anorthosite, websterite, and diorite. In a small portion of the pluton, previous studies have recognized six variably incomplete cyclic units that consist of plagioclase-bearing lherzolite at the base, olivine gabbronorite and gabbronorite in the middle, and anorthosite at the top. The intrusion has been variably altered, with hematite replacing mafic minerals and serpentine replacing olivine in ultramafic rocks; mafic rocks are relatively unaltered. Epidote and serpentine occur along shear zones in all rock types. The Mechanic Settlement Pluton contains stratabound, but not necessarily stratiform, horizons of anomalously high platinum- group element concentrations (Pt + Pd up to 2.4 ppm over 1 m in drill core, and 5.7 ppm in grab samples), typical of reef-type mineralization such as in the Merensky Reef of the Bushveld Intrusive Complex, South Africa, and the J-M Reef of the Stillwater Complex, Montana. These mineralized horizons have caused the pluton to be the focus of various exploration efforts from 1968 to present. Exploration in the earlier years focussed on copper and nickel, but now is directed to the platinum group elements.

The goals of this project are (i) to document layering and mineralized horizons in drill core for correlation between drill holes in order to assess the number, pattern and continuity of layers in the pluton, and (ii) to better understand the petrogenesis of the pluton, including controls on the distribution of potentially economic elements, especially platinum group elements. Logging, sampling, and magnetic susceptibility measurements of 5420 m of core from 20 archived holes drilled by Noranda, BHP, and Wildhorse Resources were completed in the summer of 2003, and detailed petrographic descriptions of the core samples, as well as an extensive surface sample collection archived at Acadia University, are in progress. Surface sample rock types correlate well with those in the subsurface. Magnetic susceptibility measurements coupled with archived downhole platinum group element assays, allow confident correlation of units between drill holes. Preliminary correlations suggest that at least two igneous contacts dip 68 degrees south.

Historical lithogeochemical data, supplemented by new data from representative drill core samples, are being evaluated using Pearce element ratio analysis to provide insight into compositional controls in the pluton. Preliminary results suggest that compositional change in the pluton can be explained by fractionation of olivine and plagioclase, with subordinate clinopyroxene control. In peridotite samples compositional variation can be best explained by 80% olivine and 20% plagioclase fractionation, whereas in gabbroic samples compositional variation can be explained by about 43% olivine and 57% plagioclase fractionation. Trace element compositions show patterns consistent with these observations; for example, Ni concentrations correlate well with olivine fractionation measures. Future work will include investigations of silicate and sulphide mineral compositions using electron microprobe analysis, and identification of platinum group element-bearing minerals.

Gravity activities at the Nova Scotia Research Foundation: 1952–1995

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Gravity surveys were started by J.E. Blanchard in 1952 employing summer students to make measurements over the Carboniferous Basins in mainland Nova Scotia and Cape Breton Island for the Nova Scotia Government and various exploration companies. The gravity surveys were for a variety of purposes including oil and gas, salt, potash, and minerals. These surveys continued on an annual basis until 1966 when D.E.T. Bidgood took over the Geophysics Group at NSRF. Though contract gravity surveys continued as before, considerable emphasis was placed on improving survey procedures and reprocessing the older surveys. At the same time, the gravity data processing was computerised and software written for gravity data storage and retrieval by A. Jost and K. Howells. This was one of the first such systems in Canada. In 1971, K. Howells was given responsibility for the gravity program. Computer modeling and plotting were introduced and densities measured for Nova Scotian rocks. With the incorporation of NSRF in 1975, the emphasis was placed on contract work using in house staff. Some summer student gravity surveys, funded by the Federal Government, were carried out in northeastern Cape Breton and southeastern and central mainland Nova Scotia. Underwater gravity measurements were made in Georges and Chedabucto bays in 1972. Gravity surveys were terminated in 1988 and the Geophysics Group at NSRFC was shut down in 1992. In 1994–1995, K. Howells, I. Hawboldt and D. Clarke reprocessed approximately 37 000 of the NSRFC gravity stations. These now form the bulk of the Nova Scotia gravity database used by industry, government, and university geoscientists. These stations also form part of the National gravity database and have been used for solid earth studies.

Lithostratigraphy and sedimentary petrography of early Cretaceous outlier basins, northern Nova Scotia

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In late 2002, early Cretaceous sediments <50 m thick were cored in two small outliers: Belmont in Colchester County (3 holes), and Brierly Brook in Antigonish County (7 holes). The aim of the drilling was to delineate the across and along-strike facies variations and to obtain quality samples for petrographic analysis. In both localities the early Cretaceous deposits are preserved within small linear fault bound basins. Lithofacies are similar to those in the better known deposits of central Nova Scotia. Two holes at Belmont penetrated sorted silica sand (stone) with minor mudstone. Four lithostratigraphic units are recognised at Brierly Brook. The upper Unit A comprises mottled red and grey mudstone and sand facies. Unit B consists of grey debris-flow mudstones that interfinger with sands in borehole BB-02-7. Unit C, mottled red and grey mudstones and grey sandstones and the thin basal Unit D, polymictic pebbly sandstone, are present only in borehole BB-02-2.

Thin section studies and X-ray diffraction show that the Belmont sandstones are typically finer grained, better sorted, more rounded, and contain more quartz arenite and mudstone clasts, compared with Brierly Brook. Sandstones at both localities contain abundant kaolinite and chlorite is present in some. Pseudorutile and rutile are present in sandstones of Units B and C but not A at Brierly Brook. Pebbles within Unit B debris- flow deposits at Brierly Brook are of locally available lithologies. Mudstones of Unit A have a high kaolinite, low illite, little or no vermiculite and chlorite, and generally abundant 21–25 A mixed layered clays. Unit B mudstones show mineralogical variability reflecting their debris-flow origin. In three holes, high detrital calcite and dolomite concentrations occur at a correlatable horizon. Darker grey mudstones in BB-02-2 pass laterally into lighter grey mudstone with interbedded sand in BB-02-7, where the mudstone contains much higher kaolinite and chlorite and less pseudorutile. Such variations result from later clay mineral diagenesis aided by meteoric water flow through the permeable sands. Although Unit C is sedimentologically similar to Unit A, it differs in containing anatase, some calcite, and dolomite, and only rare mixed layered clays.

The range of depositional and diagenetic environments is similar to that inferred for the Chaswood Formation of central Nova Scotia. Rapid changes in facies at Brierly Brook reflect active tectonics during sedimentation and preservation of only the northern margin of the basin following younger tectonic activity.

Offshore crustal structure of the Meguma Terrane: seismic constraints on its origin

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We conducted a marine wide-angle reflection/refraction experiment along the coast of Nova Scotia. It repeats, with modern techniques, the profile published by Ewart Blanchard and others in the first volume of the Canadian Journal of Earth Sciences. Their general results are confirmed.

Modelling of the arrivals indicates that near-surface rocks have velocities of 5.5–5.7 km/s typical of the Meguma Group with a thickness of only 3 km. The average velocity of the crust is 6.2–6.4 km/s with a maximum velocity of 6.6 km/s and a total crustal thickness of ~37 km. To the east, the Meguma Terrane overlies the 6–12 km thick lower crust of the Avalon Terrane that has a velocity of 6.8–6.9 km/s over a 200 km long distance. The velocity contrast from these overlapped terranes produces strong reflections that are observed by several ocean bottom seismometers (OBS). This is consistent with a multichannel reflection profile that clearly images Avalon crust underneath the Meguma Terrane. Numerous reflections in the lower crust are clearly observed by many OBS, consistent with a crossing reflection profile that images ~8 km thick reflective lower crust, 17 km thick less reflective mid crust, and ~14 km-thick non-reflective upper crust. A possible origin for the lower crustal reflectivity is lenses of felsic and mafic rock.

Several models have been suggested for the origin of the Meguma Terrane. Using the velocity constraints from both the P and S waves, we examine hot-spot, post-orogenic extension and delamination hypotheses. The extensive granites of the Meguma Terrane indicate temperatures hot enough for the lower crust to flow. Not only is the Moho flat but also the crustal thickness is less than under the adjacent Avalon Terrane as predicted by delamination. Removal of the entire crustal root could result in complete melting of the lower crust consistent with our velocities. The P-T conditions of the granulite-facies xenoliths suggest they come from greater depths than the present Moho and are a feature diagnostic of delaminated terranes. The consequences of delamination for the overlying crust are uplift and erosion. Within a few million years of their emplacement at about 10 km depth, the granitoid plutons were exhumed based on the rapid cooling of the plutons and on miospores from the base of the overlying unconformity. Following uplift a thermal sag basin was created based on the widespread distribution of 2–3 km Carboniferous strata.

Paleoceanography and its implication for the Nova Scotia margin hydrocarbon exploration

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Most earth system changes in climate, ocean circulation, ocean-water chemistry, tectonics, and geography are archived in sediments deposited in the oceans; therefore, sediment studies allow us to interpret the history of the Earth and its ocean basins. Deep parts of the continental margin off Nova Scotia have recently become of interest to oil companies as a potential new gas province, under the assumption that success in hydrocarbon exploration on the shelf can be expanded and extended to the deeper parts of the continental margin. Is such an assumption supported by our knowledge of processes in the recent oceans and of the paleoceanography of the late Mesozoic North Atlantic?

Of all the components of the petroleum system, the presence of source rocks should be considered as the most critical, as without them, all the other components, such as presence of a reservoir, trap, and maturation history, are of minimal value. Exploration of the North Atlantic ocean basin has documented that sedimentary basins developed on the shelf mostly evolved under different oceanographic systems than those at continental slopes, therefore indicating the existence of different settings and conditions for the generation and accumulation of organic carbon.

Occurrence of source rocks depends on marine organic matter generation and preservation, with the generation controlled by the availability of nutrients supplied either by continental runoffs (therefore dependant on the climate), or as result of coastal upwellings, surface water mixing, and open ocean divergence. For deep margin exploration, one more oceanographic parameter has to be considered, and that is dissolved oxygen levels in the ocean water. Studies of the west Tethys margins provide evidence that in some areas, such as east of the Florida-Georgia border, intermediate waters during the Aptian- Cenomanian were highly oxygenated, and therefore no source rocks are preserved. Could such conditions extend to, or influence depositional regimes on the deep margin off Nova Scotia?

Deep sea drilling has documented that during the Oxfordian to early Tithonian, and again during post-Turonian to early Eocene time, all deep waters in the central North Atlantic were highly oxygenated, leading to deposition of deep sea red beds lacking any organic carbon accumulation. Such conditions severely decrease the probability of any source rocks of those ages existing on the deep margins of Nova Scotia. However, it remains unknown whether the upper margin off Nova Scotia during the middle Cretaceous could have been a region of upwelling (results of exploratory drilling of the Nova Scotia margin are kept confidential by the oil companies) and the paleowind directions for the Cretaceous time period remain unconstrained.

Anomalous seismic features in a lesser known Grand Banks basin

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The Carson Basin has not seen any exploration activity since 1986, and has only been tested by four wells along its westernmost edge. We review these tests with regards to the style of the petroleum play concepts. Also, we explain the setting for a potential deep water turbidite play, based on the amount of sediment eroded throughout the early Cretaceous during the Avalon uplift, as shown by the Bonnition and St. George paleo-canyon systems. We show seismic morphological features that suggest turbidite deposits. Evidence for significant hydrocarbon charging is presented by localised seismic direct hydrocarbon indicators such as high amplitude "flat spots".

Mafic dykes and associated peperites in the Upper Devonian to lower Mississippian Saint-Jules Formation of southern Gaspésie, Québec

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The recently identified upper Devonian to lower Mississippian red beds of the Saint-Jules Formation unconformably overlie rocks affected by the middle Devonian Acadian orogeny. They host a mafic dyke swarm near the town of New Carlisle, Québec. The dykes are believed to be the result of post-Acadian extension and appear to correlate with early stages in the development of the composite upper Paleozoic Maritimes Basin. They are up to 30 m wide and strongly enriched in high-field-strength elements such as Zr, which exceeds 1000 ppm in some samples. Mobilization of the high-field-strength elements is inferred to have occurred during secondary fractionation in a magma chamber developed within the calcareous rocks that form the basement to the Saint-Jules Formation. These calcareous rocks also form the bulk of clast lithologies within the red bed unit, which was sourced from local fault scarps.

During dyke emplacement, several types of magma – host sediment interactions occurred as the dykes reached the wet and poorly consolidated material of the Saint-Jules Formation. As a result, the mafic rocks are strongly oxidized, albitized and autobrecciated near and above the Acadian unconformity, where blocky juvenile clasts of devitrified mafic glass and porphyritic basalt have mingled with molten and fluidized calcareous sediments of the Saint-Jules Formation, forming a peperite zone several metres thick. As opposed to most peperite occurrences, the New Carlisle peperites are associated with dykes rather than with sills or invasive lava flows. We argue that more heat can be concentrated above a dyke than above a sill, as the former provides an efficient pathway for heated waters to invade the sedimentary basin above the unconformity. Superheated groundwaters issued from the sides of the dykes appear to have promoted melting of carbonate components in the calcareous clastics of the Saint-Jules Formation, locally generating large volumes of carbonate melts.

Cambrian-Ordovician rocks of White Bay, Newfoundland: geology, stratigraphy, and disseminated gold mineralization

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The deformed Cambrian and Ordovician sedimentary rocks of western White Bay have long been recognized as equivalent to the undeformed platformal sequence of the west coast of Newfoundland, but detailed correlation has proved difficult due to their lack of fossils and structural complexity. Recent work indicates that western White Bay hosts a relatively complete stratigraphic sequence that includes the Cambrian Labrador and Port-au-Port groups, the lower Ordovician St. George Group, and possibly the middle Ordovician Table Head Group. Despite strong deformation and numerous structural complexities, the original depositional features of these rocks are well preserved. All of the Cambrian and Ordovician formations are cut by undated diabase dykes, of which there may be two generations. This improved knowledge of the stratigraphy leads to revised interpretations of the structure. A major fault zone within phyllitic schists of the Forteau Formation represents a detachment surface along which the platformal rocks were transported westward over the Precambrian basement. This zone accommodated much of the motion, and the sub-Cambrian unconformity thus remained largely intact. A newly recognized fault zone within the Cambro-Ordovician sequence causes structural repetition, and this probably also originated as an early thrust. Subsequent deformation appears to have taken place largely in a regime of dextral shearing, and dextral motions also accompanied emplacement of the later diabase dykes. The area contains the only known examples of gold mineralization in the platformal sedimentary rocks of western Newfoundland, and has recently attracted exploration interest for "Carlin-type" disseminated gold deposits. Disseminated gold mineralization, associated with pyrite and arsenopyrite, is hosted by Cambrian quartzite and limestones in a structurally complex area adjacent to a larger zone of disseminated gold mineralization in Precambrian granitoid rocks.

Pilot study on fluid inclusions in salt (halite) from the Osprey H-84 well, Carson Sub-basin, Grand Banks, Newfoundland

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A descriptive study of fluid inclusions in halite has been initiated to investigate whether they can provide useful informa-

tion about the physical and chemical nature of the brines from which the halite precipitated, and relative timing of its recrystallisation, diagenesis, and petroleum migration. Evaporites of late Triassic to early Jurassic age form the basal parts of the sedimentary succession of the Scotian Basin and the Grand Banks. The salts (Osprey Evaporite) were penetrated by the Amoco-Imp-Skelly Osprey H-84 well which is located on the western flank of the Carson Sub-basin, some 400 km southeast of St. John's, Newfoundland, and 30 km from the present shelf edge. The drilled depth is 3473 m, 2054 m of which is essentially halite (depth interval 3606 – 1252 m). Cleavage or doubly-polished chips were used. The fluid inclusions in the studied salt crystals are numerous, small (submicroscopic to 30 µm in length), and rarely contain gas bubbles or solid inclusions. The most abundant inclusions occur in planar swarms that occupy either growth zones or healed cleavages parallel to (001). Fluid inclusions are generally of rectangular or square outline, and they are tabular, spindle-like, cylindrical, drop-like or irregular; and the majority contain only a liquid phase. Other fluid inclusions occupy clearly cross-cutting cleavages, showing irregular or worm-like shapes. A small proportion of the fluid inclusions are dark-rimmed, semi-cylindrical, elongate regular or irregular; they have high relief and contain only one phase, a gas. Homogenization temperature measurements in salt are generally suspect, due to necking down, metastable fluids, stretching, and leakage. The small proportion of 2-phase inclusions yield homogenization temperatures from 45 to 140°C, the majority between 45 and 93°C, and are often not consistent within a population. T_h does not show a regular pattern of variation with depth. Behaviour of many inclusions during heating runs is consistent with the presence of natural gas rather than water vapour. Freezing experiments yield consistency of results. Freezing temperatures range between –62°C and –89°C (average –69.5°C). On re-heating, nucleation of a gas bubble usually occurs at a narrow range of temperatures (–21 to –24.5°C; average –24 °C eutectic initial melting) and at –28.3 to –34.5°C; average - 31.3°C (metastable eutectic). Melting temperatures range between +1 and –2 °C with an average value of –0.04°C (peritectic final melting). These results suggest that the fluid inclusions in halite of the Osprey Evaporite consist of solutions in the system $NaCl-H_2O$. We plan to analyze the composition of the inclusions with Raman spectroscopy.

Magnetic and gravity modeling in southern New Brunswick

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The geology of southern New Brunswick is complex, and at least six major fault-bounded tectonostratigraphic subdivisions, or terranes, have been recognized, based on differences in pre-Carboniferous rock units. The more inboard terranes were intruded by numerous mid-Paleozoic plutons (Saint George Batholith and Mount Pleasant Complex), and recent gold discoveries in the area have focused attention on the economic potential of these units, previously known for their Sn-W deposits. During the past two years, we have been using magnetic and gravity data to gain new insight into the three-dimensional character of these terranes and their plutonic units. The work included compilation of regional gravity and magnetic data, acquisition of new gravity data, and physical property measurements (magnetic susceptibility and density) on approximately 3000 samples from southern New Brunswick. Regional magnetic and gravity map patterns (e.g., vertical gradient, horizontal gradient, and residual Bouguer anomaly) were interpreted using constraints from mapped geology. Cross- sectional and longitudinal models were drawn using gravity and magnetic data, constrained by density and magnetic susceptibility information. These models provide a quantitative analysis of the internal geometry of rock units and terrane boundaries.

Models and long wavelength map patterns indicate that the boundaries between the Caledonia, Brookville, Kingston, and New River terranes are sub-vertical or dip slightly to the southeast, and that some map units in each terrane extend to depths ranging from 5000–8000 m. The models are consistent with the Mascarene terrane being a cover sequence over the boundary between the St. Croix and New River terranes. The terranes are associated at depth with geophysically distinct bodies that are interpreted to correspond to the basements, from southeast to northwest, of Avalon terrane sensu stricto, Brookville-Bras d'Or terrane, and Gander composite terrane. The geophysical data vary significantly among the various components of the Saint George Batholith and exposed satellite plutons. Large plutons have been identified in the subsurface north of the Saint George Batholith that may be related to mineralized components of the Mount Pleasant Complex, based on physical property data.

Re/Os analysis of arsenopyrite from Meguma lode gold deposits: implications for timing of gold metallogeny and age of Acadian deformation in the Meguma Terrane, Nova Scotia

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Meguma lode gold deposits (MLGD) occur within Cambro-Ordovician metaturbidites of the Meguma Group, which were deformed into upright, northeast-trending box and chevron-type folds during the Devonian Acadian orogeny. The MLGD are dominated by quartz veins with associated carbonate and arsenopyrite and trace Fe, Pb, and Zn sulphides. Geological mapping and structural analysis of several gold districts indicate that bedding concordant, discordant, en enchelon, and saddle reef vein types dominate and that they can be related kinematically. In addition, the mutual cross-cutting relationships of all vein types suggest a similar time of emplacement, which is inferred to have been late in the folding history of the host rocks. This timing of vein emplacement is consistent with the following observations: (1) veins locally cross-cut hornfels adjacent ca. 375 Ma granites (e.g., Mooseland and Beaver Dam districts); and (2) ca. 375 Ma $^{40}Ar/^{39}Ar$ plateau ages for hydrothermal vein minerals (amphibole, biotite, muscovite) from several gold districts (n=7). In order to further constrain the timing of vein formation, we have undertaken Re/Os analyses of vein and wallrock arsenopyrite from three gold districts where the absence of hydrothermal vein minerals preclude dating by the $^{40}Ar/^{39}Ar$ method - The Ovens, Dufferin, and the Touquoy Zone (Moose River district). Whereas The Ovens and Dufferin are similar geologically (i.e., hinge area of anticlines) and contain all vein types typical of MLGD, the Touquoy Zone represents vein-free, disseminated style gold mineralization. The results of Re/Os analyses indicate ages of 408 ± 4 Ma for The Ovens and 381 ± 3 Ma for Dufferin and Touquoy. These data along with previous $^{40}Ar/^{39}Ar$ ages have implications for gold metallogeny and tectonism within the Meguma Terrane: (1) vein formation and, hence, gold mineralization is coincident with two widespread events within the Meguma Terrane, namely regional deformation and felsic plutonism; and (2) the timing of regional deformation is now constrained to -408 Ma, which contrasts with current estimates based on $^{40}Ar/^{39}Ar$ whole rock and mineral ages (i.e., ca. 400–390 Ma). The difference in time of deformation is considered to reflect the higher blocking temperature of the Re/Os chronometer in arsenopyrite compared to the K-Ar system in mica and clearly demonstrates the need for additional high-temperature chronology to better constrain the absolute timing of deformation and gold mineralization in the Meguma Terrane.

Fluid inclusion constraints on the formation of emerald-bearing quartz veins at the Rist tract, Hiddenite, North Carolina

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Emerald-bearing quartz veins at the Rist property, Hiddenite, North Carolina, cross-cut highly deformed schists of the Inner Piedmont metamorphic belt. The quartz veins locally widen into open fissures that are lined with crystals of quartz, albite, calcite, siderite, ankerite, chabazite, nontronite, beryl, hiddenite, muscovite, tourmaline, pyrite, and rutile, with rare monazite and xenotime. Quartz-hosted fluid inclusions were studied to determine the composition of the vein forming fluids and to constrain the P-T conditions of vein formation.

Abundant secondary and pseudosecondary fluid inclusions in quartz entrapped both low and high XCO_2 aqueous carbonic fluids. The coexistence of these two types of fluid inclusions is regarded as evidence for fluid immiscibility during vein formation. Three phase ($Car._{(v)} > Car._{(l)} > Aq._{(l)}$), high XCO_2 fluids are most abundant in all samples and have salinities between 2.4 –3.7 wt. % NaCl eq. Homogenization temperatures were not measurable in such inclusions due to decrepitation. Two phase ($Aq._{(l)} > Car._{(v)}$), low XCO_2 have salinities between 5.2 – 6.1 wt. % NaCl eq. and homogenization temperatures between 220–240°C. Trapping pressure of these fluids is estimated to be between 0.6 and 1 kb using experimental H_2O-CO_2-NaCl solvi. We suggest that fluid unmixing occurred in response to a decrease in fluid pressure as homogeneous aqueous carbonic fluid ascended along an extensional fissure system.

The second round of Targeted Geoscience Initiative: evaluation of resource potential of the Appalachian basins in eastern Canada

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The second round of TGI 2 activities was announced in the last federal budget. A total of 10M$ was allocated over a two year period (2003–2005). In collaboration with the provincial geological surveys of Quebec, New Brunswick, Nova Scotia and Newfoundland, the Geological Survey of Canada proposed a 1.8M$ (federal operating dollars) Appalachian project which was accepted by the TGI 2 steering committee. On-going activities vary from one jurisdiction to the other; however, all have in common a better understanding of the Appalachian geological framework and its resource (hydrocarbon, minerals) potential.

In Quebec, activities focus on 1) the definition through a marine seismic program, of the architecture of the gas-bearing Quaternary sands in the St. Lawrence estuary, and 2) the subsurface Paleozoic architecture of eastern Quebec based on interpretation and integration of new gravimetric and high-resolution aeromagnetic surveys and reprocessing of ground seismic reflection data. In New Brunswick, activities include 1) definition, through detailed maturation, potential source rock, and reservoir studies, of the recently documented hydrocarbon potential of the post-Taconian successions in the northern part of the province, 2) construction of a web-accessible database for the extensive set of organic matter and maturation data in the Carboniferous basins of southern New Brunswick, and 3) definition through a high-resolution aeromagnetic survey of the subsurface architecture of Carboniferous and pre-Carboniferous units in the Marrtown – Sussex area. In Nova Scotia, the project is focussed on the Carboniferous basin limited by the Cobequid – Chedabucto fault system. Integration of new and reinterpreted geological and geophysical data will provide key synthesis for the resource potential of this poorly known area. In western Newfoundland, the activity will target the definition of the geological evolution of the Humber Arm Allochthon and the evaluation of its hydrocarbon source rock and reservoir potential. Almost all these activities are in progress and acquisition of geophysical data is planned to be completed in the first year of the project in order to have the release of interpreted and integrated products at the end of the two-year project.

Secondary ion mass spectrometry (SIMS) for stable isotope microanalysis of trace light elements: the determination of ä¹¹B and ä³⁷Cl in small objects

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Secondary ion mass spectrometry (SIMS) has several general advantages for the determination of light stable isotopes occurring at trace element concentrations in natural samples. Ion microprobe SIMS instruments sputter nanogram quantities of material from a well-defined, micrometer-sized analytical crater. The extremely small quantity of sample extracted allows analysis of very small objects, for example, igneous melt inclusions.

Sputter ionization of many light elements (e.g., Li, B, S, Cl) is efficient enough (>>l%) to allow precise determination of isotope ratios at elemental concentrations as low as 1 – 100 ppm. Primary bombardment of the sample is performed in close proximity to the initial extraction optics of the mass spectrometer, enabling very stable and efficient secondary ion collection. Consequently, instrumental mass fractionation (IMF) can be maintained at a very consistent and reproducible level.

B isotopes. Use of SIMS for the determination of ä^{11}B is simplified because compositionally diverse matrices are amenable to calibration for IMF with a single standard. This attribute is particularly convenient in subduction-related volcanic systems, where tephra sequences may contain a wide spectrum of major element chemistries. For example, the combination of ä^{11}B and trace element microanalyses has been particularly valuable in modeling the contribution of a metasomatized mantle wedge to the Neogene Izu Arc Front volcanics.

Cl isotopes. ä^{37}Cl is readily amenable to SIMS microanalysis in a variety of matrices, due to the vigorous ionization of Cl (as Cl^-) under bombardment by positive primary ion beams such as Cs^+ Determination of ä^{37}Cl in glassy matrices requires using a Normal Incidence Electron Gun (NEG) to compensate for sample charging. A series of well-typified standards are also essential to calibrate for IMF, which can vary up to 10 per mil relative between basaltic and rhyolitic matrices. However, precise determinations of ä^{37}Cl are possible for glasses or silicate minerals with as little as 100 – 200 ppm total Cl. With special preparation, ä^{37}Cl can also be determined in microlitre aliquots of some natural fluids, containing as little as 1 microgram of total Cl.

Calc-alkaline lamprophyric dykes around the Lake George antimony deposit, New Brunswick: age constraints and petrogenetic aspects

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Several east-west trending, very steeply south-dipping narrow (<4 m wide) early Devonian lamprophyre dykes (414.4 ± 2.4 Ma; plateau $^{40}Ar/^{39}Ar$ phlogopite ± hornblende) are found on the Lake George property and many more occur along the southern boundary of the Pokiok Batholith (10 samples). The dyke (DDH 76-1OA-29.3m – sample 80-12) dated at Lake George is cogenetic with the Hawkshaw Granite in the multiphase Pokiok Batholith. These very fine-grained lamprophyric to coarse-grained dykes are hornblende and phlogopite phyric with abundant interstitial plagioclase and K-feldspar, and minor apatite, titanite, and Fe-Ti oxides with later carbonate, quartz, and pyrite (± chalcopyrite). Granophyric texture is common in the interstices. Argillic to sericitic alteration in these dykes is related to various episodes of Au-W-Mo and later Sb-Au mineralization in the area. Emplacement of the dykes seemed to immediately precede the Lake George granodiorite, based on cross-cutting relationships and earlier K-Ar dates. Based on this study (n=2 1) and an earlier compilation (n=3), these lamprophyric dykes are trachybasaltic to basaltic trachyandesitic in composition; they also have ultrapotassic geochemical characteristics with high MgO (4.7 to 13.4 wt. %), K (1.1 to 5.4 wt. %), and K (0.78 to 11.6), i.e. potassic to ultrapotassic (shoshonitic). The high LOI and CO_2 are consistent with secondary alteration rather than a primary feature, although the dykes are enriched in H_2O and CO_2. Their composition is consistent with chemical fractionation with decreasing Mg#, MgO, and FeO^t with compatible siderophile elements such as Cr and Ni, and increasing incompatible elements (Zr, Th, REE, Y). The Cr varies considerably from 170 up to 1100 ppm in the most primitive parts of these dykes. There is considerable evidence of host rock contamination with sedimentary xenoliths evident locally, especially near their margins. The Nb/Y ratio is also consistent with alkalic parentage. Overall, they have immobile-element geochemical characteristics consistent with within-plate tholeiitic to alkalic mafic magmas that have arc geochemical associations (low Ti, Y, Nb, and high U, Th, La, Ce) similar to lamprophyric dykes of calc-alkaline affinity associated with continental arcs, although transitional to a within plate signature. Typically, these magmas are derived from low degrees of partial melting of phlogopite-bearing metasomatized mantle in a suprasubduction zone setting. The emplacement of these magmas as dykes reflects the existence of mantle-tapping structures with a local extensional geodynamic setting.

Law of the sea and offshore geophysics

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Carving up of the sea floor during the next ten years is unprecedented in man's extension of his dominion over the Earth. At stake is over 75 million square kilometres, equal to more than half the Earth's land surface. It is also unprecedented because the claims are to be based on hydrographic and geological principles and are to be adjudged by a Commission comprised of "experts in the fields of hydrography, geodesy, geophysics, and geology". For the first time in international relations, the last word will not be with the lawyers.

According to the "*United Nations Convention on the Law of the Sea*" (UNCLOS), "States that believe to have wide continental shelves and a right to sovereign jurisdiction over the ocean floor up to 350 km offshore, can submit their claims to the "*Commission on the Limits of the Continental Shelf* (*CLCS*)". These submissions must be made within ten years of a state ratifying the Convention, or by November, 2009 for the states that ratified the Convention before 1999. Canada ratified the Convention on November 6, 2003, so our "date with destiny" is November, 2013.

To make a claim, Canada, and every other coastal state, must document the position of five lines on a chart: i) baseline (coastline); ii) 2500 m isobath; iii) "foot of the slope"; iv) "Gardiner line" (1% sediment thickness); and v) a 350M constraint line. In theory, defining these lines is not "rocket science", but because geology of the continent ocean transition zone is complex, it will require a massive data collection program and prudent judgment to make a successful bid.

The procedures for making a submission are clearly outlined by *CLCS* and our next task is well defined. It is to conduct a "desktop study" (in the *CLCS* parlance) to perform data mining on all the existing geophysical and geological data up to 350 nautical miles offshore to prove that we have grounds for a claim (appurtenance test). This will take several years even if we started yesterday. Then, it will take more years to acquire data to fill in identified gaps and a few more years to put it all together and make a submission. In the meantime the clock is ticking.

Heavy metal uptake and translocation in *Salix* (willow): potential as a phyto-remediation agent

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Salix eriocephala (black diamond willow) and *Salix petiolaris* (slender willow) were grown from strikings for approximately six months, and then subjected to five aqueous treatment levels of thirteen heavy metals (Cu, Pb, Zn, Mo, Ag, Ni, Co, Cr, As Sb, Cd, Se, Hg; primarily as acetate salts) for three months to assess the level of uptake and distribution of these elements. The –80 mesh (–177 µm) fraction of soils in which the plants were grown were subsequently analyzed in duplicate using aqua regia digestions and ICP-OES and ICP-MS analysis; triplicates of the new growth portions of these plants were dried (at 40°C and 10% humidity), mascerated and subjected to nitric acid/aqua regia digestions and ICP-OES and ICP-MS analysis. In addition, separate plant organs (roots, leaves, old bark, old twigs, new bark, and twigs) were also analyzed by similar biogeochemical methods.

Results reveal that most element concentrations in the soils generally correlate well with respective heavy metal concentrations administered, forming generally linear relationships. In the plants, with the exception of Ni, Sb, Zn, and Ag, element concentrations generally correlate well with the respective heavy metal concentrations administered, but correlate less well with the soil concentrations, probably because of variations in the relative partitioning of these experimental components.

Analyses of the five plant organs reveal that significant translocation of the heavy metals was achieved by the plants. Different elements appear to concentrate in different plant organs, illustrating that the plants have several specific controlling metabolic mechanisms that redistribute these elements within their tissues. For example, Cu, As, Se, Cd, and Hg accumulated strongly in the roots, Mo accumulated strongly in the twigs, and Zn, Ag, Co, Sb, Cd, and Cr accumulated moderately in the bark and to a lesser extent in the leaves.

Results indicate that willow could represent an effective phyto-remediation agent for many soils contaminated by heavy metals. Significant uptake by Salix during the growing season could effectively temporarily isolate the contaminants from the environment. Subsequent removal and treatment or recovery of heavy metals from the plant tissues could represent an effective remediation strategy that is far less costly and time consuming than traditional remediation efforts.

Biostratigraphic and paleoenvironmental implications of early Cretaceous macrofossils from offshore cores of the Scotian Shelf

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In offshore wells, microfossils are of great use in biostratigraphic and paleoenvironmental studies because of their abundance and preservation, even in cuttings samples. By comparison, body macrofossils usually receive minimal attention in offshore wells. We have surveyed macrofossil distribution in conventional cores from the Alma K-85 well, which samples the Cree Member of the Logan CanyonFormation and the Upper Mississauga Formation. Substantial numbers of well preserved body fossils occur. These include callianassid shrimp (probably the producer of associated *Ophiomorpha* traces), several species of bivalves and gastropods, echinoids, and, most significantly, several species of ammonite.

With careful observation of the body fossil assemblages, it is possible to recognize stenohaline versus euryhaline faunas, adding greater precision to interpretations from trace fossils and sedimentology alone. For example, the co-occurrence of echinoids and ammonites with other diverse macrofauna indicates normal marine salinities (stenohaline), whereas the presence of monospecific oyster faunas probably implies brackish/variable salinity environments (euryhaline). Furthermore, the presence of several identifiable ammonite species (e.g., *Hypacanthoplites clavatus* and ?*Barremites* sp.) enables direct correlation of the core sections with the ammonite zonation of the stratotype sections in Europe, providing independent calibration points for Scotian Margin microfossil zonations. As the first reported ammonites of this age north of Blake Nose and south of Greenland, ammonites also have implications for the paleoceanography of the northwest Atlantic Ocean in the Early Cretaceous.

Update on the McCully gas field, Sussex, New Brunswick

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The McCully Field lies 10 km northeast of Sussex, New Brunswick. It is comprised of an interbedded lacustrine sandstone and shale sequence of the Albert Formation. To date, seven wells have penetrated the field and all showed significant intersections of gas-bearing sandstones of varying reservoir quality. These seven wells indicate a very large original gas-in-place for the field. The primary challenge lies in the recovery percentage from these low permeability sandstone bodies.

The first two wells drilled in the field have been on production to the PCS potash mill since April of 2003. The McCully A-67 (#1) well produced 101 million cubic feet from start-up to December 31, 2003 out of one interval only. The McCully P-66 (#2) well produced 313 million cubic feet over the same time period from all intervals. Build-up tests and production graphs show that the well performance is strong, especially for the P-66 well. An independent engineering report assigned proven and probable reserves of 11.6 billion cubic feet to the P-66 well.

Studies and experience have shown that the McCully reservoir is very sensitive to water damage. This is due to the unusually low residual water saturations (RWS) in these rocks. Similar sandstones elsewhere have RWS of 40 to 50%, whereas the McCully sandstone RWS are in the order of 10%. This means that capillary forces in these rocks will imbibe any water from drilling or completion operations and not release it. The imbibed water blocks pore throats and prevents the movement (production) of gas. Of the seven McCully wells, only the bottom portion of the highly production P-66 well has not been subjected to some amount of water. Water will be avoided in the drilling and completion of future wells. A recent 3-D survey was shot to provide locations for future development wells and, if the data permits, illuminate fractured areas with higher production potential.

Micro-infrared spectroscopic analysis of emerald from Hiddenite, North Carolina

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Emeralds from the Rist tract, Hiddenite, North Carolina, occur within thin, steeply dipping quartz veins that cross cut high-grade metasedimentary rocks of the Inner Piedmont metamorphic belt. Gem-quality crystals are found in open, Alpine-type, fissures that are lined mainly with euhedral quartz and carbonate minerals. New micro Fourier transform infrared spectroscopic investigations have identified different types of emeralds based on the IR profiles of the valence modes of deuterated water molecules within the structural channels. Emeralds display up to five different absorption bands in the range of OD stretching vibrations between 2500 and 2900 cm^{-1}. The presence or absence of these bands can be broadly correlated to different emerald provenances. The micro-infrared spectroscopic analyses of Hiddenite emeralds in the OD stretching vibration range display broad similarities with emeralds from Carnaiba-Socoto, Brazil, Habachtal, Austria, and the Urals, Russia. Although previous work on North Carolina emeralds suggest a genetic relationship to granitic pegmatites, no evolved pegmatites were found to be temporally and spatially associated with the emerald-bearing quartz veins at the Rist property.

Bedrock of German Bank, southwestern Scotian Shelf: offshore continuation of the Meguma terrane

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Petrographical, geochemical, and mineralogical studies carried out on fifteen igneous clasts from German Bank, offshore southwestern Nova Scotia, indicate an offshore Meguma terrane provenance. Representative crystals of iron-titanium oxides (primarily ilmenite and magnetite) in nine granite samples were analyzed by electron microprobe accompanied by backscattered electron images. Of these nine samples, eight show a strong affinity to the magnetite-bearing granitoid rocks from three short drill cores obtained in 1976 from German Bank. Using variations in Rb, Nb, and Y, the eight granite samples were classified. Four of the samples classify as volcanic arc granites (VAG), three as within plate granites (WPG), and one on the field boundary that separates syn-collision granites (SYN-COLG) and VAG. Variations in Ta, Rb, and Hf resulted in two samples within VAG, two in WPG, two in late and post-collision granites (pCIII), and two on field boundaries: the VAG and WPG field boundary and the other on WPG and pCIII field boundary. The remaining sample, an ilmenite granite, shows mineralogical and geochemical characteristics of 'Meguma granites' (similar to granitoid rocks of the South Mountain Batholith) as the sample contains primary muscovite and biotite along with the Fe-Ti oxide ilmenite.

The gabbro sample showed similar variation in trace elements and rare-earth-elements as Triassic alkaline rocks of Nova Scotia, although both its chemistry and petrography are also consistent with a source from the White Rock Formation alkaline basalts which thus cannot be precluded. Of the remaining four samples, two are meta-igneous with no conclusive provenance, and the final two samples, granite and rhyolite, respectively show chemical affinities to Avalon-type WPG and porphyritic rhyolite of WPG affinity. These latter two samples are probably erratic blocks.

Trace-element systematics of massive sulphide deposits in the Bathurst Mining Camp, New Brunswick: implications for exploration

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Massive sulphides and iron formation in the Bathurst Mining Camp are hosted within a Middle Ordovician bimodal volcanic and sedimentary sequence. Complex polyphase deformation and associated lower- to upper-greenschist grade, regional metamorphism are partly responsible for the present geometry and textural modification of these syngenetic-exhalative deposits. Despite heterogeneous ductile deformation, the hydrothermal architecture has been preserved in many deposits, with base-metal and trace-element zonation evident in massive sulphide lenses.

Major and trace elements, including rare-earth elements (REE), were determined for 212 samples of massive sulphide from 41 deposits. Overall, ∑REE concentrations average 34.0 ppm, exhibit a strong Spearman Rank correlation with Y (r' = 0.86), and a strong positive Eu correlation with P (r' = 0.71), indicating the presence of accessory minerals such as xenotime and apatite. Chondrite-normalized REE profiles for massive sulphides exhibit a consistent positive Eu anomaly (Eu/Eu*) averaging 6.0 with values as high as 30.4, and correlating with In (r' = 0.50) and Sn (r' = 0.60).

Variations in the REE signature of exhalative sediments with respect to hydrothermal centers have been shown to be a valuable vectoring tool in the exploration for massive sulphide deposits. Strong inter-element correlations between Al_2O_3, TiO_2, Zr, Sc, Th, Hf, and Nb in massive sulphide samples from the Bathurst Mining Camp indicate variable detrital and pelagic input (mass change effect), which may mask low abundance hydrothermal components like the REE. Using these immobile elements as monitors, and testing Yb (HREE) immobility, the mass contribution from intercalated terrigenous sediments can be calculated, accounted for, and stripped revealing the net hydrothermal contribution to exhalative sediment. Ytterbium-based mass balanced REE data from the Heath Steele B zone reveals a strong increase in Eu/Eu* in the proximal bedded sulphide facies with anomalies as high as Eu/Eu* = 1767, due to lower HREE and LREE contents. The underlying chalcopyrite-pyrrhotite-rich zone contains higher REE contents and a smaller Eu/Eu* (average = 18.0), likely a result of REE saturation during high temperature-low pH fluid reaction (cooling, neutralization, and exchange) during zone refining of the massive sulphide system. From an exploration standpoint, resolving the stratigraphic distribution of REE in massive sulphide deposits is beneficial for targeting hydrothermal centers.

Significance of early Devonian animal fossils from the Campbellton Formation, New Brunswick

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The early Devonian Campbellton-Atholville fossil locality, known for its fauna of ostracoderms, arthrodires, acanthodians, and chondrichthyans, has produced interesting specimens since it was discovered in 1881. New specimens suggest the locality still has much to offer. Recently discovered pterygotid eurypterids are tentatively identified as *Pterygotus anglicus* Agassiz. Although a significant collection of pterygotids was sent to the Natural History Museum, London in 1892, they have received little attention. Only a few fragments of *Pterygotus* from the Geological Survey of Canada collection have been described. In 1912 they were described as a new species, *P. atlanticus* and it was suggested it might be a small form of *P. anglicus*. Recently discovered specimens, including one relatively complete individual, indicate they might have been correct and may provide evidence of *Pterygotus anglicus* in North America.

Over the past several decades discoveries of early-middle Devonian chondrichthyans from Gondwanan or neighbouring terranes have lead to suggestions of a Gondwanan origin for sharks. However, tooth fossils of *Doliodus problematicus* described in 1892 from Campbellton presented a problem. Recent descriptions of teeth and a newly described articulated specimen of *D. problematicus* from the Campbellton Formation confirm the species as a shark, not an acanthodian as sometimes suggested. A second presumed shark, *Protodus jexi*, described in 1892, occurs in the same beds. Fin-spines from the same locality, identified as *Climatius latispinosus*, have been problematic since they were first described. Once considered as acanthodian, they are quite possibly chondrichthyan and attributed to *Doliodus problematicus*, the first shark known to have possessed paired fin-spines. If this interpretation is correct early sharks were possibly more widespread than previously thought, as early Devonian fin-spines from other localities assigned to acanthodians might also belong to sharks.

Geochemistry and mineralogy of tailings at the Cochrane Hill gold district, Nova Scotia

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Since the first Nova Scotian gold rush in the early 1860s, gold mining and milling processes have generated tailings piles containing mercury, arsenic, cyanide, and other potentially toxic elements. Most of the gold deposits occur in the Cambro-Ordovician Meguma Group of southern Nova Scotia, and mining has been carried out at more than 60 formal gold districts for a total production of 47 of gold. The Cochrane Hill gold deposit is located in Guysborough County, approximately 15 km north of Sherbrooke. The host rocks consist of amphibolite-facies quartzite and slate, and most of the gold is associated with quartz veins that intrude slate rich in arsenopyrite: Mining and milling of gold ore at Cochrane Hill took place from 1877 to 1928, and again from 1981 to 1988, resulting in two separate tailings piles. During the first period of operation, stamp milling and mercury amalgamation were used to extract gold from the ore, and the tailings were slurried into a local drainage. In the 1980s, ball milling and cyanidation were used to process the ore, and the tailings were deposited into an on-site impoundment.

The main objectives of this study are to: (1) characterize the mineralogy and metal concentrations in the two tailings piles; (2) assess the relative reactivity of metals and metalloids in the amalgamation versus cyanidation tailings; and (3) examine the downstream impacts of drainage from the tailings piles. Forty five samples of tailings were collected from 16 different sites at Cochrane Hill in September, 2003, and water samples were collected at 12 locations within and downstream of the tailings in November, 2003. Efflorescent salts were also collected from the surface of the cyanidation tailings, and stream sediments were collected to determine the distance that tailings have been transported downsteam. X-ray diffraction, scanning electron microscopy, and electron microprobe analyses have been completed on select tailings samples. The primary mineralogy of the tailings includes muscovite, biotite, staurolite, quartz, anorthite, and actinolite/tremolite. Geochemical results show that the amalgamation tailings contain significantly higher Hg concentrations (21–63 000 ppb) than the cyanidation tailings (<5–25 ppb). Both tailings piles also contain high concentrations of As (280–41 000 ppm), which occurs naturally in the ore. As a result, windblown tailings and runoff from the tailings disposal areas may have a significant adverse effect on the surrounding environment. Future work will include additional electron microprobe analyses and analyses of the water chemistry data using computer models.

Avalon-Meguma relationships in the Paleozoic: implications for the development of the Appalachian orogen

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The Paleozoic evolution of the Avalon and Meguma terranes is crucial to the understanding of the Appalachian orogen and the Iapetus and Rheic oceans. In the Avalon terrane of Nova Scotia, Ordovician-early Devonian rocks consist of bimodal volcanic rocks at the base (Dunn Point Formation) disconformably overlain by ca. 1900 m of fossiliferous siliciclastics (Arisaig Group) which contain Llandoverian to Lochkovian fossils. U-Pb zircon data from a rhyolite yields an age of 460.0 ± 3.4 Ma for the Dunn Point Formation, and together with paleomagnetic data suggest development on a microcontinent at 30°S, outboard from both Laurentia and Gondwana, possibly in a rifled arc setting. Geochemical, Sm-Nd isotopic tracer, and detrital zircon age data for Arisaig Group clastic rocks contrast with underlying Avalonian units, indicating a provenance source other than Avalonian basement. All sedimentary rocks are characterized by negative ε_{Nd} (from -4.8 to -9.3), T_{DM} >1.5 Ga, abundant Neoproterozoic-early Cambrian zircons (ca. 620–520 Ma), with lesser concentrations at about 0.9–1.2 Ga and 1.5 to 2.2 Ga. Archean zircons are very minor. The Arisaig Group is inferred to be primarily derived from Baltica-Laurentia, with increasing input from more ancient basement in the early Devonian.

Detrital zircons from coeval strata (White Rock and Torbrook formations) of the Meguma terrane contain zircon populations that are similar to Avalonia and strongly suggest contiguous rather than discrete Paleozoic histories for these terranes throughout the Paleozoic. In addition to abundant Cambrian-late Neoproterozoic and Paleoproterozoic zircons, late Ordovician-early Devonian samples have important Mesoproterozoic zircon populations (1.0 to 1.4 Ga), that strongly suggest contiguity with Avalonia by the late Ordovician-early Silurian. These coeval clastic rocks are interpreted to have been deposited adjacent to the trailing edge of Avalonia-Meguma during Appalachian accretionary events. As Avalonia had accreted to Laurentia-Baltica by the late Ordovician, these data suggest that the Meguma terrane also resided along the same (northern) margin of the Rheic ocean at that time. This interpretation is supported by the absence of a Cambro-Ordovician accretionary event, the lack of intervening suture zone ophiolitic units, and the similarity of Avalonian and Meguma basement Nd isotopic signatures in Paleozoic igneous suites. This conclusion implies that the Siluro-Devonian Acadian orogeny was not related to collision of the Meguma terrane with the Laurentian margin. Instead, we suggest that the Acadian orogeny occurred in an Andean-type setting.

Modelling the thermal sensitivity of shallow organic lakes in Nova Scotia

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Most freshwater lakes in Canada are small (<4 ha.) and shallow (<6 m av. depth). To interpret lake sediment records in terms of fluctuating climate it is necessary to understand contemporary processes operating in these lakes and within their catchments. As well, although these lakes comprise a significant habitat for a wide variety of species, very little is understood about how climate change will affect the physical state of these lakes. Canoran Lake, Lunenburg Co., and Sandy Lake, Annapolis Co., have similar volumes, areas, and elevations but have unique basin morphometries. Datalogged thermistor strings were placed in the littoral and profundal zones of both lakes and data was collected hourly from May – August, 2003. Thermistors were also placed in the canopy surrounding the lake to monitor air temperature change. The physical (morphometric) character of each lake was determined using 50 khz sonar and the water quality characteristics (in particular lake trophic state) were determined using a wide variety of standard analyses.

Sonar results indicate that these lakes have very different morphometries though surface areas and volumes are almost the same. Preliminary thermal results indicated that these two lakes reacted uniquely to thermal variation. For instance, during a rapid 10°C temperature decline (a low-pressure system influx) Sandy Lake mixed to a 5 m depth within a 24 hour period whereas only the top 3 meters of Canoran Lake mixed over a period of 50 hours. During the subsequent temperature increase (high-pressure influx) Sandy Lake stratified more rapidly than Canoran Lake. Littoral temperatures in both lakes warmed from about 15 to 25°C during the study period. Profundal lake temperatures remained nearly constant in Canoran Lake but increased consistently in Sandy Lake; at both sites profundal temperatures were unaffected by short-term thermal variation. These results indicate that Sandy Lake is more sensitive to summer air mass circulations changes, possibly as a result of its larger and largely unvegetated littoral zone. Though these changes are subtle, they are anticipated to have a significant affect on productivity. Thermal sensitivity models based on this data will allow ecologists to better understand how the lakes (as habitats) will evolve and are essential to the implementation of species monitoring and conservation programs.

The alteration of ilmenite in the Cretaceous sandstones of Nova Scotia

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Detrital ilmenite, generally in the form of its alteration products pseudorutile, leucoxene, and rutile, is widespread in the Chaswood Formation of Nova Scotia and its offshore equivalents in the Mississauga and Logan Canyon formations. This alteration is an important source of Fe for diagenetic minerals. Placer rutile is a potential ore mineral for titanium.

In borehole RR-97-23 in Elmsvale Basin, pseudorutile is the commonest alteration mineral; in boreholes from Shubenacadie, ilmenite, pseudorutile, and leucoxene are all abundant; whereas sands from the West Indian Road pit contain mostly leucoxene. Rutile is common only at the extreme base of the Chaswood Formation (where highest vitrinite reflectance and most lithification are found). In offshore wells, ilmenite is sparse and rutile dominant, with no pseudorutile or leucoxene.

The mineralogical changes involved were tracked using electron microprobe analyses, backscattered electron images, and X-ray maps. Ilmenite grains (Ti/Ti+Fe <0.48) alter patchily to pseudorutile (Ti/Ti+Fe = 0.5–0.7) with volume loss, forming a porous structure and this process continues with the development of leucoxene (Ti/Ti+Fe = 0.7–0.9). Within the pseudorutile and leucoxene, slender crystals of rutile develop, eventually forming a trellis-pattern parallel to the crystal orientation of the original ilmenite grain, leaving empty spaces between them. In more altered crystals, stubby prismatic rutile crystals also appear. Si and Al occur in the altered ilmenite, either (a) inherited from original quartz and muscovite inclusions in the parent crystal or (b) as kaolinite altered from muscovite inclusions or precipitated in the pore space, presumably under pedogenic or early diagenetic conditions.

Four styles of Cretaceous early diagenesis are recognized in the Chaswood Formation: (1) dark grey organic-rich mudstones with pyrite and siderite; (2) oxisols with pedogenic development of kaolinite and hematite; (3) thick porous gravelly sands with limonite and goethite hard pans below intraformational unconformities; and (4) light grey mudstones with development of kaolinite beneath the water table from percolating meteoric water. These four environments show progressively increasing alteration of pseudorutile to leucoxene, with much of the pseudorutile developed during source area weathering or transport. In environment (4), most leucoxene was converted to rutile. Burial diagenesis (to vitrinite reflectance values >0.4%) may not alter ilmenite, but changed pseudorutile and leucoxene to rutile.

Subsurface geometry of the Gaspé Belt in the Matapédia area (Québec): complex or simple?

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Seismic campaigns conducted by the MRNQ from 2000 to 2002 across the Gaspé Belt in eastern Québec provide high quality geophysical data. Preliminary MNRQ interpretation of these lines have shown an unexpected geometry at depth where Silurian rocks are affected by blind thrust duplexes and involved in a thin-skinned tectonic wedge that strongly contrasts with the structural style documented on surface for Devonian rocks.

As part of a GSC Targeted Geoscience Initiative-2 project, a new analysis of the seismic lines located in the Matapédia area (Québec) has been initiated. Prominent seismic discontinuity surfaces found within a highly reflective seismic unit that were interpreted as thrust faults are tentatively reviewed as sedimentary system tract boundaries. This alternative interpretation, which is presently tested by the reprocessing of key line segments, suggests that part of the lower Silurian sedimentary succession takes the form of stacked late highstand to lowstand clinoforms prograding to the southeast. If confirmed, the overall geometry would be relatively simple and would not imply a complex stacking of tectonic units or several phases of shortening.

Other key points of the seismic interpretation are as follows: 1) deformation is distributed along more faults than previously recognized, especially within the Lac Mitis syncline; 2) aerial photo interpretation as well as surface data suggest that the faults strike N60- 75°E; 3) northwest-verging faults predominate, but southeast-verging structures are also present and may be interpreted either as backthrusts or part of strike-slip flower structures; 4) some faults clearly cut the entire basin infill and offset the Taconian unconformity; 5) décollement level, if any, is not imaged; 6) sedimentary thickness changes are obvious across some faults suggesting either syn-sedimentary faulting or juxtaposition of different part of the basin by strike-slip faulting; 7) an unconformity attributed to the Salinic event is locally well-imaged; 8) high-amplitude seismic reflectors are found below the thin Silurian cover sequence that forms the Matapédia syncline. The project's objective is now to better define the sub-surface geometry by a multi-disciplinary approach including the reprocessing of some line segments, field verification and the integration of new high resolution aeromagnetic and gravimetric data.

The effects of strike-slip motion along the Cobequid-Chedabucto-SW Grand Banks fault system on the Cretaceous - Tertiary evolution of Atlantic Canada

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The Newfoundland fracture zone, the SW Grand Banks transform, and the Cobequid - Chedabucto fault zone form a linked strike slip fault system from the Atlantic Ocean to southeastern Canada. Geological evidence suggests a history of reactivation of the Cobequid - Chedabucto - SW Grand Banks fault system after the fault zone ceased to mark the transform northern margin of the Atlantic Ocean in the late Jurassic. The oldest Fogo Seamounts predate sea-floor spreading in the Newfoundland basin and their OIB chemical composition and age progression support an origin related to a hotspot. Their early Cretaceous age is synchronous with the Avalon unconformity, deposition of the Mississauga Formation in the Scotian basin, and the older basins of the Chaswood Formation. In Aptian to Albian time, more tholeiitic volcanism in Orpheus graben and on the Grand Banks is synchronous with formation of syn-sedimentary basins in a strike-slip regime in central Nova Scotia in which the upper parts of the Chaswood Formation accumulated. Rapid subsidence occurred on the Scotian margin at this time, and a little later (Albian to Cenomanian) on the deep water margin off the SW Grand Banks, as shown by ODP Site 384 and the Narwhal F-99 well. This subsidence was synchronous with an erosional unconformity on the southwest Grand Banks. These various phenomena can be linked if there was mid-Cretaceous dextral strike-slip motion on the Cobequid - Chedabucto - SW Grand Banks fault system, with extension in the releasing bend. In the Oligocene, sinistral strike-slip reactivation of the Cobequid - Chedabucto - SW Grand Banks fault system could account for the regional uplift of the eastern Scotian Shelf at that time and late deformation of the Chaswood Formation. Offsets in magnetic anomalies in the North Atlantic basin are consistent with these proposed motions.

Potential granitic aggregate sources in the Halifax Regional Municipality area

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A detailed assessment to evaluate bedrock aggregate potential in and around the Halifax Regional Municipality (HRM) is a follow- up project to the larger aggregate program developed by the Resource Evaluation section of the Department of Natural Resources. This assessment was focused on HRM because the current resources in this area are being continuously depleted by the rapidly increasing aggregate demand of the construction industry. Concurrently, the availability of resource land which could replace aggregate reserves is shrinking due to urban growth and associated land use constraints. Recent attempts to permit new quarries have been unsuccessful. If present trends continue, access to the resource will ultimately disappear.

In this project the granitoid lithologies in the South Mountain Batholith are evaluated for two reasons: 1) its proximity to HRM, and 2) the distribution of rock units within the batholith are well mapped and documented. During the 2002 and 2003 field seasons, detailed examinations of outcrops along highways and side roads were conducted in the HRM area. Observations included rock identification, determination of overburden type and thickness, and geological features present (e.g., degree of weathering, dykes, flow alignment and foliations, fractures, mineralization). These features are important as the quality is directly related to physical and chemical properties of the aggregate, which are a result of its geological origin, mineralogy, and subsequent structural deformation and alteration. Petrographic examinations were carried out on 30 hand specimens and thin sections to determine the quality of the rock by identification of microfractures, grain size, strained quartz, mineral alteration, and mica content, as well as the intensity of iron and manganese oxide staining on fractures. All samples were slabbed and stained for potassium feldspar. Thin sections were point counted to quantitatively determine the rock name and percent deleterious components. The petrographic features will be compared to aggregate test results on the samples to determine if these characteristics can be used to assess aggregate quality.

In order for a particular rock type to be considered as a high-quality aggregate for industrial use, it has to pass rigorous physical and chemical testing and procedures. However, a detailed petrographic assessment prior to these costly tests may quickly eliminate certain sites for aggregate use and promote others. Ultimately these data will be used as a template for resource evaluation in similar lithologies in Nova Scotia.

Ethnic profiling of William Henry Twenhofel, the father of sedimentology, by Canada during World War I

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William Henry Twenhofel (1875–1957) did not even begin his geological training at Yale University until age 32 in 1907. He then completed a BA, MSc, and PhD in five years, with his 1912 PhD being done on the geology, stratigraphy, and physiography of the Ordovician Silurian sediments of Anticosti Island at the mouth of the St. Lawrence River. During the field season of 1909 he walked 700 miles to circumnavigate the entire island. After a brief period at the University of Kansas, he moved in 1916 to the University of Wisconsin in Madison where he became a full Professor in 1921. It was here he published his main works, *Treatise on Sedimentation*, *Invertebrate Paleontology*, *Principles of Sedimentation*, *Methods of Study of Sediments*, and *Principles of Invertebrate Paleontology*.

In 1918 he applied to again visit Anticosti Island in June for more geological field work. He was turned down, and I expect he never knew why. The Canadian Naval Intelligence Report, once a classified document, shows that he was banned because his parents in Kentucky were originally German immigrants (in 1869, some 49 years earlier!), because Twenhofel was reported to have been outspoken about German/U.S. issues prior to the American entry into WW I in 1917, and because of "the well known fact of the amount of German influence in Wisconsin."

This long-classified footnote to Canadian geological history is particularly poignant in today's climate of hysteria about terrorists and 'WMD's. We must ask ourselves whether geoscientists with Middle Eastern, Arabic, Palestinian, or other foreign names, or with Muslim or other non-Christian religious backgrounds, are now subject to the same ethnic profiling in our own society; the same society that delayed Twenhofel's groundbreaking work on the 'passage-beds' that mark the Ordovician-Silurian boundary on Anticosti Island. Ethnic profiling, like geology and its geophysical signatures, does not respect national boundaries, and seemingly has been an operative process, even for geologists as early as WW I.

Thankfully, despite the 1918 setback, Prof. Twenhofel was soon back on Anticosti Island recording the careful observations that characterized his work, for example "Certain bays ... again of Anticosti in 1919 were inhabited by thousands of sea urchins, while other bays were found in which there were few or none". His classic work, *Geology of Anticosti Island* was published by the Geological Survey of Canada.

The Joggins Formation: sedimentological log and stratigraphic framework of the historic fossil cliffs

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The Pennsylvanian Joggins Formation crops out along the southern shore of Chignecto Bay, where the world's highest tides expose these strata in a series of 20-m-high sea cliffs and a 500-m-wide wave-cut platform. Although widely recognized as the world's best exposure of coal-bearing Carboniferous strata, the only formal measured section has remained the written description by Sir William Logan.

Over the last 160 years Logan's log has been touted as a detailed "bed-by-bed" section made during the first field project of the Geological Survey of Canada. Reviewing Logan's original field notes reveals that this idealized portrayal misrepresents what the log really came from – one man's hard work during a three day period in June 1843. Logan's notes also show that although he measured coal seam thickness to fractions of an inch, the thickness of interbedded clastic intervals was calculated by pacing their extent along the foreshore and correcting for tectonic dip.

We built upon Logan's pioneering work by remeasuring the Joggins Formation in its entirety and constructing a detailed sedimentological log. An accompanying map uses log meterage to identify the stratigraphic position of prominent sandstone 'reefs' exposed on the wave-cut platform. In the course of this documentation, we present formal revisions to the definition of the Joggins Formation, and provide an overview of cyclicity, depositional setting, and recent fossil discoveries. Hopefully, the upcoming publication of this measured section will aid in locating the exact position of future fossil discoveries and encourage further scientific research on this magnificent and historic section.

Determining the long-term persistence of Hg releases to the environment from cyanide rich gold-mine tailings

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Mining operations that utilize cyanide (CN) for the recovery of gold may mobilize mercury (Hg) from natural sources in the gold ore. Residual CN in mine tailings may result in the formation of soluble Hg-CN aqueous complexes in the pore waters that leach from the tailings and are transported to the surrounding environment. The Murray Brook gold mine, located in northern New Brunswick, represents an example of this type of Hg contamination. Quantification of the initial total mercury (Hg_T) and total cyanide (CN_T) concentrations in the tailings solids indicates heterogeneous concentration profiles versus depth, with peak values of 39.5 mg Hg/kg and 9.5 mg CN/kg. In this case, Hg mobility is intimately linked to the presence of CN. We are assessing the long-term persistence of Hg releases by studying the controls on CN losses from the tailings with a series of in situ and laboratory-based investigations.

Cyanide may degrade oxidatively through reaction with O_2 in the pore gas, and Hg may escape from the tailings in the volatile Hg^0 state. Therefore, a monitoring program for tailings pore-gas concentrations was implemented to investigate the flux of O_2 into the pile and Hg^0 from the pile. Measurements were made near the centre of the pile at 1 m intervals to a depth of 15 metres. Consistent trends were observed through time over a period of 1 year for both O_2 and Hg^0. Contradicting the initial hypothesis that downward diffusion of O_2 from the atmosphere replenishes O_2 consumed by CN degradation, the profiles display relatively high O_2 concentrations at depth, suggesting that downward diffusion is not the controlling mechanism of O_2 transport. The Hg^0 pore-gas concentration profiles are erratic versus depth, and do not provide strong support for the hypothesis that Hg^0 diffuses outward from the pile to the atmosphere.

Loss of Hg and CN from the pile may also occur through leaching with infiltrating meteoric water. Laboratory-based column experiments were designed to quantify the amount of Hg_T and CN_T that could potentially be leached. Initial aqueous effluent concentrations from the columns reached maximum values of 12 900 µg Hg/L and 16 000 µg CN/L. The concentration versus time profiles display an initial rapid decline, followed by a prolonged period of asymptotic concentration decrease. In order to assess the longevity of Hg and CN leaching from the tailings pile, numerical modelling will be conducted to scale the experimental results to the field scale.

Late Paleozoic-early Mesozoic volcanism in the Semenof Hills of south-central Yukon, northern Canadian Cordillera

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The poorly known volcano-sedimentary sequences of the Semenof Hills in south-central Yukon lies within the belt of pericratonic terranes that extends between ancestral North America, and the accreted oceanic and arc terranes of the northern Canadian Cordillera. Recent bedrock mapping and new geochronological studies of the southern Semenof Hills reveals the presence of four exceptionally well-preserved volcano-sedimentary sequences that spread from late Paleozoic to early Mesozoic age.

The Moose Formation, Devonian in age, is composed of massive to pillowed fine-grained basaltic lavas of N- and E-MORB composition, overlain by discontinuous quartz-feldspar-phyric felsic volcanic rocks of earliest Mississippian age. These rocks are probably related to the development of a back-arc system.

Unconformably overlying the Moose Formation, is the Semenof Formation, composed in the south of thinly bedded fragmental volcanic rocks interbedded with a few calcareous horizons which yielded detrital zircons with Devonian to late Triassic ages, and in the north of massive plagioclase- and clinopyroxene-phyric, locally amphibole-phyric andesitic lava flows interbedded with minor clastic layers and volcanic conglomerates intercalated with minor porphyritic andesitic lava flows. These flows have chemical characteristics of calc-alkaline rocks of island-arc suites. The northern part of the Semenof Formation represents very proximal facies within the arc system with abundant porphyritic lava flows and volcanic conglomerates. The southern part represents a more distal part with the thinly bedded fragmental volcanic rocks interpreted as megaturbidite sequences typical of an unstable volcanic environment.

The third sequence, thrust on top of the Semenof Formation, consists of massive to pillowed basaltic lavas and mafic volcaniclastic rocks, overlain by discontinuous fossiliferous late Pennsylvanian to early Permian limestone. The volcanic facies observed in the mafic volcanic rocks suggest submarine volcanism, probably related to ocean-floor spreading or back-arc basin formation.

The last sequence, the Boswell Formation, is mainly composed of clastic rocks, sandstone and chert-rich conglomerate, with minor volcaniclastic rocks, overlain by fossiliferous Pennsylvanian limestone. This sequence probably represents marginal basin sedimentation.

The Semenof Hills rocks record a unique succession of back-arc and island-arc volcanism from late Devonian to early Jurassic time. The rocks of the back-arc succession of Devonian and Pennsylvanian to early Permian age are likely equivalent to those found in the pericratonic Yukon-Tanana terrane. The Early Jurassic island-arc volcanic rocks are more likely part of the Mesozoic Stikine or Quesnel terrane. Therefore, the pericratonic Yukon-Tanana terrane is probably the basement of parts the Mesozoic Stikine and/or Quesnel terranes in central Yukon.

The development of deep towed marine seismic systems in Canada, 1970 – present

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The extension of geophysical seismic techniques into the offshore regions in the 1960s involved the application of traditional land based technology in a marine environment. For hydrocarbon exploration, techniques using explosives as seismic sources were initially adapted for marine use and large towed seismic arrays were developed as seismic detectors with appropriate multi-channel recording. However, the scaling down of these techniques enabled shallow sediments to be delineated to a degree of resolution not previously possible on land. The desire to map the extensive continental shelf areas of eastern Canada and the Arctic Ocean attracted the interest of several Canadian groups with both commercial and academic interests in mind.

In the early l970s Huntec '70 Limited of Toronto and the Nova Scotia Research Foundation in Dartmouth set off on separate paths to address the engineering and technical issues surrounding the collection of seismic profiles in deep water under open ocean conditions. Both these programs were heavily funded by various government agencies and both were technical successes to a level that has not been superseded today.

This paper will trace the development of the Huntec '70 deep towed profiler and the Nova Scotia Research Foundation deep towed Sparker from their inceptions in the early '70s up to the present day.

The nature and chronology of alpine glaciation in the Tablelands, Gros Morne National Park, western Newfoundland: preliminary results

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Alpine glacial features have long been known to exist in the highlands of western Newfoundland; however, little is known of their age or mode of formation. Of particular interest is the Tablelands plateau, whose steep NE and SW flanks are incised by cirques and small U- shaped valleys. Research over the past three years has resulted in a more comprehensive model for glaciation and landform development in this region.

Rock glaciers on the flanks of the Tablelands are of the cliff-base variety. Original ice cores in these features are indicated by closed depressions behind terminal crests. None show any signs of recent activity. The Devil's Punchbowl cirque shows considerable accumulation of colluvium which demonstrates a pre-Neoglacial age for occupation of the cirque by active ice. The cirque moraine is 20 to 25 m high on its proximal flank and 0 to 8 m high on its distal flank. It is not a protalus rampart because (a) it bulges away from the cirque headwall instead of paralleling the base of the headwall, (b) it contains a considerable volume of fines, and (c) the requisite snowbank would have a very low gradient. A black to grey peridotitic, well-consolidated, matrix-supported diamict ("Grey Fill") was found underlying colluvium, rock glacierized sediment and talus in all tributary valleys investigated and was also found to extend into the main trunk valley. This sediment is till that was formed by a variety of processes which may have involved cycles of lodgment, deformation, and meltout, consistent with deposition in a wet-based, high gradient environment. Cosmogenic dates on boulders situated on the moraines and rock glaciers indicate that these features and the underlying Grey Fill were formed prior to 18 kyr and that last glacial maximum (LGM) ice did not extended into Trout River Gulch. These data indicate that many of the glacial features on the Tablelands are older than previously thought and that significant areas remained ice free during LGM.

Numerical transformations in geochemical data: objectives, philosophy, and methods to improve information extraction and data presentation

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Concentration data derived from geochemical surveys are commonly evaluated using numerical techniques designed to facilitate data interpretation. Numerical transformations are sometimes used to impart new characteristics to the data that facilitate evaluation. Historically, geochemical data have been transformed for three reasons; these cause the transformed result to: (1) exhibit a 'normal' or 'nearly normal' distribution so that statistical techniques requiring normality assumptions can be applied, (2) exhibit a measurement error that is constant across the range of the data so that data evaluation is undertaken on a 'level playing field', or (3) exhibit the maximum geochemical contrast (variance) within the data so that all of the information contained therein can be recognized.

Unfortunately, little consideration has historically been given by geochemists to the reasons for data transformation. As a result, data transformations have sometimes been applied inappropriately, and have resulted in numerous examples of poor or misinterpretation of geochemical data. For example, many geochemists believe that use of the logarithmic transformation will 'normalize' most trace element geochemical concentration distributions so that parametric statistical procedures can subsequently reveal new information in the data. Unfortunately, most geochemical data distributions are multimodal because they derive from several lithologic sources. As a result, no monotonic transformation can hope to convert such a distribution into one approximating a normal distribution, and transformation for purpose (1) above is misguided.

Geochemical data are subject to measurement errors whose magnitudes change across the range of the data. Data interpretation can be complicated by the unequal treatment that the geochemist must employ to accommodate these data feature during evaluation. As a result, data stabilizing transformations that produce new variables whose propagated measurement error is constant (homoscedastic) can afford the geochemist substantial advantage [purpose (2) above], because the newly transformed data can then all be treated the same. Variance stabilizing transformations for common sampling and analytical error distributions such as proportional, binomial, and Poisson errors are the logarithmic, the angular, and the square root transforms respectively.

Superior geochemical data analysis involves extracting all of the embedded information. Improving geochemical contrast is one method for achieving this end, and power transformations can oftentimes achieve this result; powers >1 typically increase skewness and variance, whereas powers <1 typically decrease skewness and variance. Because the variance is a measure of geochemical contrast, transforming data using a power function cannot be used to maximize variance, because it will always increase if a higher power transform is used. However, if the data have been scaled to the interval 0 to 1 beforehand, the power transform will not change the data range. Thus, after scaling to 0 to 1, a power can be identified that will obtain a distribution at maximum variance, and will thus provide the most information available [purpose (3) above]. Examples of variance stabilizing and geochemical contrast maximizing transformations applied to regional datasets reveal the advantages in transforming geochemical data for these purposes.

Late-glacial ice advances in Maritime Canada

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Maritime Canada can be considered a canary in the coal mine of climate change, especially at the end of the last glaciation, when it was situated between the Laurentide Ice Sheet (LIS) and the North Atlantic. Three ice advance events at the end of the last (Wisconsinan) glaciation are recorded in the stratigraphy of this region. Starting about 17.0 ka (all calibrated ages) there was a major period of ice retreat, followed by readvances of several local ice caps with terrestrial and marine margins. The oldest, termed the Chignecto Phase, is dated between 15.2 and 16.0 ka and is roughly correlative with the Port Huron event of the mid-continent and the "oldest" Dryas in Europe. After this there is evidence for a short-lived re-advance dated about 13.5 and 14.0 ka (Shulie Lake Phase) correlative with the "older" Dryas.

The next major event was the advance of remnant glaciers during the Younger Dryas (YD) termed the Collins Pond Phase (~13 ka). A paleosol formed during the warming phase is preserved under surface tills, best exposed during an excavation for the Sable Island Gas Pipeline in 1999. The YD glacier margin is marked by ice-marginal lakes north of the Cobequid Highlands of Nova Scotia, and a series of glacial lakes dammed against the highland-rimmed west coast of Cape Breton Island. A 30–40 km re-advance of an ice cap centred around Prince Edward Island in the Gulf of St. Lawrence is indicated. These paleosol sites and 20 other buried wood and peat organic horizons throughout Nova Scotia allow an accurate reconstruction of YD glacier limits and provide a robust radiocarbon chronology of deglaciation.

The University of Maine Ice Sheet Model (UMISM) was used to analyze the conditions necessary for a field-based conceptual model of paleo-ice dynamics in the Gulf of St. Lawrence. The model produced a strikingly similar configuration to the empirical glaciation model of the Collins Pond Phase using a slightly modified modem climate and the GRIP ice core temperature proxy record scaled by 1.5. The Gulf of St. Lawrence region may have been the locus of increased snowfall and amplified cooling during the Younger Dryas, and during previous cold periods, as a result of deflection of the jet stream by semi-permanent high pressure cells over the LIS and sea-ice covered North Atlantic ocean.

Early Cretaceous outliers in northern Nova Scotia: the fault connection

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This project was designed to evaluate the stratigraphy, sedimentology, and provenance of terrestrial early Cretaceous outliers in Nova Scotia with the goal of assembling a paleogeographic reconstruction of that time period, linking onshore deposits with offshore basins. The study is in part funded through the Exxon/Mobil Sable Project, Petroleum Research Atlantic Canada, and NSERC. Oil and gas reservoirs have been found in the deltaic facies of early Cretaceous depositional basins offshore and further exploration and reservoir development will be enhanced by a more complete picture of paleo-drainage and fluvial systems and their detrital petrology. The Cretaceous outliers host deposits of silica sand (presently mined in both Nova Scotia and New Brunswick) and kaolin, and further drilling may uncover new deposits of these valuable industrial minerals. With these goals in mind the research team has designed a project to compile existing sources of data and obtain new data in the "hidden" Cretaceous basins of Nova Scotia.

Two outliers were drilled at Belmont, Colchester County, and Brierly Brook, Antigonish County. Seven holes were drilled at the Brierly Brook area and the known area of outcrop was extended from a single exposure to an open-ended, linear belt of occurrences 3 km long along the northern edge of the Antigonish Basin. Up to 40 m of interbedded silica sand, organic stony clay, and variegated silty clay were encountered in the narrow ~100 m wide outcrop belt. Preliminary pollen analysis implies an early Cretaceous age for the organic clay. At Belmont, three holes were drilled, in a north-south transect across the outlier, with the northernmost two holes encountering 30 m of Cretaceous sediments. Reconnaissance mapping of bedrock and water wells of the area shows a linear east-west belt of occurrences, associated with a deep trough of unconsolidated sediment and an east-west trending fault in Triassic bedrock.

There is increasing evidence that the early Cretaceous strata are preserved in downfaulted blocks along fault zones that define the margins of highland regions in Nova Scotia. Late-Mesozoic dextral slip on the Cobequid-Chedabucto -

SW Grand Banks fault system can account for the observed deformation of the Chaswood Formation, and also explains some of the major themes in the Cretaceous evolution of the Scotian Basin. A further implication of the emerging data is that much of the present Nova Scotia landscape owes its origin to late Mesozoic tectonic activity rather than differential erosion during the Tertiary.

Petrochemical analysis of various granitic intrusions and felsitic mylonites associated with the Clarence Stream gold deposit, southwestern New Brunswick

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Aphanitic felsitic mylonite and foliated granodiorite that occur within the Clarence Stream shear zone were intruded by fine- to medium-grained, weak to moderately foliated aplite-pegmatite dykes during the terminal phases of shearing. These foliated dykes seem to be related to nearby undeformed medium-grained, leucogranitic dykes and the megacrystic Magaguadavic intrusion outside the shear zone. Since the spatial and temporal relationships between these deformed and undeformed rocks are poorly constrained, whole-rock geochemical data were obtained for the (1) aplite-pegmatite, (2) megacrystic granite, (3) leucogranite, (4) foliated granodiorite, and (5) felsitic mylonite in order to compare them regionally to known chemistry for the early Silurian felsic volcanic rocks of the Waweig Formation and the megacrystic Magaguadavic phase of the Saint George Batholith.

The early Silurian felsic volcanic rocks and felsitic mylonites are subalkaline low-to-medium-K, tholeiitic dacite to rhyodacite, with low Zr/Y contents. Compared to the felsic volcanic rocks of the Waweig Formation, the felsitic mylonites have a much lower Fe/Mg with high Zr/TiO_2 and are similarly elevated in Zr and Y. The low Fe/Mg and K and higher SiO_2 contents of some mylonite samples are likely related to hydrothermal alteration and mineralization. The Nb and Y contents of these two groups overlap and extend from arc-related values to rift-related (A-type) affinities.

The foliated granodioritic rocks and exposures of the Magaguadavic pluton at Clarence Stream are subalkaline, weakly peraluminous, with low Fe/Mg and high K, typical of evolved calc-alkaline rocks. They also have similar high Zr, TiO_2 Nb, and Y and Zr/TiO_2, Nb/Y contents, which exhibit evolved I-type characteristics. The aplite-pegmatite and fine- to medium-grained leucogranite samples are weakly peraluminous, high-K calc-alkaline granites. Both suites have very low Zr, TiO_2, Nb, Y, and REE and moderate to high incompatible element contents (e.g., Rb, Th), consistent with extreme fractionation, possibly differentiates from the Magaguadavic pluton.

Immobile-element geochemical data support a genetic relationship between the felsitic mylonites and the early Silurian felsic volcanic rocks, rather than the Magaguadavic intrusion and related plutonic rocks. In fact, these felsic volcanic rocks geochemically resemble the rift-related Bacon Lake dacite units located within Silurian rocks around the Welsford intrusion at the northeastern end of the Saint George Batholith. The foliated granodioritic rocks, which in part texturally resemble the felsitic mylonites, are very similar to the Magaguadavic intrusion, and therefore may be sheared hypabyssal varieties of that intrusion within the Clarence Stream shear zone. Therefore the rhyodacitic felsitic mylonites are simply early Silurian volcanic rocks intersected by and transposed into the shear zone.

Tsunami or storm deposits? The 1929 'Grand Banks' tsunami versus the 1991 Halloween storm

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Tsunami deposits related to the November 18, 1929 'Grand Banks' earthquake and washover deposits related to the October 30-31, 1991 Halloween storm differ in their sedimentary characteristics and positions on the landscape. Sedimentary deposits from the 1929 tsunami are examined in Taylor's Bay on the Burin Peninsula of Newfoundland, and those from the 1991 Halloween storm ("The Perfect Storm") are examined on Martha's Vineyard off Cape Cod, Massachusetts. With respect to sedimentary characteristics, the 1929 tsunami deposits are composed of 1 to 3 subunits of massive to fining-upward, very coarse- to fine-grained sand, whereas the 1991 storm washover deposits consist of interbedded and laminated coarse-, medium-, and fine-grained sand, exhibiting delta foreset stratification and subhorizontal, planar stratification with channels. Regarding landscape position, the tsunami deposits occur up to 340 m inland, including landward of tidal ponds, and up to 6 m above mean sea level, as well as 3 m above the tops of the barrier-beach bars and related dunes, whereas the storm washover deposits occur up to 94 m inland, immediately landward of barrier-beach bars and in adjacent tidal ponds, and up to 1.2 m above mean sea level but no higher than the elevation of the barrier-beach bars. These observations compared with those from other studies form the basis of proposed criteria for distinguishing palaeo tsunami from palaeo-storm deposits in the geologic record. If palaeo-tsunami, or historic tsunami, deposits can be identified with confidence, they will contribute to the assessment of tsunami and seismic hazards along the coast of eastern North America and elsewhere in the North Atlantic Ocean.

Plio-Pleistocene shelf margin deltas from Trinidad: outcrop and subsurface examples

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Offshore of eastern Trinidad in the Columbus Basin oil and gas reservoirs are in stacked reservoirs within a sedimentary succession of 10 000–30 000 feet deposited during the Plio-Pleistocene. Many of these reservoirs represent shelf margin deltas, produced as the precursor to the present day Orinoco River prograded basinward, and deposited thick wedges of sediment.

The outcrops of the Pliocene Mayaro Formation along the Mayaro coastline of southeastern Trinidad comprise thick successions of sand and shale units that are the direct analogs for the subsurface fields being produced offshore. Syndepositional faulting, slumping, injection features and turbidites, a paucity of trace fossils, the absence of delta plain deposits or distributary channel deposits coupled with foraminiferal data that indicate a middle neritic setting, all point to a delta system at the edge of the shelf. Autocyclic processes can be discerned within the abandonment phase of the delta with strong evidence of burrowing by suspension feeders, during reworking by wave action and alongshore drift of the delta deposits.

Evolution of the Cumberland Basin, Nova Scotia: new insights on deposition and salt tectonics from seismic reflection profiles

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The Cumberland Basin of northern mainland Nova Scotia is one of the larger depocentres of the late Paleozoic Maritimes Basin and contains a Carboniferous succession that exceeds 8 km in thickness. New seismic profiles collected by Devon Canada in the Cumberland Basin show reflectors that can be traced to surface, allowing correlation of reflectors with mapped boundaries. In the western Cumberland Basin, the early Westphalian coal-bearing formations of the Cumberland Group (Joggins and Springhill Mines formations) can be traced at depth in the Athol Syncline. Southward, they interdigitates in the subsurface with less reflective conglomerates of the Polly Brook Formation. The Joggins Formation thins conspicuously eastward onto an evaporite-cored antiformal structure in the Springhill area, indicating that evaporites were mobile during deposition of the Joggins Formation.

Beneath the Athol Syncline, reflectors identified as the Namurian Mabou Group (Middleborough, Shepody, and Claremont formations) rest directly on a bright reflector representing the basal Windsor Group, in a structure that is identified as an evaporite weld. This indicates that the entire thickness of Windsor evaporites (some of which are seen at surface near Springhill) has been evacuated beneath the Athol Syncline. Early Westphalian evaporite withdrawal is largely responsible for the great thickness of coal-bearing Cumberland Group strata in this area.

East of Springhill, coal-bearing units are generally absent and a much thinner Cumberland Group overlies the Mabou Group on the flanks of evaporite-cored anticlines. Traced to depth, the Mabou Group thickens into synclinal 'minibasins', which have subsided into evaporite-bearing Windsor Group. Mabou minibasins are truncated by a clearly resolved unconformity at the base of the Boss Point Formation (Cumberland Group). Subsidence and tectonism in the Cumberland Basin were clearly controlled by differential flow of evaporites, which began in Namurian time and continued intermittently throughout the Late Carboniferous.

Some gold prospects in New Brunswick

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Several varieties of gold deposits/occurrences have been documented in the province, including auriferous gossans (e.g., Murray Brook) formed upon middle Ordovician volcanogenic massive sulphide deposits in the Bathurst Mining Camp, epigenetic deposits associated with intrusions and/or major structural features and some unusual occurrences that bear similarities to iron-oxide copper-gold (IOCG) deposits. Historically production has come from the auriferous gossans and from the epigenetic Cape Spencer deposit near Saint John.

New discoveries have been made in the last five years and are the focus of this presentation. These include Guitard Brook, Falls Group, Big Pit, and Anne's Creek in northern New Brunswick, as well as Poplar Mountain, Clarence Stream,

Sheba, and Armstrong Brook in southern New Brunswick. The latest discovery is the Falls Group prospect, located north of Tetagouche Falls. It is hosted within Ordovician basalts of the Brunswick accretionary complex but is clearly post-tectonic and epigenetic, though not clearly intrusion-related. To the north, Guitard Brook is within a brittle-ductile, easterly trending shear zone, hosted by back-arc, ocean-floor basalts (Fournier Group) of the Elmtree Inlier. Anne's Creek is hosted by Silurian Chaleurs Group sedimentary rocks at the edge of the contact aureole of the upper Devonian Nicholas Denys Granodiorite. Big Pit is an unusual occurrence (possibly IOCG?) hosted in basalts of the lower Devonian Dalhousie Group.

Of the new discoveries, the most significant one to date is the Clarence Stream Au-As-Sb deposit, which comprises proximal (Main Zone) and distal (Anomaly A) manifestations of an intrusion-related system. These span a major terrane boundary that juxtaposes Ordovician rocks of the St. Croix terrane and Silurian rocks of the Mascarene back-arc basin. At the Main Zone, gold mineralization is contained within granitic dykes and a parallel series of NE-trending steeply dipping quartz veins hosted by sedimentary, tuffaceous and gabbroic units, all of which are in the thermal aureole of the lower Devonian Magaguadavic Granite, an oxidized, I-type intrusion that is the source of the hydrothermal fluids. To the northeast in the Annidale Belt, the Sheba occurrence is hosted within a NW-trending shear zone that cuts Ordovician (?) gabbroic rocks. Gold mineralization at Poplar Mountain is within dilatant veins that cut a dacitic sub-volcanic intrusion (lower Devonian or older?), which is adjacent to the terrane-bounding Woodstock fault zone. Armstrong Brook is northwest of the Cape Spencer gold deposit and mainly hosted by Precambrian granitoid rocks that have been penetratively deformed during the Alleghanian orogeny.

Isotopic dating and its implications for porphyry Cu-Mo deposits in the Gangdise Orogenic Belt, Tibet

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Located along the north margin of the Brahmaputra plate junction in central Tibet, 400 km in length from the east to the west, the Gangdise porphyry Cu-Mo deposit belt is a new porphyry Cu-Mo belt confirmed by the China Geological Survey (CGS) in recent years. The Gangdise porphyry Cu-Mo deposit belt was part of the Gangdise Orogenic Belt, which is chiefly made up of calc-alkalic granitic plutons and volcanics and was believed to be formed mainly by the subduction of the Brahmaputra oceanic basin from 130 Ma to 45 Ma. Although the Gangdise porphyry Cu-Mo deposit belt and the Gangdise Orogenic Belt were highly harmonious in location, the timing data obtained from the Cu-Mo deposits usually hosted in small granite and granodiorite porphyries show the ages of the mineralization of the porphyry Cu-Mo deposits were much younger than the formation of the large-scale calc-alkalic granitic plutons and volcanics related to the subduction of the Brahmaputra oceanic plate from 130 Ma to 45 Ma in the Gangdise Orogenic Belt. The 17.58 ± 0.74 Ma (SHRIMP dating from zircons), the 15.99 ± 0.32 Ma (Re-Os dating from molybdenites), and the 15.77 ± 0.45 Ma (K-Ar dating from potassium feldspars) ages of the porphyry Cu- Mo deposits in the Gangdise Orogenic Belt suggested that the small ore-bearing dikes were formed mainly after the collision of the Asian plate and the India plate along the Brahmaputra plate junction in the Cenozoic. Our research also indicates that the porphyry Cu-Mo deposits were formed in an extension geo-tectonic setting and the mineralization of porphyry Cu-Mo deposits in the Gangdise Orogenic Belt were accompanied by the speedy uplift of the Tibet plateau and the forming of the NS-strike rifts in the Cenozoic in the region.

Geology of the Washabuck Peninsula, central Cape Breton Island, Nova Scotia

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Geological mapping on the Washabuck Peninsula in central Cape Breton Island confirmed the presence of pre-Carboniferous rocks with lithological similarities to other Neoproterozoic rocks in the Bras d'Or terrane. These older rocks are unconformably overlain by Carboniferous sedimentary rocks of the Horton Group and in faulted contact with Carboniferous sedimentary rocks of the Windsor Group.

The oldest rocks are termed the Maskells Harbour formation (MHf), and occur in two separate areas. In the northeast, the formation consists of interbedded quartzofeldspathic metasandstone and metasiltstone with thin minor quartzite and marble; however, the area in the southwest consists dominantly of calcitic to dolomitic marble interbedded with minor quartzite. The MHf in the northeastern area is intruded by unfoliated, medium-grained diorite, quartz diorite, and hornblende-biotite granodiorite of the Washabuck pluton. Associated with the pluton are late-stage coarse-grained hornblendite dykes. The MHf in the southwestern block is intruded by unfoliated medium- to coarse grained hypidiomorphic granular hornblende-biotite granite and associated aplitic dykes named the Grass Cove pluton. Similar granite occurs in the northeastern block as large dykes in the MHf and Washabuck pluton. The plutonic units contain metasedimentary xenoliths derived from the MHf, and like the MHf, are cut by numerous mafic dykes.

Regional metamorphism in the MHf reaches only biotite grade; however, close to the margins of the plutonic units, grade has increased to produce cordierite-biotite assemblages. This increase in grade has imparted a gneissic appearance to the metamorphic rocks by accentuating the bedding but it is clearly related to contact metamorphism.

Analyzed samples from the Washabuck pluton range in SiO_2 content from approximately 50% to 62%, whereas the Grass Cove pluton has higher SiO_2 concentrations, ranging from about 68% to 77%. Mafic dykes show variable compositions, but some have compositions similar to the Washabuck pluton and may be related to it. A "rhyolitic" unit in the Maskells Harbour formation is chemically similar to the intermediate rocks of the Grass Cove pluton.

Because of lithological similarity to the Blues Brook and Malagawatch formations, the MHf is considered to be part of the Neoproterozoic George River Metamorphic Suite. The similarity of the Washabuck pluton and Grass Cove pluton to dated igneous units in the Creignish Hills and North Mountain suggest similar late Neoproterozoic ages for these units.

LIDAR DEM analysis of the North Mountain and Annapolis Valley; what geological knowledge can be gained from a high resolution OEM?

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High resolution elevation data derived from a LIDAR – Light Detection and Ranging has been processed for an area of the central Annapolis Valley (Bridgetown) and Bay of Fundy shoreline and the resultant 2 m DEM used for various geoscience applications including: bedrock and surficial mapping, and quantitative geomorphology. The three flow units of the North Mountain Basalt Formation (NMB) can be traced with greater clarity with this new 2 m DEM. Several circular features have been identified that may represent volcanic pipes associated with a fissure style volcanic source area. The topographic expression of the contact between the flow units is subtle and is not visible on traditional 20 m and coarser DEM from 1:50 000 maps available for the area. The North Mountain in this area has two distinct regions based on surficial material: an area to the west has been scoured by glaciers and has minimal sediment cover; and a blanket of till covers the area to the east.

Bedrock incision is assumed to be related to a simple "stream power law", where erosion is a function of the contributing drainage area and slope of the channel, $E = k A^m S^n$, E – erosion rate, k – rock erodibility and channel geometry coefficient, A – drainage area, S – channel slope, m – exponent related to hydraulic effects, n – arbitrary exponent, m/n – related to the stream profile concavity. In order to test if sediment supply (till blanket) influences incision rates, longitudinal stream profiles have been generated from the LIDAR data for these contrasting areas along the North Mountain. In general the incision is greater for streams in the till blanketed area compared to the scoured area supporting the hypothesis that incision is influenced by sediment supply. The NMB in this area is the limb (dipping 6° to the NW) of a large southwest-plunging syncline with the fold axis going through Scots Bay. The topographic profile from a 20 m DEM of the ridge-line of the North Mountain from Blomidon to Brier Island indicates this geomorphic feature is a relatively level unit until Margaretsville. In this area there appears to be an inflection point where the ridge-line increases by 25 m then begins to dip to the southwest at a constant slope of 0.2% to Brier Island. The break in the ridge-line topographic profile coincides with a change in the strike of the NMB from 070° to 058°. The break in the ridge-line roughly lines up with the Nictaux River of the South Mountain and may be traced to a lineament that is associated with the Lahave River on the south shore of the province. The orientation of this lineament is parallel to transfer faults within the Bay of Fundy.

Cretaceous rocks of Orpheus graben, offshore Nova Scotia

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Orpheus graben is an offshore Mesozoic basin along the trace of the Cobequid - Chedabucto fault system, along strike from the lower Cretaceous Chaswood Formation of central Nova Scotia. Orpheus Graben contains up to 10 km of upper Triassic and lower Jurassic strata, including the Argo salt, overlain by a relatively thin succession of upper Jurassic to lower Tertiary strata. Seven wells provide a basic lithostratigraphic and biostratigraphic framework. In this study, the detailed lithostratigraphy, provenance, and structure of the Cretaceous rocks of Orpheus Graben are compared with correlative rocks on land.

Seismic-reflection profiles show a regional unconformity at the top of the lower Cretaceous Mississauga Formation. The overlying mid-Cretaceous Logan Canyon Formation has two facies: (1) deltaic facies with several transgressive surfaces, and seismically-imaged progradational clinoforms; (2) basinal facies with subparallel seismic reflections. Basin depocentres of this age are defined by syn depositional faults. The younger Dawson Canyon and Banquereau formations principally show continuous subparallel reflections. An unconformity has eroded these formations in the western part of the graben. Finally, the entire succession is locally offset along later faults.

Well logs and cuttings show that the Mississauga Formation consists principally of coarse-grained sandstone. The Logan Canyon Formation can be subdivided into the Naskapi, Cree, Sable, and Marmora members. In three wells, a volcanic horizon occurs at the top of the Naskapi shale member. Above the Naskapi Member the formation fines upward from medium- to very fine-grained sandstone interbedded with shale and marl, with minor phosphorite. The detrital mineral assemblage consists of: quartz, muscovite, K-feldspar, tourmaline, rutile, zircon, staurolite, plagioclase, biotite, ilmenite, magnetite, chromite, sphalerite, phlogopite, galena, and garnet. Early diagenetic cements include siderite (principally in mudstone), calcite, ankerite, pyrite, hematite, glauconite, limonite, and francolite. Later diagenetic minerals include kaolinite, illite, septochlorite, chlorite, siderite, and barite. Basalt is altered to stilpnomelane, chlorite, siderite, and calcite.

The major faults in Orpheus graben trend E-W and some are important expressions of episodic salt movement. In the Cretaceous Tertiary interval older lower Cretaceous syn-depositional faulting probably corresponds to syn-sedimentary tectonism in the onshore Chaswood Formation; while younger (Oligocene-Miocene?) faulting is interpreted to relate to the uplift and erosion of the inferred 700 m thick post-Chaswood sediments of the onshore region.

Stratigraphy, deformation, and metamorphism in the southwestern Meguma terrane, Nova Scotia

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Mapping (1:10 000 scale) related to the Southwest Nova Project concluded at the end of the summer of 2003 and results of the last three years in the Yarmouth - Shelburne area are reported here. The oldest units are the Cambrian to Ordovician Goldenville and Halifax formations of the Meguma Group. West of Yarmouth, the Goldenville Formation could not be subdivided, although a narrow metasiltstone unit (High Head member) can be traced for several km. In this member the earliest Cambrian trace fossil *Oldhamia* was identified, which suggests that the interval below this unit may extend into the Precambrian. In the area east of Yarmouth, the Goldenville Formation is subdivided into the Green Harbour member (thickly bedded, massive, metasandstone) and the overlying Government Point member (interbedded metasandstone with minor metasiltstone and slate). The Halifax Formation consists of rusty spotted slate and phyllite.

In the Yarmouth area, the Goldenville and Halifax formations are in faulted contact with the latest Ordovician to early Silurian White Rock Formation (WRF), composed of mainly metavolcanic rocks interpreted to have formed in an extensional setting together with the ca. 440 Ma Brenton Pluton. Both the Meguma Group and WRF were deformed during the Devonian Acadian orogeny into regional, north- to northeast-trending Fl folds with a well-developed axial planar cleavage. Intersection lineations plunge gently to the north-northeast and south-southwest. Deformation was accompanied by greenschist facies metamorphism, but reached amphibolite facies in parts of the WRF in the Yarmouth area and in the Meguma Group in the Shelburne area, where pelitic beds become staurolite-andalusite ± cordierite schist, garnet sillimanite schist/granofels, and migmatite. Based on structural relations and published age data, high-grade regional metamorphism in the Shelburne area was younger (ca. 373 Ma) than elsewhere in the Meguma Group. The age of high-grade metamorphism in the WRF is not yet well constrained. A major shear zone along the southeastern margin of the WRF juxtaposed the Meguma Group and WRF with abundant mafic sills on the north against the Meguma Group with contrasting internal stratigraphy and no WRF or mafic sills to the south. Published $^{40}Ar/^{39}Ar$ muscovite ages suggest that these shear zones are Alleghanian.

The ca. 373–372 Ma Barrington Passage Pluton (tonalite), and the mainly monzogranitic Shelburne and Port Mouton plutons intruded rocks of the Meguma Group in the central and eastern part of the map area. New U-Pb dating shows that the monzogranitic Wedgeport Pluton southeast of Yarmouth has an age of ca. 357 Ma, not 316 Ma as indicated by previous work. Monzogranite of the undated Seal Island Pluton outcrops on offshore islands.

New geological highway map of Nova Scotia

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The primary goal of the Atlantic Geoscience Society (AGS) is the communication of ideas and information about the Earth and Earth science to both the professional geoscience community and the general public. One of the ways in which this goal is achieved is through the use of specialized maps such as the Geological Highway Map of Nova Scotia. This map shows the road systems of Nova Scotia and, by the use of colours, the types of bedrock that exist at the surface throughout the province. This map will help people understand the origins of the many geological and geomorphological features observed from their vehicles as they travel through Nova Scotia.

Two editions of the map have already been published by the AGS, in 1980 and 1990, as well as a repackaged version in 1994. The combined sales of all editions have totalled more than 40 000 copies and the map is currently out-of-print. This situation provided an opportunity for AGS to produce a third edition of the Geological Highway Map of Nova Scotia that shows updated geology of the province and provides more detailed information about the rocks, minerals, fossils, and landforms. The final product will be a digital map from which hard copies will be printed on a sheet size of 27" by 39".

The map will have a front side containing the geological map (produced in ArcView 3.1) at the same scale as the second edition, Table of Formations, How to Use the Map, Symbols, block diagrams and Sites of Geological Interest. The reverse side of the map is similar to previous editions with emphasis on areas that are well known and/or well traveled. They will include digitally (CorelDraw 9) produced versions of Joggins, Cabot Trail, Parrsboro-Five Islands-Dinosaurs, Avon River-Burntcoat Head, Yarmouth, Arisaig, Halifax, and Louisbourg. The descriptions of each area will emphasize locations for rocks, minerals and fossils for collection, landform development, glacial history, and economic development resulting from natural resources.

We believe that the third edition of the Geological Highway Map of Nova Scotia will continue to be used in many senior high schools and university earth science classes as part of the course material, an integral part of the annual EdGeo Workshops, and a product sought by residents and visitors to the province. This widespread use contributes to a better understanding and appreciation of not only the geology of Nova Scotia, but earth science in general.

Strategies for suppressing heave effects in sub-bottom profiles from the upper Bay of Fundy, New Brunswick

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Acquisition of high resolution single-channel seismic data in shallow coastal waters imposes significant restrictions on the size of the survey vessel and on the type of acoustic source and receiver array that may be effectively employed. However, other more subtle acquisition-related challenges must also be overcome in order to produce an end product that is optimized for interpretation. Variations in the elevation of the profiling system transducers due to tides (a long period effect) and ocean swell or heave (a short period effect) are two important examples; both of these factors can lead to variations in the arrival time of ocean bottom and sub-bottom reflectors that are much greater than the vertical resolution afforded by the seismic system itself. Tidal effects must be corrected in order to eliminate reflection misties at the intersections between lines, and in order to calculate reflector depths relative to a fixed datum. Heave, due to short period swells, adversely affects the visual continuity of subsurface reflections making them difficult to follow and interpret.

We consider approaches that can be taken to limit the effects of tidal variations and ocean swell in shallow marine seismic through both heave filtering during processing and through the use of high accuracy Real Time Kinematic (RTK) GPS positioning during acquisition. The potential effectiveness and limitations of each method are discussed with reference to data collected using a surface-towed IKB Seistec™ profiler in coastal areas of the upper Bay of Fundy and lower Petitcodiac River in August, 2003. RTK GPS positioning holds great potential for advancing shallow water sub-bottom profiling as it may offer measurements of heave and tidal variations that are sufficiently accurate to open new opportunities for acquiring pseudo-3D seismic data through creative survey design.

First results of Carson Basin 4-D petroleum system modelling

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Carson Basin is one of the lesser known basins on the eastern edge of the Grand Banks of Newfoundland. It was penetrated by four wells along its westernmost edge. The wells demonstrate that the basin contains a thick Cenozoic and Mesozoic sedimentary section. In most of the basin, a major unconformity, the Avalon Unconformity, separates Triassic to Aptian formations from overlying Cenomanian rocks. Reservoir rocks, sealing formations and likely source rocks are present both within the pre- and post-Avalon sediments. As the best way to synthesize all our new and already available information, we built a computer model of this basin, based on biostratigraphy, geophysical data, geology, and geochemistry. The program Petromod (IES, Germany) simulated with this model the history of the basin and its petroleum generation. We present a brief overview of the principles of basin modelling and how we reconstructed the basin, and show a four dimensional first look at the hydrocarbon potential of this basin.

Biostratigraphic studies of Grand Banks wells: what's new in an old approach?

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Renewed exploration interest in lesser known basins of the Grand Banks – including the Carson and Whale basins – has motivated a reappraisal of their maturation history and hydrocarbon potential. As part of this project, we decided to undertake detailed biostratigraphic studies of wells from these basins with control wells from the Jeanne d'Arc Basin and surface sections from western Europe. Wells examined include: Terra Nova K-18 and Cormorant N-83 in the Jeanne d'Arc Basin; St. George J-55, Skua E-41, and Osprey H-84 in the Carson Basin; Grand Falls H-09 in the Whale Basin; and the adjacent Hermine E-94 in the Scotian Basin. Although the biostratigraphic studies were solely based on the palynomorphs, the rich terrestrial (pollen and spores) and marine (dinoflagellates) assemblages yielded encouraging results.

Much of the success is due to the revolution in dinoflagellate biostratigraphy over the last decade, allowing us to correlate the Grand Banks sections with the European stages from the Carnian to the Tortonian (a span of about 220 million years). A new development is using the relative abundances of the palynomorphs to generate paleoenvironmental plots, which delineate non-marine, coastal to marginal marine, inner neritic, outer neritic, and open oceanic environments. In the wells previously analysed, the environmental data were based solely on analyses of sidewall and conventional cores. Now, it is possible to use drill cuttings samples to develop such plots.

One major surprise has been the recognition of the late Paleocene thermal maximum in several wells. This represents a geologically brief interval of about 220 000 years at ca. 55 Ma when there was profound global warming. The warming is denoted by an abundance spike of the dinoflagellate *Apectodinium*, and is characteristic of assemblages in the North Sea, New Zealand, Austria, and now the Grand Banks. Obviously, the well locations where the peaks occur must have been influenced by the proto-Gulf Stream

GSC Atlantic collaborative projects and their significance for hydrocarbon exploration in the Canadian Arctic Islands and in the Davis Strait

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The nature, chronology, and thermal impact on the petroleum system of rift-related magmatism in the Canadian Arctic Islands and in the Davis Strait, are key aspects of basin development in Arctic and North Atlantic regions. Cretaceous magmatism in the Canadian Arctic also represents a "missing link" in models describing the role and path of the Iceland Plume. Rifting between Canada and Greenland started in the early Cretaceous, and resulted in the emplacement of two offshore volcanic successions that differ in age, eruptive style, and geochemical character. Cretaceous igneous activity in the east-central Sverdrup Basin peaked with the emplacement of flood basalts, and voluminous, intrusive sheets during the Cenomanian and Turonian (ca. 98 to 89 Ma). Late-stage bimodal volcanic successions, and associated plutons, were emplaced during the Campanian (ca. 83 to 74 Ma). During the Paleocene – early Eocene (ca. 65 – 55 Ma), igneous activity was concentrated between eastern Baffin Island and western Greenland (flood basalts), where igneous rocks are known to have been locally involved in petroleum generation.

Three projects on igneous rocks have been initiated over the past 5 years by the Geological Survey of Canada in collaboration with GEUS, and the Department of Earth Sciences at Dalhousie University, in order to improve our understanding of the history of basin and margin development in these regions: (1) geochronological and petrological data for offshore basalts recovered from drilling in the Davis Strait support the existence of a widespread volcanic episode at ca. 60 Ma, and a later episode of extension and magmatism at ca. 55 Ma; basaltic volcanism at ca. 60 Ma has also been recognized in easternmost Ellesmere Island by others, (2) new geochronological data for volcanic and intrusive rocks of the Sverdrup Basin reveal the existence of two major pulses of magmatism, at ca. 125 Ma and 97-92, (3) field studies initiated in 2003 confirm that basaltic magmas, salt structures, and Tertiary faults influenced the thermal history of the east-central Sverdrup Basin, with implications for the timing and nature of hydrocarbon generation. We present results from these collaborative projects, and preliminary conclusions of regional significance to hydrocarbon exploration models applied in the central Sverdrup Basin, and on the conjugate margins of Canada and west Greenland.

Government geoscience in managing for impact and opportunity

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Since before confederation until quite recently, the Geological Survey of Canada (GSC) emphasized the provision of maps and related products to promote the exploration and discovery of Canada's vast wealth of mineral and energy resources. This has served Atlantic Canada and the nation well and helped establish significant mining districts and assisted in opening up the frontiers to energy exploration. However, the GSC, like all federal science and technology organizations, is undergoing a major paradigm shift. The reasons for this shift are complicated, but reflect the interplay between the changing nature of the federation, the role of government science, local, regional and global economic, social and environmental dynamics strongly imprinted by the Information Age revolution – the "knowledge economy". From the government's perspective, it is increasingly important to see measurable returns from its investment in science and demonstrable impact on important "quality of life" issues. For the GSC this means that it is no longer sufficient to continue providing "map" coverage and ancillary products to a limited "professional" audience. These products and audience will continue to be important, but the GSC has to broaden its market and work toward ensuring that its work has the intended outcome. This requires a fundamentally different approach to where, how, why and with whom the GSC works. Key elements include:

- Re-definition of "partnerships" in science delivery with the provinces and territories, within the framework of the Intergovernmental Geoscience Accord, as well as with academic/industry organizations.
- Broader utility of geoscience data and information through comprehensive and efficient access on-line to a geoscience knowledge store fully integrated with provinces and territories.
- Rationalizing geoscience data collection – collect once-use many – by a multitude of traditional and new clients for decision support
- Development of a "socio-geoscience" agenda for Canada – the deployment of geoscience expertise in concert with other instruments, to address critical issues facing Canada – such as community development in the North; rural development elsewhere in Canada; security of gas supply; Canadians at risk through water related issues; at risk through environmental quality issues etc.

This talk will review these developments with a focus on what some of the opportunities and implications may be for Atlantic Canada.

Syn-sedimentary folding and boudinage in the Tournaisian Albert Formation, southern New Brunswick

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The Albert Formation section along the new Highway 1 between Sussex and Norton contains numerous deformed units that are not considered tectonic in origin. Many units consist of folded, faulted, brecciated, and boudinaged sandstone, siltstone, and shale within undeformed master bedding. Scours and erosional contacts at the base of some, and sand volcanoes and truncated folds at the top of other deformed beds, are further evidence that the deformation in the units is syn-sedimentary. Stereoplots of fold orientations from several of the deformed units show that fold plunges are subhorizontal and trend north-northeast or south-southwest, while axial planes plot on a great circle girdle. This pattern is thought to result from the slumping of Albert Formation sediment down east-southeast- or west-northwest- dipping slopes. Another deformed unit, possibly also slumped, contains brecciated mudstone and has sand volcanoes on its upper surface. This indicates that the sediment was susceptible to dewatering, possibly in association with slumping, or after liquefaction.

The pattern of deformation in the slumps is complex, with tight to isoclinal folds, refolded folds, and thrust faults all present. The slumps may be highly coherent, or may be chaotic, containing detached fold hinges and isolated blocks/clasts of siltstone and sandstone in a shale matrix. In many cases the slumps decrease in coherence from base to top. There are also significant lateral variations in fold complexity and thickness of slumps. Some of the slump units contain unusual boudin-like features. These features are up to 0.2 meters across in section, and at least several metres long, with their long direction parallel to the orientation of fold hinges in the slumps. The boudins are composed of red siltstone or mudstone, and have a variety of cross-sectional shapes, including round, elliptical, aerofoil-shaped, and complex examples. Polished slabs cut perpendicular to the long direction of the features show complex internal folding, including sheath folds parallel to the long axis of the boudins, while slabs cut parallel to the long direction show a planar lamination cut by cm-scale normal faults. These boudin-like features seem to have formed through detachment of fold hinges during slumping, followed by rolling and shearing of the detached hinges during continued slumping and compaction.

Geology of the Campbellton area, northern New Brunswick

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The Campbellton area is underlain by late Ordovician to middle Devonian sedimentary and minor volcanic rocks of the Gaspé Belt successor basin. Basement to the Gaspé Belt is assumed to be Dunnage Zone, represented in the study area by mafic volcanic rocks in the Popelogan Inlier. In northern New Brunswick, the Gaspé Belt consists of three conformable successions separated by late Silurian (Salinic) and early Devonian unconformities. The lower sequence is composed of deep-water turbidites of the Grog Brook and Matapédia groups, and slope and shelf deposits of the lower Chaleurs Group. The early to mid-Ashgillian Grog Brook Group comprises the Boland Brook Formation (thin-bedded mudstone, sandstone, and minor conglomerate), and overlying Whites Brook Formation (thick-bedded sandstone and thin shale interbeds). The Ashgillian to late Llandoverian Matapédia Group is divided into the Pabos and White Head formations. The Pabos consists mainly of thin-bedded calcareous siltstone and calcilutite, and local calcareous sandstone, whereas the White Head dominantly consists of thin-bedded calcilutite and calcareous shale. The lower part of the Chaleurs Group

comprises late Llandoverian to early Wenlockian rocks of the Upsalquitch Formation (thin-bedded calcareous siltstone) and Limestone Point Formation (fine-grained sandstone and minor fossiliferous limestone).

Above the Salinic erosional unconformity, the middle sequence forms a transgressive-regressive cycle that is assigned to the upper Chaleurs Group and the Dalhousie Group. The former consists of the Pridolian West Point Formation (limestone bioherms and associated peri-reefal facies) and Pridolian to Lochkovian Indian Point Formation (calcareous mudstone, fine-grained sandstone and calcarenite, with minor limestone and conglomerate). The Dalhousie Group is represented by the Lochkovian to early Emsian Val d'Amour Formation, comprising mafic, intermediate, and felsic subaerial lavas, tuffs, volcaniclastic rocks, subvolcanic intrusions, and locally intercalated fine grained sedimentary rocks. Rhyolite in the upper part of the Val d'Amour Formation has yielded a U-Pb (zircon) age of 407.4 ± 0.8 Ma. A middle Emsian hiatus separates the Val d'Amour Formation from overlying alluvial-lacustrine rocks of the late Emsian Campbellton Formation, which consists mainly of fine- to coarse-grained, locally feldspathic sandstone, mudstone, and conglomerate.

Acadian deformation was characterized by open to closed folds with northeast-trending axial planes and heterogeneous cleavage development, followed by reverse and strike-slip faulting. Between the Sellarsville and McKenzie Gulch-Black Lake faults, poor cleavage development and coincident low organic thermal maturation imply shallow burial depths and (or) long-lived uplift. In this area, maturation values in Devonian, Silurian, and in places upper Ordovician rocks fall within the oil and gas condensate windows. The Salinic orogeny is primarily manifested in uplift and erosional dissection of the Limestone Point, Upsalquitch, and White Head formations. It is proposed that complex patterns of Siluro-Devonian uplift and subsidence may be related to differential vertical movement during Salinic block faulting.

Metal behaviour during magmatic-hydrothermal processes in intrusion-related gold systems, southwestern New Brunswick, Canada

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Several gold deposits and occurrences associated with granitoid intrusions in New Brunswick share some similarities with newly recognized types of intrusion-related gold systems; they differ from porphyry copper-gold systems in several aspects such as fluid compositions, mineralization style, alteration, element, and mineral assemblages. In southwestern New Brunswick, two main groups of granitoid intrusions associated with gold are recognized. These are 1) a late Devonian granitic series (GS) including the Mount Pleasant, True Hill, Beech Hill, Pleasant Ridge, Kedron, and Sorrel Ridge granites, and 2) a late Silurian to early Devonian granodioritic to monzogranitic series (GMS) granitoids including the Magaguadavic, Bocabec, Utopia, Tower Hill, Evandale, Poplar Mountain, and Lake George intrusions. The former occur along the northwestern flank of the Saint George Batholith as satellite plutons, and the latter form parts of this batholith and the Pokiok Batholith to the north.

Gold abundances in these two series are fairly low compared to continental crust, although the GMS rocks appear to contain higher gold (up to 77 ppb), suggesting that the geochemical behaviour of gold during magmatic-hydrothermal evolution is a key factor controlling gold mineralization in the region. In the differentiation sequence of a granitoid complex, gold usually behaves as a compatible metal, implying that gold partitions in favour of the early phase granitoid, and therefore, late stage highly evolved granites may have a relatively low potential to generate gold deposits. In contrast, tin and tungsten behave as highly incompatible elements, and their mineralization is closely associated with highly evolved GS rocks. However, some greisenized granites contain significantly high gold (e.g., 1 g/t at Kedron, 0.1 g/t at True Hill), which indicates that the GS series could be prospective for deposits in this area.

In granitic magma systems, several other factors are important for producing intrusion-related deposits. Gold strongly enters sulphides, which constitute a large portion of gold in the granitoids based on previous experimental studies, and any sulphide formation must significantly deplete gold from residual silicate melts. Sulphide liquid saturation is a function of redox, which is controlled by the magma intensive $f(O_2)$, coupled with degree of hybridization during ascent and emplacement at this level of the crust. Further, local geological setting and intrusion-driven hydrothermal fluid systems are important. Late stage hydrothermal fluids with low pH and relatively high oxidation may scavenge Au that is incorporated into sulphides in early immiscible sulphides within granitoids. If a significant amount of Au produced in this manner is concentrated in a suitable geological environment, such as fault zones and/or hydrofracture systems, it is possible to form intrusion-related gold deposits.

Evolution of the Darreh-Zerreshk and Ali-Abad porphyry copper deposits, central Iran, within an orogen-parallel strike-slip system

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The Darreh-Zerreshk and the Ali-Abad porphyry copper deposits, two of the Iranian porphyry copper deposits (PCD) in Yazd Province, are located within the Central Iranian volcano-plutonic belt (Urumieh-Dokhtar belt) in central Iran, at an elevation of 3500m. They are genetically associated with Oligo-Miocene granitoid intrusions that range in composition from quartz-monzodiorite, tonalite, granodiorite, to granite

that intruded Eocene volcano-sedimentary and Cretaceous clastic and carbonate sedimentary rocks. Structurally, the deposits are located within the regionally extensive Dehshir-Baft orogen-parallel shear system. Hypogene mineralization and hydrothermal alteration are characteristic of PCD.

The PCD-forming history started with the eruption of Eocene felsic to intermediate calc-alkaline volcanic rocks in a transpressional phase. Next, granitoid intrusions were emplaced in a transtensional tectonic setting. Whole rock major and trace element data suggest that geochemically, the granitoids are I-type and were derived from sub-alkaline magmas in a syncollisional continental arc environment. Plagioclase and hornblende fractionation were an important control on geochemical evolution of the copper-bearing plutonic rocks in the study area. Fracture patterns within the PCD deposits and in the region integrated with new mapping by the first author suggest that these deposits were emplaced in a pull-apart domain in a secondary shear zone related to the Dehshir-Baft dextral strike-slip system, part of which is tectonically active today. The results suggest that PCD-forming systems developed during the last manifestation of the regionally extensive Oligo-Miocene phase of dioritic to granodioritic plutonism (geochronology in progress). PCD emplacement was followed by exhumation, oxidation and minor supergene enrichment of the mineralized systems, locally increasing their economic feasibility. After a pause in magmatic activity, Quaternary volcanism in the form of localized dacitic domes was superimposed on the same (Urumieh-Dokhtar) magmatic belt, giving rise to geothermal fields and extensive deposits of travertine.

Significance of salt diapirs, magmatism, and tectonics on the thermal history of Axel Heiberg Island, Nunavut

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Only one in ten hydrocarbon exploration wells in the Sverdrup Basin in the Canadian Arctic Archipelago in the 1960s and 1970s led to discoveries (18), all but one of these fields in Mesozoic clastic strata on the crests of anticlinal structures, many of which are salt cored. Previous fission track (FT) studies by our group combined with organic maturation data suggest that a better understanding of the timing of hydrocarbon generation, migration and trap formation could have significantly decreased the exploration risk. It has been proposed that the thermal effects of Cretaceous and early Tertiary magmatism and salt/anhydrite diapirs on potential source rocks, and the possible breaching of reservoirs by Tertiary faulting may be key factors to be considered in hydrocarbon exploration models for this region. This project was developed with the primary aim of better understanding the thermal and timing aspects of the petroleum system using low-temperature FT and (U-Th)/He thermochronology, fluid inclusions, and organic geochemistry.

Field work on Axel Heiberg Island during the 2003 field season consisted of reconnaissance and sampling traverses mainly in the following areas: Geodetic Hills – Stolz Thrust (Lat. 79°50' N; Long. 89°35' W); Eureka Pass (Lat. 79°35' N; Long. 89°15' W), the south shore of Strand Fiord (Lat. 79° 10' N; Long. 90° 10' W) and Colour Peak, Expedition Fiord (Lat. 79° 23' N; Long. 91° 15' W). Over 100 diapirs are superbly exposed in 3D on Axel Heiberg Island, close to the Mesozoic depocentre of the Sverdrup Basin. They consist of Pennsylvanian gypsum-anhydrite with limestone interbeds and locally halite. Diapirs pierce Mesozoic strata and locally Paleogene sediments. Strata are folded into synclines and anticlines in brain-like patterns. The diapirs often form dikes and sills along, or near reverse faults. Because of the prevalence of anhydrite (S.G. 2.9) at the exposed level, some authors ruled out buoyancy as the main mechanism of emplacement, favouring horizontal compression as driving diapir intrusion during the Paleogene Eurekan orogeny.

Many large rafts of basaltic rocks (sills and lavas) of Cretaceous age are embedded in the diapirs. In a large diapir east of Eureka pass we sampled extrusive (pahoehoe and pillowed) basalts showing evidence of high-temperature interaction with evaporite, suggesting that the diapir was rising and exposed during the Cretaceous - extensional - tectonic phase. At Expedition Fiord, we observed perennial warm (<10°C) salt springs associated with two diapirs previously described by McGill University researchers, in an area where permafrost is otherwise 600 m deep. Salt, which undoubtedly cores the anhydrite diapirs, has a far higher thermal conductivity than most sedimentary rocks. If the thermal effect of the diapir has raised the isotherms in this area, it must have affected the petroleum system in the past. Our observations lead us to believe that the diapirs are actively rising, a hypothesis that we plan to test using geodesic tools in future. The timing of thrust fault movements, their relationships with Paleogene sediments and contained fossil forests, and the level of exhumation of various salt diapirs are being investigated using low-temperature thermochronology.