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ATLANTIC GEOSCIENCE SOCIETY

ABSTRACTS

1997 COLLOQUIUM AND ANNUAL GENERAL MEETING

AMHERST, NOVA SCOTIA

The 1997 Colloquium of the Atlantic Geoscience Society was held in Amherst, Nova Scotia on February 7 to 8, 1997. On behalf of the Society, we thank Susan Johnson, Colloquium Chairperson, and members of her organizing committee for providing an excellent meeting, as well as corporate sponsors: Potash Corporation of Saskatchewan, Noranda Mining and Exploration, Brunswick Mining and Smelting Corporation Limited and Teck Exploration Limited.

In the following pages we publish the abstracts of talks and poster sessions presented at the Colloquium, which included special sessions on mineral exploration and recent discoveries in Atlantic Canada and current environmental research in the earth sciences.

The Editors

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The hydrogeology of a tailings impoundment formed by central discharge of thickened tailings: implications for tailings management

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The Kidd Creek Cu-Zn sulphide mine is located near Timmins, Ontario. Mill tailings are thickened and deposited as a slurry in a circular impoundment with an area of approximately 1200 ha. Deposition of tailings as a thickened slurry from a central discharge ramp results in a conical-shaped tailings deposit with low perimeter dykes, a relatively uniform grain-size distribution, uniform and low hydraulic conductivity, and a tension-saturated zone above the water table up to 6 to 7 m thick. These characteristics provide benefits over conventionally disposed tailings with respect to tailings management. The thick tension-saturated zone within the tailings limits the thickness of unsaturated tailings susceptible to rapid sulphide oxidation. The conical shape of the deposit results in the formation of a recharge area near the centre of the impoundment and discharge in the peripheral areas. In contrast, the elevated nature of many conventional, unthickened tailings impoundments commonly results in recharge over most of the surface of the impoundment, with discharge occurring outside the impoundment through large containment dykes. Three-dimensional porewater flow modelling suggests that approximately 90% of the total discharge from the thickened tailings occurs within the tailings impoundment. When discharge is confined within the impoundment, there is improved control over low-quality effluent, and an opportunity to design passive control measures to reduce treatment costs and environmental impact.

High temperature X-ray absorption analysis of transition metal complexes in magmatic fluids

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The synchrotron microprobe beam line (X26A) at the National Synchrotron Light Source (NSLS), Brookhaven National Laboratory, New York, was used to collect X-ray absorption fine structure (XAFS) spectra from aqueous Fe, Cu and Zn complexes in fluid inclusions at temperatures ranging from 25°C to 500°C. A modified programmable heating stage was used to control the temperature of a fluid inclusion during spectrum acquisition. High salinity fluid inclusions, believed to contain magmatically generated brines, were selected from the Bingham Porphyry Cu deposit, Utah, and from a granite pegmatite in the Granulite Massif, Germany. Microthermometry, laser Raman, SEM/EDS, and *in situ* X-ray fluorescence analyses of the fluid inclusion indicate that they trapped metal-rich NaCl-KCl-H_2O brines with variable but small amounts of CO_2. In all inclusions the chloride concentrations are about 9 *m*. Analysis of the Zn K-edge XAFS spectra indicates that the tetrahedral chlorozinc complex ($ZnCl_4^{2-}$) is dominant at high temperatures in the studied magmatic fluids. Furthermore, the Zn-Cl bond length decreases by nearly 0.01 Å for every 100°C increase in temperature.

The results show that the application of XAFS to fluid inclusions can provide direct information on metal speciation in hydrothermal solutions at ore-forming temperatures. These data are particularly useful for our understanding metal transport in hydrous-salt melts, where there are little experimental solubility data available. Unlike vibrational spectroscopic techniques (e.g., Raman, optical absorption), XAFS is element specific and can therefore be applied to structural analysis of aqueous species in a complex multicomponent system such as hydrothermal fluids. Minimum detection limit with the available X-ray microprobe is about 5000 ppm.

A new interpretation of the geology of the Kingston Peninsula, southern New Brunswick

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New mapping during the summer of 1996 shows that the Kingston Peninsula is underlain mainly by metavolcanic and minor metasedimentary rocks (Bayswater Group) intruded by high-level granitic plutons. Previous U-Pb (zircon) dating has shown that both the volcanic and granitic rocks are Silurian in age. The Bayswater Group consists of four elongate units composed dominantly of (from southeast to northwest): (1) dacitic lithic and lithic-crystal tuff; (2) dacitic and rhyolitic crystal tuff; (3) dacitic lithic tuff with less abundant crystal tuff, interlayered with metasedimentary rocks (phyllite and schist); and (4) andesitic flows and tuffs with minor volcanogenic siltstone and

slate, and rhyolite. Preliminary petrographic studies suggest that the metamorphic grade in these units is upper greenschist facies. The granitic plutons are characterized by fine grain size and abundant granophyric and locally porphyritic textures, consistent with high-level emplacement. Based on petrological similarities, minor felsic dykes in the volcanic rocks are probably related to the granitic plutons.

Both the volcanic rocks and granitic plutons are intruded by abundant amphibolitic dykes, which may originally have had dioritic mineralogy (magnesio-hornblende + andesine/labradorite), but which have been metamorphosed to greenschist facies like their host rocks. In contrast to previous interpretations, no bimodal dyke complex is present in the Kingston Peninsula.

Other map units include basaltic flows with minor tuff and rhyolite (Long Reach Formation), which form a narrow fault-bounded band along the northwestern margin of the peninsula, and the Gorhams Bluff tuff unit, which has recently yielded a U-Pb (zircon) age of ca. 555 Ma and is part of the Neoproterozoic Belleisle Group. On the southeastern margin of the peninsula, conglomerate, sandstone, and siltstone of Carboniferous age occur in faulted and locally unconformable contact with the Bayswater Group.

Many of the tuffaceous and plutonic rocks contain abundant pyrite, and, locally, minor concentrations of base-metal sulphides and slightly anomalous gold values. Minor barite veins and Cu showings occur in the Long Reach Formation. Although exploration activity in the area has been very limited, the late- to post-Carboniferous faults warrant further investigation because of a close spatial association of stream-sediment geochemical anomalies with these structures.

EdGeo workshops: continuing earth science assistance for Nova Scotia teachers

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For the past three summers, the Nova Scotia Branch of the AGS Education Committee has been offering one and a half day EdGeo Workshops for teachers. The workshops focus on earth science resources available to teachers and how to use them in the classroom in support of the curriculum. On the first day, working with rocks, minerals, ores and the variety of Nova Scotia Museum loan kits, teachers learn the rudiments of classifying rocks, identifying minerals and ores, and applying the information to the classroom. During this time they receive their own reference collection of Nova Scotia rocks, minerals and ores. The second half of Day 1 is a field trip that shows: (1) the geological history of the area, (2) the importance and methods of mineral production, and (3) different techniques and strategies for running field trips. During Day 2 the teachers learn about fossils and geological time, and using computers and the Internet for earth science information. Near the end of the morning, we ask teachers to reflect on how they might use the information presented at the workshop and to critique the workshop.

More than 80 teachers have attended previous EdGeo workshops in Halifax, Sydney and Wolfville. Most teachers are teaching grades 4 to 8, but we do have teachers from grades 1 to 12. Principal funding for EdGeo workshops is provided by the National EdGeo Workshop Committee and the Geological Survey of Canada. Saint Mary's University and the Nova Scotia Department of Natural Resources provide additional support and each of the host institutions assist with facilities. These EdGeo workshops are an important educational resource and are working extremely well according to the teachers who attend. Look for another success this August when EdGeo goes to Bridgewater, Nova Scotia.

Ground temperature histories from geothermal data: evidence of recent climatic change

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Borehole temperature-depth data from Canada have been collected and analyzed to determine past changes in ground surface temperature from temperature perturbations to the equilibrium geothermal gradient. Generalized inversion was used to extract the information from the data. Results suggest a warming by 1 to 2°C in the last 100 years for most of the sites analyzed and the existence of an earlier cool period which may be associated with the Little Ice Age, implying that the warming detected might be partially due to the recovery from this colder period. Regional ground temperature histories (GTH's) were obtained by simultaneous inversion of several temperature logs from the same areas. The inferred GTH's exhibit long-term trends similar to those obtained from tree-ring indices in nearby regions. The modern warming appears to be correlated with the atmospheric concentration of CO_2 as measured in ice cores. Ground temperature is a robust indicator of the energy imbalance at the surface of the Earth; as such it can be used to constrain proxy climatic indicators such as oxygen isotope data from ice cores and dendrochronological data. The particularities of this "calibration" method will be explained and some results presented.

Stratigraphy and mineralogy of the Goldenville Group-Halifax Group transition (GHT) of the Meguma Supergroup at Caribou gold district (drillcore LL81-5A), Nova Scotia

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Drillcore LL81-5A recovered from Caribou gold district, Halifax County, Nova Scotia, by Sherritt Gordon Mines Limited in 1981, is a 628.8 m continuous section of the Goldenville-Halifax Transition of the Cambro-Ordovician Meguma Supergroup. This drillcore provides an unusually complete section of the GHT, which appears to exert significant control on trace metal concentration in the Meguma Supergroup. The purpose of this study is to develop a stratigraphic and geochemical log of LL81-5A and to apply this to regional correlative studies, which should promote a better local and regional understanding of the GHT.

LL81-5A was studied between July and September 1996, at the Department of Natural Resources Drill Core Library in Stellarton, Pictou County, Nova Scotia, where it has been stored since 1984. Based on observations of lithology, mineralogy, sedimentary structures, metamorphism, deformation and structure, a descriptive log of the NQ-diameter drillcore was produced. Sixty-five representative ~15 cm sections of core were split by sawing for detailed study. Nineteen polished thin sections were prepared from these samples and described.

Three conformable stratigraphic units are noted in LL81-5A. Unit A - undifferentiated Goldenville Group (39.62 m): fining-upward sequences, generally consisting of massive, thickly-bedded, light grey-green, carbonate-rich, chloritic, fine to medium grained metawacke, with minor to locally significant pyrrhotite, overlain by thin, dark-grey, chloritic silty slate, with minor pyrrhotite and pyrite. Contacts between individual sequences are typically sharp. Unit B - Mosher s Island Formation, Halifax Group (123.68 m, stratigraphic thickness of 112.63 m): monotonous, thinly-bedded, light green-grey, chloritic silty slate, with thin interbeds of typically parallel-laminated, light grey-green, chloritic metasiltstone and light grey-green, locally carbonate-rich, very fine to fine grained metawacke. Pyrrhotite and minor chalcopyrite are present in all lithologies. The upper half of this unit is rich in spessartine garnet, quartz and carbonate-rich bands and nodules. Unit C - Cunard Formation, Halifax Group (465.50 m): fining upward bottom cut-out Bouma sequences, typically consisting of a basal interval of parallel-laminated, light-grey, in part carbonate-rich, pyrrhotiferous metasiltstone, overlain by an interval of cross-laminated, light-grey, locally carbonate-rich, pyrrhotiferous metasiltstone and capped by an interval of graphitic, slate with generally minor pyrite and pyrrhotite. Variations from this succession are common, with the cross-laminated interval often absent. Contacts between metasiltstone intervals are typically gradational, whereas contacts with slate are approximately evenly distributed between sharp and transitional over ~1 cm contacts. Secondary sedimentary structures related to dewatering, such as convoluted bedding, ball and pillow structures and load casts, are abundant in this unit, especially the upper half. Contacts between individual sequences are generally sharp. In all three units, sulphides are typically present as millimetre-long blebs oriented along cleavage planes.

The Carboniferous Joggins section reconsidered: recent paleoecological and sedimentological research

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The Upper Carboniferous section exposed on the Joggins shore is one of the world's classic terrestrial coal-bearing sequences, yet the details of its depositional setting and paleoenvironment have long remained elusive. Recent research into the paleoecology of the fossil forests reveals that the lepidodendrid forests grew as incipient or established mires on interdistributary plains. These fossil forests are renowned for the invertebrate and especially tetrapod fauna that occur within the lepidodendrid trees, found in the mid nineteenth century by Sir William Dawson and Sir Charles Lyell. Examination of these specimens, now in the collections of the British Museum, London and Redpath Museum, Montreal, shows a ubiquitous association with fossil charcoal. Fire scars, reported here for the first time from the fossil record, provided tetrapods with access to the interior of the trees. The occurrence of the reptiles and amphibians within the basal trunks of fire scarred trees predated infilling of the trunks. These observations, combined with the requirements of amphibian and early amniotic eggs and the analogue of a modern hollow tree guild, strongly suggest that the animals preferred the trees as dens rather than falling victim to pitfalls as long supposed. The lycopsid trees were entombed and if not earlier killed by fire, were smothered by swiftly deposited sand and mud deposits when distributary channels flooded. Disturbance adapted calamites persisted, however, assisted by adventitious growth. Prohibitive conditions for lycopsids and calamites alike are recorded by sharp-based sandstone bodies and planar laminated mudrocks

deposited in deeper water. Current graduate thesis research by DMS suggests that strata associated with persistent, basin-wide fossiliferous limestones may reflect rare but widespread transgressive signatures within the basin fill. The paleoecology of the associated fauna, which includes agglutinated foraminifera, spirorbids, limulids and cartilaginous ray-like fishes and sharks, indeed may have been more akin in the Carboniferous to their "normal" fossil record of estuarine and marine affinity than previously thought.

Innovations in imaging subsurface geological features from 3-D seismic

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New technology manipulation of 3-D seismic data volumes are revealing previously unseen stratigraphic and structural subtleties in east coast offshore basins. Cooperative associations with industry have made several 3-D seismic data volumes available for GSC Atlantic research. Advances in the computer hardware and imaging software required to manipulate and extract information from multi-gigabyte data sets have led to the discovery of geological detail not formerly possible in subsurface marine geology. One example of this increase in detail is the imaging of a braided stream development, several hundreds of metres across, and tens of metres thick and at resolutions never before possible. The combination of new technologies and access to 3-D data sets greatly enhances our ability to quantify subsurface sedimentological and structural parameters, key to the full understanding of petroleum systems.

Large slump structures in the Macumber Formation, basal Windsor Group, Ingonish area, northeastern Cape Breton Island

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Are folds in the basal Windsor Group at northeastern Cape Breton Island due to tectonic forces of middle to late Carboniferous age (as they may be in western Cape Breton), or are they due to syndepositional slumping? The Gays River Formation outcrops as an almost horizontal sheet for 1100 m along the coast of Bear Cove near Ingonish, northeastern Cape Breton. The formation consists of two lithologic zones, in upward succession: (1) carbonaceous, vuggy, black limestone (0.5 m); and (2) thinly to very thinly stratified, vuggy, peloidal dolomudstone (up to 18 m). The Gays River Formation overlies, permeable, pebbly, feldspathic sandstone (Horton Group) of braided-stream facies. Blooms of botryoidal native sulphur and malachite stain exposure surfaces. The dolomudstone is vuggy (cm-sized vugs make up 40% by volume); channels leading upward to foundered spring pits and sand volcanoes abound; mm-sized vugs create a frothy appearance and upper parts of the layer have metre-size, discordant, vuggy pipes. Micro-breccia occurs in other areas but macro-brecciation and cleavage are absent. The dolomudstone has laterally extensive, internally folded sheets arranged in stratigraphic sequence. Individual sheets intercalate either with undisturbed strata or with other deformed sheets. Folds in underlying sheets are unaffected by those in overlying sheets and the facing direction of folds differs between deformed sheets. The folds are tongue or tear-drop shaped, recumbent, isoclinal antiforms ranging in size from metres to several decametres. They form toe-like bodies with vertical separation surfaces, i.e., synforms are absent. In plan sections, folds are fan shaped, with hinges curved through 180 degrees. Vergence varies, with larger folds mainly facing south whereas smaller ones are more variable. The folding rotated lensoid barite-lined vugs up to 20 cm in diameter.

The folds in the Ingonish area are syndepositional slump structures. At the time of deposition, the carbonate ooze was heavily charged with gases. Three sources of the gas were: (1) H_2S and/or SO_2 rising through the permeable Horton Group sandstones from underlying igneous rocks (S-oxidizing bacteria now precipitate the native sulphur); (2) bacterial SO_2 reduction of organic matter in the basal carbonaceous limestone; and/or (3) H_2S and/or CO_2 released as byproducts of SO_4- reducing bacteria that precipitated the peloidal carbonate ooze. Hydrodynamic shock, probably due to earthquakes from boundary faults, increased pore-fluid pressure and released large quantities of gas, creating channels leading to mud volcanoes, and parvoids, bubbles, and spouting vents. The liquefied near-surface layers oozed down a shallowly southward inclined, basin floor. Steep flanks of large, more viscous flows failed, creating divergent, smaller, watery slumps. Refolding of underlying folded layers did not occur because the earlier folding bled prerequisite, excess pore-fluid pressures. The folds are not tectonic.

Stratigraphy of the Upper Carboniferous Colindale Member of the Port Hood Formation, western Cape Breton Island, Nova Scotia

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The Westphalian A Colindale Member comprises the upper portion of the Port Hood Formation in western Cape Breton Island. The member is exposed at Colindale (type section) in the Port Hood area, and at the Evan's Coal Mine, MacRae's Beach, and Chimney Corner in the St. Rose area. A number of diamond drill cores, drilled as part of a coal resource evaluation, intersected portions of the Colindale Member, providing additional documentation of this stratigraphic unit in both areas.

The Colindale Member is both conformable and transitional with bounding strata. The contact with the underlying Margaree Member of the Port Hood Formation is marked by a transition from a sandstone-dominated succession with red overbank deposits, to a succession dominated by grey, fine grained overbank deposits with fewer abundant channel sandstone bodies. This contact can be seen at Chimney Corner and MacRae's Beach, and occurs within a thin concealed interval in the Colindale type section. The upper contact of the member with the overlying Henry Island Formation is known in cores from two holes drilled on Port Hood Island. There, the member is transitional through intercalation with overlying fine grained, red overbank materials of the Henry Island Formation. The Colindale Member reaches more than 830 m thick in the St. Rose - Chimney Corner area, and is approximately 620 m thick in the Port Hood region.

Thick intervals of dark grey to black shales, mudstones, and siltstones typify the Colindale Member, with intercalated sandstones as thick channel sandstone bodies, and as thinner beds within the overbank succession. The fine grained grey rocks of the member consist of shales containing abundant bivalves and ostracodes, mudstones characterized by blocky weathering with slickensides and root traces (paleosols), laminated siltstones, and coal seams with associated carbonaceous shales.

Coal seams of present and former economic significance occur in the upper part of the Colindale Member. The No. 5 seam, up to 2.6 m thick, is a useful local datum for correlating strata of the Colindale Member in the St. Rose - Chimney Corner area. The so-called 6-Foot seam in the Port Hood area provides a comparable local datum. The overall similarity of the member in each of these respective outcrop areas suggests that these two relatively thick coal seams may be correlative.

Digital mapping of the Wentworth plutonic complex, Cobequid Highlands, Nova Scotia, and petrology of its felsic phases

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The Wentworth plutonic complex (the Folly Lake and Hart Lake - Byers Lake plutons of Donohoe and Wallace) is late Devonian-early Carboniferous and is located in the eastern Cobequid Highlands. Mafic magma produced as a result of extension of the Magdalen Basin was the heat source for lower crustal melting to produce felsic magma. Both magma types were emplaced along the Rockland Brook fault. New 1:10 000 mapping of the plutonic complex shows it to be a composite pluton of mafic rocks (gabbro/diorite) and felsic rocks (granite, rhyolite and granodiorite). The southwestern part of the pluton between Fountain and Sutherland lakes consists almost exclusively of gabbro/diorite. Farther east, around Folly Lake, gabbro-diorite includes about 10% granite magma pods and veins. The gabbro/diorite is bounded to the north by a zone, 1 to 3 km wide, of subequal amounts of granite and gabbro/diorite. The northern and eastern parts of the pluton form a belt, 1 to 4 km wide, of principally medium grained granite, becoming fine grained to rhyolitic in the extreme east.

The granites have A-type chemistry and their trace element composition is typical of "within plate" granites. Amphiboles, either calcic or sodic, are abundant within the granites. Sodic amphiboles are restricted to coarse grained granites and include arfvedsonite, riebeckite, katophorite, winchite and richterite. The replacement of other sodic amphiboles by riebeckite and alteration of the dominant K-feldspar to albite both suggest sodic metasomatism. The calcic amphiboles, which have been found in a variety of rock types but never coexisting with sodic amphiboles, include edenite, ferro-edenite, ferro-edenitic hornblende, ferro-actinolite, ferro-hornblende, magnesium hornblende and silicic ferro-edenite. Hedenbergite and ferrohedenbergite replace calcic amphiboles. Biotite is found in almost all lithologies and chemically belongs to the phlogopite-annite series. Thus, the mineralogy of felsic phases of this plutonic complex resembles that of Devonian alkaline complexes in the Avalon zone, such as that of the Welsford igneous complex in New Brunswick.

Determination of bulk permeability within the Morien Group using the forcing of ocean tides in the Sydney Basin in Cape Breton, Nova Scotia

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Since November 1992 the Lingan Colliery in the Sydney coalfield has been steadily filling with water. At the same time the water level in the previously flooded 1B region in the No 26 Colliery has been gradually decreasing. There are no direct excavated links between these two collieries but it is believed that influences of the longwall mining in the Phalen Colliery have caused damage to the barrier pillar between the Lingan and No 26 collieries, resulting in a hydrological connection.

The water levels in the workings in question have been monitored and recorded by the Cape Breton Development Corporation (CBDC) since 1986. In Lingan, water level data recorded by CBDC since 1992, shows a strong tidal signal that overprints the increasing water level signal in the mine. Comparison with regional tidal records over the same time period has confirmed this correlation between water level data and the tidal signal. It is this similarity that is key to determining the bulk permeability of the material surrounding these mines.

An analysis of the phase shift and amplitude of the tidal signal in the water level records provides a direct estimate of formation permeability, following the methods of Wang and Davis. Water level data, analyzed to remove the longer time period fluctuations in levels, are presented with tidal data. Preliminary estimates of permeability based on the tidal signal in these de-trended records are also presented.

Facies correlations within the Ordovician Pointe de la Martinière Formation, Orléans Group, Québec

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The Orléans Group outcrops for some 20 km to the west of Québec City, along the southern shores of l'Île d'Orléans and the St. Lawrence River. The group, part of the Taconian allochthonous sequence, forms the Bacchus Nappe. It is bounded to the northwest by Logan's Line and the Lévis Nappe, and to the southeast by the River Boyer Nappe. The Orléans Group succession comprises the largely conformable Anse Maranda, Lauzon and Pointe de la Martinière formations. The sequence records the transgression of the Cambro-Ordovician, Laurentian, "Atlantic-type" passive margin. This study focuses on the Pointe de la Martinière Formation, with particular emphasis on depositional controls and facies correlations.

The Lauzon and Pointe de la Martinière formations are composed primarily of interbedded turbidites and shales, with the latter characterized by the appearance of red shales. Additional facies developed within the Pointe de la Martinière Formation include black shale-limestone intervals, dolomitic siltstones and shales and limestone conglomerates. These facies are interpreted to reflect deposition within a base of slope/rise setting, with the contemporaneous Lévis Formation within the Lévis Nappe representing a more proximal depositional environment.

Black shale-limestone intervals are well-documented within the Lévis Formation. These intervals have been attributed to the intensification of the oxygen minimum layer during periods of marine onlap and coastal upwelling. The high level of biostratigraphic control displayed by the Lévis Formation enables the correlation of the black shale-limestone intervals, with those developed in the Pointe de la Martinière Formation. Further to the east, the black shale limestone intervals are not developed. However, dolomitic shales do form and are assumed to be genetically related to the black shale-limestone intervals and therefore possibly correlative.

The approach adopted in this study suggests that the Lauzon, Pointe de la Martinière boundary, when taken as the first appearance of red shale, is diachronous. This conclusion is corroborated by field observations of lateral facies shifts.

Overview of seismic reflection results from the western Maritimes Basin

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Recent seismic reflection work in the western part of the Maritimes Basin has focused on the onshore basins. These onshore studies allow a direct comparison with offshore structure and stratigraphy, using an extensive seismic reflection data base consisting of more than 45,000 line km of data.

Seismic horizons were mapped in the Moncton, Cumberland, Antigonish-Mabou, and Magdalen basins. Up to eight seismic horizons were mapped in the Cumberland Basin, whereas only three to four horizons were mapped in the other basins. The base of the Windsor Group was a key

seismic horizon mapped in all of the above noted basins. An upper Windsor Group horizon was mapped in all basins, but correlation with lithological control suggests this horizon may correspond to different stratigraphic levels of the Windsor Group in different basins. A base Horton Group horizon was mapped in the Moncton and Magdalen basins, and a base of the Boss Point Formation was mapped in the Cumberland Basin. This seismic stratigraphic framework provided the basis for onshore-offshore stratigraphic correlation.

Onshore tectonic elements which were identified offshore include the Westmorland Uplift, Sackville Subbasin, Hastings Uplift, and the Scotsburn Anticline. Major faults which were traced from the onshore area into the Gulf of St. Lawrence, include the Belleisle, the Rockland Brook and the Hollow faults. The transition between the numerous structural basins onshore and the one large basin offshore, can be mapped and studied using the seismic data. In general, the western Maritimes Basin is asymmetric, with a deformed southern margin and a gently tapering northern margin.

Photographic Record of A.G.S. Activities

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A selection of photographs taken at the Atlantic Geoscience Society's Symposia, Colloquia on Current Research and Field Trips is presented for the delectation of current members. Starting with the 1976 Colloquium held at Mount Allison University, the panels display photographs of many of the characters who have been active in the A.G.S. over the years, as well as guest speakers, award winners, field trip leaders, and many "significant others". Colloquia and Symposia at various locations are highlighted, e.g., Fredericton (1983), Wolfville (1990), and Amherst (1979, 1989, 1991 and 1994). The Society's first "Summer Field Trip" (to the Parrsboro area in August, 1989) shows members enjoying the great outdoors along with their parents and offspring. The large selection taken on the field trip associated with the 1986 "Basins Symposium" shows members guiding visiting scientists from China, Russia, USA and the UK over some of the interesting geology of Nova Scotia and New Brunswick.

The collection of photographs from which this selection has been taken may well provide a useful database for the "History of the A.G.S." (which is about to be prepared by Howard Donohoe and Laing Ferguson) and our Archives.

First reported occurrence of schwertmannite related to acid rock drainage (ARD) from the Halifax slates, Nova Scotia

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Schwertmannite [$Fe_8O_8(OH)_6SO_4$] is a secondary iron oxyhydroxysulphate mineral associated with acid rock drainage (ARD) that results from sulphide oxidation. In the past, secondary iron minerals have been loosely termed "amorphous ferric hydroxide" and are grouped under the general term "ochre deposits". Mainly, this has been because of their very fine grain size and poor crystallinity, which has led to difficulty in characterizing their crystal structure and chemical formula. Recently, it has been recognized that ochre deposits related to ARD are composed of identifiable minerals such as jarosite, ferrihydrite, goethite and schwertmannite. Each of these minerals has its own distinct crystal morphology, size and degree of crystallinity. These characteristics, in turn, are known to be important controls for the activity of iron, as well as several other environmentally significant trace elements such as Cu, Pb, Cd, etc. Therefore, it is important to identify each individual phase present in such secondary deposits.

Schwertmannite occurs in an ochre accumulation, approximately 25 km north of the city of Halifax, Nova Scotia. The ochre occurs as a reddish precipitate on the surface of semi-submerged rock fragments in a small pond at the base of a quarry, that exploited black slates of the Halifax Group, Meguma Supergroup. The mineral is associated with ARD formed from disruption and oxidation of sulphide minerals (pyrrhotite and pyrite) in the black slates. Two pH measurements of the water in the pond gave values of 2.69 and 2.72 (June 20, 1995). The mineral has the typical fibrous or "pincushion" morphology described for schwertmannite deposits elsewhere. Its XRD pattern is characterized by eight broad peaks with d-spacings between 1.4 and 5.3 Å. The fibrous crystals coalesce to form larger, spherical aggregates and, in places, encapsulate bacterial cells. It is likely that crystallization resulted from the microbial oxidation of Fe^{2+}.

Revised stratigraphy of the Rollingdam area, (NTS 21 G/6), southwestern New Brunswick

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Stratigraphic relationships suggest that sedimentation was continuous in the Rollingdam area from the early Ordovician to mid-Silurian, a time span of some 80 million years. Deposition of the fine grained turbidites of the Woodland Formation took place in a back-arc basin that separated chains of peri-Gondwanan island arcs from the Avalon Platform. Grain-flow deposition of thick-bedded, quartz-rich sandstones of the Kendall Mountain Formation marks the cessation of rifting and consequent filling of the back-arc basin in the mid-Ordovician. Abundance of coarse, volcanic and subvolcanic detritus in feldspathic wackes of the Digdeguash Formation and calcareous wackes of the Flume Ridge Formation reflect tectonic uplift and erosion of the outlying volcanic islands during the transformation from a back-arc to a deepening foreland basin environment. Detrital mica from the Digdeguash Formation has a relatively uniform Ar-Ar age of 484 Ma suggesting that the remnant Annidale volcanic arc, with a U-Pb date of 493 Ma, is a possible source. An Ar-Ar date of 453 Ma on detrital mica from the relatively fine grained Flume Ridge Formation indicates that a change in source occurred between the latter part of the Ordovician and the mid-Silurian. The Tetagouche back-arc volcanic complex of central and northern New Brunswick provides a suitable source since mica-bearing granites from that area have yielded U-Pb ages ranging from 479 to 451 Ma.

Decreasing intensity of deformation up-section from the Woodland Formation to the Flume Ridge Formation suggests that the foreland sedimentary wedge containing these rocks was thrust over the Avalon Platform along a major detachment zone in mid-Silurian time. Subsequent extension in the accreted wedge led to the development of listric faults and deposition of the late Silurian Oak Bay-Waweig successor sequence.

Miramichi-Tetagouche stratigraphic relationships

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Mapping the boundary between the Miramichi and Tetagouche groups has important implications for exploration in the Bathurst Mining Camp, since stratiform sulphide deposits appear to occur only within the volcanic-dominated Tetagouche sequence. Along the Tetagouche River, local uplift during initiation of Tetagouche volcanism has resulted in the deposition of a conglomerate horizon that provides a useful marker to define the Miramichi-Tetagouche boundary. Two sections located on the Tetagouche River, one at Little Falls and the other 3 km upstream at the confluence of Patrick Brook, expose the contact relationship between the Tetagouche and Miramichi groups. The basal beds of the Tetagouche Group, the Vallée Lourdes Formation, are best exposed at Little Falls, where a thin (50 cm) conglomerate, containing siltstone pebbles derived from the underlying Patrick Brook Formation of the Miramichi Group, is overlain by some 25 m of calcareous sandstone and nodular limestone topped by 1 to 4 m of laminated, dark grey silty shale. Felsic tuff (Little Falls Member) of the overlying Nepisiguit Falls Formation contains tongues of shale injected from below. Both the tuff and underlying calcareous sandstone are trough cross-bedded indicating deposition in relatively shallow water.

Dark grey shale and medium- to thick-bedded, medium grey, wacke and siltstone exposed on the Tetagouche River at the confluence with Patrick Brook, constitute the type-section of the Patrick Brook Formation. Disruption of wacke beds has produced local horizons of blocky mélange within this turbidite sequence. Turbidites at the Patrick Brook type-section correlate with lithologically similar rocks of the Miramichi Group occurring downstream beneath the unconformity at Little Falls. Conglomerate in fault contact with the turbidites of the Patrick Brook type-section contains pebbles of siltstone like those observed at Little Falls, clearly indicating that the faulted conglomerate was originally deposited stratigraphically above the Patrick Brook Formation. A Celtic brachiopod assemblage from calcareous siltstone overlying the conglomerate indicates that the Vallée Lourdes Formation is late Arenigian to early Llanvirnian (early Ordovician) and correlates with the conodont-bearing Vallée Lourdes conglomerate at Little Falls. In other parts of the Bathurst Mining Camp, the Vallée Lourdes Formation is not present, and shales and wackes of the Patrick Brook Formation (Miramichi Group) are directly overlain by volcanic rocks of the Tetagouche Group.

Possible raised marine sediments on the east coast of the Avalon Peninsula, Newfoundland

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This paper presents descriptions and preliminary interpretations of sedimentary sequences exposed in coastal sections near Tors Cove, 40 km south of St. John's, on the Avalon Peninsula, Newfoundland. Interbedded diamictons and pebbly mud, up to 20 m thick in places, outcrop discontinuously along the coast and on offshore islands. Diamictons, which comprise the bulk of the coastal deposits, have a sandy matrix and generally appear stratified with some evidence of inverse grading. Erratics and striated clasts are common. Individual clast fabrics display a range of azimuths in a girdle-type pattern. These characteristics suggest a debris flow origin for the diamictons, possibly in an ice-marginal environment, as glaciers retreated inland to local ice centres on the Avalon Peninsula.

Pebbly mud, up to 4 m thick and 15 m above sea level (asl), varies from structureless to finely laminated and is composed of 80% clay. Individual laminae, ranging in thickness from millimetres to centimetres, are laterally continuous and drape underlying structures. Vertically-oriented clasts that deform underlying laminae are interpreted as dropstones. Preliminary interpretation of this unit suggests a subaqueous origin in a relatively low-energy environment. The occurrence of dropstones implies ice rafting and the close proximity of a calving glacier margin. Although marine fossils (e.g., foraminifers) were not identified during preliminary analysis, a marine origin for the mud is considered plausible given its areal extent and thickness. Former high sea levels in the area are also suggested by a gravel ridge at 13 m asl and discontinuous terraces up to 23 m asl.

If a marine origin can be verified for the pebbly mud near Tors Cove, then it would represent unequivocal evidence for a high sea level stand along the east coast of the Avalon Peninsula, where it was previously thought that sea level since the last glaciation was always below present. The sedimentary characteristics of the mud and its stratigraphic relationship with glacigenic deposits suggest that the high sea level stand occurred immediately upon deglaciation of the coast.

$^{40}Ar/^{39}Ar$ thermochronology of the southeast Central Gneiss Belt, Grenville Province, Ontario

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As different minerals begin to retain Ar at distinct temperatures (i.e., the "closure" temperatures), $^{40}Ar/^{39}Ar$ dating of suites of minerals can be used to reconstruct the cooling history of rocks in ancient orogenic belts. This information furthers our understanding of tectonic processes by placing constraints on the timing and relative rates of uplift/erosion and is required to test tectonic models.

The Grenville Province, exposed from Georgian Bay, Ontario to southern Labrador, is generally accepted to represent the deeply eroded remains of a collisional mountain belt formed during the ca. 1.0 to 1.2 Ga Grenville Orogeny. During this event, magmatic arcs and/or continental terranes, represented in Ontario by the Central Metasedimentary Belt (CMB), were accreted to the pre-existing Laurentian Craton. The Central Gneiss Belt (CGB) represents the reworked Laurentian Craton and is separated from the CMB by the Central Metasedimentary Belt boundary thrust zones (CMBbtz), a major crustal-scale thrust belt. Previous studies have reported relatively uniform $^{40}Ar/^{39}Ar$ ages across the northern part of the CGB (in the Britt and Shawanaga domains); from these data, uniform, slow post-orogenic cooling has been inferred. This contrasts with data from rocks further to the north, in the Grenville Front Tectonic Zone, which have a two-stage cooling history with initial cooling occurring at a much higher rate. At present insufficient Ar data exist to constrain the cooling history for the southern margin of the CGB, which represents the footwall of the CMBbtz.

For this study, fourteen samples from within ~30 km of the northern margin of the CMBbtz were selected for dating. The samples complement a recent U/Pb study and include seven hornblende separates, four K-feldspars, and three biotite single grain samples. To date, analyses have been obtained from three K-feldspars. In the McClintock subdomain, K-feldspar age spectra show two-phase release patterns with the first phase attaining Ar closure at ~900 to 920 Ma and the second phase at ~800 to 825 Ma. A single-grain feldspar sample from just north of the CMBbtz in the Muskoka domain shows a single phase release pattern with a minimum age of ~800 Ma. These results are compatible with known structural/age differences in this part of the CGB. Additional data and interpretation will be presented.

Windsor Group stratigraphy, Magdalen Islands, Quebec

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Windsor Group rocks on the Magdalen Islands, transported to the surface as tectonic rafts by salt diapirs rising from depths as great as 10 to 12 km, provide key insight into the character of the marine Viséan in the north-central portion of the western Maritimes Basin. Volcanic rocks, closely associated with regionally more typical marine carbonate rocks and evaporites, make this local succession unique in the Viséan of eastern Canada. Lithostratigraphic and biostratigraphic assessment suggests that carbonate marker beds represent equivalents of middle and upper parts of the Nova Scotia 'type' Windsor Group, including the highest marine beds known in the type area. Carbonate members equivalent to both the Herbert River and Kennetcook limestone members of the upper Windsor type succession can be recognized on the Magdalen Islands, attesting to the widespread distribution of these relatively thin marine bands in the Late Viséan of eastern Canada. The volcanics, including vesicular and amygdaloidal basalts with minor pyroclastic rocks, occur only in association with middle Windsor Group gypsum, limestone and siltstone in surface exposures. Volcanic rocks occur at two main stratigraphic levels within the middle Windsor, in a succession estimated at approximately 1000 m in thickness. Similar sedimentary suites higher in the Windsor Group lack any associated volcanic rocks (Île Boudreau) or are in tectonic contact with volcanic-bearing successions (Île d'Entrée). Thick salt deposits, which underlie and are presumed to diapirically intrude middle and upper Windsor Group strata, represent the product of the first major cycle of Viséan marine sedimentation in the region. The Magdalen Island Viséan succession, except for its regionally unique volcanic component, is most comparable to that of central and eastern Nova Scotia. This seemingly complete Windsor Group succession contrasts with rocks of similar age in southeastern New Brunswick and northwestern Nova Scotia, which lack Upper Windsor marine carbonate members. The Magdalen Islands' exposures, albeit imperfectly preserved and structurally complex, help to constrain the interpretation of regional Viséan facies in the western Maritimes Basin.

ESR and OSL geochronology of the East Milford, Nova Scotia, Canada, mastodon locality, and the timing of the Illinoian-Sangamon transition

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The final results of a multidisciplinary geochronological study of sediments and the fossil remains from the East Milford, Nova Scotia mastodon locality, are reported. The unconsolidated sediments containing the fossil were dated using optical dating (OSL), the fossil dental enamel was dated using electron spin resonance (ESR), and the fossil bone collagen was dated using ^{14}C dating. Analyses of two sediment samples, based on added radiation doses of up to 2400 Gy, yielded statistically indistinguishable ages of 127 ± 13 ka (EMM1) and 143 ± 16 ka (EMM2), with an average of 135 ± 15 ka. This suggests that the sediments mantling the wall of the cavity in which the mastodon foundered were deposited during late Illinoian deglaciation (end of oxygen isotope stage 6), or at the beginning of the Sangamon Interglacial (oxygen isotope stage 5). Pollen data confirm an interglacial climate, which provides a low-precision, independent geochronological support for the early onset of stage 5 suggested by the Devil's Hole data of Winograd and others. The fossil dental enamel was ESR dated at 74.5 ± 6.9 ka, and indicates death at the end of oxygen isotope stage 5a, when the climatic cooling leading to the Wisconsinan glaciation had already begun. Fission track analysis of the tooth showed minimal U uptake, restricted to <10 to 25 μm in enamel and to 100 to 300 μm in dentine. Some U uptake in the much more porous bulk bone was present. We suggest that the gypsum geochemistry and very long residence at subzero temperatures during the Wisconsinan inhibited U mobility. This direct age indicates that the specimen became mired in a cavity that was already infilled with much older, probably waterlogged, sediments. The dosimetric ages are in agreement with independent, non-finite radiocarbon ages on the mastodon and fossil wood from an overlying organic horizon. Our results also confirm that pre-Sangamon glacial and interglacial sediments are preserved in Nova Scotia, and that finite absolute ages for them can be obtained using luminescence dating techniques.

Geology and geochemistry of the Upsalquitch Lake Anticlinorium, northwestern Bathurst Camp, New Brunswick

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The Upsalquitch Lake Anticlinorium, an east-northeasterly-trending D_1 structure, is cored by sedimentary rocks of the Cambro-Ordovician Miramichi Group and flanked by volcanic and sedimentary rocks of the Middle Ordovician Tetagouche Group. However, the stratigraphy of the Tetagouche Group is different on either side of a major thrust zone, that

occurs along the southeastern limb of this anticlinorium. South of this thrust, dacitic, quartz-feldspar-phyric volcanic rocks of the Nepisiguit Falls Formation (recently dated at 473 +5/-3 Ma) constitute the lower part of the Tetagouche Group. In contrast, on the northwestern limb, feldspar-crystal, lithic tuffs with subordinate aphyric to sparsely feldspar-phyric flows of the Mount Brittain Formation constitute the base of the Tetagouche Group and are overlain by alkali basalt, slates and cherts of the Camel Back Member, Boucher Brook Formation. A preliminary age of 468 ± 2 Ma has been obtained from a sample of feldspar-phyric, lithic tuff from near the top of the Mount Brittain Formation.

Most samples of the Mount Brittain Formation have equal or slightly greater abundances of high field strength and rare-earth elements than the Nepisiguit Falls Formation and Zr/Y ratios are generally higher than characteristic for the Spruce Lake Formation found to the east. However, four samples (including the sample dated) have distinctly different Nb/Y signatures and REE patterns, and are interpreted to represent a highly fractionated phase of Mount Brittain magma. Amygdaloidal pillow basalts and a distinct amygdaloidal feldspar-phyric, lapilli tuff and agglomerate unit found near the base of the Camel Back Member have Nb/Y ratios averaging 1.6 and moderately low Cr contents (<49 ppm).

The Restigouche (Zn-Pb rich) massive sulphide deposit is hosted by felsic volcanic rocks of the Mount Brittain Formation, whereas the Murray Brook (Cu-rich) deposit occurs in sedimentary rocks that either directly overlie or underlie this formation, at the eastern end of the Upsalquitch Lake Anticlinorium. The stratigraphic position of the sedimentary rocks is problematic because they are overthrust by rocks of the Camel Back Member. Recent work in the Bathurst Camp has shown that the sedimentary rocks intercalated with mafic volcanic rocks of the Boucher Brook Formation, can be geochemically distinguished from Miramichi Group sediments. Ten samples of sedimentary rock from the Murray Brook area were, therefore, analyzed to clarify the stratigraphic position of the Murray Brook deposit. Fine grained sedimentary rocks that host the Murray Brook deposit have a "Miramichi- type" geochemical signature, i.e., they have lower Cr, Ni, V, Sc and higher Th, Nb, Zr and REE than shales from the Boucher Brook Formation found in this area.

Seafloor pockmarks in Passamaquoddy Bay: evidence for a biogenic methane origin

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Pockmarks are now well-known morphological features of the sea-floor, having been identified in marine and lacustrine environments throughout the world. This phenomenon was first discovered in the Maritimes by King and MacLean in 1970, therefore, it is appropriate that one of the most extensively mapped pockmark fields in the world is also local, that of Passamaquoddy Bay, New Brunswick.

Most studies suggest methane gas as the venting fluid (gas or liquid) that current theories of pockmark formation require to initiate failure of sea-floor sediment. The origin of this methane is debated—indeed there are convincing examples of both thermogenic- and biogenic-gas generated pockmarks in the literature. A case is made here that the Passamaquoddy Bay pockmarks are produced by the escape of biogenic methane gas, generated within rapidly-deposited Holocene silts and clays. Support for this conclusion is derived from GIS modeling of sediment, bedrock, and pockmark distributions within the bay.

Additional support for this conclusion is provided by anecdotal evidence, of the sort reported in journals such as **Science** and **Nature**, near the dawn of the twentieth century. Many seemingly unrelated phenomena, reported from lakes and coastal areas throughout the world, begin to assemble into a coherent, plausible hypothesis. These phenomena, such as "Barisal" or "lake guns", "mistpouffers", and even reports of beach sands catching fire, can all be explained by the venting of methane gas from the sea-floor. This contribution presents images of the Passamaquoddy Bay pockmark field, as well as anecdotal descriptions of the aforementioned phenomena, demonstrating their possible relationships.

Fission track research in Halifax, Nova Scotia: technical procedures and research directions in a changing fiscal environment

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The Fission Track Research Laboratory (FTRL) at Dalhousie University is now well established with new equipment and set procedures. The bulk of the FT work is dedicated to apatite, using the external (mica) detector method. Counting and track length measurement are performed in dry conditions utilizing Autoscan™ AS3000 stages mounted on Zeiss Axioplan microscopes. Irradiations are performed in the Slowpoke-2 reactor located in the same building. The 7 hours of irradiation in the lower flux (5.4×10^{11} n/cm^{-2} s^{-1}) of the Slowpoke-2 reactor lead to less internal gradients and inter-capsule variation than irradiation for 900 seconds in the 5×10^{12} n/cm^{-2} s^{-1} flux previously used at the McMaster University reactor.

Enhancement of confined tracks by irradiation with ^{252}Cf fission fragments is done routinely on aliquots of apatite separates. Samples are irradiated at Rensselaer Polytechnic

Institute, Troy, New York and an enhancement of ca. 500% in confined track visibility is normal. Apatite composition is monitored using etch pit size and shape and, if required, samples are analyzed using a JEOL 733 superprobe for F, Cl, and O, allowing for a calculation of OH and CO_2 by subtraction. The probe also determines La, Ce, Nd, Nb, Y, and Sr, which can be used in provenance studies. Modelling is done using Sean Willett's (Penn State University) inverse modelling algorithm, which has been upgraded by Dale Issler (GSC - Calgary).

University research funds for operation are non-existent, and grants from government research organizations are increasingly scarce. The lab therefore does more than 1/2 contract work to finance technical personnel, students, and development research. All revenues are reinvested in the lab. Diversification has been necessary, and the lab's equipment is shared with other research groups involved in mineral deposit exploration and environmental research. In several projects we are coordinating FT thermochronology with K-feldspar $^{40}Ar/^{39}Ar$ thermochronology (with Peter Reynolds, Dalhousie). In addition, we are contributing uranium distribution maps of tooth enamel for the Dalhousie University, Department of Dentistry, and radiation dosimetry for the Dalhousie Luminescence lab of Dorothy I. Godfrey-Smith. We are as well intercalibrating FT, Thermoluminescence (TL), Optically Stimulated Luminescence (OSL) and $^{40}Ar/^{39}Ar$ in suites of rocks younger than 0.5 Ma. The three labs have informally associated as a Geochronology Centre. We are also setting up our own vitrinite reflectance (R_0) equipment and new fluid inclusion heating and freezing equipment, for integrated basinal studies.

Geological and geophysical interpretation of the Rawdon Fault, central Meguma Zone, Nova Scotia

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The Rawdon Fault is a regional-scale, northeast-trending structure that locally separates the Rawdon Block, comprising Cambrian-Ordovician metasediments to the south, and the Kennetcook Basin, comprising Carboniferous strata, to the north. Interpretation of seismic and gravity data and diamond-drilling constrains the Rawdon Fault as steeply dipping, with more than 2 km of apparent dip-slip (south-side-up) offset. A regional Bouger gravity low in the Kennetcook Basin adjacent to the fault is explained by the rotation to near vertical and thickening of low density evaporites. The Rawdon Block is dominated by the Meguma Supergroup, consisting primarily of the northeast-trending, slightly inclined (south) Rawdon Syncline (F_1 fold). A wide zone (>1 km) of fault-related deformation in the Rawdon Block, characterized by rotation of bedding and regional cleavage (S_1) from steep to shallow near the fault, is supported by modelling of aeromagnetic data. Locally, bedding and cleavage are folded into decimeter-scale, low amplitude, upright folds (F_2). Attached Horton Group strata and the unconformity with the Meguma Supergroup are similarly rotated. Bedding-parallel faulting, defined largely by graphitic zones in slate, is common with local development of a shear-related crenulation cleavage (S_2). Locally, S_2 defines a penetrative fabric which is roughly axial planar to F_2 folds. Striations, slickenfibres and crenulation vergence indicate northwest-directed movement, as do local south-dipping discordant brittle faults. Extensional quartz veins are perpendicular to crenulation lineation, suggesting a related origin.

Based on geological and geophysical data, the Rawdon Fault is interpreted as a steep reverse, with movement of the Rawdon Block to the northwest. Fault-related folding, of the fault propagation type, explains relative upward rotation of stratigraphy in the footwall (Kennetcook Basin) and downward rotation of bedding and cleavage (S_1) of the Rawdon Block. The age of faulting is constrained by geological relationships within the Kennetcook Basin including: (1) an angular unconformity of mid-Westphalian strata deposited on deformed Viséan strata, followed by (2) tilting of the mid-Westphalian and Viséan. This indicates the latest movement on the fault is post mid-Westphalian. In addition, the major (pre-middle Westphalian) deformation of the Viséan and older basin fill may also be related to the Rawdon Fault.

Geochemical changes in the soil profile due to deforestation

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It is generally known that deforestation can lead to increased concentrations of K, Al and H^+, in near surface drainage water. Chemical and physical processes governing the formation of soil profiles and the mechanisms that may give rise to fluxes of these elements in the surface water as a result of deforestation are studied here. Soil profiles were studied for a natural growth and a two-year-old clear-cut forest near Lake George, New Brunswick. These two sites are on the same till unit and have a similar magnitude and direction of slope. Samples were taken from discrete soil horizons within the unsaturated portion of the vadose zone. The water table depth varied within 1 to 2 m of the surface. Quantitative estimates of fluxes of Fe, Ca, K, Si, Al, Mn, Mg, Na, Ti, Rb, Sr, Y, Zr, Nb, which occur throughout the profiles, were determined independently of apparent mass changes caused by mass, concomitant volume, and density changes. Results of the mass-balance calculations show differences in soil chemistry between the two profiles as a result of deforestation.

Revisions to Carboniferous stratigraphy on Maringouin Peninsula, Cumberland Subbasin, New Brunswick

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Detailed geological mapping on the Maringouin Peninsula and west of Shepody Bay has recently led to a new understanding of Carboniferous stratigraphy in the Cumberland Subbasin in southeastern New Brunswick. The oldest rocks exposed on the peninsula are evaporites of the Windsor Group, which occupy the core of the Maringouin anticline. The Windsor strata are succeeded conformably by the Maringouin, Shepody and Enrage formations of the Mabou (Hopewell) Group. The Maringouin, Shepody and Enrage formations are interpreted to be distal or axial basin facies of the proximal Hopewell Cape Formation, which occupies a similar stratigraphic interval.

Mabou Group strata are conformably (?) to disconformably (?) overlain by drab maroon redbeds formerly included in the upper part of the Enrage Formation. These rocks have been given member status (Chignecto Bay Member) within the Boss Point Formation, at the base of the Cumberland Group. The Cumberland Group on the Maringouin Peninsula comprises the Boss Point Formation, including the Chignecto Bay Member and the structurally overlying Grande Anse Formation. Grande Anse strata are unconformably (?) overlain by rocks of the Pictou Group exposed at Wood Point.

Major revisions to stratigraphy include: (1) redefining the Shepody - Enrage contact to a position approximately 50 m stratigraphically above previous definitions; (2) restricting the use of the term Enrage Formation to brick-red arkosic grit, conglomerate and mudrocks which conformably overlie the Shepody Formation; (3) reassigning drab maroon and brownish-red, commonly ripple bedded sandstone and mudrocks (formerly Enrage Formation), to the Chignecto Bay Member of the Boss Point Formation; (4) dividing the Grande Anse Formation, traditionally thought to be entirely part of the Pictou Group, into two distinct lithostratigraphic units, one part of the Cumberland Group; and (5) interpreting the unconformity, thought to define the Grande Anse - Boss Point boundary near Johnson Mills, as a fault, most likely part of the Shepody - Beckwith fault system.

Relative chemical and biological oxidation of sulphides in the Meguma Supergroup, Nova Scotia: the role of mineralogy, texture and composition

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Large-scale sulphide oxidation in areas of disturbed bedrock causes acid rock drainage (ARD), which is environmentally damaging and expensive to ameliorate. The extensive outcrops of the Meguma Supergroup in Nova Scotia contain disseminated sulphide minerals, which are an on-going environmental problem, because they lead to acidity and high concentrations of toxic metals in surface- and ground-waters. The problem is most intense in the basal Halifax Group where a well-defined suite of sulphide minerals is dominated by monoclinic pyrrhotite and lesser pyrite. Other sulphide minerals found in Meguma rocks include hexagonal pyrrhotite, arsenopyrite, chalcopyrite, galena, and sphalerite. The same sulphide may occur in different textures, sizes, orientations, or mineral associations, depending on such factors as the degree and type of metamorphism, structure, rock type and composition.

This study was conducted to determine the relative rate of chemical and bacterially assisted oxidation of a selected suite of sulphide minerals. Six pairs of polished thin sections containing a wide selection of sulphide minerals and textures were oxidized in a controlled laboratory experiment. One thin section of each pair was placed in a natural uncultured sample of ARD collected from a quarry near the Halifax International Airport (pH between 3.62 and 3.76). The matching thin section of the pair was placed in ARD effluent from the same source but double filtered at 0.2 microns to remove bacteria (pH = 3.16). Air continuously pumped into the water maintained an aerobic environment.

Surface changes were monitored on a regular basis and recorded with photomicrography. Degree of oxidation was determined by the presence of tarnish (color changes) and depth of etching in pits, cracks and polishing scratches. Preliminary evidence of oxidation indicates a significant difference between the treatments. In general, sulphide minerals exposed to unfiltered, biologically active ARD oxidize faster than in filtered ARD. In the bacterial treatment, the relative degree of oxidation among sulphides is galena > hexagonal pyrrhotite > monoclinic pyrrhotite >> sphalerite > arsenopyrite, chalcopyrite and pyrite. In the non-bacterial treatment, the relative degree of oxidation is galena > monoclinic pyrrhotite >> hexagonal pyrrhotite and sphalerite > arsenopyrite, chalcopyrite and pyrite. Although some of the relationships are explainable in terms of solution chemistry, others are unexpected. This study confirms the essential role played by biological agents in ARD, but also shows that sulphide mineralogy, texture, grain size and geology must be considered in the evaluation of ARD potential in Meguma rocks.

A reassessment of ichnofacies, with emphasis on those present in nonmarine strata

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In the 1960s, Adolf Seilacher observed that, within several globally selected rock sequences, certain trace fossils commonly occurred in association with one another. Where recurrent, these trace-fossil associations (ichnocoenoses) were considered, from the environmental interpretation of co-occurring physical sedimentary structures, to be diagnostic of particular marine bathymetric zones. Accordingly, these recurrent ichnocoenoses were identified as 'ichnofacies' (specifically, from deep to shallow water, the *Nereites*, *Zoophycos*, *Cruziana*, and *Skolithos* ichnofacies, though the bathymetric relationships have since been recognized to be a generalization). Regrettably, Seilacher subsequently looked at nonmarine strata and, failing to identify potentially recurrent ichnocoenoses and the plethora of nonmarine environments that actually exist, placed all the disparate ichnocoenoses within the *Scoyenia* ichnofacies.

We have attempted to correct this inconsistency first by identifying, from selected nonmarine sequences including, in particular, the Carboniferous of the Maritimes, globally recurrent ichnocoenoses, and then by equating them with various nonmarine environments through the environmental interpretation of accompanying sedimentary structures. Six categories of recurrent ichnocoenoses are considered to be present in these nonmarine strata, five of which are sufficiently recurrent for modelling as distinct ichnofacies. These ichnofacies appear to indicate particular combinations of a few major controlling environmental factors: (a) hydrodynamic energy and/or degree of desiccation of the environment; (b) substrate organic-content; and (c) the stability or predictability of (a) and, or, (b) in nonmarine environments.

The *Skolithos* ichnofacies, which is extended from the marine to nonmarine realm, remains indicative of environments of essentially continuous (i.e., predictable) high energy (or desiccation or other stressful environmental conditions), which means that the substrate would be lacking in organic detritus and frequently subject to erosion. The newly introduced *Diplichnites* ichnofacies is indicative of environments of low, generally stable hydrodynamic energy where, for whatever reasons, organic detritus does not accumulate (the ichnofacies representing environments of low, generally stable hydrodynamic energy and abundant organic detritus, equivalent to the *Zoophycos-Nereites* ichnofacies, is not well documented in nonmarine strata). The *Scoyenia* ichnofacies, as emended, reflects conditions where hydrodynamic energy is likely high but yet unpredictable (?seasonal), and the organic content of the substrate continuously low. The *Mermia* ichnofacies, as emended, is indicative of fluctuating hydrodynamic conditions that can interrupt the normal, low energy conditions where organic detritus can accumulate in the sediment. The *Cruziana* ichnofacies, also extended into the nonmarine realm, can be considered a mega-ichnofacies comprising components of several others. Fluctuations between the extremes of high organic accumulation (with low energy and desiccation), and high energy and/or desiccation (with low organic content) in the substrate would be the environmental conditions reflected by this ichnofacies.

Nitrate dynamics in a heavily fertilized agricultural watershed: identification of sources and reduction processes using natural abundances of N-15

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Nitrate loading of surface and ground waters is a widespread problem, particularly in agricultural areas where loading of mineral N fertilizers and animal manure is intensive. Analyses of the stable isotopes of nitrate-nitrogen ($^{15}N/^{14}N$) have been used to identify groundwater nitrate sources, as different nitrate sources have distinct isotopic ratios. Problems arise in the implementation of this technique, however, as the isotopic ratio can be altered when nitrate is reduced (denitrification). Although this presents a problem in using N-15 values to identify sources of nitrate contamination, it provides a great deal of information about the biogeochemical cycling of nitrate, and points to zones where denitrification is an important process.

The present study was conducted in a 500 hectare agricultural watershed located within the St. Lawrence Lowlands where the use of mineral fertilizers and pig manure as N- sources is extensive. Nitrate concentrations and N-15 values have been monitored in streams, tile drains, streamside soil water and streamside shallow groundwater zones in order to characterize both the potential of these zones to reduce nitrate and the degree to which these zones retain the nitrate N-15 source signatures. Changes in nitrate N-15 values consistent with denitrification have been measured in streams and saturated soil water zones.

Compartmentalization of formation waters in the Prince Colliery, Cape Breton, Nova Scotia

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The Prince Colliery is located offshore from Point Aconi, Cape Breton, Nova Scotia. The Colliery is presently extracting coal from the Hub seam of the Morien Group, part of the Carboniferous Sydney Basin. A large channel sandstone body lies above the Hub seam and a calculated salinity profile from resistivity and porosity logs for the sandstone shows a high-salinity water (~65 000 mg/L) separated from a low-salinity water (~10 000 mg/L) below.

Water samples were taken from roof boreholes directly above the coal and from waters flowing from mined-out areas (gob water). Two formation waters (low and high salinity) and a mixed (gob) water are distinguished. The low-salinity formation waters show total dissolved solids less than 35 000 mg/L and a gradual increase in salinity and Ca/Na ratios down dip. The high-salinity formation waters are characterized by total dissolved solids greater than 35 000 mg/L and a higher Ca/Na ratio. Gob samples are a mix of waters from the entire sandstone (as opposed to formation waters which are directly above the coal) but exhibit much higher salinities than formation waters from the same area. Gob samples increase in total dissolved solids down dip and the Ca/Na ratios are similar to those of the high-salinity formation water. Both gob waters and high-salinity waters contain high Br/Cl ratios that distinguish them from local seawater sources.

Petrological analysis divided the channel sandstone into 3 units: (1) an upper 10 m thick sandstone (porosity 13.9-16.9%; permeability 4.44-60.5 md.); (2) an intermediate mudstone (24 cm); and (3) a lower 2.5 m sandstone, with a lower permeability (0.96 md.) upper portion and a higher (2.11 - 4.15 md.) permeability lower portion.

We suggest the compartmentalization of the sandstone by an area of low permeability which separates the two distinct waters. The gob waters are thought to comprise a mix between high-salinity waters from the thicker upper sandstone and the lower salinity waters from the thin lower sandstone. Therefore, the majority of water entering the mine is derived from local basin brines and not from modern seawater.

A $^{40}Ar/^{39}Ar$ study of whole rock slate samples from Meguma gold deposits, Nova Scotia: implications for the timing and duration of auriferous quartz vein formation

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Previous field and laboratory work ($^{40}Ar/^{39}Ar$ dating) on select Meguma Supergroup gold deposits (Beaver Dam, Moose River, Upper Seal Harbour, Fifteen Mile Stream, West Gore, Caribou) indicate vein formation occurred at ca. 370 ± 5 Ma, thus post dating peak regional metamorphism and deformation, based on: (1) retrogression and deformation of contact metamorphic minerals transected by veins in aureoles of 370 Ma granites (e.g., Musquodoboit, River Lake); (2) discordant veins cutting regional (S_1) fabrics (e.g., West Gore); (3) presence of saddle reef veins *sensu stricto* (e.g., Dufferin, The Ovens); (4) late emplacement of bedding concordant and discordant veins during flexural slip folding which overprints regional (S_1) fabrics (e.g., The Ovens, Mooseland); and (5) concordance of $^{40}Ar/^{39}Ar$ ages for hydrothermal vein minerals (biotite, muscovite, hornblende). In order to better constrain the absolute timing of vein formation in deposits not containing hydrothermal minerals amenable to $^{40}Ar/^{39}Ar$ dating (i.e., K-bearing), a reconnaissance program using whole rock slate samples was undertaken. Material from eight gold districts wholly within the greenschist facies of the Meguma Zone was collected, including areas where hydrothermal vein minerals have been previously dated using the $^{40}Ar/^{39}Ar$ method (i.e., Beaver Dam, Moose River, Caribou). Material for analysis was collected from within ribbon-textured veins, adjacent veins and away from deposit areas (i.e., 1-2 km). All material was irradiated together and subjected to the same step-wise heating schedule. The experimental results for all samples are similar, with internally concordant age spectra produced such that for any deposit the same ages are obtained using plateau, correlation plots and integrated dates. Collectively the data indicate a total spread in ages from 403 to 380 Ma, but similar results (i.e., ≤1-2 Ma difference) are indicated for samples from the same deposit, whether hosted by veins, adjacent veins or collected regionally. Where $^{40}Ar/^{39}Ar$ data are available for hydrothermal minerals, the whole rock samples give older ages by ≤10 Ma. The results are interpreted to indicate the following: (1) regional metamorphic ages are retained by vein-hosted slate samples, despite having been bathed in hydrothermal solutions (i.e., 400-450°C); (2) the whole rock ages reflect diachronous metamorphism or cooling throughout the central Meguma Terrane, as also suggested by previous workers; (3) vein emplacement and attendant deformation post-dated peak regional metamorphism and deformation in the areas studied; (4) vein emplacement was rapid enough to prevent diffusive loss of Ar in the slates, even for the least retentive, low-temperature sites; and (5) the vein-forming fluids must have originated at a deeper structural level since the fluids were in obvious thermal disequilibrium with the wall rocks.

$^{40}Ar/^{39}Ar$ ages and the paragenetic sequences in a multi-staged hydrothermal breccia in central Maine

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The multi-stage Abbot Breccia in central Maine is exposed in a 30 by 80 m outcrop in sharp contact with the early Devonian Madrid Formation. The Madrid and other local metasedimentary rock formations are the predominant source of the fragments. The fragments are commonly angular to subangular, elongate, and open-packed. The four mineral assemblages of the hydrothermal cement are predominantly composed of either biotite, chlorite, albite, or quartz, with lesser to minor calcite, muscovite, siderite, hematite, sulphidic opaques, rutile, and apatite. At least two brecciation events have been identified in the Abbot Breccia. The larger second-stage breccia is cemented dominantly by the quartz assemblage. However, the western contact of the second-stage breccia shows a 2 to 3 m wide zone of aligned fragments that are cemented by the biotite, chlorite, and albite assemblages; this zone is <1 m wide along the remainder of the contact. The biotite, chlorite, and albite assemblages form a consistent paragenetic sequence of hydrothermal cements around most of the breccia fragments. The paragenetic sequences of cement and alteration assemblages are comparable to that of alkaline porphyry copper deposits, suggesting that the hydrothermal fluids exsolved from a nearby felsic pluton. The breccia may have been formed by the collapse of a vapour cavity at the apical portion of a cooling pluton. Potassic and phyllic hydrothermal alterations of greenschist minerals within the metasedimentary rock fragments, deformation fabrics in these fragments, and the absence of metamorphism or deformation fabrics in the matrix indicate that the breccia formed after folding and metamorphism of the Madrid Formation during the Acadian Orogeny. Conventional $^{40}Ar/^{39}Ar$ age spectra of bulk mineral separates provide ages of 395 Ma to 400 Ma for hydrothermal muscovite, which is consistent with the known ages (400 Ma to 360 Ma) of the Acadian plutons in central Maine. However, single grain $^{40}Ar/^{39}Ar$ ages for hydrothermal biotite from the same separates range from 430 Ma to 460 Ma, which predates the late Silurian - early Devonian age of the adjacent Madrid Formation. The apparently older hydrothermal biotite may represent excess argon.

Phosphorus-enriched, S-type Middle River rhyolite, Tetagouche Group, northeastern New Brunswick

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In the Middle River area north of the Brunswick No. 12 massive-sulphide deposit, flow-banded rhyolite lenses are underlain by Middle Ordovician, passive margin sedimentary rocks of the Miramichi Group and overlain by immature wackes and black shales of the Boucher Brook Formation (Tetagouche Group) in the autochthonous part of the Bathurst Mining Camp, in northern New Brunswick. Some elements are disturbed by very weak to moderate alteration and mass-balance changes. The least-altered rhyolites are mesoscopically aphyric, although they have well developed microscopic, alkali feldspar spherulitic textures (<0.5 mm). Limited berlinite substitution is evident in these feldspars (P-Al for 2Si) with up to 0.32 wt.% P_2O_5 that may represent disequilibrium partitioning associated with diffusion-limited feldspar growth during devitrification of glass.

The least-altered Middle River rhyolites are peraluminous (ASI = 1.1 to 1.4) and have high silica (73 to 76 wt.%) and low CaO (<0.5 wt.%) contents. They also have very low TiO_2 (0.043 to 0.053 wt.%), Zr (36 to 42 ppm), Th (1.5 to 2.4 ppm), Y (9 to 14 ppm), Nb (12 to 14 ppm), V (<1 to 3 ppm), Sc (2 to 3 ppm), and rare-earth elements (REE = 16 to 19 ppm), but have high P_2O_5 contents (0.2 and 0.3 wt.%), relative to other subalkaline, felsic volcanic rocks in the camp. The low Zr contents indicate that the eruption temperature of these rhyolites was less than 700°C, based on zircon saturation thermometry. The low TiO_2, V, Sc, Zr, Hf, Th, Nb and Ta probably reflect their low fusion temperature, although their strong covariation within these small rhyolite lenses probably reflect very low-temperature process of fractionation. The weak covariance of P_2O_5 and Y indicates fractional crystallization is probably controlling the decrease in rare-earth elements (REE), although the correlation with other REE is poor. Restite REE-bearing phases in the source protolith may account for the overall very low REE abundances. The high Nb/Y (>0.7), Ta/Yb (>4.3), Nb/Ta (<6) and Rb (>200 ppm) values indicate an S-type parentage, which is consistent with the high ^{18}O (13.4 to 15.4‰) for three of the least-altered rhyolite samples. Elsewhere along the belt, these rhyolites seem to be comagmatic with alkaline mafic igneous rocks erupted in a continental back-arc setting. Analogous to the younger felsic volcanic rocks in the camp, these rhyolites are interpreted as fusion products of supracrustal rocks associated with heat advection from intruding mafic magmas and then underwent further low-temperature fractionation of Fe-Ti oxides, zircon and apatite.

A proposal to judge environmental change on Bon Portage Island, Nova Scotia using landsat thematic mapper imagery

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Landsat Thematic Mapper (TM) Imagery has been recognized as a useful tool with which to detect short-term environmental change. In this study, two Landsat TM mini-scenes separated by eight years (7/6/87; 31/7/95) were used to determine whether short-term environmental change on Bon Portage Island, Nova Scotia could be detected. We focused on detecting changes in floral ecology over the study period by determining the change in the spectral signature of 7 test plots on the island. Changes in the spectral signature of two deep water sites near the island were used to calibrate the two mini-scenes.

The majority of the test plots showed an increase in the mean DN values over the study period for bands 1, 2, 3, 4, and 7. Ambiguous results occurred in test plot 7 for bands 4 and 7. Four of the seven test plots showed an increase in the mean DN value in band 5, whereas for the other 3, the DN values dropped. These results suggest that over the study period significant change occurred in the floral communities within the test plots. An overall increase in DN values could be attributed to an increase in the health, vigour, and floral biomass of the test plots. However, this increase may have been influenced by higher rainfall and a longer growing season that characterized the months before the acquisition of the 1995 imagery. We conclude that short-term environmental change detection at coastal sites is possible, however, the noise created by specific events preceding the acquisition of the imagery must be considered in the assessment of the magnitude of this change.

Comparative thermoluminescence dating of Quaternary North American obsidians and mafic lavas

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Thermoluminescence (TL) dating is one of a very small number of techniques that can be applied to a variety of geological material to accurately determine ages of Quaternary deposits. TL dating of solid Quaternary North American volcanic rocks such as obsidian, basalt and dacite, may be extremely useful for thoroughly understanding regional volcanism by allowing correct spatial and temporal correlation of young, solid volcanic deposits. TL dating applied to glass separates from North American Quaternary solid volcanic rocks has not previously been attempted. The focus of this research project is to determine TL age estimates of known-age obsidians and basaltic glass extracts from mafic lavas collected from various localities in western North America. This study will attempt to date 5 obsidians and 11 mafic lavas. All samples have been independently dated with other Quaternary dating methods. Once the TL ages of the samples are obtained, they will be compared with the known ages of the obsidians and basalts. This contribution is presented as a work in progress.

Preliminary analyses of the samples have been completed, including major element analysis, microprobe analysis, and thick source alpha-counting, to determine the dose rates of samples. Alpha counting data of the samples show that the U activity is equivalent to 0.70 to 12.51 ppm, and Th activity is equivalent to 0.39 to 24.05 ppm.

A dose response test was designed to determine the intensity, reproducibility and short term stability of the TL signal of the samples. Samples which showed low reproducibility and extensive short term fading were discarded as unsuitable for TL dating. Unsuitable TL characteristics were noted in 4 samples. The obsidians which showed low disk to disk reproducibility are either extremely old (>3 my), contain extremely high levels of U and Th, as well as radioactive mineral inclusions such as zircon (Mt. Edziza, B.C., obsidian) or possess a saturated level of TL (Crater Lake, Oregon, obsidian). The basaltic glass sample which showed extreme short term fading (Tree Molds Flow, California, basalt) contains low Ca concentrations compared to the glass compositions of other basalt samples. Further detailed microprobe analysis of the glasses is needed to elaborate on the connection between chemistry and TL output. Excellent TL properties were displayed by Ice Springs basalt, Utah, and Callaghan Flow basalt, California, and are expected to yield favourable results.

Magdalen Basin NATMAP program preliminary 1:250 000 compilation of central Nova Scotia and Prince Edward Island

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One of the objectives of the Magdalen Basin NATMAP program is the digital compilation at 1:250 000 scale of new and existing geological maps encompassing northern Nova Scotia, Prince Edward Island, and southeastern New Brunswick. Broad stratigraphic correlations are effectively outlined at this scale, and the large scale nature of important structures becomes evident, while many of the details established at 1:50 000 are still preserved. A new compilation of central Nova Scotia and Prince Edward Island is displayed here and represents the first 1:250 000 scale geological map published from this region. The map draws upon an extensive database and incorporates numerous maps, as well as a wealth of geochronological and paleontological age determinations. The compilation reflects the diversity in the geology of the region, with rocks ranging in age from Proterozoic to Triassic, and also illustrates some of the major structures. Basement rocks are from the Meguma and Avalon terranes, and the Cobequid-Chedabucto fault is the central structural feature. Devonian to Permian cover rocks from the main groupings of the Maritimes Basin cover much of the region. Map production and editing were accomplished using initially Autocad drawing and then Arc-Info GIS programs. Availability of the map in digital format and representation at 1:250 000 will allow for advanced spatial analysis of geological trends with geophysical overlays, which will greatly assist resource exploration as well as research.

An investigation of drumlins in southwestern Nova Scotia: distribution, orientation and mode of formation

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Research in western Nova Scotia focuses on determining the form and spatial distribution of drumlins in the Lunenburg and Halifax drumlin fields. These data were compared to similar data collected from the Livingstone Lake drumlin field, Saskatchewan and the Beverley Lake drumlin field, Northwest Territories, and were evaluated with reference to existing models of drumlin formation. Drumlin form, long axis-short axis (a/b) ratio, average orientation and inter-field long axis variability data were collected for all sites. Drumlins in the Lunenburg field are irregular in shape with few spindle forms present; a/b ratios averaged 3.7 and a-axis orientations averaged 124° and varied by 36°. The Halifax drumlins are similar to those in Lunenburg but are smaller (average a-axis length of 4.7) and less densely distributed; they have a/b ratios of 2.9 and a-axis orientations averaged 150° and varied by 33°. These data contrast to those observed at other drumlin fields. The Livingstone Lake drumlins are spindle, parabolic and asymmetrically shaped and have an average a/b ratio of 7.2 and inter-field a-axis variability of 4°. The Beverley Lake drumlins are spindle shaped and have an average a/b ratio of 14.1 and a-axis orientation varied by 6°.

The Halifax and Lunenburg drumlin fields are markedly different in character from the Livingstone Lake and Beverley Lake drumlin fields. The converging field orientation, inter-field a-axis variability and low a/b axis ratios observed at the two Nova Scotian sites are not features that, when combined, can be easily explained using subglacial meltwater formational models. We conclude that alternate models must be considered to explain the formation of drumlins in western Nova Scotia.

Saline brines of the Sydney Basin: origin as evaporative Windsor residues?

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The Phalen and Prince collieries are mining coal from the Morien Group of the Carboniferous Sydney Basin, Cape Breton, Nova Scotia. The mines are situated beneath the sea, as much as 5 km offshore. Retreat longwall mining techniques allow the roof to collapse behind the mine operation and create an overlying fracture system that taps into the formational aquifers. Understanding the origin of mine waters is critical to the development of conceptual and physical models.

Major ions and selected isotopes were analyzed on samples from both mines. Despite dramatic salinity variation (4,400-160,000 mg/L) within and between mines, most waters are chemically similar Na-Ca-Cl brines that are depleted in K and SO_4 relative to seawater. High Br/Cl ratios favour an

origin of the brines from the residue remaining from the evaporation of salts, probably from the Windsor salt event. Dissolution of halite by groundwater, in contrast, generally produces low Br/Cl ratios, as seen in analysis from local salt springs. Regression lines through both Cl and Na versus Br intersect the seawater evaporation curve at values of 25 to 30 times seawater. This is the concentration where halite precipitates, consistent with Windsor salt mineralogy. The brines were possibly expelled from the underlying Windsor and older sediments during basin compaction and diagenesis.

The waters are greatly enriched in Ca and Sr in comparison to evaporated seawater. $^{87}Sr/^{86}Sr$ ratios range between 0.710051 and 0.711422 and increase with increasing salinity. These are much higher than Windsor (or later) seawater values. The ^{87}Sr may have originated from water-rock interaction with K-rich minerals. Abundant kaolinite pore-filling supports the interpretation that Ca was derived from the breakdown of anorthitic feldspars by acidic waters. The ^{18}O and ^{2}H isotopes plot near the GMWL between SMOW and local rainwater, which is unusual for evaporative brines that underwent water-rock interaction. ^{18}O and ^{2}H isotopes within the brine may have been lightened by extended evaporation, removal of heavy isotopes in hydrolysis reactions and/or by meteoric dilution.

Mineral exploration and development highlights in northern New Brunswick

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In 1996, exploration expenditures in northern New Brunswick were approximately $12.3 million, up $3.6 million over the previous year. About $10 million of this total was spent by half a dozen companies exploring for VMS deposits in the Bathurst Mining Camp of the Miramichi Zone. Another $1.75 million was spent by two companies exploring for VMS deposits in the Tobique-Chaleur Zone and the remainder was largely spent by one company exploring for porphyry copper/skarn deposits in the Aroostook-Matapedia Zone.

The main players in the Bathurst Camp in 1996 were Noranda Mining and Exploration Inc. (including Brunswick Mining and Smelting), Inmet Mining Corporation, BHP Minerals Canada Ltd., Teck Exploration Ltd., and Stratabound Minerals Corp. These companies concentrated their exploration efforts on the lower, felsic-volcanic part of the Middle Ordovician Tetagouche Group, which hosts most of the known massive sulphide deposits in the Camp. All of them acquired additional claims during the year as a result of the ACOA-funded, multiparameter, airborne geophysical survey of the Camp, the results of which were released in July. However, Noranda has been the first company to discover a new massive sulphide occurrence/deposit as a direct result of this survey. Noranda has also been the first company to try using high-resolution seismic in the Camp as a VMS exploration tool.

Exploration in the Tobique-Chaleur Zone was focused on the Shingle Gulch-Sewell Brook area, near Plaster Rock, where the main player has been Chapleau Resources. Chapleau's exploration is directed toward delineating stratabound, ore-grade lenses contained in fragmental volcanic rocks (mostly felsic and mafic hyaloclastites) of the Lower Devonian Tobique Group.

In the Aroostook-Matapedia Zone, the exploration targets are small, high-level, late Silurian to early Devonian intrusions that cut calcareous rocks of the Matapedia and Chaleur groups; these intrusions host and/or are genetically related to known copper ± gold mineralization in several localities, the best known one being McKenzie Gulch. Noranda is virtually the only company exploring in the Aroostook-Matapedia Zone.

On the development side, East-West Caribou Mining Limited took steps to reopen the Caribou VMS deposit in the northwestern part of the Bathurst Camp, which included preparations to open-pit the Restigouche VMS deposit for processing at the Caribou mill. Restigouche is located approximately 25 km west-southwest of Caribou.

Zeolite assemblages in the North Mountain Basalt along the north shore of the Minas Basin, Nova Scotia

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New X-ray diffraction and electron microprobe analysis shows the following assemblages to be present in mafic flows and necks of the upper Triassic-lower Jurassic North Mountain Basalt. Wasson Bluff: chabazite, analcime, stilbite, natrolite, heulandite/clinoptilolite, laumontite, thomsonite, gmelinite. The dominant zeolites are chabazite, stilbite and heulandite and the associated minerals are silica minerals, mica and malachite. Cape Sharp: stilbite, chabazite. The associated minerals are: silica minerals, calcite, malachite. Five Islands: chabazite, heulandite, stilbite, barrerite/stellerite, analcime. The dominant zeolites are chabazite and stilbite and the associated minerals are silica minerals, calcite, and barite. Western Cape D'Or: stilbite, chabazite, analcime, stellerite, natrolite, thomsonite, scolecite, laumontite, heu-

landite/clinoptilolite, mesolite. The dominant zeolites are stilbite, analcime and natrolite and the associated minerals are silica minerals, malachite and magnetite. Horseshoe Cove: heulandite/clinoptilolite, stilbite. The associate minerals are silica minerals and calcite. Partridge Island: stilbite, analcime, chabazite, epistilbite, natrolite, heulandite. The dominant zeolites are stilbite and chabazite and the associated minerals are silica minerals, mica, calcite, malachite, magnetite and ?galena. Two Islands: analcime, gmelinite, chabazite, stilbite and natrolite. The dominant zeolite is analcime.

At Wasson Bluff, the geological events related to the zeolite formation, based on our field observations, are as follows (from early to late): (1) extrusion and cooling of basalts; (2) deposition of sediment in columnar joints and formation of zeolites in vesicles; (3) early faulting, with some brecciation and rotation of columnar joints (sediment in joints has zeolites in vugs and rosettes); (4) deposition of sediment in rotated columnar joints; (5) deposition of monomictic conglomerates and breccias off fault scarps, rotated or widened columnar joints have cavities filled with zeolites; (6) repetition of sequence 1-5; (7) deposition of polymictic conglomerate, no zeolites; and (8) later jointing and faulting. Formation of zeolites thus appears to be closely associated with basalt extrusion, rather than being a result of burial diagenesis.

Responding to increased demand for east coast geoscientific data information and knowledge

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The creation and maintenance of digital databases are a unique and valuable product of the GSC Atlantic's petroleum geoscience research program. Historically, access to such databases has been cumbersome, often requiring the help of data extraction experts. The GSC's internal need for easy access to the data coupled to the dramatic increase for external access by oil companies has driven our utilization of Internet and the World Wide Web technology in conjunction with the relation database protocol to create easy to use graphical user interfaces that access and display data quickly and effectively. This contribution will present examples of completed database interfaces and illustrate those under development. It will also highlight the GSCA Web site as an important knowledge distribution medium.

The nature of the Triassic-Jurassic transition, Bay of Fundy region, eastern Canada

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Key geological elements of a defining interval in earth history are preserved in Triassic-Jurassic rift basins associated with the breakup of Pangea. In eastern North America, the Fundy Basin is the largest and deepest of nine major early Mesozoic basins of the Newark Supergroup. It consists of a more than 10 km-thick sequence of middle Triassic to middle Jurassic continental sediments and interbedded tholeiitic flows. The largest portion of Jurassic strata is located offshore. Onshore, typical Triassic palynoflora are succeeded by a fern-dominated "spike" at the putative Triassic-Jurassic (T-J) boundary. This transition is located within a few metres of the base of the 400 m thick, 191 ± 2 Ma old North Mountain Basalt (NMB). Overall, the stratigraphic succession is that of continental sediments, primarily fluvial, eolian and playa lacustrine facies.

The breakup of Pangea coincided with the early evolution of the dinosaurs and crocodylomorphs, the appearance and proliferation of tritheledonts and the cessation of numerous typical Triassic life lines. At the T-J boundary ca. 45% of all life at the family level disappeared from the fossil record. Indications from the studies of invertebrate faunas suggest that mass extinctions during the early Jurassic occurred on a time scale of millions of years. However, an abbreviated time frame seems indicated for the "great dyings" at the T-J transition in Nova Scotian continental sediments. In strata overlying the NMB, footprint assemblages (e.g., *Anomoepus, Batrachopus* and *Otozoum*) are compatible with the distinct character of Lower Jurassic footprint fauna. Continental tetrapod assemblages in Hettangian strata above the NMB include tritheledonts, ornithiscian and prosauropod dinosaurs, crocodylomorphs, archosaurs and lepidosaurs, but lack late Triassic forms such as procolophonids and parasuchian and rauisuchian archosaurs. These have been described as "survivor assemblages".

If meteorite impact is held to account for the extinction of Triassic (Norian stage) tetrapods, then shocked quartz, the most important and unequivocal evidence of terrestrial impact, should be preserved in strata of the appropriate time interval. We present here the first results of a search for shocked quartz at the T-J boundary of the Newark Supergroup. Quartz-bearing rocks sampled 1 m below the NMB display in thin section up to five different sets of sub-parallel, sub-planar features, which contain numerous tiny voids causing the optical contrast. To test the nature and origin of

these features they have been investigated by universal stage and transmission electron microscopic (TEM) techniques. Within error limits, universal stage measurements reveal that the features seem to be oriented parallel to rhombohedral planes, which would favour their shock origin. However, detailed follow-up TEM observations of the same grains show that the optically visible features are sub-grain boundaries. Also, many perfect dislocations are present in the quartz grains, which clearly indicate tectonic origin. This microstructure is distinctly different from that of shocked quartz, which is free of dislocations and contains amorphous silica lamellae, the so-called planar deformation features (PDFÕs). The preliminary results of this study demonstrate that careful TEM analysis of microscopic features in quartz is necessary to unequivocally test for impact origin. A catastrophic impact event at the T-J boundary cannot be excluded because this boundary has not yet been comprehensively investigated.

Fingerprinting natural and anthropogenic organic matter in recent sediments from Lake Ontario

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Selected surface sediment samples (sediment depth 0-10 cm) collected along the central east-west axis of Lake Ontario in Canadian waters (water depth 64-121 m) were chosen for organic matter (OM) characterization using organic petrological and geochemical techniques normally reserved for the study of coal, petroleum source rock, and crude oil. The study was performed to assess the effectiveness of these techniques in discriminating between natural and anthropogenic OM and to determine the extent of organic pollution of the lake sediments.

Most analyzed samples have more than 3% total organic carbon. Forty to seventy-five percent by volume of this organic matter is derived from anthropogenic pollutants. The natural components are derived from cellulose bark tissues, lignin-rich stems, charcoal, fungal spores, lacustrine algae (also biodegraded), and bacterial clusters. Organic petrology and pyrolysis-gas chromatography/mass spectrometry revealed presence of bituminous and semi-anthracite coals, carbonization residues (char and fly ash) possibly derived from shipboard combustion or nearby power plants, biodegraded crude oil, chemicals, plastics, and sewage products. The variation of organic pollutants in different sites in Lake Ontario is caused by the location of industries, past shipping lanes, river flow, and water circulation.

Speciation of elements in the feed coal and combustion residues from the Lingan Power Plant, Sydney, Nova Scotia

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Systematic changes in mineralogy, enrichment and depletion of selected elements, mineralogical speciation of selected elements in fly ash and bottom ash samples from the Lingan Power Plant were compared to run-of-mine and pulverized feed coal from the Sydney coalfield, Nova Scotia. The analytical techniques used for this research were incident light microscopy, SEM-EDX, XRD, microprobe with EDS and WDS, INAA, and heavy liquid separation.

Three types of glasses (Fe/O-rich, Fe/Al/Si/O-rich, and Al/Si/O-rich) were identified in the combustion residues; these glasses and neoformed minerals were evolved as a result of interaction between melted pyrite, carbonate, and phyllosilicates. Most priority elements (e.g., As, Pb, Cr, etc.) were concentrated in the fly ash and mostly in the noncrystalline phase of the Fe/O or Al/Si/O. X-ray mapping suggested that some of the priority elements such as arsenic are also associated with Fe/O and Fe/S crystalline phase in the bottom ash. The speciation of various elements indicates the possible leachability pathways.

Ice-flow history, eastern Bathurst Mining Camp

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One objective of the EXTECH-II project is to complete Quaternary mapping of the Bathurst Mining Camp (BMC) at 1:50 000 scale to define: (1) the distribution and character of surficial materials, (2) the relative chronology of ice flow, and (3) the contrast in glacial features in different parts of the BMC. During 1996, surficial mapping and till sampling were conducted in the Nepisiguit Falls map area, with emphasis on the area between the Captain North Extension and Brunswick No.12 deposits. Eighty-five till samples have been collected to date, filling gaps in a pre-existing regional survey. Exploration trenches and a Geological Surveys Branch pitting program assist in defining the stratigraphy, glacial shearing, and facies changes in glacial and pre-glacial surficial materials.

The western part of the Nepisiguit Falls map area is host to many known massive-sulphide deposits. The underlying bedrock comprises mainly sedimentary and bimodal volcanic rocks of the Miramichi and Tetagouche groups respectively. Carboniferous sedimentary rocks underlie the eastern part of the area. Outcrop is sparse and regolith thicknesses of >4 m are common locally. However, any large outcrops shown on the bedrock maps were visited because they commonly have well developed striae, grooves, and whaleback forms, indicating multiple phases of glacial flow.

A compilation of ice-flow indicators from this project and previous work indicates that the glacial history of the eastern part of the BMC is complex. An ice-flow domain boundary (Miramichi Highlands/New Brunswick Lowlands physiographic boundary) crosses the area in a northeast direction approximating the western margin of the Curventon-Bathurst Valley (CBV), a low-lying, poorly drained area with many swamps and glacially streamlined and fluted bedrock. Initially, ice flowed off the highlands in an eastward (070–110°) direction into the extreme western part of the Nepisiguit Falls map area (California Flow Pattern). Just southwest of the Nepisiguit Falls map area, ice flow was in a southeast (140°) direction (Sevogle Flow Pattern). Subsequently, ice flowed in a north-northeast to north direction through the CBV to the Baie des Chaleurs (Nepisiguit Flow Pattern). There is evidence (striations) of a late-stage ice flow (Tracadie Flow Pattern) in a northwest direction across the CBV. At some locations, there is evidence for early northeastward (020–030°) and southeastward (130°) flow preceding the dominant eastward ice flow. A till fabric in the southern part of the area in thick till over Carboniferous rocks trends at approximately 035°, matching striations and grooves nearby and indicating till deposition in the CBV by the Nepisiguit Flow Pattern.

Dating of alteration at the Radomiro Tomic porphyry copper deposit, northern Chile, by the high-precision $^{40}Ar/^{39}Ar$ method

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The Radomiro Tomic (RT) porphyry copper deposit is located approximately 5 km north of the Chuquicamata mine and 245 km northeast of the port city of Antofagasta. Estimates place the deposit at 800 million tonnes of ore with an average grade of 0.59% Cu (mostly supergene ore) and a mine life of 22 years. RT does not outcrop and has been known only from drillcore and limited underground workings. The entire deposit is buried beneath Miocene piedmont gravels up to 200 m in depth. Stripping is now underway and the mine is due to start operating in 1997 as a new separate division of CODELCO.

The deposit is hosted within an intrusive body of granodiorite to monzodiorite composition that is approximately early to middle Oligocene in age and was emplaced within the regional, north-south trending Domeyko Fault system. This system is spatially associated with all the major porphyry deposits in northern Chile.

The intensity of copper mineralization (bornite and chalcopyrite) is proportional to the intensity of potassic alteration. Quartz-sericite alteration is structurally controlled and overprints the potassic alteration zone. The quartz-sericite alteration is also associated with relatively unimportant chalcopyrite and covellite mineralization. The propylitic zone surrounds the potassic zone and is characterized by the presence of epidote, chlorite, quartz and carbonate. Hypogene mineralization (bornite, chalcopyrite and pyrite) is extensive, where supergene mineralization is generally contained between 100 m subcrop and 400 m depth, with localized areas associated with the more fractured quartz-sericite alteration extending to a depth of 800 m. Supergene mineralization consists of chalcocite and covellite. It underlies a thick blanket of oxidized ore consisting of soluble copper oxides and copper halides.

This study will date both the potassic and quartz-sericite alteration assemblages. K-feldspar, biotite and sericite grains were hand-picked from the six drillcore samples and dated by the high-precision, stepwise degassing $^{40}Ar/^{39}Ar$ technique at Dalhousie University. Preliminary results indicate the influence of a single major hydrothermal event of Oligocene age rather than the two events that have been defined at the Chuquicamata deposit. The K-feldspar spectra are suitable for thermal modelling which will be done in

order to ascertain closure temperatures and cooling rates. A full suite of ancillary data is being generated on the dated samples to establish not only the petrology, mineralogy and chemistry of the dated rocks but to compare them with similar rocks at Chuquicamata. The study is expected to help place RT within the context of the regional geology and other mineralized centres in northern Chile.

Origin of zeolites in zoned amygdales from the North Mountain Basalt, Nova Scotia

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A variety of analyses (XRD, electron microprobe, SEM, EDS) have been made on eighteen samples of zoned amygdales and veins from the North Mountain Basalt between Morden and Ross Creek. Amygdales and veins consist principally of zeolites, but silica minerals are also common. Mordenite, the highest temperature form, is found on the rims of amygdales, with a pink outer zone and a greenish inner zone. The green colour is the result of an Fe-Mg-Na-rich mineral, possibly smectite. The cores of the amygdales consist of one of heulandite/clinoptilolite, epistilbite, or the stilbite group. Contact zones of different zeolites show porosity between crystals in the SEM. These pores appear linear and resemble fractures in thin sections. Barite rosettes, gypsum, Au, Cu, and Ni occur in pores in all zones. There is no evidence that these fractured or porous zones result from chemical corrosion. The limited extent of the porosity also suggests that it is not mechanical, resulting from hydraulic fracturing. Rather, it appears to be residual inter-crystal porosity, perhaps as a result of rapid precipitation. Although most authors have attributed the North Mountain zeolites to burial metamorphism, several lines of evidence suggest that the zeolites are of hydrothermal origin. The presence of mordenite with labradorite suggests temperatures in excess of 250°C. Repetitive series of zeolites suggest repetitive changes in hydrothermal fluids. The variability in heulandite/ clinoptilolite composition in a single sample indicates considerable variation in Si/Al and Na/K of circulating fluids. Concentration of minerals such as barite and gold in pores is also much more consistent with a hydrothermal than a burial metamorphism origin. A given sequence of zeolite minerals represents a gradually decreasing temperature of formation, such as mordenite precipitating first followed by Na-K-rich clinoptilolite and then by heulandite + Ca-rich clinoptilolite or epistilbite - epistilbite from fluids rich in Ca and heulandite/clinoptilolite from fluids rich in K-, or heulandite precipitating first and stilbite minerals later. The recognition of hydrothermal circulation in the North Mountain Basalt has implications for economic mineral potential.

New draft 1:50 000 digital maps of the Cobequid Highlands

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We present draft copies of new 1:50 000 maps of the Cobequid Highlands of Nova Scotia, for criticism and correction. These maps show the distribution of pre-Windsor rocks. They result from mapping by ourselves and our students over the past 13 years, and build on the maps of Donohoe and Wallace. The maps are supported by a fieldlog data base with over 15000 station entries, including the sample stations of Murphy and others.

Most of the new scientific findings arising from the mapping have been published already. Highlights include: the wide distribution of the Jeffers Group in the western and central Cobequids; the complexity of distribution of igneous phases in latest Devonian plutons, generally in east-west striking sheets; interpretation of the Salmon River pluton as largely Neoproterozoic; the reinterpretation of the Great Village River gneiss as a tectonic complex of other Neoproterozoic units; recognition of significant early Carboniferous thrusting in the northeastern Cobequids; the importance of east-west faults in the north central Cobequids; clarification of the different developments of the Fountain Lake Group; and re-interpretation of the relationship of the Horton Group to igneous activity.

Bedrock and Quaternary geology of the Scotian Shelf southwest of Yarmouth, Nova Scotia

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A large area of the continental shelf north of Browns Bank, around 42°55'N latitude and from longitude 65°50'W to 66°30'W, has bedrock exposed at the seafloor. Bedrock distribution was mapped from previous boomer and sidescan surveys of King and his colleagues and targets were selected for swath bathymetry mapping. Approximately 250 km^2 of seabed were mapped with the EM-100 system and 1800 line-km of magnetometer profiles were collected in June 1996. Most of the seabed consists of folded and faulted Meguma Supergroup, locally overlain by Quaternary landforms. The contribution presents a preliminary geological map of the area.

Geology of the Belle Côte Road orthogneiss, Cape Breton Highlands, Nova Scotia

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Geological mapping (1:10 000 scale) and sampling of the Belle Côte Road orthogneiss and associated units, south-central Cape Breton Highlands, was undertaken in the summer of 1996. The purpose of this study is to better characterize and interpret the Belle Côte Road orthogneiss by more fully describing the field relationships of the units, carrying out a petrographic study of the rocks, and obtaining geochemical and $^{40}Ar/^{39}Ar$ data to constrain the tectonic setting and metamorphic history of the rocks.

Field mapping during this study has revealed that the Belle Côte Road orthogneiss (previously dated at 442 ± 3 Ma; U-Pb zircon) intruded the First Fork Brook gneiss and that both of these units are intruded by the Taylors Barren Pluton (previously dated at 430 ± 2 Ma; U-Pb zircon). The Belle Côte Road orthogneiss is a relatively homogenous, well foliated, locally megacrystic, leucocratic granite containing quartz + K-spar + plagioclase + biotite ± epidote ± garnet ± muscovite ± titanite ± opaque minerals ± apatite. It exhibits a mainly gneissic texture while still preserving some of its original igneous texture. The unit also includes minor amounts of glimmerite, amphibolite, and paragneiss.

The First Fork Brook gneiss consists of mainly heterogeneous, strongly foliated, coarse to fine grained amphibolite containing hornblende + K-spar + plagioclase + quartz ± biotite ± garnet ± titanite ± epidote ± opaques. Minor units of paragneiss are also present within the amphibolite and are conformable with the principle foliation. The First Fork Brook gneiss occurs mainly in the eastern side of the map area and may represent mafic flows interbedded with sediments, much like the rocks observed in the Jumping Brook metamorphic suite elsewhere in the Cape Breton Highlands.

Preliminary geochemical data suggest the Belle Côte Road orthogneiss has a granodioritic to tonalitic composition with an average SiO_2 content of about 70%. The orthogneiss is peraluminous with A/CNK ratios of 1.05-1.2. The First Forks Brook gneiss is of basaltic to andesitic composition. Trace element data suggest that both units may have formed in a volcanic arc setting.

An occurrence of perchloroethylene and implications to groundwater resources at Sussex, New Brunswick

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In response to a reported perchloroethylene (PCE) occurrence of 3.9 µg/l in the Albert Street well, one of three municipal water-supply wells at Sussex, New Brunswick, a subsurface groundwater sampling program was undertaken in 1996 to delimit the extent and nature of the contamination. At Sussex, a lower, confined aquifer, serves as the main source of the municipal water supply, presently through two major production wells. The lower aquifer consists of a well-sorted, glaciofluvial/ice-contact, sand and gravel unit, approximately 10 m thick, overlying till and/or bedrock. The unit underlies a laminated silt-clay glaciolacustrine unit (middle aquitard) of variable thickness. The middle aquitard is in turn overlain by coarsening-upward sand, and sand and gravel with occasional lenses of clay, silt and diamicton, and occurs to a variable depth of up to 18 m. The upper unit extends to surface, is under atmospheric pressure and is informally referred to as the upper aquifer.

A total of 72 water samples were collected from 31 boreholes and 41 established observation wells. Dissolved PCE was detected in concentrations up to 28.0 µg/l in samples collected within the upper aquifer and up to 1.6 µg/l for samples from the lower aquifer. A contaminant dispersal plume was identified in cross-section contours of PCE concentrations, as underlying the central area of urban development. The concentrations increase towards Main and Summer streets, suggesting that the PCE likely originated from a surface spill near the centre of the business district. Contamination of the lower aquifer has likely originated from the drawdown of contaminant through the upper aquifer and through "windows" in the middle aquitard, into the lower aquifer during pumping of the Albert Street well. The extent of the PCE contamination is due to: (1) the volume of PCE involved in the initial surface spill, (2) the length of time the substance has been within the groundwater system, (3) the permeability of the upper aquifer, (4) the frequency and rate of pumping of municipal water-supply wells, as well as (5) the topographic expression of the middle aquitard, and (6) its integrity. PCE contamination has compromised only the recovery of potable groundwater from the Albert Street well, but this may limit future exploitation of the municipal water supply.

The Mesoproterozoic Nain Plutonic Suite in eastern Canada, and the setting of the Voisey's Bay Ni-Cu-Co sulphide deposit

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In 1993, a world-class magmatic nickel-copper-cobalt massive sulphide deposit, containing probably in excess of 150 million tonnes, was discovered near Voisey's Bay, Labrador. The mineralization is hosted by rocks of the Nain Plutonic Suite (NPS), a 1350 Ma to 1290 Ma assemblage of coalesced mafic and silicic plutons emplaced across an 1860 Ma collisional suture between the Archean Nain Province and the Paleoproterozoic Churchill Province. The NPS covers 20,000 square km and encompasses a diverse group of rocks of which the main "families" are anorthosite, troctolite, diorite and granite. These rocks represent a significant magmatic contribution to a tectonically quiescent crust, probably generated in an intracontinental extensional zone above a mantle plume.

The Voisey's Bay deposit sits within a massive troctolite, the Reid Brook intrusion, interpreted to be the oldest pluton of this type within the NPS. The Voisey's Bay mineralization is disposed as intercumulus concentrations and as massive sulphide (pyrrhotite, pentlandite, and chalcopyrite) zones in several settings, including a steeply-dipping dyke, a bowl-shaped "ovoid", and a bifurcating lens ("Eastern Deeps") at the base of the intrusion. The Ni-Cu-Co mineralization represents gravitational accumulation and concentration of a sulphide liquid in the plutonic environment, coeval with formation of the Reid Brook intrusion. The sulphide liquid is interpreted to have been an integral part of the silicate magma at the time the Reid Brook intrusion was emplaced. The formation of the sulphide liquid is interpreted to be a result of contamination of the metal-laden Reid Brook magma by crustal-derived sulphur from underlying metasedimentary rocks.

Groundwater contamination by agricultural nitrate: a 'multi-point source' conceptual model

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The agricultural 'non-point source' conceptual model for groundwater impacts caused by the standard use of nitrogen fertilizers holds that N reaches the groundwater in a laterally homogeneous front. Groundwater nitrate concentrations are assumed to be horizontally constant both spatially and temporally. Typically, one-time sampling of a single multi-level sampler is considered sufficient to characterize groundwater nitrate impacts under any given farm field.

Groundwater nitrate concentrations, observed during a ten-month intensive monitoring study in shallow groundwater at a southern Ontario field site, exhibited high spatial and temporal variability and did not reconcile with this conceptual model. Field data at the site support an alternative 'multi- or micro-point source' conceptual model which incorporates (i) preferential flow through the vadose zone; and (ii) a 'stagnant flow' zone in the upper metre of the phreatic aquifer. At field sites where the multi-point source conceptual model is valid, the usual method of investigating groundwater nitrate from agricultural sources is inadequate.

Sustainable Development and the Precautionary Principle: implications for acid rock drainage regulations in Nova Scotia

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Sustainable Development is defined by Brundtland as "...development which meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition is vague and is clarified by describing principles which guide development in a sustainable fashion. The Precautionary Principle can be used in this capacity, stating that in cases of potentially serious environmental damage, a precautionary or anticipatory approach should be taken "even in the absence of scientific certainty". These concepts will influence the development of environmental legislation, and pose a challenge to the practice of geoscience.

The Precautionary Principle is explicitly mentioned in the **Nova Scotia Environment Act** (SNS.1994-95, c.1) as a guiding principle of Sustainable Development, and as an overall goal. The **Sulphide Bearing Materials Disposal Regulations** (NS Reg. 296/95) were enacted under the Act in response to the threat of acid rock drainage (ARD) from Halifax Formation (now Halifax Group) slates. The regulations state that anyone excavating a stated volume of slate

which is sulphide-bearing must obtain approval before excavation can begin. Proponents requesting approval must prove that their plans for excavation/disposal of slate will be consistent with the notification, screening, sampling, analysis and disposal procedures for acid generating materials outlined in the regulations.

The Precautionary Principle could substantially change the way in which sulphide bearing minerals are managed by promoting an anticipatory approach, thus deterring the disturbance of slates before any damage to the surrounding environment occurs. For this type of approach to be efficiently used, a major effort must be made in understanding the factors and processes involved in the context of each geological/mineralogical situation in order to improve predictive criteria. If these scientific improvements are not achieved the Precautionary Principle could, alternatively, impede safe development or aggravate the lack of confidence the public has developed for scientific opinion. Scientists and policy makers must cooperate and share information and experience if the Precautionary Principle is to be used effectively in the management of sulphide- bearing materials.

An investigation of late-glacial lacustrine sediments from western Nova Scotia: evidence of ice-free conditions during Younger Dryas time

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An investigation of lacustrine sediments in western Nova Scotia has focused on determining whether glaciers of Younger Dryas (YD) age existed in this region. Sediment records were recovered from seven lakes using the Reasoner percussion coring system. Basal dates and the presence or absence of a YD-equivalent clastic oscillation were used to reconstruct late glacial environments for this region. All sediment cores were stratified and exhibited a sharp contact between a basal diamict (interpreted to be till, LOI 5%) and overlying, post-glacial organic-rich sediment (LOI 30%).

Results from Sand Lake (South Mountain) indicate that the site was deglaciated by 11,550 B.P. The sediment core contained a YD-equivalent silt-rich layer (11,100-10,100 B.P.) characterized by low LOI values and a decrease in sedimentation rates. Image analysis techniques indicate that there is little variability in quartz fragment grain size between this layer and the bounding organic-rich sediments. This layer is interpreted as having formed during regional cooling when organic sediment production in the lake basin was suppressed. Ramsey Lake (North Mountain) was deglaciated by 11,760 B.P. The lake sediment core contained no sediment variability above the basal diamict boundary, an indication that a discernible suppression of organic production did not occur at this site.

Western Nova Scotia was probably ice free by 11,500 B.P. The YD-equivalent sediment oscillation likely resulted from reduced organic input rather than an increase in clastic sedimentation. Local environmental and geomorphological conditions govern both the formation and the distribution of these sediments within the lake basin. These data suggest that a YD-equivalent ice advance in western Nova Scotia was unlikely.

Discovery of Cretaceous basins in Nova Scotia and the potential for kaolin mining

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Lower Cretaceous deposits of unconsolidated, quartz-rich sediment, kaolinitic, variegated clays and lignite occur in the Carboniferous and Triassic basins of Nova Scotia and New Brunswick. At present these deposits are mined for brick, aggregate and glass-sand, and the potential uses include ceramics and refractory clay. The goal of a joint NSDNR-GSC surficial mapping program within these basins was to construct a three-dimensional model of the Quaternary and Cretaceous sedimentary cover using previous water well, mineral assessment and geotechnical drilling data, new diamond drilling and refraction-reflection seismic data. We have substantially increased the known areal extent of these deposits, and have shown that these basins harbour substantial quantities of light-grey kaolin, potentially suitable for use in the paper industry.

The Cretaceous sediments occur in asymmetric, steep-sided basins with a maximum thickness of 200 m. The sedimentary architecture can be characterized by cyclic 0.5 to 10 m thick sections of white to light-grey, coarse to fine gravel-sand capped by 0.5 to 2 m of light-grey or variably-coloured silty clay. Several widespread, correlative black lignite horizons up to 2 m thick and a light-grey, calcium carbonate-cemented silica sand occur within the Cretaceous section. The sand units are dominated by subangular quartz grains (95-99% SiO_2), with poor roundness sorting. Heavy minerals are dominated by opaques, mostly ilmenite, pyrite and hematite.

Fining-upward cycles, armoured clay balls and channel geometries suggest a fluvial origin. The lack of feldspar and abundant kaolin in these sediments suggests intense source area weathering prior to deposition. Source areas of the kaolinite and silica sand are believed to be deeply weathered, crystalline Appalachian and Shield bedrock terranes to the north, with an input from local Carboniferous quartzose sandstones. Regional grain-size variation insinuates west to east paleoflow. Post-depositional tectonism is indicated by the juxtaposition of mineralogically-mature, fluvial sediments in steep sided (faulted?), brecciated basins.

Characterization of outburst channel sandstones in the Phalen Colliery, Cape Breton Island, Nova Scotia

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The Phalen Colliery of New Waterford, Cape Breton Island, Nova Scotia is currently mining coal from the Phalen Seam of the Sydney Mines Formation, part of the offshore Carboniferous Sydney Basin. Since opening in 1984, the colliery has experienced several rock outbursts within the massive channel sandstone that overlies the Phalen coal seam. An outburst is a violent explosion of rock and gas, the occurrence and intensity of which depends on the presence of high lithostatic pressures, high gas pressure, high modulus of rigidity (brittleness), and very low permeability. Samples of the channel sandstone have been obtained from two cores drilled into the roof of drivage tunnels, distal (PH-102) and proximal (PH-250) to the site of a recent outburst, and from the outburst site.

Sandstones from PH-102 are very fine grained, and have evenly distributed intergranular porosity (range 6.9 to 12.1%, mean 8.5) and horizontal permeability ranging from 0.030 to 3.020 millidarcies (mean 0.88). Sandstones from core PH-250 are very fine grained to very coarse grained, and show generally high amounts of compacted lithic fragments. Isolated porosity occurs within corroded feldspars and pore-filling kaolinite and ranges from 4.5 to 7.7% (mean 6.5). Horizontal permeability is lower than PH-102, ranging from less than 0.01 to 0.19 millidarcies (mean 0.05).

The sandstone in PH-102 is interpreted to represent a lower outburst risk. The evenly distributed intergranular porosity and higher permeability allow for a more controlled release of gas, decreasing the potential energy of the system. Under similar depth conditions, sandstone from PH-250 is interpreted to have a much higher risk for outbursts. The restricted porosity within rock from PH-250 allows for the storage of methane (energy), but the very low permeability greatly restricts the escape of gas when pressure on the rocks is reduced during mining, spawning an outburst. Preliminary work on outburst sandstones from the Phalen Colliery, No 26 Colliery, and Merlebach Colliery, France, show the same characteristics of corroded feldspar, kaolinite pore filling, low permeability, and predominantly intragranular porosity as rock from PH-250.

Late Archean turbidites in the southern Slave Province: very like the Meguma

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Submarine fans are characterized by turbidity current deposits; thin bedded units frequently show Bouma sequences, but thick bedded sandstone beds (>50 cm) are more difficult to interpret because they typically show different suites of sedimentary structures. In the Cambro-Ordovician Meguma Supergroup of Nova Scotia, the Goldenville Group is an example of a submarine fan deposit dominated by thick-bedded sandstones. Until recently, recovery of thick-bedded sandstones from modern fans was very poor, adding to the difficulty of their study.

Successions strikingly similar to the Meguma Supergroup are found in the upper Archean Burwash Formation in the Slave province. The Slave province is unusual among the Archean cratons in containing a large proportion of supracrustal material. The succession may be as thick as 10 km. The Burwash Formation is spectacularly exposed on lake shorelines; groups of beds can be traced for kilometres using air photographs. Volcanic ash beds (one of which is dated at 2661 ± 2 Ma) provide additional opportunities for stratigraphic correlation.

In outcrop, Bouma sequence structures in thinly bedded, laterally continuous, graded sands indicate that most of the formation was deposited by turbidity currents. Thick bedded (>50 cm) sandstones generally do not show Bouma sequences; they closely resemble thick sandstones in the Meguma Supergroup that contain multiple, dune-like scour and fill structures, traction carpets, and downward-branching water-escape sheets. The scour and fill structures locally mimic hummocky cross-stratification, especially where paleocurrents are raked steeply in near-vertical bedding surfaces. However they differ in showing clearly unidirectional character in down-current sections. The thick-bedded sandstones are interpreted as deposits of high-concentration turbidity currents.

Careful examination of air photos reveals low-angle discordances within the Burwash turbidite package, comparable in scale and proportions with channel-levee complexes on modern fans. Thick bedded sandstones, which make up the majority of the formation by volume, are interpreted as levee complexes several kilometres in width. Channels were filled by massive sandstones and granule to pebble conglomerates.

These features are closely comparable with Phanerozoic sandy fans such as the Goldenville Group, and with modern sandy fans such as the Amazon fan. They indicate that submarine fan environments have persisted essentially unchanged since the Archean, and suggest a sizeable cratonic or arc-related source for the Burwash Formation.

The Last Billion Years: A Geological History of Maritime Canada

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There is a pressing need for a "Popular Geology of Maritime Canada", a book that explains the evolution of our region in approachable language. Most people are interested in the land around them, but geologists tend to mystify their science by writing too technically and using too many scientific words. The text of about 100 pages will describe the geological history of the three Maritime provinces, focusing on the biological evolution of animals and plants. The emphasis on fossils will provide an opportunity to introduce such topics as plate tectonics, landforms, rocks and minerals, extinction cycles, weathering, hydrology, environmental concerns, and climatic warming. Because a picture is reputedly worth a thousand words, the book will be lavishly illustrated with location maps, reconstructions, scenic and historical photographs, line drawings, photographs of rocks, minerals and fossils, and diagrams, many in colour. There will also be several side boxes on such selected topics as: plate tectonics, extinctions, what happened to the dinosaurs, glacial erosion, the New Brunswick Museum, and geologic time. We intend to publish the book in late 1998, so that it will be a suitable Christmas present.

Petroleum geoscience research in support of Canada's east coast hydrocarbon energy option

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The GSC Atlantic, in part through its Hydrocarbon Charge Modelling initiative (HCMP), performs research of direct value to the petroleum industry and government agencies at all levels, in their efforts to assess geological risk and uncertainty associated with eastern Canada's hydrocarbon energy option. Multidisciplinary in scope, the science focus of the HCMP makes quantitative statements regarding the petroleum systems operating in offshore basins (chiefly Sable, Jeanne d'Arc and Gulf of St. Lawrence). This involves reconstruction of the dynamics of the basins' source, reservoir, seal and trap conditions. The business focus translates these research products into tools, concepts, methods and knowledge of direct practical value to industry/government technical specialists and decision makers. Examples from the Sable Basin include the role of gas generation and migration in relation to overpressure generation, and the evaluation of fault seal risk for hydropressure gas pools. From the Jeanne d'Arc Basin, an example is the assessment of the risk of encountering heavy, biodegraded oil in shallow targets. Another element of the project ensures easy access to the GSC Atlantic's vast data holdings (well geology, engineering and seismic), and the information/knowledge base for east coast areas built up over three decades. The GSC Atlantic's WWW home page at URL http://agcwww.bio.ns.ca/ provides an example of this.

A significant feature of research projects performed under the HCMP and others at the GSC Atlantic is the close link with industry. The project described in this contribution is funded through a combination of petroleum companies and government resources, which has also allowed linkage to university research through funding of Dalhousie University's Department of Earth Science graduate students.