Atlantic Geoscience Society

ABSTRACTS

1998 COLLOQUIUM AND ANNUAL GENERAL MEETING

WOLFVILLE, NOVA SCOTIA

The 1998 Colloquium of the Atlantic Geoscience Society was held in Wolfville, Nova Scotia, on February 6 to 7, 1998. On behalf of the Society, we thank the organizers, Rob Raeside and Ian Spooner, and members of their organizing committee who assisted in a variety of ways. Additionally we acknowledge the support of the following corporate sponsors: Brunswick Mining and Smelting Corporation Limited, Fundy Gypsum Company, Noranda Mining and Exploration Limited and Potash Company of Saskatchewan Incorporated. Special thanks are also extended to Peter Reynolds, Dorothy Godfrey-Smith and Keith Taylor for providing a pre-Colloquium short-course workshop on luminescence, fission track and argon dating methods at Dalhousie University, and to Tim Webster for conducting a visit to the College of Geographic Services, Lawrencetown.

In the following pages we publish the abstracts of oral presentations and posters given at the Colloquium, which included special sessions on structural geology in memory of the late Jack Henderson (organized by Chris Beaumont-Smith) and on environmental geoscience.

The Editors

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The Last Billion Years: a dream approaches reality

AGS Book Committee
Geological Survey of Canada (Atlantic), Mount Allison University, New Brunswick Department of Natural Resources, Nova Scotia Museum, Nova Scotia Department of Natural Resources, Saint Mary's University, University of New Brunswick, New Brunswick Museum

The concept of a generally readable book on the geology of the Maritime Provinces, written for the non-expert, was first mooted at the 1995 AGS Colloquium in Antigonish. Initial progress was slow, but by the end of the year a Committee had determined the feasibility of the project and drawn up a preliminary outline. Everyone agreed that the book must include superb graphics and photographs, primarily in full colour. Text is important but the illustrations are what will attract most potential readers. Today, two years later, what have we accomplished besides holding meetings? We have raised $15,525 towards the cost of preparing camera-ready copy and printing the book. We have a fourth draft of the text outlining the geological evolution of our region. As well, we have some outstanding dioramas and scenic photographs, several new geological maps, impressionist-like plate reconstructions, excellent line drawings of fossils and some imaginative schematics. Perhaps the most encouraging development, however, has been the support of the geological communities in all three provinces. With this and continuing financial support, we hope to go to press in 1999 with a publication worthy of the new millennium.

Comagmatic volcanic and granitoid rocks of the Kingston belt, southern New Brunswick - a Silurian volcanic arc?

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Mapping and petrochemical studies in the northeastern part of the Kingston belt in southern New Brunswick show that earlier interpretations of the belt as a bimodal dyke swarm are not correct. The Kingston belt consists mainly of Silurian metavolcanic rocks of the Bayswater Group, intruded by high-level comagmatic granitoid plutons. The Bayswater Group consists mainly of dacitic and rhyolitic crystal and lithic-crystal lapilli tuff, with less abundant basaltic to andesitic flows and tuffs, rare dacitic and rhyolitic flows, and minor volcanogenic siltstone. The associated Sand Point, Centreton, Bradley Brook, and Redden Brook plutons are characterized by fine grain size and granophyric and locally porphyritic textures, consistent with high-level emplacement. Both the Bayswater Group and granitoid plutons are intruded by abundant mafic dykes, now amphibolite, which have been regionally metamorphosed together with their host rocks to upper greenschist facies. Primary volcanic layering, metamorphic foliation, and mafic dykes all trend north-northeast, and are steeply dipping. The rocks commonly display a steep intersection lineation, and are not mylonitic. Major faults now separate the Bayswater Group and associated plutons and mafic dykes from unmetamorphosed Silurian volcanic rocks to the northwest, and from Neoproterozoic to Cambrian rocks of the Brookville terrane to the southwest.

Most of the volcanic and plutonic rocks in the Kingston belt have experienced chemical alteration, resulting in wide compositional variations and considerable ambiguity in interpreting original chemical characteristics and tectonic setting. However the volcanic and plutonic rocks appear to be calc-alkalic, and may have been emplaced late in the evolution of a continental margin volcanic arc. In contrast, the mafic dykes are tholeiitic, and may have formed in a subsequent extensional tectonic regime.

EdGEO Workshops: Experience the Excitement of Earth Sciences

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The first EdGEO Nova Scotia Workshop, "The Earth Sciences: New Resources for Teachers", was held in Halifax, 22-23 August 1994. The enthusiastic response of those attending encouraged the local committee to continue the program, with equally successful workshops in Sydney (1995), Wolfville (1996) and Bridgewater (1997). Each workshop highlights earth science resources available to K-12 grade teachers and how these can be used in the classroom. The program, which emphasizes hands-on activities, includes: identifying rocks and minerals common in Nova Scotia, use of the Nova Scotia Museum's mining and fossil kits, accessing the Internet and especially AGS's EarthNet, improvising in the classroom, and ideas for explaining the concept of geological time to young students. The highlight of each Workshop has to be the field trip, which is always to local sites. For Bridgewater, we visited a local quarry, Broad Cove, Crescent Beach, and The Ovens Natural Park, where we panned for gold. After the excitement of the half-day trip, everyone really enjoyed the evening's talk on the geology of Nova Scotia.

What were the teachers' reactions to the day and a half of intense activity? I quote from some of the evaluation sheets: "All the handouts are fantastic", "Excellent resources, excellent and enthusiastic resource people", "Without a doubt, the best workshop I have ever attended".

The 1998 workshop will be in Truro on 17-18 August. Because of the rapidly evolving format, this workshop will be titled, "Experience the Excitement of Earth Science". Handouts will include a rock and mineral kit, a fossil kit, four videos and video guides, maps, books, lesson plans, posters, and leaflets. The success of the EdGEO program is dependent upon funding from the National EdGEO Workshop Committee and the Geological Survey of Canada. The Nova Scotia Department of Natural Resources, Saint Mary's University, the Nova Scotia Museum and GSC allow staff to participate in the workshops and provide numerous resources. And the volunteers are all enthusiasts. Why don't you consider becoming involved? Your commitment will help further interest in the earth sciences where it's most important, in the schools throughout our province.

EarthNet: An Internet Teaching Resource

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EarthNet (http://agc.www.bio.ns.ca/schools/esrc/esrhome.html) is an Internet virtual library, which provides information on earth science resources suitable for classroom use in grades Primary through 12 and first year university. The sophisticated, tailor-made software has been developed at GSC Atlantic and features simple, icon-directed retrieval. The database presently includes more than 800 earth science resources and links. Fields completed for each resource are: type, grade level, earth science topic, year released, cost, source, description and support material. By obtaining information on appropriate resources, teachers can readily design a lesson or course, complete with exciting, readily available resources.

EarthNet is intended to be much more than an on-line catalogue. The website will provide a communication link for all teachers who access the database and use the resources. Feedback and reviews of individual resources will be encouraged and special emphasis will be given to the exchange of lesson plans prepared by teachers. Such supplementary information will be attached to the specific resource and hence will be available in future retrievals. EarthNet will foster Internet discussion or news groups for educators and students, for example discussions of recent volcanic eruptions and dinosaur fossils.

Day to day operation of EarthNet is through a secretariat at GSC Atlantic, Dartmouth. The project coordinator is assisted by other geologists throughout Canada who constitute a National Resources Group of provincial and territorial representatives and is in the process of establishing a National Teachers Advisory Committee.

To be successful, EarthNet needs several thousand dollars annually. Financial support has been provided by the Geological Survey of Canada (Atlantic), the Canadian Geological Foundation, the Canadian Geoscience Council, the Canadian Society of Petroleum Geologists, and the Atlantic Geoscience Society. EarthNet is a project of the Atlantic Geoscience Society and the Canadian Geoscience Education Network.

The role of conjugate crenulation cleavage and stepwise porphyroblast growth in the development of "Millipede" microstructures

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This paper describes the results of a microstructural study into the development of 'Millipede' microstructures found in Archean metaturbiditic rocks surrounding the Back River volcanic complex, eastern Slave structural province. Millipede microstructures are locally developed within andalusite porphyroblasts which developed late in the deformation history of the study area in response to the intrusion of late kinematic granitoids. The mechanism for the development of the millipedes involves the stepwise porphyroblast growth with andalusite growth occurring after initial D_3 buckle folding. These initial andalusite porphyroblasts represent a rheological heterogeneity resulting in the development of conjugate crenulation cleavage along the porphyroblast margin. Subsequent porphyroblast growth included the crenulation cleavage with the inclusion trail within the porphyroblasts defined by the trace of the quartz-rich crenulation cleavage microlithon. The classical reversal in inclusion trail vergence is the result of the porphyroblasts overgrowing conjugate pairs formed along the porphyroblast margin.

Experimental determination of cation exchange capacity of sandstones and shales in the Phalen Colliery, Cape Breton

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This study experimentally quantifies cation exchange capacities (CEC) of sandstones and shales in the Phalen Colliery, Sydney Coalfield, Cape Breton. Phalen Colliery rocks belong to the Sydney Mines Formation, Morien Group, which is Upper Carboniferous Westphalian D to Stephanian in age. Phalen formation waters are the inferred evaporative residues from Visean Windsor Group salt precipitation, but have been modified from their original evaporative chemistry. Waters are saline, moderately undiluted, and stagnant. A trend of increasing Na with decreasing salinity, balanced by Cl, suggests cation exchange modified the water composition.

This experiment tests the exchange hypothesis by determining mineralogy and measuring cation exchange capacities of Phalen sandstones and shales. The clay portions of the samples are predominantly chlorite, mica, and kaolinite groups, with minor illite. Nine clay samples were reacted with four equilibrating solutions to invoke exchange between solution and clay cations. The equilibrating solutions (sodium adsorption ratios 70 and 120 mmol/L, total concentration 4000 and 5400 mmol/L, pH 5.6) were modeled after Phalen formation waters. A 0.25M $Ba(NO_3)_2$ solution extracted exchanged cations from the clay.

Calculated exchangeable Na ranges from 0.058 to 0.786 meq/100g, with a 0.167 meq/100g mean. Exchangeable Ca ranges from 0.008 to 0.141 meq/100g, with a 0.036 meq/100g mean. The ratio of exchangeable Na to exchangeable Ca ranges from 0.702 to 10.9, with a 4.72 mean, and CEC ranges from 0.073 to 0.927 meq/100g with a 0.209 meq/100g mean. Phalen sandstones and shales contain low exchange capacity clay types. Experimental cation exchange capacity results suggest even lower cation exchange capacities than normal. The preliminary interpretation is that cation exchange would not fully account for the chemical trends observed.

Late Paleozoic events affecting the Acadia fold belt in the Meguma Terrane: fold reactivation, pluton emplacement and rift inversion

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The main phase of Acadian folding occurred at ca. 390 Ma -- probably during docking of Gondwana with Laurentia. Later peripheral deformation of the terrane resulted from transpression along the Chedabucto-Cobequid fault. In addition, reactivation of the fold belt at locations internal to the fold belt appears to be widespread.

Flexural-slip folding is an important mode of reactivation in Meguma folds and may locally account for up to thirty percent of limb dip and accompany evolution of chevrons from box folds. A variety of auriferous quartz veins may accompany flexural slip. Close resemblance of the flexural-slip vein systems to published descriptions of many Nova Scotian deposits suggests a model for gold deposits in the Meguma Terrane. Flexural-slip structures cut porphyroblasts of the thermal aureole of the ca. 370 Ma South Mountain Batholith, giving an age constraint on this mode of reactivation.

In the Halifax area, Acadian folds in the roof of the South Mountain Batholith are undisturbed by emplacement and stoping is active here. By contrast, at the steep margin of the batholith, the Acadian folds are deformed, and bedding is flexed downward and youngs toward the batholith. It seems likely that the sheet-like South Mountain Batholith made space for itself by depressing its floor. Roof-lifting did not occur but the roof may have been eroded by stoping.

In southwest Nova Scotia, Carboniferous reactivation of folds affecting the Meguma and Annapolis Supergroups is restricted to a belt thirty kilometres wide. The belt of deformation is likely an inverted rift in which the Annapolis Supergroup was originally deposited. This interpretation is consistent with various stratigraphic, geochemical and field data.

Characterization and interpretation of Late Cretaceous to Eocene erosional features and associated submarine fan deposits in the Jeanne d'Arc Basin, offshore Newfoundland

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Several canyons, channels and incised valleys have been identified, characterized and mapped in Late Cretaceous to Eocene successions of the Jeanne d'Arc Basin. Erosional features act as conduits which funnel sediment into deeper marine settings during lowstands in relative sea level. Their location and timing have important implications for the distribution of reservoir rocks in the Jeanne d'Arc Basin. Seismic and sequence stratigraphic methods reveal three periods of canyon, channel and incised valley development. Each period is associated with a regional unconformity.

During the latest Cenomanian to Coniacian, a deltaic succession (Otter Bay member) and a basinwards condensed section (Petrel Member) developed. In the Santonian, a drop in relative sea level initiated the development of an unconformity with a north-trending canyon and branching channel system. Clastics and carbonates were eroded from the south-southwest and ponded towards the north. A rise in relative sea level during the Santonian to Maastritchian caused a second deltaic phase (Fox Harbour member) and basinwards condensed section (Wyandot Formation) to develop. A significant drop in relative sea level during the Early Paleocene caused the incision of three east-trending basin periphery canyons and several smaller gullies. These eroded clastics of the Fox Harbour member and re-deposited them basinwards in an Early Paleocene basin floor fan and wedge. Minor north-trending channels, along the eastern periphery, indicate that sediment was also entering the basin from the southeast. During the Latest Paleocene to Early Eocene, relative uplift of the Cormorant Horst caused the incision of several southeast-trending gullies and incised valleys. These transported sediment across a basement high into a thick clastic wedge in the southern Jeanne d'Arc Basin. In the central Jeanne d'Arc Basin, canyon activity continued to feed Early Eocene submarine sands into the basin.

The EdGEO Workshop Story: Building On Success After Success After . . .

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The Atlantic Geoscience Society has had many successes for such a small organization. Some are one-time events or projects such as GAC/MAC Wolfville '92 or the Geological Highway Map Project. Other successful projects continue almost with a life of their own; the best example is the Video Committee and its remarkable work. Another project qualifies for praise and this is the EdGeo Workshops. Like most successful projects, this one made its name because it met a real need for Nova Scotia teachers in supplying "hands on" work about the earth sciences. Teachers from grades 3 to 12 attend this workshop to increase their awareness about the earth sciences and to learn how to apply the information and resources from the workshop to the classroom. In August 1998, the fifth workshop will be held at the Nova Scotia Agricultural College in Truro. Participants will work with six to ten instructors that represent a variety of employers in Nova Scotia: federal and provincial governments, universities, and public schools. The teachers learn about (1) identifying minerals, (2) classifying rocks, (3) using Nova Scotia Museum of Natural History school loan kits, (4) the mineral industry, (5) the connection between earth science and the environment, (5) fossils and geological time, and (6) use of computers and WWW resources. Coupled with all of this information are the instructors who "model" effective teaching methods and the many practical exercises for the teachers' classes. The workshop's successful formula of two half day class room sessions separated by a field trip and evening speaker has changed little since the start five years ago. What has changed is the renewed sense of importance and of relevancy that the 100 "graduates" of the workshop have for earth science!

The hidden record of Silurian and Devonian stratigraphy in the Cobequid Mountains, northern Nova Scotia

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Hidden in the gorges of the Cobequid Mountains are important sections of the Silurian and Devonian systems in the Avalon composite terrane. Few researchers have studied these rocks. These sections, well exposed in southerly flowing streams, show the entire section of the Silurian and the Lower Devonian. The best sections are in the central area on the Portapique, Bass and Economy rivers. On the Portapique River 2.9 km of strata are exposed from the Rockland Brook Fault in the south to the covered interval at the contact with the Fountain Lake Group. Fossiliferous strata record ages from Late Llandoverian to Pridolian. More than 700 m of strata lie below the oldest fossil horizon offering the possibility of continuous deposition from the Ashgillian. Above the last Pridolian fossil horizon, 1.1 km of red mudstone and quartz wacke (Portapique River Formation) lie conformably on top of the grey quartz wackes and mudstones (Wilson Brook Formation). The red strata probably range upward into the Gedinnian similar to the Knoydart Formation at Arisaig. On the Economy River, Early Llandoverian (A2) fossils have been found. Other fossiliferous Silurian inliers are found east and west of the central part of the Cobequids. Between the Economy and Portapique rivers the Middle Devonian aged Murphy Brook Formation crops out in a syncline. It rests with apparent uncomformity on the Wilson Brook Formation without the intervening Portapique River Formation. Flora from the Murphy Brook are the "classic" *Psilophyton* flora similar to that found in the Trout River Formation in the Katahdin region of Maine. Conglomerates contain clasts of granite and volcanic rocks but the source area is not known. With further study, these three units can help clarify the distribution of Silurian and Devonian lithofacies in the Avalon composite terrane and shed additional understanding about the nature and timing of the Acadian orogeny.

Geochronology of the Port Mouton Pluton, Meguma Zone, southwest Nova Scotia: a U-Pb and $^{40}Ar/^{39}Ar$ study

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The Port Mouton Pluton (PMP) is distinguished from other Late Devonian peraluminous granitoid intrusions in the Meguma Zone of southwestern Nova Scotia by its lithological heterogeneity, extensive physical and chemical interaction with country rocks, clear evidence for mingling and mixing with mafic magmas, and abundant pegmatites. Previous $^{40}Ar/^{39}Ar$ geochronology indicated a complex post-intrusion history for this part of the Meguma Zone, with the majority of age determinations < 350 Ma. These ages probably represent resetting of isotopic systems by fluids associated with shear zones. Here we report new U-Pb data for the PMP that constrain its crystallization age. New $^{40}Ar/^{39}Ar$ incremental heating data for muscovite, coupled with the first reported laser work (total fusion and spot analysis) from the peripheral plutons, provide further insights into the post-intrusive history of the PMP and surrounding Meguma Zone.

Two monazite analyses from a tonalite yield identical ages of 373 ± 4 Ma and 374 ± 2 Ma. Monazite from undeformed granodiorite and monzogranite yield similar ages of 373 ± 2 Ma and 374 ± 1 Ma respectively. We consider the minimum crystallization age of all intrusive phases to be 374 ± 1 Ma. Muscovite from undeformed samples generally yield higher spectral ages than undeformed samples. Muscovite from the undeformed monzogranite yields a flat $^{40}Ar/^{39}Ar$ spectrum with a preliminary age of 365 Ma. Three total fusion ages from this sample agree well with the spectral data. Muscovites from the remaining samples yield $^{40}Ar/^{39}Ar$ age spectra characterized by slight age gradients over the range ca. 355 to 360 Ma. Muscovite from undeformed granodiorite and pegmatite have preliminary total fusion ages greater than or equal to their respective maximum spectral ages, some approaching the U-Pb crystallization age. Muscovites from deformed monzogranite have preliminary total fusion ages that overlap the range of spectral ages. Some laser spot ages appear comparable to the U-Pb crystallization age, but some appear older possibly reflecting isotopic fractionation during laser heating. Total fusion ages of carefully selected muscovite grains may provide the most reliable estimate of the time of cooling to the muscovite closure temperature.

Hydrogeological analysis of the watersheds of two tributaries of the Cornwallis River, Nova Scotia: implications for stream restoration and enhancement

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The Cornwallis River watershed has been under increasing pressure due to agricultural, commercial, urban and residential exploitation and is presently the subject of water quality, landuse and river restoration studies. In the summer and fall of 1997 the watershed was subject to a severe drought. These naturally stressed conditions provided the opportunity to monitor and study the mechanics of ground and surface water storage and transferal within two tributary brooks of the Cornwallis River. Data on the hydrogeological, geomorphological, geochemical and environmental characteristics were gathered over a two-month period. Elderkin Brook is a relatively high gradient (30m/km), largely ungraded river that has a watershed of 3 km^2. It originates on the South Mountain, a regional highland (max. elev. 272 m) dominated by granitic and metamorphic rocks and empties into the Cornwallis River at sea level. Surficial sediment cover is generally thin and consists primarily of clay-rich till. Fishwick Brook is a low gradient (4.6 m/km) graded meandering river that has a watershed of 8 km^2. It originates within the Cornwallis River valley and is underlain by variable amounts of postglacial outwash, kame and aeolian sediment and clay till.

Data from Elderkin Brook indicated that during drought mean river discharge (0.01m^3/sec) and stage were well below normal levels but appeared to stabilize as the drought lengthened. Discharge data indicated that reaction to discreet input events was swift and short lived. Water temperature was highly variable and correlated closely with air temperature fluctuations. pH data indicated that regional strata buffered acidic rainwater (pH 4.7). Data from Fishwick Brook indicated that although mean river discharge (.023 m^3/sec) was reduced, stage was closer to normal levels. Discharge data indicated that reaction to input events was swift but relatively prolonged. Overall, it was found that in Fishwick Brook water quality, rather than quantity, was most affected by the drought conditions; the opposite was true for Elderkin Brook.

These data indicate that each tributary must incorporate unique restoration and enhancement programs if these programs are to be successful.

Digital Elevation Modelling using relative sea level and deformed shorelines for reconstruction of Late Wisconsinan and Holocene paleogeography of fhe Atlantic Canada and Great Lakes regions

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Isostatic recovery of the earth's crust (lithosphere) during and since retreat of the Laurentide Ice Sheet has resulted in differential uplift of over 250 m over the past 11,000 years in the Great Lakes basin. This uplift continues today. Compiled lake-level data were contoured as isobases and applied as adjustments to digital elevation models (DEMs) of present topography and bathymetry to reconstruct palaeogeography at various times from 11.2 to 7.5 ka BP. The DEMs originate from a series of 30-arc second grids and provide high quality resolution for representation of regional-scale palaeo-terrain. Shoreline migration is easily visualized by comparing successive maps of reconstructed topography. In Atlantic Canada, isostatic rebound, forebulge migration, eustatic sea-level rise, and other effects have resulted in temporal and spatial variations in relative sea level (RSL) during and after retreat of Laurentide and associated glaciers. In this case, the modern DEM was adjusted using two sets of empirical RSL data, which differed with respect to the RSL history of the Baie des Chaleurs region. The reconstructed palaeogeographies of the southern Gulf of St. Lawrence at 9 ka BP contrast greatly. These reconstructions and comparisons in the Great Lakes and Atlantic regions help focus future research in geographic areas where critical observations can be made to improve the understanding of regional-scale postglacial earth history.

Controls on the mobility of mercury from gossan mine tailings

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Between 1989 and 1992, gold was recovered from a gossan overlying the Murray Brook massive sulphide deposit in northern New Brunswick by cyanide heap leaching. Following mining, previous workers found that elevated mercury concentrations in ground water below the tailings correlated well with elevated cyanide concentrations. Those data indicated that residual cyanide from the gold leaching operation contributed to increased mercury mobility from the tailings through solubility enhancement by cyanide complexation. The concentration of cyanide in the ground water has declined since 1993 with a coincident decline in mercury concentration. Residual cyanide in the tailings is expected to continue to degrade and the present study is designed to evaluate the degree of mercury mobility within the tailings pore water that could occur in the future as a result of complexation with natural ligands such as humic acid, OH^- and Cl^-. Based on X-ray diffraction, optical and scanning-electron microscopy examination of the tailings, mercury is distributed, probably through co-precipitation, within the secondary ferric oxy-hydroxide and sulphate minerals such as goethite [$FeO(OH)$], jarosite [$KFe_3(SO_4)_2(OH)_6$] and beudantite [$PbFe_3(AsO_4)(SO_4)(OH)_6$]. Batch leaching experiments were conducted on the tailings by varying the concentrations of humic acid, OH^- and Cl^- to determine the effect on mercury concentration in the leachate. Mercury concentrations in the leachates ranged from 11 to 54 μg/L. Humic acid concentrations had no significant effect on mercury concentrations compared to a de-ionized water control. The pH and Cl concentration have the greatest effect on the mercury concentration, probably as a result of the competing effects of OH^- and Cl^- complexation with mercury adsorption to solid surfaces. These results may have implications with respect to plans for rehabilitation of the gossan tailings.

Chemical and textural variations in the Bonnell Brook Pluton, Caledonian Highlands, New Brunswick

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The ca. 550 Ma Bonnell Brook Pluton in the Caledonia terrane of southern New Brunswick consists mostly of medium- to coarse-grained granite with lesser amounts of fine-grained granite, rhyolite, granodiorite, tonalite, diorite, and gabbro. The purpose of this study is to investigate the mineralogical, textural, and chemical variations in the pluton and the possible causes of these observed variations. Two large granitic bodies comprise most of the pluton. The largest of these is spatially associated with a dioritic intrusion to the southeast and a rhyolitic intrusion to the north. Field relationships among these units are in part ambiguous. The relative ages among the rhyolite, fine-grained granite, and me-

dium- to coarse-grained granite remain unclear. However, it is known that the mafic rocks are the oldest unit. Little evidence has been found for the relationships of the granodiorite and tonalite, which commonly occurs as dykes at or near the contact between the granite and diorite.

Some systematic variations in texture and composition have been identified in the Bonnell Brook Pluton. Fine-grained granite generally occurs along the margins of the larger bodies and in a separate small body. The medium- to coarse-grained granite differs chemically from the fine-grained granite, although there seems to have been a lot of mingling between these two rock types. The fine-grained granite is more similar in chemistry to the sub-volcanic rhyolitic samples than the medium- to coarse-grained granite. Preliminary investigations suggest that at least two cogenetic magmas, felsic and mafic, were responsible for the formation of the granite and diorite, respectively. The close spatial association of the other lithologies with the granite and diorite suggest that it is unlikely that they represent separate magmas. Hence, the differences may be explained by contamination, thermogravitational diffusion, or some type of hybridization or magma mingling. The fine-grained granite may be due to chilling at margins of magma chambers or higher level emplacement.

Geology of the Meguma Group, Kennetcook (NTS Sheet 11E/04)

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The Cambrian-Ordovician Meguma Group within the Kennetcook area (NTS sheet 11E/04) consists of the lower metasandstone-dominated Goldenville Formation and overlying slate-dominated Halifax Formation. The Goldenville Formation has not been subdivided and consists of thickly-bedded metasandstone with lesser thin green metasiltstone and rare dark slate beds. Carbonate concretions are locally common at the top of the Goldenville Formation. The Halifax Formation has been subdivided into three conformable stratigraphic members. The lowermost Beaverbank member, which conformably overlies the Goldenville Formation, consists of distinctive metasiltstone characterized by brown (Mn-rich?) laminations and, locally, distinctive orange, carbonate-rich laminations. The Cunard member overlies the Beaverbank unit and consists of sulphide-rich black slate and thin metasiltstone beds. Locally this unit is subdivided into a lower sulphide-rich unit and upper sulphide-poor unit. The uppermost Glen Brook member consists of green-gray, banded metasiltstone/slate. This unit is extremely monotonous and, except for a few beds near the bottom, devoid of metasandstone. Stratigraphy of the map area is clearly reflected by aeromagnetic data.

Northeast-trending, kilometre-scale, regional folds (F_1) are the dominant structure of the area and include the Rawdon Synclinorium and Renfrew Anticlinorium. At the present level of erosion these structures are defined within the Halifax and Goldenville formations respectively. The Rawdon Synclinorium is slightly inclined to the south and plunges moderately to the northeast. Minor folds are common within the Glen Brook member (core of the synclinorium) and are defined by bedding-cleavage relations and parasitic fold geometry. These folds define upright to inclined plunging structures which plunge northeast or southwest. The Renfrew Anticlinorium defines a modified box-fold, where the Renfrew and Rawdon Gold Mines anticlines represent the hinges of the box fold and the Long Lake Syncline represents the folded, flat top of the box fold. All F_1 folds are upward facing and associated with a common, axial planar cleavage. Joints, kink folds, veins and other minor structures are ubiquitous and define systematic regional trends related to the fold geometry.

Several regional-scale faults occur within the area. The Rawdon Fault is a major northeast-trending structure along the northern margin of the Rawdon Synclinorium which separates the Rawdon Block, including the Meguma Group and locally attached Horton Group, from the Carboniferous Kennetcook Basin to the north. A wide zone of fault-related deformation occurs within the Meguma Group adjacent the fault, including F_2 folds, locally developed crenulation cleavage (S_2), northwest-trending extensional veins, and south-dipping brittle faults. Geophysical data and diamond drill holes indicate a steep attitude with significant dip slip offset and the fault is interpreted as a northwest-directed reverse fault. The northeast-trending Roulston Corner Fault is defined by a narrow cataclastic zone within the Goldenville Formation south of the Rawdon Synclinorium. The Rawdon and Roulston Corner faults bound an elevated plateau (Rawdon Hills), and may define a horst structure. Several small-scale, northwest-trending faults occur throughout the area and may be related to kinks.

Several mineral occurrences occur within the Meguma Group in the area, including several past producing gold and antimony-gold deposits. A slate quarry within the Glen Brook member is currently producing flagstone and tiles.

Dispersion of neutralized mine tailings from the Stirling Zn-Pb-Cu Mine Site, Nova Scotia

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The Stirling Zn-Pb-Cu base metal mine (located at Stirling, Richmond County, Nova Scotia) was active between 1935 to 1938, and 1952 to 1956, when one million tons of ore was produced grading 6.7% Zn, 1.6% Pb, and 0.8% Cu. Recovery was only about 65% efficient in the 1930s and the tailings were dumped directly into Copper Brook, whereas in the 1950s processing was about 70% efficient, and the waste was contained in a tailings pond.

Forty-five samples of tailings and stream sediments were analyzed by AAS for Fe, Mn, Zn, Pb, Cu, Ag, Ni, and Co, and sixteen selected samples were analyzed by ICP-INA for 46 elements. Results show close similarities in metal concentrations between the tailings and downstream sediments, although there is greater variability in the downstream sediments. Mean metal enrichment in the downstream sediments over the upstream sediments is by factors of approximately 70x for each of Zn, Pb, and Cu, As 38x, Ag 42x, Au 20x, Ca 7x, Mg 16x, Mn 10x, and Fe 3.3x.

Six water samples from upstream, downstream, and mine site locations were analyzed for 66 elements using ICP-MS. Results show that the tailings pond water is strongly enriched in Ca, Mg, Fe, Mn, Zn and Cu, and slightly enriched in As, Sb, Se, Co and Ni; however, the downstream water is only slightly enriched in Mn, Zn, As, Sb and Se.

The main mechanism resulting in the dispersion of the tailings into Copper Brook is by physical erosion and transport, involving both wind and overflow during flooding. Transport of metals in solution is less important due to i) neutralization of acid mine drainage by carbonates associated with the sulphides, and ii) dilution of the effluent from the tailings pond.

Probably the most serious environmental problem involves the widespread dispersion of the tailings both downstream and into Framboise Inlet at the mouth of Copper Brook. Site remediation and amelioration are possible, but will require capping of the tailings pond to stop ongoing erosion and minimize percolation through the tailings. The dispersion into Framboise Inlet could be reduced by locally elevating the base level of Copper Brook at the Framboise-Stirling road culvert (4 km downstream from the mine site and 0.5 km above the inlet).

Applied Quaternary geology and till geochemistry of the Loch Lomond Area, Cape Breton Island, Nova Scotia: implications for mineral exploration

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Southeastern Cape Breton is host to several former industrial minerals and base metals mines. These deposits were discovered by traditional prospecting methods; however, subsequent exploration has been hampered by thick glacial overburden, limited outcrop and a complex glacial history. Given these conditions, a detailed understanding of the glacial history of the study area is required in order to properly interpret till geochemistry. Three distinct tills were identified in the study area. The lowermost gray till is fine-grained, compact and contains few clasts. It is sparsely distributed and is usually found in local depressions. The middle red silty till contains some exotic clasts but with local representation; the upper brown sandy till is widely distributed over the study area and contains abundant angular local clasts. Pebble lithologies within the upper two tills suggest that these tills represent, respectively: i) a regional glacial advance and ii) a latter local glacial advance. Large scalloped ridges up to 50 m high dominate the landscape in the southern portion of the study area. The ridges are composed primarily of the upper sandy till and are usually bedrock cored; inter-ridge areas are overlain by post-glacial organic deposits and occasionally late-glacial outwash sand and gravel.

Till samples were collected at reconnaissance scale (3-5 km spacing) to determine regional background levels of base and precious metals and to identify anomalous areas that may indicate local mineralization. Preliminary data indicate that elevated Pb and Sr concentrations occur in local till samples near known deposits, the distance of dispersal is less than 4 km. Cu and Ba values, closely associated in some deposits, exhibit an easterly regional expression. This may indicate either remobilization of regional tills or additional occurrences of Cu-Ba mineralization. Background Cu values are also prevalent in the southern half of the project area, possibly reflecting dispersal of sulphide occurrences from the Stirling Group. Ni values are widespread in the southern half and likely represent the westerly regional dispersion of the St. Peter's gabbro.

Stratigraphy, petrochemistry and tectonic setting of the Silurian New Canaan Formation, Meguma Terrane, Nova Scotia

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The New Canaan Formation consists of Upper Silurian sedimentary and volcanic rocks, exposed in a double synclinal structure in the west-central Meguma terrane of Nova Scotia. The formation conformably overlies slate and metasiltstone of the Kentville Formation, also of Silurian age, which in turn overlies the Lower Silurian(?) through Cambrian White Rock, Halifax, and Goldenville formations.

Based on limited surface exposure combined with core samples from 6 drill holes, the New Canaan Formation has a total thickness of about 500 m, and is divided into seven stratigraphic units. The lowermost unit includes calcareous siltstone, slate, mafic lithic tuff, and vesicular basalt. Units 2, 4, and 6 are mainly composed of fossiliferous limestone and calcareous siltstone, whereas units 3 and 5 are dominated by varied crystal and lithic tuff, with minor pillow basalt also present in unit 5. The uppermost unit, the top of which is not preserved, consists of amygdaloidal basalt and crystal tuff. The tuffaceous units are intensely altered and contain abundant chlorite, quartz, and calcite. Mafic flows are less altered, and relict clinopyroxene survives in some of the amygdaloidal basalt units, and in basaltic clasts in some lithic tuff units. Limestone units and some of the tuffaceous units contain abundant fossil debris, including bryozoans, corals, crinoids, and brachiopods. Biotite and/or actinolite are present in samples within the thermal aureole of the Devonian South Mountain Batholith, which intruded the New Canaan Formation along its southern margin.

Geochemical data from basaltic flows and mafic tuff units show that the rocks are alkalic, with Nb/Y ratios between 1 and 3, and high Zr and TiO_2 contents. They formed in a within-plate setting. These data are consistent with limited published chemical data from the older White Rock Formation which also suggest a within-plate setting.

Geological and geophysical investigation of the western St. Mary's Basin, central mainland Nova Scotia: implications for palaeoplacer potential

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Horton Group clastic rocks in the St. Mary's Basin are predominantly derived from auriferous Meguma terrane lithologies to the south. Lithological and sedimentological criteria indicate the contact between the lacustrine Little Stewiacke River Formation and the fluviatile Barrens Hills Formation represents a shoreline facies which is a potentially favourable palaeoplacer gold horizon. The contact is marked by the occurrence of a thick sequence (<10 m) of quartz-pebble conglomerate beds. Micron-scale (<150 μm) gold present in the matrix of the conglomerates displays a "nuggety" appearance and flaky micro-texture indicative of a detrital origin. Other minerals identified within the conglomerates are also typical of palaeoplacer deposits.

The orientation of the contact has been affected by northeast-trending D_1 periclinal structures, which are locally kinked by north-northwest-trending D_2 folds and fractures. A series of magnetic surveys enabled more precise definition of the contact, which is recognized as an abrupt 5 to 10 nT "drop" from the Little Stewiacke River Formation to the Barrens Hills Formation.

Geochemical analyses indicate the near-contact siltstones were derived predominantly from the Meguma Group metasediments, while the near-contact sandstones are comprised primarily of Meguma terrane granitic detritus. The matrix of the quartz-pebble conglomerates consists predominantly of granitic Meguma detritus, while the quartz pebbles were likely derived from Meguma vein quartz. Minerals within the quartz-pebble conglomerates indicate source regions included both the granitic and metasedimentary rocks of the Meguma terrane, along with lithologies of the Liscomb Complex and the tin domain of southwestern Nova Scotia. The near-contact rocks exhibit several geochemical features which distinguish them from other intra-basinal lithologies, including an accumulation of zircon grains within the lacustrine littoral system.

Lithological, sedimentological, and geochemical characteristics of rocks in the vicinity of the contact, along with other intra-basinal lithologies, indicate a wet-dry seasonality related to orographically-induced precipitation effects which are attributed to the Late Devonian uplift of the Meguma terrane. A gradual reduction of orographic precipitation effects may account for the increasing dominance of arid conditions in the later depositional history of the region.

Results of mineral deposit studies at the granite-hosted Dunbrack (Zn-Pb-Cu-Ag) and Kinsac (Ba-F) localities, Central Meguma Terrane, Nova Scotia: possible implications for Carboniferous Zn-Pb-Cu-Ag-Ba-F metallogeny in the Meguma Zone

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Two mineralized areas within the ca. 370 Ma Musquodoboit and Kinsac plutons have been examined in order to evaluate the nature and origin of the base-metal (Dunbrack) and barite-fluorite (Kinsac) mineralization, respectively, and determine their implications for regional metallogeny. Although mineralization in both areas is vein-style and of hypogene origin, it is not clear whether the timing of mineralization coincides with emplacement of the host granitic rocks and/or reflects later igneous or hydrothermal events. The setting and nature of the mineralization, as discussed below, indicates that hydrothermal activity might relate to a younger metallogenic event(s) at ca. 300 Ma which may, therefore, have implications for the genesis of Zn-Pb mineralization within the basal Windsor Group (e.g., Gays River).

Base-metal (Zn-Pb-Cu-Ag) mineralization at Dunbrack occurs within a single, 1 m wide quartz vein (100°/62°N) characterized by cockade, comb and crustiform textures with multiple episodes of brecciation. The footwall comprises fine-grained, red felsic dyke (1.2 m), whereas the hanging wall is monzogranite of the Musquodoboit Batholith. The REE profile of a silicified dyke rock sample deviates markedly from the REE signature of the batholith lithologies which possibly suggests a different petrogenesis. Vein mineralogy includes quartz, K-feldspar (Or_{86-100}), muscovite (≤2 wt. % FeO, ≤0.8 wt. % F), kaolinite, Ag-poor galena, chalcopyrite, sphalerite (≤4 wt. % FeO), bornite and an array of Cu, Fe, Pb, Zn sulphides of both hypogene and supergene origin. Pseudosecondary, two-phase (L_{H2O}-V) fluid inclusions in quartz are of equant to negative shape and have uniform T_h values of 138 ± 2°C (n=40; salinities are pending), but trapping conditions are estimated at ≥250°C and ca. 2 kbars. Sulphur isotopes ($\delta^{34}S$; cpy, sph, gal; n=5) range from +2.3 to +6.9‰, except for a single value at -3.1‰, and for T = 200 to 250°C indicate $\delta^{34}S_{H2S}$= +4.6 to +6.7‰. $\delta^{18}O$ values for vein quartz (n=9) are uniform at +15.3 ± 1.2‰ and for T = 200 to 250°C indicate $\delta^{18}O_{fluid}$ = +6 to 8‰. Thus, both ^{34}S and ^{18}O data are consistent with a magmatic fluid. The age of mineralization is estimated at ca. 300 Ma based on $^{40}Ar/^{39}Ar$ dating of altered dyke rock and vein muscovite.

The Kinsac pluton, an extension of the Musquodoboit Batholith to the east, consists of medium-grained, two mica, cordierite monzogranite that contains abundant joints, dykes (aplites, pegmatites) and quartz-tourmaline veins. The dykes are oriented west-northwest/subvertical, whereas the joints and veins have no preferred trend. Areas of closely spaced shear fractures with horizontal slicken lines define steep northwest oriented shear zones. Veins (125-140°/subvertical), dominated by barite ± fluorite ± quartz and of ≤0.6 m width, are locally abundant throughout the eastern part of the Kinsac pluton in areas where the granite is sheared. The veins are zoned, undeformed and characterized by open-space infilling textures, and are dominated by randomly oriented, bladed barite euhedra (≤6-10 cm) with minor late quartz-fluorite (zoned from clear to purple); fluorite also occurs on joint faces. Barite is Sr poor (n=12; ≤0.35 wt. % Sr) and fluorite (n=5; Sr ≤65 ppm) has slightly concave REE patterns at 10x chondritic abundances with Eu_N/Eu^* = 0.65 and contrasts with the patterns, abundances and Eu_N/Eu^* exhibited by fluorite from the South Mountain Batholith. $\delta^{34}S$ for barite (n=8) is 13.3 ± 2.3‰, which precludes a magmatic source for sulphur assuming equilibrium SO_4^{2-}-H_2S fractionation, whereas $\delta^{18}O$ for vein quartz (n=3) is 22.1‰, which equates to $\delta^{18}O_{fluid}$ = +13‰ for T = 200°C. Quartz from quartz-tourmaline veins in the pluton has a magmatic $\delta^{18}O$ signature (+12.2‰). Thus, both ^{34}S and ^{18}O data suggest a non-magmatic component was involved in formation of the barite veins with the S probably sourced in Windsor Group evaporites.

We suggest that both sulphide and barite mineralization at the above localities are part of a ca. 300 Ma metallogenic event that also includes other centres of mineralization (e.g., Gays River, Walton, Tobeatic Lake, etc.). This metallogenic event coincides with elevated geotherms, magmatic activity (e.g., 312 Ma Wedgeport Granite) and Alleghanian deformation (e.g., southwest Nova Scotia) in the Meguma terrane and suggests that Carboniferous Zn-Pb-Cu-Ag-Ba-F metallogeny is contingent on the conjugation of several geological phenomena.

Relationships between foliation development, porphyroblast growth and large-scale folding in a metaturbidite suite, Snow Lake, Manitoba

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Complex relationships exist between cleavage development, metamorphism and large-scale folding in the well-bedded, polydeformed, staurolite-grade metaturbidites of the Burntwood suite, internal Paleoproterozoic Trans-Hudson Orogen at Snow Lake, Manitoba, Canada. It is demonstrated (a) that cleavage in anisotropic pelitic rock develops whenever microfolding is possible and that commonly initiation of a cleavage, which is pervasive on the scale of a fold, predates folding; (b) how a new axial planar fabric can develop on one fold limb of a symmetrical fold and not on the other; and (c) how two cleavages of different generations can be present in adjacent beds. Finally, dissolution of cleavage septa is suggested here as an alternative mechanism for the generation of schistosity.

The Burntwood suite is exposed on the dismembered limb of a macroscopic, isoclinal F2 structure and preserves a domainal cleavage (S2), which locally grades into a schistosity. S2 developed from crenulation of a generally bedding-parallel S1 cleavage that is axial planar to F1 isoclinal folds at around 1.84 Ga. Porphyroblast growth coincided with crenulation of S1 during early F2 folding at 1.815 to 1.8 Ga. Early stages of S2 development are recorded by inclusion trails (Si) in the porphyroblasts. During F2 flexural flow folding, variations in magnitude of bedding-parallel shear in lithologies of different competency resulted in a strong S2 refraction and thus heterogeneous strains between beds. S2 was crenulated prior to F3 large-scale folding, where favourably oriented. F3 crenulations were tightened on the eastern F3 limb and unfolded by sinistral layer-parallel shear on the western limb, where F2 and F3 layer-parallel shears were of opposite and the same sense, respectively. As a result, the initial developmental stages of an S3 are developed only on the eastern F3 limb and there only in incompetent layers, whereas S2 is preserved in the competent layers. On the western limb, S2 is preserved and appears axial planar to the F3 structure. The S2 domainal fabric was locally transformed into a schistosity by dissolution of the septa during widespread fluid activity, which endured until syn- or post-F3.

The use of Chernobyl-derived radiocaesium as a marine sediment tracer in two major bays in the eastern Mediterranean

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Several days after the Chernobyl accident, radiation derived from the destroyed reactor fell over large sections of eastern Europe and the Levant. The short- and longer-lived radioisotopes which are not naturally present afforded us unique tracers to study the distribution of the fallout along the coast and the transport of sediment from land into adjacent marine basins.

Two areas were studied, Haifa Bay, Israel, and Iskenderun Bay, Turkey. The radioactive Cs was monitored by gamma-ray spectrometery. Two isotopes of radiocesium, the short-lived Cs-134 and the longer-lived Cs-137 were readily detected by their characteristic gamma-ray energy peaks using a large, high resolution intrinsic Ge detector. A Cs-134/Cs-137 activity ratio of 0.5 was noted in the marine surface sediments in both regions. This ratio is characteristic of the Chernobyl release a few years after the accident. It demonstrates that residual Cs-137 derived from atmospheric weapons testing is only a minor component.

Two streams drain into Haifa Bay. Studies of the soils in the drainage area show that the deposition of the radiocesium was patchy, as has been previously noted for contaminated areas in Europe. By chance, the radiocesium was concentrated primarily near the small Na'aman stream, which thus acted as a point source of discharge into the Bay. The radiocesium was adsorbed onto clay-size particles, which were dispersed and deposited in deeper water, far from the river mouth.

In Iskenderun Bay the radiocesium distribution pattern is different. Although very large, this bay is relatively shallow and closed. The large Ceyhan River is the major sediment source. Muddy sediments are deposited fairly close to shore, and so the radiocesium concentrations are highest near the river's mouth. A smaller source of influx is located at the town of Iskenderun, at the opposite side of the Bay. The radiocesium concentrations throughout Iskenderun Bay was used to determine that a single, counterclockwise gyre is transporting and distributing the influx of land-derived sediment around the Bay.

The radiocesium in the surface sediment near the mouth of Iskenderun Bay is approximately an order of magnitude greater than the highest values measured off the Israeli coast. This may be due to the earlier arrival over Turkey, by several days, of the radioactive plume.

Mass-balance constraints on solution transfer fabric development in the footwall felsic volcanic rocks of the Brunswick No. 6 massive-sulfide deposit, Bathurst Camp, New Brunswick: effects of deformation-induced mass transfer on host rock compositions

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Lithogeochemical analysis of deformed rocks is commonly employed in determining primary igneous and/or sedimentary features, as well as secondary features like syngenetic hydrothermal alteration associated with ore deposit formation in the Bathurst VMS Camp and most other areas. In order to assess the chemical effects of solution transfer fabric development, four samples were studies within the felsic volcanic footwall rocks to the Brunswick No. 6 massive-sulfide deposit, because of the well-developed fabrics present. Wide beam electron microprobe traverses across a selected fabric (microlithon-septum-microlithon) show no obvious chemical change within the microlithons and, using Al-based, mass-balance of the averaged contents, principally show Si (± Na) and Zn removal from the septae with some notable, but not consistent, changes in Fe, Mg, Mn, and K; whole-rock (XRF) compositions of hand separates of the microlithons and septae show similar changes, but of a lower magnitude due to imperfect separations of the two. On average (n = 4) there are no net changes in trace-element contents, although individually several samples had significant inferred mobility of HFSE (< 50%), in particular the LREE (50 to 150%), if the microlithons are considered as closed systems, the favoured end-member hypothesis. $\delta^{18}O$ of the septae are lower than the microlithons, on average -0.13‰ per 1 wt.% SiO_2 depletion within the septae indicative of metamorphic fluids (1 to 7‰) that have either exchanged with isotopically light host rocks at depth, began formation (septae) at much lower temperatures, or were derived from low temperature (< 300°C) fluids evolved from sedimentary rocks in the accretionary wedge. Interestingly, the high salinities (2 * seawater) in fluid inclusions from syntectonic vein quartz from an earlier study at the Brunswick No. 12 deposit would be compatible with the latter interpretation.

Two end-member hypotheses for the fabric development are possible and affect the interpretation of the inferred mass changes. The pressure-solution of silica in the septae may

have been mobilized out of the system (open) or into the microlithons (closed system) during extension. The degree of alteration in the microlithons should be less simple because permeability is evidently lower. If correct, there was considerable mass transfer of silica out of the system. Based on qualitative estimates of silica solubility (10 g/kg) and degree of under-saturation (20%) within the foliation, the fluid-rock ratio in the septae is greater than 40. Several processes may explain the degree of silica under-saturation that was responsible for the fabric development. Buoyant infiltration of low-temperature fluids from under-thrusted sedimentary rocks when they were incorporated in a subduction complex provides a constant source of silica under-saturated fluids thus explaining the silica mobility, and the decrease in ^{18}O in the septae.

Earth science and engineering: urban development in the metropolitan Halifax region

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This poster highlights illustrations including geological maps and shaded relief images from a chapter about the geology and geotechnics of Halifax in a new GAC Special Paper "Urban Geology of Canadian Cities" edited by P.F. Karrow and O.L. White. The landscape of metropolitan Halifax, which surrounds Halifax Harbour, is dominated by a plain of bedrock and stony till exposures, and drumlins made of fine-grained tills. These rest unconformably on a folded and metamorphosed sedimentary rock sequence of Cambrian-Ordovician slate over metasandstone intruded by Devonian granitoid plutons. Halifax Harbour and Bedford Basin were converted to a marine embayment with typical estuarine circulation between 7.7 and 5.8 ka by post-glacial sea-level rise. Seismic hazard is relatively minor in the Halifax area. Other, local hazards are arsenic contamination in some mineralized gold districts, radon contamination in granitoid and granite-rich till terrain, rapid shore recession of the Atlantic coast, and flooding at times of storms, high tides or tsunamis. The bedrock is an excellent foundation material, with the granitoids and metasandstones rating somewhat higher in quality than the more closely fractured slates. The tills, typically dense with low compressibility, also provide good foundation conditions. Construction aggregates are readily available. Geotechnical concerns for construction include: moisture ingress and strength loss in fine-grained tills, and unpredictable or low strengths of fill, peat, and harbour mud. Most data used in engineering practice arise from boreholes drilled by consultants. Environmental protection procedures minimize acid drainage from excavation of sulphide-rich slate, or toxic metal release from dredging of contaminated harbour sediment. Local lakes provide abundant water supplies of high quality. Basal impermeable clay-bearing tills and sandy tills for cover materials facilitate landfill development for disposal of solid wastes. The continued disposal of sewage in the Harbour is an outstanding environmental issue.

Petrology and tectonic implications of the Silurian Sarach Brook Metamorphic suite, southern Cape Breton Highlands, Nova Scotia

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The Sarach Brook Metamorphic suite is located in the Aspy terrane of Cape Breton Island, and consists of metavolcanic and metasedimentary rocks of Silurian age. This study focuses on the eastern part of the Sarach Brook Metamorphic suite, and is based on field mapping and petrographic examination of 52 samples, as well as whole-rock geochemical analyses of 20 representative samples and mineral analyses in 6 samples. The metavolcanic rocks range in composition from basaltic to rhyolitic and metasedimentary rocks are dominantly metasiltstone. Relict bedding (S_0) and foliation (S_1) vary from easterly trending in the south to northerly trending in the north, with mainly steep dips. The unit has been deformed along its western edge by the Southern Highlands Shear Zone. Mineral assemblages in the Sarach Brook Metamorphic suite are dominated by plagioclase (An_5 to An_{20}), hornblende, epidote, chlorite, biotite, and rarely garnet, and indicate greenschist to lower amphibolite facies regional metamorphism. Locally, contact metamorphism has produced hornfels containing staurolite, andalusite and fibrolite. Geochemical data indicate that the volcanic rocks in the Sarach Brook Metamorphic suite are tholeiitic, and a back-arc tectonic setting is postulated. The Sarach Brook Metamorphic suite is correlated with other Ordovician-Silurian units in the Aspy terrane, including the Taylors Barren Pluton, the MacRae Brook Formation, and the Money Point Group.

The Brunswick No. 6 VMS Cu Zone, Bathurst Camp, New Brunswick: petrology, geochemical composition and petrogenesis

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Cu-rich massive sulphides envelope the north-end and base of the Brunswick No. 6 Pb-Zn massive-sulphide lens. Preliminary ore reserve calculations indicate 1.7 Mt grading 0.9% Cu (William Luff, personal communication). Mineralogically, the principle minerals are pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, magnetite, and trace arsenopyrite, cobaltite, and cassiterite. Generally, chalcopyrite and pyrite are fine-grained, although cataclastically deformed pyrite porphyroblasts (porphyroclasts) are hosted in a recrystallized pyrrhotite-rich matrix. In this study, 11 sample intervals 5 feet long from 10 drill holes into the Cu zone were re-assayed yielding an average of 0.90% Cu, 1.28% Zn, 0.42% Pb, 28.6 g/t Ag, 0.046% Bi, and 0.225 g/t Au, as well as 0.131% As, 0.030% Sb, 0.069% Co, and Sn values below the detection limit of 0.005%. Diamond Drill hole B-259 into the exhalative was re-assayed (n = 6) and yielded an average of 0.78% Cu, 1.08% Pb, 3.46% Zn, 0.051% Bi, 0.311% As, 0.063% Sb, 0.07% Co, 58.62 g/t Ag and 0.495 g/t Au. Bulk sulphur analyses (n = 11) conducted on 10 drill holes within the Cu zone yielded an average $\delta^{34}S$ value of 14.6 per mil. Additionally, Hole B-259 sampled (n = 6) from the Pb-Zn exhalative deposit averaged $\delta^{34}S = 14$ per mil creating an increasing trend of $\delta^{34}S$ values entering the Cu zone. A similar trend occurs at the Brunswick No. 12 deposit. There is a notable decrease in Cu, Pb, Ag, As, and Sb concentrations and marked decrease in Zn values with increased depth into the Cu zone. Bi and Au concentrations exhibit a "U" shaped trend with the lowest concentrations occurring at approximately the centre of the Cu zone. The high Cu and low base-metals within the basal massive-sulphide zone compared to the Zn-Pb-Ag exhalative massive sulphides in both the No. 6 and No. 12 deposits is common in proximal VMS deposits. It is usually interpreted as a hydrothermal zone-refining feature, which is consistent with: 1) the relatively high pyrrhotite to pyrite abundance and higher abundance of chalcopyrite, arsenopyrite, bismuthinite, and cassiterite that have higher temperature-sensitive solubilities; 2) lower sphalerite, galena, tetrahedrite/tennantite, and argentite concentrations; and 3) its occurrence above the stockwork feeder zone that formed the deposit.

Nova Scotia zeolites: mineral oddity or mineral commodity?

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The Jurassic basalts of the North Mountain, Nova Scotia, are host to unique zeolite deposits. Recent exploration suggests commercial quantities of zeolite are present in a number of locations, giving Nova Scotia an opportunity to become a commercial producer for the large east coast markets of North America. Zeolites were first discovered in the early 1600s during the settlement of Port Royal. F. Alger published the first paper discussing the mineralogy of the North Mountain in 1827. Geological investigations flourished during the 1800s and into the middle of the next century. The village of Morden, located on the northern shore of the North Mountain, is the type location for the zeolite mordenite that was discovered in 1881. In the 1920s, the Deputy Minister of Mines, an avid rock collector in the Bay of Fundy region, decided that the zeolite mineral stilbite should become the provincial mineral for Nova Scotia and has remained to the present day. Research has been sporadic for the last 70 years, with the focus mainly on the basalts hosting a mineral oddity rather that a commodity. The goal of recent investigations on the North Mountain is to make the leap from mineral oddity to mineral commodity.

The demand for zeolite continues to expand with the increasing need for environmentally friendly materials. Technology has advanced to the point where extraction of zeolite from basalt is not only possible but also highly effective. Zeolites are currently used in a broad base of industries which include; purification of waste water streams for mining and industrial operations, radioactive water containment systems, as a gas absorbent and catalyst, in ion exchange processes as well as in agricultural and animal nutrition products. The most common zeolites found on the North Mountain are stilbite, heulandite and clinoptilolite. Laumontite, chabazite, gmelinite, mordenite, analcite and the natrolite family of zeolites are less common in this region.

Acid-generating/neutralizing conditions within Nova Scotia coal mines: relationship to different mining methods

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Pyritic coal (up to 7%) is mined from the Morien Group of the Carboniferous Sydney Basin, Cape Breton, Nova Scotia. Interaction with the atmosphere oxidizes the pyrite to create Fe^{2+}, SO_4^{2-} and acid (H^+) through the reaction:

$$FeS_2 + 7/2O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad (1)$$

The products are carried down into the mine waters or immersed as water levels rise in flooded mines. High SO_4^{2-} values within the mine waters indicate that significant amounts of pyrite have undergone dissolution. Despite this, many waters do not show the low pH and high metal content commonly associated with acid mine drainage. This is due to acid neutralization by the dissolution of other minerals within the mine setting. An example is calcite dissolution:

$$CaCO_3 + H^+ = Ca^{2+} + HCO_3^- \quad (2)$$

Neutralization follows a mineral sequence with an associated pH. The general order is calcite/dolomite (6.5-7.5), siderite (4.8-6.3), and gibbsite (4.0-4.3). Calcite is the most reactive mineral and the metal content is low due to the high pH. Gibbsite is the least reactive and the metal content is high. Six populations were distinguished from three mine areas. The 1B Shaft was buffered by calcite in the top portion of the shaft, by siderite in the bottom portion and by gibbsite when the shaft was pumped for a day or more. The gibbsite buffered waters were high in metals and were derived from the underlying 1B Colliery. The flooded Lingan Colliery waters were siderite buffered and the underlying Phalen Colliery waters were calcite buffered despite being derived from the Lingan Colliery.

The mining method greatly affects the acid generation and neutralization reactions. 1B Colliery was mined by the room and pillar method, which left pillars to support the roof. This left a large surface area of coal exposed to the atmosphere and oxidation. In addition, a supported roof limited the interaction of the mine waters with the overlying roof-rock that was rich in siderite. The Lingan and Phalen collieries utilized the retreat longwall mining method which removes all the coal over a large area, greatly reducing the amount of pyrite available for oxidation. In addition, this mining method causes the roof to collapse down to the floor, which fractures the roof, creating a siderite-rich rubble that fills the vacant space. As a result, the Lingan Colliery waters are buffered by siderite and are low in most metals. Waters flowing from Lingan to the underling Phalen Colliery must travel through carbonate-rich zones. There they are buffered by calcite which raises the pH and causes iron to precipitate in siderite through the reaction:

$$Fe^{2+} + HCO_3^- = FeCO_3 + H^+ \quad (3)$$

The resulting Phalen waters are very low in metals. 1B Shaft waters are also buffered by the minerals within the shaft face. The transition from calcite to siderite buffering occurs in the general area of the Backpit Limestone.

Any future pumping to reduce water levels in the mines may dramatically reduce treatment cost by pumping waters from the retreat longwall workings and avoiding workings mined by room and pillar methods.

Biomineralization of gold: myth versus reality

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Traditionally, experts well versed in experimentation, maintained that gold was so noble as to be virtually insoluble. However, popular wisdom has long held otherwise. Results of selected experimental work on the biomineralization of gold are reviewed against the background of historical accounts. The ability to bind metals is an integral characteristic of most micro-organisms. They thrive under diverse geochemical conditions and a tremendous variety of habitats, wherever there is liquid water, and up to temperatures of about 120°C. Their versatility and wide ranging occurrence has generated various ore deposits throughout geologic time. Prokaryotes play a particularly important role in the genesis of placer gold deposits. Under various experimental conditions, widely encountered in nature, micro-organisms (especially bacteria) are able to: dissolve gold, immobilize gold in colloidal condition, and catalyze the formation of crystalline gold.

Whether micro-organism, or a higher or lower plant, the role of photosynthesis in life and growth processes is therefore implicit and of paramount importance in biomineralization. In the case of gold, the link to chemical reactions driven by photosynthesis is clear. The intrinsic ability of certain plants, and of micro-organisms generally, to bind metals, functions in diverse ways to dissolve, immobilize, transport, or precipitate gold under a wide range of geological conditions, and in exceptional cases, to form ore deposits.

Fault reactivation in suspect terranes: insights from the Avalon terrane in the Canadian Appalachians

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Suspect terranes commonly have faults with movement histories that reflect their original tectonic setting and subsequent re-activation during terrane accretion and dispersal. Since later movements tend to obliterate evidence of earlier motions, documenting fault re-activation is a difficult task. We present evidence from two northeast-trending fault zones within Avalonia. The Hollow Fault Zone of mainland Nova Scotia and the Bellisle-Kennebecasis Fault Zone of southern New Brunswick preserve evidence for reactivation in a variety of tectonic settings between the Neoproterozoic and the late Carboniferous. During this time period, Avalonia migrated from its original setting along the Gondwanan margin in the Neoproterozoic, was accreted to Laurentia by the late Ordovician, and was dispersed by sinistral followed by dextral strike-slip faults between the Silurian and the late Carboniferous.

Evidence of Neoproterozoic motion is preserved in pre-final crystallization deformation fabrics in igneous complexes which intrude the shear zones. This reflects strike-slip motion related to oblique subduction along the Gondwanan margin. Cambrian motion along the Hollow Fault is inferred to have controlled facies variations in an intra-continental rift sequence. Subsequent mid-Ordovician to earliest Silurian deformation is limited to these shear zones and is characterized by basin inversion in mainland Nova Scotia and formation of mylonites and injection of dikes into brittle fractures in southern New Brunswick. This deformation and magmatism is attributed to the sinistral accretion of Avalonia to Laurentia.

Evidence of mid-Silurian to late Carboniferous terrane post-accretionary dispersal is recorded in the mylonitic and cataclastic fabrics recorded in the shear zones themselves, the orientations of spatially related fold structures, local controls on sedimentary facies and offsets in stratigraphy. This motion was predominantly dextral in sense and was predominantly related to convergence between Laurentia and Gondwana associated with the amalgamation of Pangea.

Drift prospecting in the vicinity of the Restigouche deposit, Bathurst Mining Camp

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The Restigouche and C4-C5 massive sulphide deposits are located in an area where eastward ice movement (070°-115°) was followed by northeastward (035°-065°) flowing ice. The Restigouche deposit sits on the down-ice side of a hill, protected from glacial erosion, thus explaining the preservation of a gossan cap, whereas the C4-C5 zone is on top of a hill exposed to intense glacial erosion, thus accounting for the absence of a gossan cap and the high percentage of till clasts transported from the Silurian-Devonian rock units farther up-ice. A thin (<2 m) layer of sandy/clayey basal till covers much of the area, although north of the deposits a borrow pit is located in till 5 m thick. Locally, preglacial weathered bedrock is present in the vicinity of the Restigouche deposit, commonly overlain by basal till. A transported gossan/cemented till, outcropping and also overlying fresh till, is present down-ice and downslope from the Restigouche C4-C5 zone and may have been partially transported as an ice-thrusted sheet. The transported gossan/cemented till is highly anomalous in base-metals (Co 770 ppm, Ni 3300 ppm and Zn 6300 ppm) and may be associated with mafic dykes.

Geochemical analyses on the 63 μm size fraction of basal till samples by ICP-ES, ICP-MS and INAA, from a 250 m grid survey (126 sites) in 1994 and 102 sites (till, B-horizon soil, humus and balsam fir) on a detailed 25 m grid survey (1995) around and down-ice (060°-090°) from the main Restigouche deposit revealed highly anomalous Cu, Pb, Zn, and Sn values in till samples within 1 to 2 km east-northeast of the deposit. Open ended anomalies at or exceeding these values were found 1 km north of the deposit. During 1996, 53 till samples were collected on approximately 250 m centres, around and down-ice from the Restigouche C4-C5 zone to close off the northern anomaly. Anomalous values in basal till from the south end of the detailed grid are dispersed down-ice toward 070°, from the deposit and contain maximum concentrations of Cu (1400 ppm), Pb (30 000 ppm), Zn (1600 ppm), Au (506 ppb), As (1600 ppm), Sb (77 ppm), Ag (36 ppm), and Sn (28 ppm). At the C4-C5 zone fresh sulphides are exposed and therefore glacial dispersal of base metals is more evident than at the main Restigouche deposit. A large Zn anomaly (750-6300 ppm) is centred on the C4-C5 zone and extends down-ice (glacial dispersal) for approximately 2 km including the northern part of the detailed grid, and downslope in the up-ice direction (hydromorphic dispersion). In contrast the Zn anomaly around the main Restigouche deposit is smaller in length (300 m) and concentration (300-400 ppm except in samples directly over the deposit). Cu, Pb, and Sn have similar patterns.

Trace fossils from the Cenozoic of southeastern coastal Jamaica

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The eastern side of Port Morant Harbour, southeastern coastal Jamaica, exposes three Cenozoic lithostratigraphic units of Pliocene to Pleistocene age, and each of which, for varying reasons, is of interest ichnologically. The oldest (Pliocene) unit comprises the Bowden Formation, a 5 m succession of basal? turbiditic conglomerates, historically referred to as the Bowden shell bed and the most fossiliferous sequence in Jamaica, overlain by an estimated 145 m of deep-water silty and sandy 'marlstones' with thin and sporadically developed pebbly sandstone horizons. Disconformably overlying this sequence is a Lower Pleistocene unit referred to as the Old Pera beds, a shallow-marine, siliciclastic, storm-dominated sequence, at least 30 m thick. Unconformably overlying the Old Pera beds is the Upper Pleistocene Port Morant Formation that consists of approximately 10 m of muddy, calcareous and highly fossiliferous, fine-to-coarse-grained sandstones with a basal boulder conglomerate unit and sporadic pebble conglomerate horizons, and interpreted as lagoonal in origin.

Each sequence is characterized by a distinctive suite of trace fossils. The Bowden shell bed contains at least 45 benthic mollusc species that exhibit predatory gastropod borings referable to the ichnotaxa *Oichnus simplex* and *O. parabaloides*, produced respectively by mucricids and naticids. A resedimented limestone clast in the shell bed contains rather unique examples of the bivalve borings *Gastrochaenolites* cf. *cluniformis* preserving their producer (*Rocellaria (Gastrochaena) hians).* The overlying 'marlstones' contain the soft-sediment ichnotaxa *Chondrites, Circulichnis montanus, Ophiomorpha, Palaeophycus tubularis, Palaeophycus? heberti, Phycosiphon incertum, Planolites, Skolithos, Taenidium cameronensis, Teichichnus rectus* and *Thalassinoides,* and the bivalve wood boring *Teredolites longissimus.* Collectively, these ichnotaxa support the interpretation that the Bowden Formation was deposited in relatively deep-water conditions.

The Old Pera beds exhibit a relatively low diversity of ichnotaxa but do include *Thalassinoides, Ophiomorpha, Skolithos* and rare *Chondrites.* Of particular interest, however, is the locally abundant occurrence of *Bichordites monastiriensis,* an ichnospecies produced by spatangoid echinoids, and previously recorded from only two other locations, one in Tunisia and the other in northern Italy.

Finally, the Port Morant Formation preserves both soft-sediment ichnotaxa and those produced by bioerosion. The former include *Thalassinoides paradoxicus, Ophiomorpha nodosa* and rare *Palaeophycus tubularis,* and the latter, *Caulostrepsis* cf. *contorta, C. cretacea, C. taeniola* and *Clioniodes thomasi* (all produced by spionid polychaete annelids); *Entobia ovula* (produced by sponges); *Gastrochaenolites* cf. *cluniformis* and *G.* cf. *torpedo* (many still preserving their bivalve producers, respectively *Rocellaria (Gastrochaena) hians* and *Lithophaga artillarum)*; *Meandropolydora* cf. *sulcans* (produced by polychaetes); and *Oichnus simplex* and *O. paraboloides.* Such a diverse assemblage of bioerosional ichnotaxa has not previously been reported from Jamaica.

The HydroPunch tool: a cost-effective method of groundwater sampling

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The HydroPunch provides a fast and relatively inexpensive method for delineation of groundwater contamination. Constructed almost entirely of stainless steel, it is used in environmental investigations to acquire *in situ* groundwater samples without the need for installation of permanent monitoring wells. The HydroPunch is not recommended as a replacement for monitoring wells. However, the tool is re-useable and provides a highly effective method of sample recovery.

The HydroPunch tool is driven into the subsurface from the bottom of a borehole. The unit is essentially a long pipe containing a sealed intake screen and 1.2 litre sample chamber, isolated from the surrounding material behind a cone-shaped drive point as the tool is advanced. The tool is driven to the desired sampling depth using an attached threaded drive rod. The drive point is held in place by friction during advancement of the tool, occasionally aided by an o-ring and a heavy elastic band.

Field tests indicated that consistent recovery and results can be achieved from a target zone when the tool is placed within a high permeability area or slightly above any underlying low permeability clay or silt stratum. Once installed at the desired level, the drive rod is pulled back approximately 0.5 m. This action causes the drive point to disengage and the outer casing to rise, exposing a screened collection chamber and allowing it to be filled with a non-aerated sample. Screens can be interchanged (0.125 mm or 0.250 mm) to accommodate the grain size of the target unit. Sample collection can take from 30 minutes to 2 hours depending on the permeability and hydrostatic subsurface conditions at each site. When the Hydropunch tool is pulled further upward, frictional resistance on the drive point causes an upper and lower check valve to close sealing the sample chamber. The tool, with a filled sample chamber, is then retracted to the surface and fitted with a threaded discharge valve allowing the sample to be decanted into a sample bottle. Decontamination of the HydroPunch tool requires disassembly and thorough cleaning at a location away from the investigation site. Septas and o-rings are removed and discarded. Small re-useable parts can be cleaned in a stainless steel cage. The entire assemblage should be spray cleaned with a high pressure hot water/steam jenny and rinsed with laboratory grade acetone and hexane.

Minor problems identified from use at over sixty locations included, leakage at threaded joints, failure to release the drive point due to insufficient friction, and siltation due to installation of incorrect screen size. Overall, the use of the HydroPunch tool provided an efficient environmental sampling technique during examination of unconsolidated deposits.

Optically and thermally stimulated luminescence dating of Birimi, a multi-component archaeological site in Ghana, Africa

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Birimi is an archaeological site located in the sub-Saharan northern region of Ghana, Africa, south of the Gambaga Escarpment. The site, situated on a river terrace of the ephemeral Birimi stream, contains archaeological remains of three cultural components. The oldest component is of Middle Stone Age (MSA) technology and is overlain by the Late Stone Age ceramic producing Kintampo cultural level and the youngest Iron Age component. The MSA artifacts consist of stone implements only, hence this component was dated by optically stimulated luminescence (OSL) used on the quartz-rich sediment surrounding the tools. The Kintampo level was dated by two geoarchaeological chronology techniques, namely thermoluminescence (TL) used on both ceramic and burnt house daub fragments, and radiocarbon dating used on small pieces of charcoal. Smelters used for iron refining are also present at Birimi and were dated by TL. The MSA level yielded an age of 32.5 ± 7.5 ka, the only absolute age for the MSA in Ghana. TL dates on 12 house daub fragments revealed three chronological occupation periods of the site by Kintampo peoples, 2300 to 2500 years, 2800 to 3300 years and 3800 to 4500 years, a culture formerly thought to have migrated intact into Ghana and to have remained for only ~500 years. The ceramic TL dates support the daub results, with the first two dates of 2653 ± 174 years and 4815 ± 281 years falling into the early and late chronological occupation periods. Four Kintampo associated radiocarbon dates in the range 3400 to 3800 years coincide with the middle occupation. TL smelter ages show that iron technology was practiced at the site as early as 1550 ± 80 years and continued at Birimi until 1020 ± 60 years. These results indicate that Birimi was a favoured living site for three separate cultures. This, along with SEM evidence that shows similar chemical weathering and diagenetic features on quartz sand grains of several levels, argues for a continuously favourable climate and relatively constant weathering regime in northern Ghana over the last 30,000 years.

Underground natural gas storage in the Maritimes

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It would appear that the Sable Island Bank natural gas will come ashore in late 1999 or early 2000 and some of the gas will be available for use in Nova Scotia and New Brunswick while the majority is on its way to markets in the United States. Storage of the gas to allow for daily and seasonal variations in demand becomes essential for local distribution companies (LDCs). The most economical and safest storage is underground in depleted oil and gas reservoirs or in salt caverns located at depths of 12 to 1600 m so as to allow the storage to be operated as a pressure vessel. Similar containers at depths of 300 to 800 m can be used to contain compressed air energy storage (CAES) to provide electrical peaking power.

Nova Scotia and New Brunswick have few hydrocarbon reservoirs that can serve for underground storage but do have numerous Carboniferous salt deposits. Prince Edward Island has no known reservoirs and few opportunities for salt storage. The ideal salt is thick and at the correct depths, is very pure with a minimum of insolubles that remain behind after dissolution of the salt to create a cavern, has little structural disturbance and is tight, has a low moisture content and low temperature to minimize salt mobility, has no potash mineralization to distort the dissolution process and cavern shape, has fresh water available for dissolution, is in an area where disposal of the brine can go to the ocean directly, and is close to the market to be served.

Nova Scotia and New Brunswick have over 35 known salt deposits in some seven to eight geographical areas. Of these probably less than ten may be suitable to serve as underground storage. Active evaluation of possible sites is known to be occurring in at least four or five locations.

Simple geophysically-imaged shear zones with complex histories: an example from the southern Trans-Hudson Orogen, Manitoba

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The Berry Creek shear zone (BCSZ) transects the southern portion of the Palaeoproterozoic Trans-Hudson Orogen in Manitoba for more than 150 km. It lies below the northern limit of Ordovician limestone cover for much of its length, and its trace was originally geophysically defined on the basis of truncations of aeromagnetic patterns, confirmed in the third dimension by truncation of reflectors in seismic profiles.

The BCSZ was investigated at six locations where it is exposed in windows through the limestone cover. Fabrics and minor structures vary from ductile to brittle along the zone, owing to different ages of deformation, and different tectonothermal conditions during a protracted history.

P–T estimates from across the northeast segment of the BCSZ indicate identical metamorphic conditions on both sides, suggesting little to no offset after the thermal peak of metamorphism. Conversely, across its western segment, metamorphic grade changes southward from greenschist to amphibolite facies. This pattern may have resulted from scissor-like faulting along the BCSZ, with the rotation axis pinned in the northeast. Alternatively, the age of deformation is different at each location. The solution to this problem requires geochronological investigation.

The structure has previously been referred to as a fault or a shear zone, depending on personal preference and the local data set. We interpret the sharp, vertical truncations of geophysical features as most likely resulting from late brittle–ductile and brittle features, such as cataclastic zones. Brittle deformation appears to have reactivated and overprinted earlier ductile shear zone fabrics. The earliest manifestation (ductile) of the BCSZ pre-dates the Tramping Lake granite (1837 +8/-6 Ma) and the thermal peak of amphibolite grade metamorphism (1820–1805 Ma). A later ductile manifestation of the BCSZ truncated the pluton. The youngest (brittle) deformation in the zone occurred at sub-greenschist metamorphic conditions during uplift (probably after ~1770 Ma). The BCSZ, as imaged geophysically, therefore represents an anastomosing shear zone/fault system that underwent multiple reactivations during a period in excess of 70 Ma. Different early ductile segments that are presently aligned were probably originally unrelated, but collectively formed a plane of anisotropy that was reactivated during late brittle deformation. The coincidence between the trace of the BCSZ and the northern limit of the Paleozoic cover may not be fortuitous.

Effect of flocculation on the grain-size spectra of fine-grained turbidites

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The formation of flocs as settling entities is a significant influence on fine-grained sediment deposition because it produces the same settling speed for all grains small enough to be caught up and incorporated into flocs and results in a bottom sediment that mirrors the size distribution of the suspension (Kranck, 1980; Kranck and Milligan, 1985; Kranck, 1993). The change in grain-size distributions or spectra recorded in bottom sediments reflects the variation in flocculation of the depositing suspension as it evolves with time and distance. The "flocculation limit" (Schell, 1996) is a proxy for determining the degree of flocculation that was active in a depositing fine-grained suspension, and is a useful tool in interpreting the energy regime of the past depositional environment. Conceptually, the floc limit is the upper limit in the size of grains that deposit within flocs. It marks the upper limit of the "flat" portion on a log volume versus log diameter of component grain-size curves.

To test the theory of floc limits, a representative core study on Laurentian Fan/Sohm Abyssal Plain, Wisconsinian age, reddish-brown turbidites was conducted, followed by an analysis of disaggregated grain-size spectra and the determination of their floc limits. Based on these sedimentological observations, we propose two possible mechanisms (gradient versus turbulent shear sorting) that may be responsible for the observed downslope 10-fold fining trend in the flocculation limit. These observations are consistent with the shear sorting model for fine-grained sediments (Stow and Bowen, 1980) by which grains bound up in flocs are sorted during cycles of floc destruction and reformation. With the aid of scaling arguments of the pull apart forces acting on flocs (turbulent shear versus settling), we provide evidence based on the indicative shape of the disaggregated grain-size spectra that turbulent shear sorting for particles smaller than 8 microns becomes ineffective because the shear stress that allows particles this small to deposit is not strong enough to break apart flocs.

Sedimentation in a macrotidal estuary environment: a multidisciplinary web site

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A web site that focuses on sedimentation processes in the Cornwallis River Estuary is currently under development at Acadia University. The Cornwallis River Estuary is macrotidal (tide-dominated), is located in northwestern Nova Scotia and drains into the Minas Basin which is found within the Bay of Fundy. The web site is being designed to provide web users with a wide range of written and visual information on a variety of processes that are unique to the macrotidal estuary environment. Satellite, ground-based and airborne imagery will all be incorporated into this site. Though the site focuses mainly on processes of sedimentation within the Cornwallis River Estuary, information on geomorphology, ecology, and the anthropogenic impacts (past and present) will also be presented.

With over 50 images, accompanying text and an extensive and up-to-date reference list this site could be accessed as an educational tool by educators from a wide variety of disciplines. It is also anticipated that the site will serve as a research tool as it may provide those studying both modern and ancient estuarine systems with a unique perspective. The incorporation of both a "Comments" and a "Links" page will enhance the utility of the site. The final draft of the web site will be completed by the end of February, 1998. Upon completion the site will be connected to the Acadia Geology Department home page: (URL http://ace.acadiau.ca/science/geol/home.html).

Transpaction in Meguma Group rocks during emplacement of the South Mountain Batholith, Nova Scotia

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Preliminary study of porphyroblast/cleavage relationships in the South Mountain Batholith's (SMB) aureole in Nova Scotia, shows that the earliest metamorphism occurred at the same time as regional cleavage formation in Meguma Group country rocks. The space required for batholithic intrusion into a regional general shear zone was in part generated by extensive volume loss in the country rocks. Cleavage continued to develop until very late in the batholith emplacement history.

Previous workers have documented up to 60% volume loss during the regional cleavage formation in Meguma Group rocks. We have identified three stages of porphyroblast growth in the contact aureole of the SMB related to pressure solution cleavage formation. The earliest assemblage is represented by biotite, qtz-chlor-Fe oxide pseudomorphs after garnet, and elliptical qtz-white mica aggregates which were either cordierite or an aluminosilicate mineral and are aligned with their long axes parallel to a domainal spaced cleavage. These early minerals are preserved in lithons between solution-cleavage planes. Garnet pseudomorphs were unaltered before deformation because cleavage wraps around them, and the alteration products lack the strength to maintain garnet morphology. The second assemblage includes andalusite, cordierite, and a second generation of biotite. Deformed andalusite was stretched parallel, and shortened perpendicular, to the foliation; post-andalusite strain ratios of $R_s = 2.5$ in XZ sections were obtained using Fry and deformed line distribution analyses. Cordierite porphyroblasts preserve a widely spaced cleavage that is parallel to a more closely spaced cleavage, containing new biotite, which wraps around them. The cleavage relationships are consistent with growth of these minerals during cleavage formation. The youngest metamorphic minerals are chlorite, muscovite, and undeformed staurolite porphyroblasts surrounded by moats of equant quartz; these may represent a retrograde reaction of biotite and aluminosilicate to staurolite, muscovite, and chlorite. Post-deformation alteration of the quartz/mica ellipses and garnet may be related to this retrogression event.

Formation of cleavage during transpression should result in steep stretching lineations unless the coaxial contribution is relatively small compared to the non-coaxial component. However, the Meguma Group rocks are seldom lineated, and magnetic lineations in the plutons are sub-horizontal (Benn *et al.*, 1997). These findings are consistent with regional "transpaction", in which intrusion of dikes and laccoliths is assisted by non-coaxial strain and normally-directed volume loss.

Glacier retreat and relative sea-level changes in Maritime Canada

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The Scotian Shelf End Moraine Complex, formed between 18 and 15 ka at the tidewater margin of a glacier centred over Nova Scotia (Scotian Ice Divide). Isostatic rebound from a more extensive ice sheet at the Late Wisconsinan maximum (Escuminac Ice Centre) helped to stabilize this ice margin. These moraines are found between 170 and 85 m below present sea level. The depth variation can be attributed to differential uplift and proximity to post-Scotian Phase, Late- glacial ice centres, assuming that the moraines all formed at the same critical buoyancy depth.

Raised marine deposits formed between 14 and 12.5 ka following rapid ice retreat in the Gulf of Maine and Bay of Fundy. Post-glacial emergence patterns over Maritime Canada are controlled by rates of glacier retreat and variations in ice loads over the region. AMS dating of basal lake sediments and buried organic sections has shown that glaciers persisted over mainland Nova Scotia, until 11 ka, several thousand years after ice was removed from the Gulf of Maine and the Bay of Fundy. Marine limits decline towards local centres of ice flow, reflecting diachronous emergence under low-profile, or smaller ice caps.

At 11. 6 ka, relative sea-level along the inner Scotian Shelf of Nova Scotia stood at -65 m below MSL. A shoreline developed, marked by the abrupt transition from moraines and drumlins to truncated landforms and muted topography, terraces and cliffs, and deltaic deposits. In contrast to earlier, tilted emerged shorelines, this inner shelf lowstand shoreline is relatively undeformed and can be traced along the entire length of eastern mainland Nova Scotia. Recently collected seismic reflection data from Browns Bank, show prominent, bank-edge deltas with upper lapout contacts between 40 and 70 m. Terraces, clinoforms and significant erosional unconformities on glaciomarine sediments below 90 m, may also indicate greater sea-level lowering in the offshore banks and the Bay of Fundy.

The patterns of post-glacial relative sea-level change in Nova Scotia and Maine are similar, if emergence under late-melting ice is considered. The high amplitude and short wavelength of the relative sea-level curves are not consistent with geophysical models of sea-level change that emphasize slow-response mantle deformation.

Provenance of the Namurian Lismore Formation, mainland Nova Scotia

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The Namurian Lismore Formation of the Mabou Group, mainland Nova Scotia is a 2500 m thick upward coarsening fluvio-deltaic sequence deposited during terminal orogeny associated with the amalgamation of Pangea. At the time the region was located in the equatorial belt. The sequence consists of a lower fine-grained sandy to muddy redbed member and an upper member of medium-grained green organic-rich micaceous sandstone interbedded with red siltstone. Organic-rich shales from the lower part of the lower member contain Namurian B spores.

Palaeocurrent data show a shift from a southwest sediment source to a northwest sediment source passing up from the lower member to the upper member. Evidence of a change to a wetter climate upsection includes upsection increase of abundance of organic debris, of cross-bedded channel sand deposits versus upward fining cycles with flat bedded bases (suggestive of flood deposits), of frequency of carbonaceous pebble conglomerates and decrease in abundance of desiccation cracks. Thick channel sand deposits are indicative of a strong seasonal (monsoonal) influence.

Based on geochemistry, the sandstones of the Lismore Formation have been divided into two units, A and B. This division does not correspond to the lower and upper members which were divided stratigraphically. Unit A includes the lower member and 115 m of the upper member. Unit B consists of the remainder of the upper member. In general, unit A exhibits a more restricted range of major and minor oxide compositions which fall within the field of unit B samples.

In order to identify a source area, the geochemical and isotopic composition of the Lismore Formation are compared to several suites of rocks which reside within and around the Maritimes Basin. The data show considerable overlap between unit A of the Lismore Formation and the unconformably underlying Martin Road Formation suggesting that both formations have similar provenance. Similarities also exist between unit A and the Silurian Arisaig Group (Beechill Cove Formation).

Further evaluation of possible mixed sources has led to the discovery that the sedimentary rocks of the Beechill Cove Formation and the plutonic rocks of the Cobequid Highlands could combine to produce the sedimentary rocks of the Lismore Formation. The percentage contribution attributable to the Cobequid Highlands plutonic rocks increases higher up section from approximately 15% - 25% to 50%. A minor influence of Meguma metasedimentary rocks within the Lismore Formation is apparent on isotope plots and is probably the result of transport of resistant detritus from the Meguma metasedimentary rocks or of reworked detritus from the St. Mary's Basin.

Dispersal in areas of variable terrain: examples from west-central British Columbia

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Topography and thick till cover has hindered conventional exploration techniques in much of the alpine and intermontane region of west-central British Columbia. As an area of high mineral potential, the glacial dispersal of till geochemistry and clast lithologies were examined as one part of a GSC-BCGS Nechako-NATMAP Project covering an area of about 11 000 km^2. Samples of till matrix and clasts were collected during regional mapping and from till overlying known mineral deposits at the Bell and Equity Silver mines. Dispersal patterns, or trains, were identified from the concentrations of chemical elements and lithology of the till clasts. The length and shape of these trains from samples collected in areas of known deposits, were then used to model anomalous occurrences identified from regional sampling and to delineate sources of buried mineralization. The project contributed to the discovery of several copper-bearing breccia pipes on the Hearne Hill property at Babine Lake.

Some dispersal patterns do not occur in the classical mode of a linear or fan-shaped down-ice decrease in concentration. Trains in till at the Bell Mine and in soil at the Equity Silver Mine were found to be displaced in directions transverse to the dominant ice flow direction as indicated locally from glacial landforms and striae. At Bell Mine, southeast dispersal of copper, zinc, nickel and mineralized biotite-feldspar porphyry clasts in till are offset to the southwest of the source unit. At Equity Silver Mine, southwestward-decreasing silver concentrations form a dispersal pattern that is displaced to the east-northeast of the source. These displacements were found to be the result of several phases of Late Wisconsinan ice flow events, that could be simplified as: advance, maximum and retreat phases. Advance and retreat ice flow phases were controlled predominantly by topography, while glacier movements, during the maximum flow phase were controlled by: (a) location of snow accumulation centres, (b) elevation of outlet valleys along the Pacific Coast, and (c) ice sheet profile. In some locations ice flowed in opposite or oblique directions during some phases, resulting in: (1) complex dispersal trains overlying uni-directional striae and (2) linear trains overlying striae indicating multiple ice flow directions.

Our study indicates that an understanding of glacial history is imperative for the correct interpretation of glacial dispersal in areas of variable terrain such as the Cordilleran and Appalachian regions of North America.

The metamorphic development of the McMillan Flowage Formation, central Cape Breton Island

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The Cape Breton Highlands form a critical part of the Appalachian orogen. In Cape Breton Island, four tectonostratigraphic zones, including the Bras d'Or terrane, can be recognised within this system. The Bras d'Or terrane consists of metamorphosed stratified rocks and plutonic suites, representative of an island arc to collisional setting. Pressure estimates of intrusion of diortic and tonalitic plutons have ranged up to 8 kilobars. The plutons have yielded U-Pb zircon ages between 575 to 556 Ma, which are interpreted to represent ages of intrusion. Titanite ages of 548 ± 2 and 521 ± 2 Ma represent the minimum age of amphibolite-facies metamorphism in the area. Previous studies had postulated metamorphic conditions up to kyanite grade, although no kyanite has been positively identified in the Bras d'Or terrane.

The McMillan Flowage Formation is the largest, most continuous, and most compositionally variable stratified unit within the Bras d'Or terrane. Metamorphism in the McMillan Flowage Formation ranges from chlorite to sillimanite grade in the central Highlands. Typical maximum P-T assemblages include silliminite-muscovite-quartz ± potassium feldspar. TWEEQU determinations of equilibration from pelites show pressure ranging from 2.8 to 4.5 kilobars, and generally increasing towards the south. The temperature ranged between 550 and 620°C with the exception of the Cross Mountain area, near the middle of the McMillan Flowage Formation, where a temperature estimate of less then 500°C was obtained.

The McMillan Flowage Formation therefore consists of low-pressure metamorphic rocks surrounded by high-pressure plutons. This juxtaposition may have occurred as a result of rapid uplift during the time period between the intrusion of the plutons, and the peak of metamorphism.

The Fundy Basin story

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Transtensional rifting of the central part of Pangaea during the Mid and Late Triassic resulted in the formation of a series of half graben extending from Florida to The Grand Banks of Newfoundland. Many of these, such as the Newark and Hartford basins in the U.S.A., are onshore and are well studied, whereas others, particularly those in the offshore, are poorly known. One of the latter is the Fundy Basin (~16,500 km^2), which lies mainly to the south of the Cobequid-Chedabucto fault system in Nova Scotia and beneath the Bay of Fundy. From studies of outcrops, the rocks in the Fundy Basin have long been recognized as being part of the Triassic-Jurassic Newark Supergroup. However, little has been known of the nature and petroleum potential of the extensive sedimentary section beneath the waters of the Bay of Fundy.

Continental red clastics and basalt flows of Triassic and Early Jurassic age crop out continuously along the Bay of Fundy and Minas Basin coast of Nova Scotia and at several sites in southern New Brunswick. These units thicken beneath the waters of the Bay to a maximum of nearly 10 km. Proximal facies preserved along the New Brunswick margin of the basin consist of upper alluvial fan and fluvial clastics, which grade laterally into sheet flood deposits. Along the gently north dipping Nova Scotia margin, facies consist of distal alluvial fan, sheet flood and playa mud flat deposits. Facies projections suggest the probability that lacustrine sequences will be widespread along the basin axis.

Petroleum exploration programs in the Bay of Fundy from 1968-75 and 1980-83 resulted in the acquisition of over 4600 km of variable quality seismic data and the drilling of two exploratory wells. These data, combined with published material, the study of outcrop sections in Nova Scotia and New Brunswick, and regional synthesis, provide the basis for our model of areas of thick lacustrine facies within the basin, which could contain rich petroleum source rocks. In the Wolfville Formation and the lower part of the Blomidon Formation these may be overmature, but the upper Blomidon Formation and the Scots Bay Formation have the potential for appreciable quantities of hydrocarbons.

Loading the Laurentian margin: correlating foreland basin subsidence with eclogite metamorphism

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Paleozoic loading of the former Laurentian continental margin is recorded both in the subsidence history of the Appalachian foreland basin and in metamorphic rocks now exhumed in internal parts of the Newfoundland Humber zone.

The Cambrian-Ordovician passive margin of Laurentia underwent a transition to a foreland basin setting beginning in Early Ordovician time. Middle Ordovician ('Taconian') foreland basin sediments (Table Head and Goose Tickle groups), in part derived from the Humber Arm Allochthon, are relatively thin (ca. 250 m in offshore industry seismic data, thinning to the west). The overlying Late Ordovician Long Point Group is preserved in outcrop only on the west coast of Port au Port Peninsula, but can be traced on seismic data offshore beneath the Gulf of St. Lawrence. Limestone at the base of the Long Point Group (Lourdes Limestone) is overlain by a 1.25 km thick succession of siliciclastic sediments (Winterhouse and Misty Point formations) representing marginal marine and deltaic environments. In sharp contrast to the thin "Taconian" succession, this significant thickness of Late Ordovician clastics indicates rapid subsidence of the foreland basin, with corresponding rapid sediment supply from the orogen to the east.

In the internal Humber zone, metamorphic equivalents of the Cambrian-Ordovician passive margin succession (Fleur de Lys Supergroup) are exposed in the Baie Verte Peninsula and elsewhere. These units record Barrovian metamorphism with peak temperatures around 700 to 750°C at 7 to 9 kbar; isotopic data indicate that peak temperatures were reached in Early Silurian time ('Salinian orogeny'), followed by rapid exhumation. Amphibolite facies metamorphism overprints an earlier eclogite facies assemblage, for which minimum pressures of 1.2 GPa at 500°C require burial of the Laurentian margin beneath at least 40 km of overburden, which may have included thrust sheets of continental margin rocks and allochthonous arc terranes of the Dunnage zone. The eclogite facies metamorphism has not been dated directly, but by analogy with thermal models for Barrovian metamorphism involving overthrusting, peak pressures probably preceded peak temperatures by at least 10 My.

We suggest that Dunnage zone arc terranes were tectonically emplaced above the Laurentian margin on a crustal scale in a previously undocumented episode of major Late Ordovician tectonism, resulting in both high-pressure metamorphism of the Fleur de Lys Supergroup, and in rapid subsidence and sediment supply to the foreland basin now largely hidden beneath the Gulf of St. Lawrence.

Geology of the Guysborough - Isle Madame - L'ardoise area, Nova Scotia

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Based on new mapping, Devonian and Carboniferous rocks in the Guysborough-Isle Madame-L'Ardoise area are divided into the Guysborough Group in the south and the Horton Group in the north. Mylonite, amphibolite, and garnet-sillimanite schist occur within the western and southern parts of the Guysborough Group along the Chedabucto and Guysborough County faults and along faults in the Petit-de-Grat area. Granite and associated mylonite and phyllonitic rocks of unknown age occur along the Strait of Canso, in faulted contact with the Carboniferous units.

The early to mid-Devonian Guysborough Group is a fault-bounded sequence of volcanic and sedimentary rocks, intruded by gabbroic plutons and dykes, that extends from mainland Nova Scotia to the Petit-de-Grat area of southernmost Cape Breton Island. It is bounded on the south by the Chedabucto and Guysborough County faults, and on the north by the Roman Valley and Arichat faults. The Guysborough Group is divided into five formations: Minister Brook (feldspathic greywacke and quartz wacke), Sunnyville (mafic volcanic rocks and conglomerate), Glenkeen (conglomerate), Roman Valley (quartz arenite, conglomerate and laminated siltstone), and Hoppenderry (mafic and felsic flows and tuffs).

Units of the Horton Group extend from the northern mainland through the Isle Madame and L'Ardoise areas of southern Cape Breton Island, as far as Loch Lomond. In the latter area, the absolute age of the uppermost Horton Group is constrained by the presence of intrusions of dykes, plutons, and related flows of the ca. 340 Ma St. Peters gabbro. The Horton Group in the map area is divided into three formations (Clam Harbour River, Tracadie Road, and Caledonia Mills), which are broadly equivalent to the Creignish, Strathlorne, and Ainslie formations of the Horton Group in western Cape Breton Island.

In contrast to units of similar age elsewhere in Nova Scotia, rocks of the Guysborough and Horton groups in the map area are typically well cleaved and locally strongly deformed. This deformation may be related to a more complex history of juxtaposition of the Meguma terrane with the Avalon terrane than generally thought.

Upper crustal deformation associated with carbonate-rich fluid infiltration, Denali Fault system, Yukon

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The Denali Fault system, southwestern Yukon, comprises an array of fault slices bounded by the Duke River and main Denali Fault traces. Up to 400 km of displacement has been suggested along the fault system and it remains seismically active, although the major Pacific-North America plate displacements have moved outboard. Time-space analyses of earthquakes demonstrates an abrupt truncation of seismicity at about 18 km depth, consistent with a transition to ductile deformation. There is also a suggestion of initiation of seismic activity at depth with subsequent migration of events towards the surface. A dominant attribute of these rocks is the introduction of large volumes of carbonate veins in which deformation is commonly localized. Metamorphic grade in basaltic units is prehnite-pumpellyite, limiting the observed deformation to uppermost crustal conditions. An apparent paradox exists in the extensive plastic deformation, recrystallization and twin migration observed in calcite, effects commonly associated with higher metamorphic grades. These observations are part of a larger data base being assembled by several workers that questions many of the preconceptions existing about carbonate deformation and the range over which ductile deformation is operative. This is turn has implications for the activity of faults in carbonates as seals and/or conduits for fluid transport, including hydrocarbons.

Geochemical dispersion in a neutralized mine drainage environment, Walton, Nova Scotia

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Magnet Cove Mine located near Walton in Hants County, Nova Scotia, was active between 1940 and 1978 when it produced about 4 Mt barite and 0.3 Mt of Cu-Pb-Zn-Ag sulphide ore. Investigation of the mine site and adjacent Rainy Cove Brook, supported by air-photo evidence from 1945 to 1991, shows that the primary dispersion mechanism of heavy metals from Magnet Cove Mine site into the downstream environment is (and has been) by physical erosion and transport of tailings. Sediment samples (n = 69) collected from the tailings ponds and from upstream and downstream drainage were analyzed by AAS for Fe, Mn, Ba, Zn, Cu and Pb. Results show that the downstream sediments are very similar to the tailings in their metal contents, and anomalously enriched over upstream sediments on average by the following fac-

tors: Mn 5x, Ba 4x, Zn 1.3x, Pb 2.7x, and Cu 6x. ICP-NA analysis of selected tailings samples shows that there is close correlation of the heavy metals: Ag, As, Sb, Co, Ni, V, Cr, Th and U with the metals Fe, Mn, Ba, Zn, Cu and Pb.

The secondary process for the release of contaminants into the downstream environment is through solution and precipitation. Selected water samples collected from mine site, upstream, and downstream locations were analyzed by ICP-MS and other methods. The open pit water, which overflows into Rainy Cove Brook, shows strong enrichment in sulphate, chloride, Ca, Mg, Na, K and Mn (but not Ba), and also in Se, As, Co, Ni, Cr, V and U. Mixing of the more alkaline open pit water (pH 7.9) with the more-or-less acidic waters from on-site leachates (pH 3.9 - 6.9), and from upstream tributaries of Rainy Cove Brook (pH 5.7 - 6.7) results in (i) neutralization of pH, (ii) dilution of heavy metal concentrations by an order of magnitude, and (iii) flocculation of Fe-Mn oxyhydroxides (which probably further reduce, by adsorption, the concentrations of heavy metals in the water). As a result, the downstream water (pH 7.2 -7.6) is only slightly enriched, over upstream water, in As, Mo, Th and U, but moderately enriched in sulphate, chloride, and Na.

Other processes which are contributing to the amelioration of the affected area include the post-mining natural stabilization of the flood plain at the lower end of Rainy Cove Brook and its gradual conversion to a wet-land environment.

Fish trace fossils from the Horton Bluff Formation (Lower Carboniferous) of Nova Scotia

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The Blue Beach Member of the Horton Bluff Formation (Horton Group) has yielded a variety of fish trace fossils from Tournaisian nearshore lacustrine sandstones and shales. Two basic types of marks were left by fish swimming close enough to the bottom to leave traces: (1) isolated and discontinuous drag marks of fin spines, possibly made by acanthodian fish and (2) sinusoidal trails left by fins and tails of unidentified osteichthyans. These fish trace fossils are associated with arthropod trace fossils, amphibian footprints, coprolites, and fish scales. Most of our work to date has concentrated on the sinusoidal trails which consist of two identified species of *Undichna* Anderson, up to three possible new ichnospecies of the same genus, and several forms in need of further study. Their description is being augmented by an attempt to model their form with formulas for simple harmonic motion. The sizes of these fish can also be estimated. All of the sinusoidal trails are attributable to *Undichna* Anderson and are preserved as hypichnial ridges (hypichnial groove casts) except for *U. bina* which is an epichnial groove. *U. britannica* Higgs is represented by two unpaired waves with different amplitudes but similar wavelengths that are attributable to the caudal and anal fins. *U. bina* Anderson is represented by one set of paired waves produced by pelvic fins. The additional trails are not attributable to any known ichnospecies. *Undichna* sp. 1 is a solitary wave that may represent an anal or caudal fin marking. *Undichna* sp. 2 consists of two discontinuous waves 180 degrees out of phase that may represent scallop-like marks of pectoral fins. *Undichna* sp. 3 consists of two sets of paired asymmetric waves bounding an unpaired medial wave. These markings were probably made by paired pelvic fins and an anal fin.