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ABSTRACTS

1996 COLLOQUIUM AND ANNUAL GENERAL MEETING BATHURST, NEW BRUNSWICK

The 1996 Colloquium of the Atlantic Geoscience Society was held in Bathurst, New Brunswick on February 2 to 3, 1996. On behalf of the Society, we thank Michael Parkhill, Colloquium Chairman, and members of his organizing committee for providing an excellent meeting.

In the following pages we publish the abstracts of talks and poster sessions presented at the Colloquium which included a special session on "EXTECH-II, the Bathurst Mining Group", and a geophysics workshop, as well as contributions of a more general aspect. An explanation of "EXTECH-II" is provided in the abstract by Langton and McCutcheon included herein.

The Editors

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Constraints on the emplacement of the Fortuna Granodiorite, Chuquicamata Mine, Chile

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Chuquicamata, Chile, is the largest open-pit porphyry copper mine in the world. A near-vertical regional fault (Falla Oeste) sharply truncates the mineralization within the Chuquicamata pit. West of Falla Oeste is the Fortuna Granodiorite. Nearly one-third of the rock mined from the pit is the Fortuna Granodiorite, a relatively unaltered, unmineralized granitoid, the origin of which is debated. It has been proposed that the Fortuna Granodiorite represents the uplifted root of the Chuquicamata porphyry system. Other workers have referred to it as a co-magmatic precursor for the Chuquicamata mineralized porphyries.

In an attempt to understand any relationships between the Fortuna Granodiorite and Chuquicamata porphyries an integrated study of geochronology, geobarometry and geochemistry has been initiated. The detailed step-wise degassing of ^{39}Ar and ^{40}Ar from K-feldspar and hornblende indicates that the mineralized Chuquicamata porphyry is 2 to 4 million years younger than the Fortuna Granodiorite exposed in the pit.

Amphibole geobarometry shows the Fortuna Granodiorite was intruded at depths of less than 6 km. Whole-rock geochemistry shows the Fortuna Granodiorite and Chuquicamata porphyries have similar compositions, which is expected since the rocks formed in a similar tectonic environment and they are of similar ages. However, the Fortuna Granodiorite is enriched in LREEs with slightly elevated HREEs compared to the Chuquicamata porphyry.

The Fortuna Granodiorite is not a root zone nor a co-magmatic precursor intrusion for the Chuquicamata porphyry copper system. This is consistent with recent work by others suggesting that the motion along Falla Oeste was strike-slip with tens of kilometres of displacement.

Petrology and geochemistry of the Indian Brook and Birch Plain plutons in the southeastern Cape Breton Highlands, Nova Scotia

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The southeastern Cape Breton Highlands are dominated by Late Precambrian plutonic rocks ranging from dioritic to granitic in composition. Previously, the petrology of the more mafic plutons had been studied in detail, but the more felsic plutons had received only reconnaissance petrological study. Hence this research was undertaken in order to provide detailed information about the two largest such plutons, the Indian Brook Granodiorite and Birch Plain Granite, based on a collection of about 200 samples from the plutons.

The plutons have similarities in grain size and texture but the Indian Brook Granodiorite contains both hornblende and biotite, in contrast to the Birch Plain Granite which contains only biotite. Other minerals are plagioclase, perthitic microcline, quartz, and abundant accessory phases including magnetite, titanite, allanite, zircon, and apatite. The contact relationships between these two elongate plutons are not clear, but the presence of xenoliths of the Birch Plain Granite within the Indian Brook Granodiorite indicates that the Birch Plain Granite is older. Based on texture, both plutons were intruded at relatively shallow crustal levels, and likely during the same general episode of igneous activity related to a continental margin subduction zone. More detailed interpretations of depth of emplacement and petrogenesis will be based on studies of mineral compositions and whole-rock geochemical data now in progress.

Devonian and Carboniferous stratigraphy in the Guysborough - Loch Lomond area, Nova Scotia

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Devonian rocks in the Guysborough area are divided into four stratigraphic units. The oldest unit (Sunnyville Formation) consists mainly of basalt and rhyolite (U-Pb zircon age of 389 ± 2 Ma). It is overlain by polymictic, locally tuffaceous, conglomerate and sandstone (Glenkeen Formation), which can be traced east through southern Cape Breton Island, and unnamed quartz wacke and siltstone units, the latter hosting the Copper Lake Fe-Cu deposit. All of these units are intruded by gabbroic dykes and plutons, one of which has yielded a U-Pb (baddeleyite) age of ca. 385 Ma. These early to mid-Devonian units are in faulted contact to the north, west, and south, mainly with Carboniferous rocks of the Horton Group. North of the Guysborough area, the Horton Group is divided into four units: quartz sandstone, mainly grey to black laminated siltstone, interlayered grey-green and red-maroon siltstone, and red-maroon siltstone.

The lower sandstone and siltstone units may correlate with the Fall River and Barrens formations of the Horton Group in the St. Mary's Basin, now displaced by dextral motion on the Minas fault system. Some of these Carboniferous units can also be traced to the east through Isle Madame to the Loch Lomond area in Cape Breton Island, where they have been intruded by Carboniferous gabbroic plutons (St. Peters gabbros; 339 ± 2 Ma; U-Pb zircon and baddeleyite). The strata are locally strongly deformed with north-south to east-west trending open to tight folds and rare recumbent folds. A subhorizontal to moderately southeast-dipping foliation occurs throughout the area.

The Devonian rocks in the Guysborough block, together with associated fault-bounded slivers of high-grade mylonitic granite, amphibolite, and sillimanite-garnet schist, may represent the "basement" of the St. Mary's Basin, now exposed in a positive flower structure. This structure may have formed at a megakink in the Minas fault system as a result of dextral motion between the Meguma and Avalon terranes. This structural and stratigraphic interpretation is supported by integrated airborne radar imagery and vertical gradient magnetic data.

EdGeo Workshops: the success is in the marketing

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The success of the 1994 EdGeo Workshop in Halifax - the first held in Nova Scotia in 11 years - convinced the organizing committee that future efforts would be sell-outs. Thus, failure to attract more than eighteen teachers to the second Workshop, held in Sydney in 1995, was a humbling experience. Where did we go wrong? We had distributed an attractive flyer in early May and given teachers about six weeks advance warning of the registration deadline. The 1994 participants confirmed that late August was an appropriate time to hold the workshop. And for the exorbitant registration fee of $20, we included lunch on the Monday, a half-day field trip, a banquet, and resources estimated to be worth about $400. However, we made a serious mistake in our inability to recognize the importance of communication and marketing. This is changing. Through the support of the Nova Scotia Science Teachers Association, and our increased experience, we are learning how to inform the teachers with maximum effect. The results: by December 1995 we already had a probable ten registrants for the 1996 Wolfville Workshop, more than the number of initial registrants for the 1995 Sydney Workshop. This is no guarantee of success but it does show a heightened awareness of the EdGeo Workshops and their benefit to science teachers. This should, ultimately, mean a bigger impact on earth science education in the province and readily available resources for most teachers, a priority in this era of diminishing funding for education.

Electromagnetic prospecting for massive sulphide deposits

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The objective of the course is to provide students with a basic knowledge of airborne electromagnetic (EM) interpretation. It focuses on helicopter electromagnetic (HEM) interpretation in anticipation of the data from the helicopter multi-parameter geophysical survey carried out in the Bathurst Mining Camp last fall, scheduled for release this summer.

The course is divided into two sections. The first section presents the basic principles of EM prospecting and discusses the relationship between physical parameters and EM responses. Examples of ground and airborne responses over ore deposits and graphitic conductors in the Bathurst Mining Camp and graphitic conductors in the Timmins clay belt are shown. Some interpretation pitfalls are discussed as well. The second section focuses on helicopter EM interpretation using examples from existing surveys. Data presentation and interpretation techniques are illustrated using maps and sections from these surveys.

Seasonal variation of the beach profile at Miscou Island, New Brunswick: effect of ice

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Most previous studies on beach dynamics have been carried out in low-latitude regions or in summer, when the effect of ice is negligible. The objective of this research is to describe and quantify the active mechanisms that control the beach profile over the entire year, including the winter when ice processes affect the morphology and sediment budget. The basis of the field work was the repeated measurements of a dense set of beach profiles at monthly intervals on a small linear beach at the northeastern end of Miscou Island, New Brunswick. The results show that changes in beach profile related to ice processes were similar in magnitude to storm-induced changes. Most of the important changes occurred during early winter as the ice foot was forming, when there remained open water offshore. During this period storm waves hit the developing ice foot and sand was washed onto its surface where it accumulated. At the same time, some profiles showed substantial erosion immediately in front of the ice foot due to wave reflection on the artificially steepened profile. Parts of the ice foot were observed to break off periodically and move offshore during early winter storms. This may provide a mechanism for net loss of sediment from the beach at this time of the year. In the spring, after the ice was gone, sediment had accumulated as irregular mounds in the region of the ice foot, indicating that most of the ice foot thawed *in situ* and that there was little export of sediment by ice rafting at this time.

Deformation related to Carboniferous salt tectonics, western Cape Breton, Nova Scotia

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Within western Cape Breton several diapiric structures are exposed as coastal outcrops or imaged on seismic sections. The diapiric structures vary in height from 1.5 to 4.3 km, with height being proportional to the age and maturity of the salt structure. Diapirism uplifted overlying middle and upper Windsor Group sediments as a carapace or cap rock above lower Windsor halite and deformed the adjacent Upper Carboniferous overburden into diapir drag zones. Within the diapirs, middle and upper Windsor strata are folded into kilometre-scale curtain folds with sub-vertical fold axes. Meso- and micro-scale parasitic folds are tight to isoclinal with steeply plunging fold axes. Deformation within the diapiric structure is always asymmetric, with strain increasing gradually towards the diapir/overburden contact zone (peripheral shear zone). Middle and upper Windsor gypsum units have been mylonitized and preserve a sub-vertical foliation, while more competent evaporite and thin limestone lithologies within gypsum mylonites are boudinaged. Thick upper Windsor limestones are used as marker horizons and show extremely variable deformation related to position within the diapir. Limestones within the diapir interior show little deformation other than folding, whereas limestones which intersect the peripheral shear zone are either fragmented into metre-scale blocks within gypsum mylonite, or completely disseminated into gravel sized particles within gypsum mylonite. Inverness Formation sandbodies and Port Hood Formation siltstones and mudstones are exposed within diapir drag zones in continuous sections up to 600 m in length. The thick (~100 m), competent, Inverness Formation sandbodies preserve pervasive conjugate joint sets, granulation seams, flexural slip and extensional faults. At the diapir/overburden contact, deformation is such that the sandbody has been completely brecciated. Deformation of the sand bodies is restricted to within 250 m of the diapir. The relatively incompetent silts and muds of the Port Hood Formation preserve a fundamentally different deformation style. Strain is accommodated primarily by two generations of extensional faults; the first formed early and have been passively rotated, maintaining a high angle to bedding, the second formed late and dip parallel to steeply inclined drag zone strata. Within 250 m of the peripheral shear zone the extensional faults strike at 90° (orthogonal) to the diapir, while between 250 m and 500 m away from the peripheral shear zone the extensional faults strike parallel (tangential) to the diapir. The change in fault orientation can be attributed to a re-orientation of the stress field probably related to diapir-induced stress.

Fission track, and compositional analysis of detrital apatite in terms of tectonic history and sedimentary provenance: Sawtooth Range, Sverdrup Basin, Canadian Arctic Islands

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The Sverdrup Basin is the largest sedimentary basin in the Canadian Arctic. Its sediments were deposited in two sequences: Proterozoic to mid-Palaeozoic and late Palaeozoic to early Cenozoic, and affected by both the Ellesmerian and Eurekan orogenies. Detrital apatite samples have been obtained from two measured sections in the Northern Sawtooth Range. The first measured section transects the East Cape Thrust with Permian rocks in the hangingwall and Triassic to Miocene rocks in the footwall. The second measured section traverses up-section from the Permian rocks in the hangingwall of the East Cape Thrust into Triassic-Jurassic rocks. Together the two sections form a continuous lithological record from the Permian to the Miocene.

The apatite samples are analyzed for fission track histories and compositional variation. The analyses of fission tracks in apatite grains yield information on burial, cooling and exhumation events in sedimentary rocks. By contrasting fission track cooling histories of samples offset by the East Cape Thrust it is possible to constrain the timing of thrusting and exhumation in the north central Sverdrup Basin.

The chemical composition of detrital apatite determined in the electron microprobe is studied in terms of two major applications: (1) The concentration of F, Cl, OH, CO_2 controls both the thermal annealing of fission tracks and their etching behaviour, therefore affecting the time-temperature models for cooling and exhumation that can be computed from them; and (2) the composition of detrital apatite grains reflects the primary composition of the melt from which it crystallized. In this study apatite samples are classified in terms of major and rare earth element composition. Chondrite normalized plots reflect the enrichment or depletion of these elements in the source melt. Thus a shift in type of sediment source rocks may be reflected in the composition of the resulting detrital apatite grains. This study defines discrete populations of apatite and relates shifts in the presence of discrete populations to shifts in sediment sources through time.

Predicting acid drainage from rocks of the Halifax Formation, Meguma Group, Nova Scotia

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Two of the most widely accepted acid drainage static tests are the B.C. Research Initial Test (IT) and the U.S. Environmental Protection Agency's Acid-Base-Accounting procedure (ABA). Considerable controversy exists over which of these two tests provides the best results for predicting acid drainage. In most areas of North America the ABA procedure is the most widely accepted; in Nova Scotia the IT is commonly applied. We are currently conducting a study that compares these two tests on rocks from a variety of geological environments within the Halifax Formation. Samples from contact metamorphic (containing cordierite and andalusite) and regional greenschist facies (biotite grade) environments near the city of Halifax, and from the Eastville zinc-lead deposit (40 km southeast of Truro) have been collected to date.

All samples contain sulphide minerals in various proportions. Only two of the samples (from Eastville) contain visible carbonate minerals. These two samples also contain the lowest percent total S (0.011 and 0.017). Paste pH values are generally between 7.00 and 8.00. Acid Potential (AP), which is calculated from total percent sulphur, ranges from 0.344 to 191.3 tonnes $CaCO_3$ equivalent per 1000 tonnes. Acid consuming tests are currently in progress. However, based on past experience the acid consuming ability of rocks from the Halifax Formation is likely to be relatively low except in localized areas containing carbonate minerals. Our work to date shows that rocks from the Halifax Formation vary considerably in the sulphide type, abundance, texture and mode of occurrence. We recommend that a complete geological assessment should be performed in areas where Halifax Formation rocks are to be disrupted. For example, we have found that bedding, cleavage, and joints or fractures are possible controls for sulphide occurrence. Therefore the prediction of acid drainage from the Halifax Formation includes the sampling procedure as well as the type of analytical test used.

The Miramichi-Tetagouche boundary and its relationship to the Patrick Brook Formation

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Mapping the boundary between the Miramichi and Tetagouche groups has important implications for exploration in the Bathurst Mining Camp since stratiform sulphide deposits appear to occur only within the volcanic-dominated Tetagouche sequence. Along the Tetagouche River, local uplift during initiation of Tetagouche volcanism has resulted in the deposition of a conglomerate horizon that provides a useful marker to define the Miramichi-Tetagouche boundary. A similar rapid change in depositional environment across the Grand Pitch-Shin Brook formational boundary in central Maine has been attributed to the early Paleozoic Penobscot disturbance.

The basal beds of the Tetagouche Group, the Vallée Lourdes Formation, are best exposed at Little Falls on the Tetagouche River, where a thin (50 cm) conglomerate, containing pebbles derived from underlying siltstones of the Miramichi Group, is overlain by some 25 m of calcareous sandstone topped by 1 to 4 m of laminated, noncalcareous, dark grey silty shale. Feldspar-rich tuffite of the overlying Nepisiguit Falls Formation contains tongues of shale injected from below. Both the tuffite and underlying calcareous sandstone are trough cross-bedded indicating deposition in relatively shallow water.

A Celtic brachiopod assemblage from calcareous siltstone, located on the south side of the Tetagouche River 3 km upstream from Little Falls, indicates that the Vallée Lourdes Formation is late Arenigian to early Llanvirnian (Early Ordovician). Dark grey shale and medium- to thick-bedded, light grey, fine grained sandstone and siltstone exposed further upstream from the fossiliferous Vallée Lourdes siltstone, constitute the type-section of the Patrick Brook Formation. Disruption of wacke beds has produced local horizons of blocky mélange within the Patrick Brook turbidite sequence.

The stratigraphic relationship between the Patrick Brook type-section and the fossiliferous Vallée Lourdes siltstone is obscured by a gap in exposure. Rocks of the Patrick Brook type-section had been previously correlated with lithologically similar rocks of the Miramichi Group lying beneath the unconformity at Little Falls. More recently, however, they have been correlated with the dark grey shales at the top of the Vallée Lourdes Formation at Little Falls, and hence, included in the Tetagouche Group. A newly discovered outcrop of conglomerate in fault contact with the Patrick Brook Formation on the north side of the Tetagouche River, opposite the fossil locality, strongly favours the former correlation. The conglomerate contains pebbles of siltstone like those observed downstream at Little Falls, clearly indicating that the conglomerate was originally deposited stratigraphically above the Patrick Brook turbidites. Therefore, the Patrick Brook Formation must be considered, by definition, to belong to the Miramichi Group.

Stratigraphic relationships in the Big Bald Mountain area, southern Bathurst Mining Camp

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Recent mapping on 1:20 000 scale has permitted clarification of stratigraphic relationships in the complexly deformed rocks of the Big Bald Mountain area. Although the area has been dissected by a series of low-angle thrust faults (often steepened by later deformation) and high-angle, strike-slip faults, the stratigraphic succession within each fault slice can be interpreted with a high degree of confidence by comparison with established stratigraphic sections in the northeastern part of the Bathurst Mining Camp. Missing sections at various locations within the Big Bald Mountain area suggests the presence of major shear zones that can be further delineated on the basis of high strain indicators.

The stratigraphic succession in the Big Bald Mountain area differs on opposite sides of the Moose Lake-Mountain Brook shear zone. North of the fault zone, the felsic volcanic sequence of the Middle Ordovician Tetagouche Group is divided into the Nepisiguit Falls (quartz-feldspar crystal tuff, tuffite, ironstone) and Flat Landing Brook (aphyric flows, fragmental rocks) formations, whereas south of the fault, it is divided into the Clearwater Stream (plagioclase-rich crystal tuff) and Sevogle River (alkali-feldspar-phyric flows) formations. Mafic volcanic rocks intercalated with ferromanganiferous shales of the Boucher Brook Formation comprise the upper part of the Tetagouche Group in both areas. Subvolcanic intrusions of trachytic composition are commonly associated with the mafic volcanic rocks.

Sedimentary rocks assigned to the Cambrian-Lower Ordovician Miramichi Group occur only to the south of the Moose Lake-Mountain Brook shear zone. From oldest to youngest, these include the Chain of Rocks Formation (thick-bedded quartzite), Knights Brook Formation (medium-bedded pyritiferous quartzite, feldspathic wacke, and shale), and the Patrick Brook Formation (interlaminated shale and siltstone).

The Miramichi Group is intruded by an abundance of generally plagioclase-phyric sills referred to as the Squirrel Falls Felsite. A large coarse grained pluton, the Mullin Stream Lake Granite, was emplaced into the lower part of the Miramichi Group at 458 Ma. Small composite plutons of fine grained alkali-feldspar-phyric granite and associated gabbro of the

Stony Brook Complex are abundant in the upper part of the Miramichi Group and overlying felsic sequence of the Tetagouche Group to the south of the Moose Lake-Mountain Brook shear zone. Locally, apophyses from these plutons have risen to the stratigraphic level of the Boucher Brook Formation. High level plutons emplaced into the felsic volcanic sequence to the north of the Moose Lake-Mountain Brook shear zone, such as the South Little River Granite, contain quartz phenocrysts in contrast to those further south. Dykes of weakly deformed red felsite appear to represent the latest stage of Ordovician igneous activity.

Palaeotectonic setting and petrogenesis of the Takla Group volcano-sedimentary assemblage, north-central British Columbia

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The Upper Triassic Takla Group volcano-sedimentary assemblage is located within the Stikinia Terrane of the Intermontane Belt in the Canadian portion of the Cordillera. The assemblage consists of basalts and pyroclastic rocks of equivalent composition, that are interlayered with sandstones, siltstones, argillites and conglomerates. Deposition of the assemblage occurred primarily under marine conditions that became subaerial as the volcanic pile built above sea level. Major and trace element analysis indicates that the Takla Group basalts are arc-related tholeiites. They are characterized by a slight large ion lithophile element (including Th and light REE) enrichment relative to high field strength elements. Trace element plots show that the tholeiites are depleted in Nb, which supports an arc-related origin. Low Zr:Y ratios indicate that the tholeiites are primitive and were probably extruded through a thin crust.

A contemporaneous volcano-sedimentary assemblage occurs in fault contact with the Takla Group of the Stikinia Terrane. This group, also named Takla, occurs in the neighbouring Quesnellia composite terrane to the east and contains basalts also of arc-related genesis. In the past, interpretations of the origin and relationship between the two groups have differed. They have been interpreted as a single cogenetic unit as well as two separate, non-related units. Similarity in petrography, mineral chemistry and incompatible trace element distribution indicate that the eastern and western Takla groups are broadly equivalent. A cogenetic origin of the two groups limits the offset of a major fault system in the study area and constrains the timing of the Stikinia and Quesnellia terrane amalgamation.

Sequence stratigraphic framework for coals of the Sydney Basin, Nova Scotia

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Coals have a periodic occurrence in the rock record, and "windows" for the accumulation of peat (coal precursor) commonly were available with a periodicity of tens to hundreds of thousands of years. Sequence stratigraphy has highlighted the relationship between peats and base-level/climatic changes over these time scales. Upper Carboniferous cyclothems of the Sydney Basin have a systematic succession of facies that allows the setting of coals studied to date to be inferred with some confidence. Our broad conclusions are:

(1) Thick, economic coals (e.g., Backpit, Point Aconi coals) developed under transgressive conditions (in the Transgressive Systems Tract, TST), and near the transgressive maximum as indicated by their close proximity to an inferred maximum flooding surface (MFS). The accumulation of these rheotrophic (groundwater-fed) peats was closely related to the rate of creation of accommodation space and to minimal detrital supply. Peat accumulation was initiated as transgression inundated a stable, alluvial platform, and kept pace with rising sea level for thousands of years. Humid climatic conditions are indicated.

(2) Some coals (e.g., the split Hub and Bonar coals) lie close to a maximum transgressive zone, but a discrete maximum flooding surface (MFS) cannot be identified. These coals could span the upper TST and lower Highstand Systems Tract (HST).

(3) Coals in the HST are thin and impure, cap bayfill units (parasequences), and die out upward. Conditions for peat accumulation became progressively less favourable as the rate of creation of accommodation space decreased, the coastline began to advance seaward, and detrital supply resumed.

(4) Lowstand surfaces (sequence boundaries) are represented by calcretes with fabrics indicative of relatively arid conditions. Braided-fluvial sandstones above the Mullins Coal form an erosional sequence boundary.

(5) Red, vertisol-like palaeosols with ephemeral, anastomosed channel bodies overlie the calcretes. Rare restricted-marine foraminifera suggest that these beds belong to the TST and that abundant sediment supply promoted aggradation of alluvium during initial transgression. Climates were probably too arid and groundwater level too low for peat to accumulate.

Namurian and early Westphalian stratigraphy of western and southwestern Cape Breton Island

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The post-Windsor Group succession of western Cape Breton Island comprises the Hastings and Pomquet formations of the Mabou Group, overlain unconformably by the Port Hood Formation (latest Namurian/Westphalian A) of the Cumberland Group. The Port Hood Formation is overlain unconformably by the Inverness Formation (Cumberland Group) in northwestern outcrop areas, and by strata of uncertain affinities of Westphalian B and C age in the Port Hood area. In the Strait of Canso area, post-Windsor beds were assigned by Belt to the Hastings Formation, the Pomquet Formation comprising both a Grant Point Tongue and a Glengarry Tongue, and the Emery Brook Formation, all part of Belt's Mabou Group. The Emery Brook Formation separates the two tongues of the Pomquet Formation in Belt's Mabou Group, and is characterized by abundant grey and black shales with associated sandstone and thin coals.

Correlation of the upper part of the Port Hood Formation (Cumberland Group), here informally termed the Colindale member, with Belt's Emery Brook Formation (Mabou Group) of the Strait of Canso succession, is suggested on both litho- and biostratigraphic grounds. The Emery Brook Formation, like the Colindale member of the Port Hood Formation, contains thin coal seams and is here assigned to the Cumberland Group applying currently accepted definitions at the group level. The underlying Grant Point Tongue contains, in its upper parts, thick channel sandstones closely comparable to those of the lower Port Hood Formation. In practice, workers in the Strait of Canso area have not used Belt's stratigraphic subdivisions, but have followed earlier workers in that area in using these thick channel sandstones to mark major lithostratigraphic boundaries. Historical data support this practice, and allow close comparison of the Strait of Canso succession with that of western Cape Breton Island. Re-assignment of the upper part of Belt's Grant Point Tongue of the Pomquet Formation to the Cumberland Group is suggested by regional correlation with the Port Hood Formation. The lower portion of Belt's Grant Point Tongue should be re-assigned to an undivided Pomquet Formation. The Glengarry Tongue of the Pomquet Formation should be abandoned, and the strata overlying the Emery Brook Formation in the Strait of Canso area re-assessed.

Palyno-stratigraphic assessment of Belt's Grant Point Tongue is not presently possible, but is essential to ascertain the possible presence of a basal 'Westphalian A' unconformity. The latter is known in the Loch Lomond area of southeastern Cape Breton Island, and in western Cape Breton Island, and is strongly suspected in the Strait of Canso area as well.

Black shales of the Emery Brook Formation, the Colindale member of the Port Hood Formation, the Parrsboro Formation and the Joggins Formation of the Cumberland Basin are regionally correlative. Together, they establish an important Westphalian A marker horizon within the thick fill of the western Maritimes Basin and attest to widespread similarity in depositional setting in the latest Namurian - early Westphalian.

Beta dosimetry of potassium feldspar extracts using imaging microprobe analysis and small sample gas flow beta counting

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We provide a comparison of two independent methods used to determine the absolute K content of potassium feldspar extracts from sand-sized lacustrine, colluvial and aeolian sediments. The methods used were gas flow beta counting and imaging microprobe x-ray fluorescence analysis.

Imaging analysis demonstrated that the proportion of potassium feldspar grains in a nominally pure K-feldspar extract varied from a low of 7% to a high of 84%. All extracts included a significant proportion of quartz, and some also contained a few plagioclase feldspar grains. However, the absolute K_2O content in individual potassium feldspar grains of all eight extracts examined was within the range of 15.5 = B10.7% K_2O by weight. The K_2O contents in four of five extracts, measured using gas flow beta counting, were significantly lower than this value. This reflects the dilution effect of significant amounts of non-K bearing grains in these extracts. This difference can result in up to an 80% underestimate in the internal beta dose rate of a potassium feldspar grain. A 14% underestimate in the total dose rate to potassium feldspar grains, and therefore a 14% overestimate in sediment ages determined by luminescence dating of nominally pure potassium feldspar extracts is thus possible.

We suggest that gas flow beta counting is suitable for the determination of K contents of bulk sediments and therefore the external beta dose rate, but that internal beta dosimetry is best performed by imaging microprobe x-ray analysis. An alternative, inexpensive approach would be to assume a 15.5 = B10.7% K_2O content for all nominal K-feldspar extracts separated using a heavy liquid with specific gravity of 2.58, and use this value to determine the internal beta dose rate. Dose rate errors incurred with this approach are expected to be significantly less than those incurred by the small sample gas flow beta counting method.

Geology of the Portage Brook area (NTS 21 O/7h and part of 21 O/10a), northwestern Bathurst Camp, New Brunswick

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In the northwestern corner of the Bathurst Mining Camp volcanic and sedimentary rocks of the Tetagouche and Miramichi groups are deformed into a series of northeast-trending isoclinal F_2 folds that constitute a major, overturned anticlinorium that has subsequently been folded around a northwest-trending F_4 antiform. The Chain of Rocks and Knights Brook formations form the core of the anticlinorium and on the southeastern limb are in thrust contact with quartz-feldspar phyric volcaniclastic rocks of the Nepisiguit Falls Formation. In contrast, on the western limb, slates and wackes assigned to the Patrick Brook Formation are conformably overlain by felsic volcanic rocks (Mount Brittain volcanics) consisting mainly of feldspar-crystal, lithic tuff with minor aphyric to sparsely phyric flows and pyroclastic rocks. The Restigouche massive sulphide deposit occurs within the felsic volcanic package near the contact of feldspar-crystal-rich (hanging wall) and feldspar-crystal-poor (footwall) sequences. Mafic volcanic rocks, slates and cherts of the Boucher Brook Formation occur at the top of the section.

To the west, the Tetagouche and Miramichi groups are juxtaposed against a northwest-dipping homoclinal sequence of Siluro-Devonian rocks by the north-south trending Portage Brook Fault. Sedimentary and volcanic rocks of the Chaleurs Group have been recognized for the first time in this area and are conformably overlain by volcanics of the Tobique Group.

The Popple Depot granite, a fine- to medium-grained, foliated, biotite granite that intrudes the lower part of the Miramichi Group in the southeastern part of the map area, has yielded a U-Pb zircon age of 474 ± 4 Ma. Flow banded troctolite (Portage Brook troctolite) and a series of associated gabbro plutons were emplaced into Cambro-Ordovician rocks along a north-northwest trending structure, parallel to the Portage Brook Fault. In the southwestern part of the field area, a Late Silurian (414+11/-1 Ma) alkaline granite intrudes Silurian clastic rocks and appears to be coeval with felsic volcanic rocks of the Chaleurs Group.

Siluro-Devonian tectonostratigraphic relationships, in the Portage Brook area, northern New Brunswick: implications for timing of D_2 deformation in the Bathurst Mining Camp

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The Portage Brook area, located near the northwestern part of the Bathurst Camp, is underlain by Siluro-Devonian rocks of the Matapedia Cover Sequence which are in fault and unconformable contact with Cambro-Ordovician rocks of the Bathurst Camp. Chaleurs Group rocks have been recognized for the first time west of the Portage Brook Fault, a northerly trending fault that forms the boundary with Bathurst Camp rocks to the east. In this area, the Chaleurs Group consistently dips to the northwest and has been subdivided into three lithological units: conglomerate, sandstone and siltstone of the Simpsons Field Formation; felsic volcanic rocks of the Benjamin Formation; and thickly bedded, brown-grey to reddish grey sandstone of the Greys Gulch Formation. The Greys Gulch Formation is conformably overlain by volcanic rocks of the Devonian Tobique Group. A northeast-trending normal fault that runs through second Portage Lake repeats the Siluro-Devonian sequence to the north and cuts off the Portage Brook Fault.

Four, or perhaps five, stages of deformation are now recognized in the Bathurst Camp, which are attributed to: Late Ordovician subduction, associated with closure of a back arc basin (D_1); Late Silurian sinistral transpression resulting from oblique collision (D_2); Early Devonian extensional collapse (D_3); and Middle Devonian dextral transpression (D_4). In the Portage Brook area Cambro-Ordovician rocks were deformed into a series of tight to isoclinal, upright F_2 folds and imbricated by associated D_2 thrusts. Near Upsalquitch Lake the F_2 folds are re-oriented by D_3 deformation into a "flat belt" of recumbent folds overturned to the southeast. The earlier structures are subsequently folded around a north-northwest-trending, regional-F_4 antiform. East-northeast-trending, upright folds and a northeasterly striking slaty cleavage, are most likely coeval with late stage D_4 or perhaps D_5 deformation in the Bathurst Camp.

The Late Silurian to Early Devonian Mount Elizabeth Intrusive Complex cuts both the Silurian and Cambro-Ordovician rocks. A Late Silurian (414 +11/- 1 Ma) alkaline granite appears to grade laterally into and be coeval with volcanic rocks of the Benjamin Formation and has clearly intruded, and altered to hornfels, clastic rocks of the Simpsons Field Formation. The presence of two pre-entrainment cleavages in Ordovician pebbles in the Simpsons Field Formation, therefore, suggests that D_2 deformation in the Bathurst Mining Camp occurred prior to Late Silurian, contrary to earlier interpretations. Furthermore, an elongated, north-northwest trending, composite mafic intrusion, interpreted to be contemporaneous with Late Silurian (418 ± 1) peraluminous granite of the Mount Elizabeth Intrusive Complex, is situated within the Cambro-Ordovician rocks and clearly truncates D_2 thrusts and folds.

Problem solving in copper ores - integrated lithochemistry, ore petrography, concentrate chemistry, and ore mineral chemistry: examples from northern Chile

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A considerable database exists on the chemical and mineralogical character of ores for most operating mining districts. Day-to-day problems of ore processing and mine planning typically cannot be solved by generating a new comprehensive database for that specific purpose due to constraints in time, financial resources, or management flexibility. These problems can often be addressed by conducting modest additional work to allow integrated interpretation of existing components from the database to address the problem in terms of ore geology. The goal should be to maximize the usefulness of existing data for the problem at hand and, at the same time, upgrade the value of the database for future problem solving. Care, of course, must be taken throughout to verify and quantify the quality of data and add this evaluation to the data base.

Several examples from projects on copper ores from Chilean ore deposits are used to illustrate the application of modern trace element analyses by various techniques in concert with ore and gangue petrography and evaluation of large existing ore databases to respond to specific problems in mine operation.

Shear wave velocities of sulphide minerals as determined from high pressure laboratory measurements

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High pressure laboratory measurements of seismic wave velocities, notably shear waves, on a large suite of sulphide-bearing samples from major mines (i.e., Kidd Creek) and important prospects (i.e., the Tulks-Tally Pond Belts, Newfoundland) provide a means for estimating the shear wave reflectivity of sulphides. Confining pressures up to 600 MPa were achieved using the high pressure vessel at Dalhousie University. Velocities were measured on oriented mini-cores using the pulse transmission technique of Birch. Preliminary analyses of sulphide modal abundances were performed using a point counting algorithm on the electron microprobe.

Preliminary results indicate that sulphide minerals occupy Vs-density fields which are distinct from those of common silicate rocks. Most sulphide minerals have higher acoustic impedances than common host rocks and hence sulphide deposits would be expected to appear as 'bright spots' on seismic records. Both qualitative and quantitative analyses of sulphide phase modal abundances in the samples studied indicate that velocity is related to the sulphide mineralogy of the rock. In theory this suggests that the shear wave velocity can be either predicted from the mineralogy or the seismic signature of the sulphide body. P-wave's also support this conclusion.

Rapid early Holocene basin fill of Manitounouk Strait, Hudson Bay: proglacial, prodelta or neotectonics?

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A seismostratigraphic study of Manitounouk Strait on the east coast of Hudson Bay provides some new information on the postglacial history of this region where relative sea level is falling at approximately 1 cm/a. The basal unit of the succession is interpreted as bedrock which forms a series of linear basins parallel to the length of the strait. The thickness of overlying sediments is greater than 40 m in the central basin, decreasing to zero along the northwestern coast.

Five seismic units have been identified. Unit 1 is conformable with the bedrock surface, forming a well-stratified, draped interval with a constant thickness of 7 to 8 m, except in the central parts of the basins where it thickens locally, or along bedrock highs where it is eroded. Unit 2 is 3 to 4 m thick and is also conformable with Unit 1 and the bedrock, but is transparent except for a single internal reflector. In shallow water, the upper surface of this unit is characterized by strong reflectors. Tracing these reflectors into the basins, they are observed to correspond to Unit 3 which is typically transparent and reaches up to 7 m in thickness. Unit 4 is also only found in the deeper basins where it shows an onlapping relationship with the underlying unit. Unit 5

has a thickness varying from 0 to 11 m as a result, largely, of erosion along the basin margins. The base of this unit is well-stratified, but the unit becomes transparent upwards. This unit shows a downlapping relation with unit 4.

Units 1 and 2 are interpreted through correlation with previous work to be glaciolacustrine deposits laid down in glacial lake Ojibway. Unit 5 is clearly postglacial, representing sedimentation similar to the present, but influenced by the falling relative sea level. However, Units 3 and 4 represent a period when sedimentation was limited to the basins and gravity processes such as turbidity currents and debris flows predominated. This caused a rapid infilling of the basins which may have corresponded to paraglacial conditions when meltwaters could have constructed proglacial deltas along the margins of the strait. Earthquakes related to rapid isostatic rebound during early postglacial time may also have contributed to the failure of prodelta slopes or basin margins with the subsequent generation of debris flows and turbidity currents.

Lithostratigraphic revision of Upper Carboniferous (Westphalian-Stephanian) fluvial strata in southeastern New Brunswick

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A 1:50 000 scale mapping program, funded by the NATMAP Magadalen Basin Project was initiated in 1994 to investigate the stratigraphy of Carboniferous rocks in southeastern New Brunswick. Results of the project will be part of a regional synthesis of Carboniferous stratigraphy in the Maritimes Basin of Atlantic Canada.

Westphalian- to Stephanian-aged rocks in the map area constitute, from base to top, the Boss Point, Salisbury, Richibucto and Tormentine formations. A considerable disconformity spanning latest Westphalian A and Westphalian B time was previously thought to separate the Boss Point Formation from the overlying Salisbury and Richibucto formations, which were considered to be facies equivalent.

Mapping at the formation level using lithostratigraphic criteria such as composition, ratio of fine to coarse facies, colour, and the presence of laterally persistent palaeosol horizons, in addition to new exposure of critical contacts, necessitates the following revisions in stratigraphy: (1) The Boss Point Formation is gradational and conformable with the overlying Salisbury Formation; therefore, no hiatus occurs at this formation boundary. However, a condensed section in the vicinity of a basement inlier (Westmorland Uplift) near Moncton suggests that the Salisbury Formation thins onto this basement ridge, and (2) the Salisbury and Richibucto formations are not facies equivalent. The Salisbury Formation forms a distinct lithostratigraphic unit underlying the Richibucto Formation.

Electrical characteristics of mineralized and non-mineralized rocks from ore deposits in the Bathurst Camp

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Electrical characteristics of mineralized and non-mineralized rock samples from the Caribou, Restigouche and Brunswick No. 12 deposits are being studied, in order to determine the conductivity of the mineralization and hence its relationship to tectonic history and mineral deposition. The objective of the study is to assist in the interpretation of resistivity surveys by airborne, ground and borehole EM methods. These three deposits were chosen because of the variation in their EM responses, and of their variation in sulphide mineral grain-sizes.

Results for mineralized and non-mineralized rock samples from Brunswick No. 12 indicate that the resistivities are in the range of less than 1 Ω-m to 2000-7000 Ω-m, with varied degrees of resistivity anisotropy seen in the rocks with low sulphide mineral content. These results are being, and will be compared with those from the other deposits, and from the field surveys.

Mudstone-pebble conglomerates and trough-shaped depressions in Carboniferous fluvial strata from Cape Breton Island. How did they form?

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Several occurrences of what appear to be mudstone-pebble conglomerates infilling trough-shaped depressions are documented from the Port Hood Formation (Carboniferous) of western Cape Breton Island. The origin of these features may be critically debated: were they produced by the deposition of coarse grained bedload within scour channels, or by the slumping of channel banks, or by intrusion associated with reverse-density gradients in the shallow subsurface?

A geochemical and geological examination of surface water and ground water quality in Kingston, Nova Scotia: preliminary results

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The geochemistry of ground and surface waters may vary considerably within a specific watershed and can be greatly influenced by land use practices and surficial geology. The town of Kingston is rapidly expanding, contains mixed urban-rural land use, increased housing density and, in the study area all residences have private wells. Concern has been raised over maintenance of water quality standards in light of these stresses.

To evaluate existing and potential water quality a surface and ground water sampling program was initiated in the spring of 1995; samples were also collected in the fall of 1995 to provide temporal and seasonal control. Investigations of land use practices and surficial geology were also initiated. Surficial sediments are mostly glacial in origin and consist of Lawrencetown till overlain, in places, by thick deposits of fine- to coarse-grained, poorly sorted sand. Most households are situated on, and derive their water from, this highly permeable sand. Post-glacial alluvial deposits are found in the major stream valleys of the watershed.

Water samples were analyzed for pH, dissolved oxygen (DO) and conductivity (COND), Na+, K+, Ca2+, Mg2+, Fe2+, Cl-, $NO_3$2-, $PO_4$3-. Surface water samples and isolated well water samples (those displaying depressed DO values) were tested for the presence of coliform. Although sample spacing was relatively dense there was a high degree of variability at adjacent or nearby sample stations. This variability is, in part, a result of the complex interplay between water source, depth and the geological conditions inherent in a particular water source. Three distinct geochemical zones were recognized in the study area on the basis of aberrant pH, DO and COND values; however, only at isolated sites did these values exceed provincial drinking water standards (DWS).

Preliminary results indicate a shift in concentration of specific ions from spring to fall. Most notable was a decrease in Cl- concentration and an increase in Ca2+ concentrations. Data indicate that agricultural practices, road salting and natural iron in the bedrock and overlying sediment all adversely affect water quality at the study site. Anomalous and potentially unsafe pH values occurred at isolated locales and must be studied in further detail.

Geothermometry, geobarometry and fluid chemistry in Au, Pb-Zn and Ba-F deposits in Nova Scotia as constrained by fluid inclusion studies

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Fluid inclusions provide a means to reconstruct the ambient conditions (PTX) during a variety of geological processes if the origin of the inclusions is constrained. By measuring the homogenization T (T_h), composition (e.g., salinity, CO_2) and volumetric properties of inclusions one can determine the isochores and in combination with independently derived T and P data, infer the T(°C) and P(bars) of fluid entrapment. Such information (PTX) constrains the nature and origin of the fluids of interest.

Meguma lode-gold deposits in the eastern Meguma Terrane formed at ca. 370 to 380 Ma ($^{40}Ar/^{39}Ar$ dating) within mixed psammitic-pelitic lithologies due to focusing of basement-derived, metamorphic fluids into deformation zones. Isotopic and geochemical data indicate the fluids interacted with the wall rocks and derived C and S via reaction of graphite and sulphides. Vein quartz, variably deformed and recrystallized, contains equant- to negative-shaped fluid inclusions of L- and V-rich H_2O-CO_2-CH_4-NaCl types. Fluid unmixing or effervescence is rare, but can be demonstrated at West Gore. Thermometric data indicate fluids are of low salinity (<5-6 wt. % NaCl), have variable proportions of CO_2:CH_4 and Th=ca. 350 ± 50°C. Isochoric projections (to 400-500°C) indicate a range of 2 to 4 kbars within single deposits, thus consistent with seismic pumping models for

vein formation. The maximum inferred pressures (to 6.5 kbars) are too high (i.e., above kyanite-andalusite curve) and suggest vein formation is in part related to over pressuring of fluids.

Carbonate-hosted replacement deposits (Zn-Pb-Ba-Cu-Ag) at Gays River and Walton have been studied in detail. At Gays River, fluid inclusions in ore and gangue phases indicate mineralization occurred at ≤250°C from highly-saline (20-28 wt. %) $NaCl-CaCl_2-H_2O$ brines with variable $NaCl/(NaCl+CaCl_2)$ ratios (0.3 to 1); rare liquid petroleum occurs in late-stage calcite and fluorite. The highly variable $CaCl_2$ contents of the fluid inclusions may indicate that the infiltrating fluid was Ca-poor and that Ca was derived from dissolution of the host carbonate. The presence of up to 0.62 mole % CH_4, isochoric projections for aqueous and gaseous inclusions, and the occurrence of liquid petroleum constrain P during mineralization to 400 to 500 bars, consistent with mineralization being post burial. At Walton, barite hosts abundant aqueous and liquid petroleum inclusions. The aqueous inclusions have T_h ≤250°C, salinities of 0 to 28 wt. % eq. NaCl, but most fall in the narrower range 20-28 wt. % eq. NaCl, and $NaCl/(NaCl+CaCl_2)$ ratios of 0.2 to 1. Rare V-rich, CO_2 type inclusions, with up to 40 mole % CH_4, occur. Petroleum inclusions occur as L-V and L_{H2O}-Lp-V types, rarely contain bitumen, and have T_h=70° to 300°C. The presence of rare bitumen and the high T_h indicate the mineralizing event was short lived (i.e., <0.5 Ma). The petroleum originated by pyrolysis of organic-rich sediments in a manner similar to generation of high T (300°C) liquid petroleum venting from black smokers within sediment-rich troughs on the ocean floor. Fluid inclusions constrain the P during mineralization to ca. 300 to 400 bars.

The Lake Ainslie vein Ba-F deposits occur in either Fisset Brook rhyolites or diorite-gneiss basement rocks. Fluid inclusion types in vein fluorite include (1) L-V, (2) L- and V-monophase, and L-V-Solids. The mineralizing fluids were high salinity (18-28 wt. % eq. NaCl) $NaCl-CaCl_2-H_2O$ brines with Th=60 to 130°C and $NaCl/(NaCl+CaCl_2)$ ratios of 0.1 to 0.85. Using a lithostatic load equivalent to ca. 700 bars equates to P corrected T_h of 90 to 170°C, which indicates a thermal gradient of 60°C/km. Such an elevated gradient suggests advection of heat into the crust, perhaps from related magmas at depth or derivation of heated fluids from magmatic source.

Upper Ordovician to Lower Silurian foreland basin rocks in the eastern Bathurst Camp: implications for exploration east of the Pabineau Thrust

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The boundary between allochthonous (i.e., accretionary wedge) and parautochthonous (i.e., foreland) rocks in the eastern part of the Bathurst Camp is represented by the north-south trending Pabineau thrust-fault zone. East of this zone, an east-west-trending stretch of the Nepisiguit River transects the core of the shallowly south-plunging Nepisiguit River antiform exposing the Knights Brook and Chain of Rocks formations of the Miramichi Group. However, south of the Nepisiguit River, along strike from the section there, three new sedimentary units, not present in the river section, have been identified. The Tomogonops Formation comprises a coarsening-upward sequence of thinly bedded calcareous siltstone, lithic- and quartz-wacke, grey slate, and conglomerate, that lies gradationally and locally unconformably on Tetagouche Group and Miramichi Group rocks. It is interpreted as a flysch derived from a southeastward-advancing accretionary wedge. A second unit, informally named the Gordon Meadow Brook Formation, consists of greenish-grey, characteristically micaceous, fine grained sandstone and siltstone, and lies locally unconformably on the Miramichi Group. The Gordon Meadow Brook Formation was probably derived from the southeast (i.e., Avalon Terrane) as no known micaceous source rocks are present in the Miramichi Anticlinorium. The Portage River Formation gradationally overlies the Knights Brook Formation of the Miramichi Group and comprises interlayered, typically micaceous, dark bluish-grey, fine- to medium-grained quartz wacke and siltstone. The Portage River Formation also contains orthoquartzite beds analogous to those in the Knights Brook Formation, and micaceous wackes typical of the Gordon Meadow Brook Formation.

The base-metal rich Brunswick horizon exists at the Brunswick Mines and Key Anacon deposits, which occur in opposite limbs of the Nepisiguit River antiform. Previous exploration programs in the area of these deposits have outlined many geophysical anomalies, but follow-up drilling typically intersected sedimentary sequences previously interpreted as Miramichi Group, i.e., below the Brunswick horizon. If these sedimentary rocks are in fact part of the Tomogonops or Gordon Meadow Brook formations, they may overlie the Brunswick horizon, concealing potential mineral deposits at depth.

The EXTECH-II project (1994-1999), Bathurst Mining Camp, northern New Brunswick

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EXTECH, an acronym for EXploration and TECHnology, is a five-year federal program that is focused on a specific mining camp with the objective of developing new exploration ideas and methods. It is a co-operative program involving the Federal and Provincial governments, universities, and the mineral industry. EXTECH-I was focused on the

Flin-Flon/Snow Lake belt of Manitoba; EXTECH-II is focused on the Bathurst Mining Camp of New Brunswick. Project operating expenditures over five years will be approximately $4.5 million. This includes A-base funding ($2.1 million from the Geological Survey of Canada and $1 million from the New Brunswick Geological Surveys Branch), as well as funding from other sources ($1 million from the Research and Development Corporation for an airborne survey and the remainder from the International Partners Project).

The EXTECH-II project will involve a collaborative effort between earth scientists from the Geological Survey of Canada, the New Brunswick Geological Surveys Branch, mining/exploration companies, and various universities, and their support staff. Research in the Bathurst Mining Camp will have six main areas of focus: (1) geologic and tectonic setting; (2) genesis of massive-sulphide formation; (3) surficial geology and geochemistry; (4) hydrology and hydrochemistry; (5) geophysical surveys including ground, borehole, and airborne methods; and (6) compilation of a digital database using a Geographical Information System (GIS).

Chemostratigraphy and depositional environment of an Ordovician sedimentary section across the Miramichi Group - Tetagouche Group contact, northeastern New Brunswick

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A thick section of Ordovician sedimentary rocks underlies and overlies felsic to mafic volcanic rocks of the Tetagouche Group, Bathurst Mining Camp. The dark grey quartzose slates and siltstones of the Patrick Brook Formation (Miramichi Group) occur below the volcanic rocks, whereas the dark grey to black slates and siltstones of the Boucher Brook Formation (Tetagouche Group) are intercalated with the volcanic rocks and overlie the sequence. The Miramichi-Tetagouche contact represents the interpreted Gander-Dunnage boundary in northeastern New Brunswick. Distinguishing between these two similar formations is important for stratigraphic and geotectonic interpretations of the Bathurst Mining Camp and for exploration in these sequences. The geochemical composition of a semi-conformable section of rocks from the Boucher Brook (Middle to Late? Ordovician) and Patrick Brook (Early to Middle Ordovician) formations was determined to identify geochemical chemostratigraphic discriminants, as well as to determine the palaeodepositional environment in which these were deposited.

The high Al_2O_3 and distinctly higher high-field-strength elements (LREE, Th, HREE, and Y) in the Patrick Brook rocks are mature sedimentary rocks indicating intense chemical weathering (tropical environment) in the source regions, which is consistent with their compositional similarity to Avalon-derived shales analogous to Gander Zone sedimentary rocks. The Boucher Brook slates and siltstones are immature sedimentary rocks based on the preservation of albite and less coherency of trace-element systematics to phyllosilicate indices (Al_2O_3 and K_2O). They are probably derived from the associated volcanic rocks.

The higher Mn and Fe and positive Ce/Ce* anomalies in some Boucher Brook rocks compared to the Patrick Brook rocks indicate that the Boucher Brook rocks in this section were deposited in a transitional anoxic/oxic environment. The Patrick Brook rocks that immediately precede felsic volcanism and formation of massive sulphide deposits are highly reduced based on C and S contents, which is consistent with the sulphur isotope data. Moderately heavy $\delta^{34}S$ values are indicative of SO_4^{2-} reduction to H_2S under anoxic conditions, which is significant in the formation and preservation of massive sulphides in the basal Tetagouche sequence.

Preliminary geochemical interpretation of metalliferous sedimentary rocks in the Miramichi Anticlinorium, New Brunswick

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Connell and Hattie subdivided sedimentary rocks from the Miramichi Anticlinorium by rock type into Ordovician maroon to red argillite and shale (n = 50), maroon chert (n = 14), green to grey shale and chert (n = 23), and black shale and chert (n = 89), as well as Cambro-Ordovician maroon shale (n = 7). This analysis of their lithogeochemical data was conducted in order to help elucidate the processes responsible for the geochemical characteristics of these different rock types. In general, the immobile-element contents are a function of the Al_2O_3 contents, which are in turn inversely related to the proportion of quartz that may be either detrital, biogenic or hydrothermal in origin. Fe, Mn, Cu, Pb, Zn, (Ag), Co, and Ni are enriched by hydrothermal processes, although their deposition is related to redox variations within the stratified ocean. Fe/Mn contents reflect the degree of oxygenation with low values indicative of oxic conditions, high values of anoxic conditions, and intermediate values of the redox transition zone. Manganese and cobalt are enriched in rocks with low Fe/Mn contents, whereas Fe, base-metals, U, V, Mo, Cr, and to a lesser extent Ni, contents are higher in black shales, which have high a Fe/Mn ratio.

Characterization of primary sulphide assemblages at the Chuquicamata porphyry copper deposit, Chile, section 4500N

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The Chuquicamata porphyry copper deposit has been mined continuously in one form or another for over a century. Oxide and supergene ores with copper grades from 2 to 10 times higher than the hypogene (primary) grades have been mined for most of the first seventy-five years of this century. Hypogene ore has only recently started to be mined. Published detailed descriptions of Chuquicamata sulphide assemblages date from 1939, years before hypogene sulphides became a significant part of the mined ores. In order to aid in the formulation of a genetic model of the deposit, mineralogical data from a sequence of internal reports by the mine staff must be re-evaluated and synthesized with current studies at Dalhousie University.

Working from three deep drill holes in the representative 4500N cross section, a detailed petrographic study is being conducted to determine whether the different zones of alteration (quartz-sericite, potassic and propylitic) contain characteristic ore assemblages, and how these assemblages change with depth, with respect to mineral paragenesis and compositional variations of phases. Those of particular interest so far, include the copper-rich assemblage digenite + covellite, found dominantly in zones of quartz-sericite alteration, while the equilibrium assemblage chalcopyrite + bornite is localised deep in zones of potassic alteration. Covellite (CuS) is found throughout the system: in zones of quartz-sericite alteration, acicular covellite occurs in equilibrium with high-temperature digenite, while in intermediate levels of zones of potassic alteration, covellite is often found in thin lamellar crystals replacing other Cu-sulphides, most frequently chalcopyrite, where it forms an arrangement of loose lattices. Veins of hypogene pyrite + enargite + sulphate run through the intermediate level of the system. Using experimentally-determined phase equilibria in the Cu-Fe-S system, an attempt is made to impose limits on the temperature of formation of various hypogene ore assemblages.

The upper expression of a deep fault, Falla Oeste, northern Chile

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The open pit of the Chuquicamata porphyry copper deposit, northern Chile, provides unprecedented exposure of the upper levels of a deep fault system. With 3.3 km lateral and 0.55 km vertical outcropping of the system with an additional 0.56 km depth encountered in drillcore, the fault zone can be defined and characterized in some detail. A 400 to 500 m cataclastically-deformed zone is overprinted by wide fractured areas, breccia zones, and gouge-bearing fault planes. A concentration of gouge-bearing planes constitutes the contact between mineralized Chuquicamata rocks and non-mineralized rocks of the Fortuna complex. The cataclastic zone, best exposed to the west of the fault, is characterized by amphibole growth, later biotitic and chloritic alteration, and even later clays associated with supergene processes. Brecciated areas are present on both sides of the contact. The east side breccia contains irregular anastomosing gouges ($\leq$10 cm) through the sericite-clay matrix of the fragments to matrix-poor breccias with variably-lineated angular fragments. Extreme grain size reduction is present in the foliated gouge bearing zones. Where deformation has been concentrated in a single fault, greater than 50% of the gouge particles are $\leq$15 microns in diameter. Where deformation has been partitioned along multiple gouges, there is a bimodal distribution of grain size. Assemblages of primary and secondary copper minerals are present in the majority of grain size fractions as is supergene zinc mineralization. Fragmentation of all assemblages is consistent with late fault movements. The presence of illite, montmorillonite, and nontronite within the gouges facilitates fault movement creating rock instability within the open pit.

Neotectonic assessments from deformation structures in raised marine deltas: examples from the Bay of Fundy area

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Earthquake-induced deformation structures serve as evidence for historic and prehistoric ground failure within glaciomarine and ice-contact deposits along the margins of southeastern Canada and the northeastern United States. Historic earthquakes with magnitudes greater than M5+ have produced liquefaction structures within waterlain sediments at: Newbury (1727) and Cape Ann (1755), Massachusetts; Massena, New York (1944); and Saguenay, Quebec (1988). Other historic earthquakes with epicentres located within the Bay of Fundy area, and that could have produced local soft-sediment deformation, include: the Passamaquoddy Bay area (e.g., 1817, 1904 earthquakes), the Miramichi area (e.g., 1869, 1982 earthquakes) and the Moncton-Dorchester area (e.g., 1855 earthquake).

Deformed proglacial deltaic deposits that represent an ice-proximal, glaciomarine environment were examined as possible indicators of postglacial seismic activity at St. George, New Brunswick and Lower Five Islands-Economy Point, Nova Scotia. Despite a distance of 230 km between the study sites, the deformation structures demonstrated similar features, facies and origins. Several styles of deformation structures were recognized that could be attributed to penecontemporaneous deformation and common to particular mechanisms of formation and facies, including ball and pillow structures associated with: (1) loading by rapid sedimentation, (2) glacial movement, or (3) from percussion by dropstones. These were common in the bottomset units. Crumpled, rolled-up or boudinaged layers were likely formed by several mechanisms, including: (1) intra layer or intra-unit compaction or stretching; (2) in association with gravity slumping, mainly in the foreset units; and (3) from loss of support due to (i) ice-melting, (ii) glacier movement, or (iii) fluid-escape structures, common in the foreset and topset units. Deformation associated with catastrophic fluidization of topset facies or overlying Holocene sediments is considered to be the best indication of possible seismic shock.

These preliminary results demonstrate that physical structures within deltaic sediments can provide a record of neotectonic activity and contribute valuable data for assessment of earthquake occurrence and/or recurrence.

Rusticles from the R.M.S. Titanic

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The supposedly unsinkable ship Titanic went underwater on April 15, 1912 and was recorded in the history books as one of the worst ocean tragedies. Measurements of the ship were 28.7 m. in width, 269.1 m. in length, and 53.3 m. in height (measured from the keel to the top of the funnels). The canyon where the Titanic now rests, in the North Atlantic, is well oxygenated, with wave undercurrents at a depth of 3.8 km. The environment is slightly alkaline with a pH of 8.2. The organic material, represented by wood, human remains, clothing, etc., has all decayed, but the china, shoes, bottles and metal material remain. The ship is decorated by rust-like stalactites referred to as "rusticles". These are formed partly by corrosion and microorganisms. The deep ocean water contains little iron and rusticles are good examples of biological cycling of metals, enhanced by bacteria. Parts of the rusticles are actually minerals and special crystals, which will be demonstrated by using overhead transparencies and other media. The rusticles are partially precipitated by different microorganisms as they use the metal as a source of energy, creating a unique shape and microenvironment. The microenvironment will be explained in detail, with emphasis on the microorganic ecosystem.

Copper skarn-associated felsic intrusive rocks in the McKenzie Gulch area (NTS 21 O/10), Restigouche County, New Brunswick

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The McKenzie Gulch area contains numerous Cu-mineralized garnet-pyroxene skarn occurrences. The most significant of these is the Legacy Deposit containing approximately 500,000 tonnes grading 1.7% Cu. The occurrences are hosted by Upper Ordovician through Lower Silurian calcareous sedimentary rocks of the Matapedia Group and are spatially associated with Lower through Middle Devonian, high-angle, northeast-trending, syntectonic felsic intrusive rocks. Detailed petrographic and geochemical investigations of cores recovered by Noranda Mining and Exploration has enabled subdivision of these intrusive rocks, providing a better understanding of their petrogenesis and temporal relationship to skarn mineralization.

Felsic intrusive rocks in the McKenzie Gulch area can be subdivided into two compositionally and texturally distinct units: the Plagioclase-Hornblende Porphyry unit and the Quartz-Plagioclase Porphyry unit. Of these, the Plagioclase-Hornblende Porphyry unit can be further subdivided on the basis of textural variations into two subunits or phases, a fine grained Aplitic Porphyry phase and an equigranular Tonalite phase. Cross-cutting relationships indicate rocks of the Quartz-Plagioclase Porphyry unit are younger than those of the Plagioclase-Hornblende Porphyry unit.

The Plagioclase-Hornblende Porphyry unit is probably temporally and genetically related to Cu-mineralized garnet-pyroxene skarn occurrences as indicated by local development of endoskarn within this intrusive unit, its overall fractured and altered appearance, and reactive contacts with sedimentary country rocks. In contrast, the younger Quartz-Plagioclase Porphyry unit is typically more massive and only weakly altered and commonly possesses unreacted contacts with sedimentary country rocks suggesting that it is not associated with skarn mineralization.

Geochemical data indicate the felsic rocks are grano-

dioritic to tonalitic in composition, subalkaline with a calc-alkaline affinity, metaluminous and have an infracrustal (I-) type, volcanic-arc signature. Geochemical results also support the petrographic discrimination of distinct felsic units on the basis of select major and trace elements. Overall these data indicate a trend towards increasing SiO_2 and decreasing TiO_2, Al_2O_3, MgO, P_2O_5, Sc, V, Y, and Nb from the Plagioclase-Hornblende Porphyry unit through to the Quartz-Plagioclase Porphyry unit, consistent with evolution by fractional crystallization. This interpretation is supported by intrusive contact relationships. Rare-earth-element (REE) contents are similar for all felsic intrusive units being characteristically low with steep negative slopes and positive Eu anomalies. Similarities in REE contents suggest the individual felsic intrusive units were likely produced from the same magmatic source and the observed geochemical variations between these units are likely attributable to fractionation processes.

Geochemical comparison of the McKenzie Gulch porphyries with other Devonian felsic intrusive rocks in the region suggests the McKenzie Gulch porphyries are most similar to felsic porphyritic rocks of the Mount Sugarloaf stock. Rocks of the McKenzie Gulch porphyries and Mount Sugarloaf stock, together with those of the Mount Squaw Cap stocks and Nicholas Dénys Granodiorite in New Brunswick, as well as the Mines Gaspé, Mont Hog's Back and Mont Chauve porphyries in Quebec, constitute an Early to Middle Devonian calc-alkalic magmatic suite. These rocks are characterized by depleted concentrations of incompatible elements and have an inherited volcanic-arc signature that reflects the tectonomagmatic signature of their source rocks. This intrusive suite was emplaced during the Acadian Orogeny, at which time collision between the Laurentian and Gondwanan plates resulted in juxtaposition of hot mantle asthenosphere against the base of the crust causing partial melting of the lower crust and mantle.

Tectonic evolution of the Late Paleozoic St. Mary's Basin, Nova Scotia

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The St. Mary's Basin, Nova Scotia, is underlain by Late Devonian-Early Carboniferous fluviatile to lacustrine clastic rocks of the Horton Group. The basin straddles the east-west boundary between the Meguma and Avalon terranes, and has been interpreted as a graben or as a pull-apart basin generated by post-accretionary strike-slip activity. We propose that the St. Mary's "Basin" is a tectonic slice of the much larger northeast-belt of Horton Group rocks, originally contiguous with those in Cape Breton Island and the Annapolis Valley. Namurian-Early Westphalian dextral motion along the Chedabucto Fault dismembered this belt, and generated folds and thrusts adjacent to active faults.

An Early Carboniferous reconstruction, based on the minimum subsequent motion required along the Chedabucto Fault, restores ca. 100 to 150 km of strike-slip movement and places the western edge of the St. Mary's Basin against the southeastern Antigonish Highlands as part of a northeast-trending belt of Horton Group rocks. This reconstruction suggests former continuity of lithologically similar Ordovician-Early Devonian volcanic and siliciclastic sequences of the Antigonish Highlands, Guysborough and the Annapolis Valley, and a potential genetic association between the Antigonish and Shubenacadie basins. The reconstruction also has implications for the accretion of the Meguma terrane, because pre-Carboniferous motion along east-west faults that bound the terrane cannot be demonstrated. Northwest-directed telescoping between the Avalon and Meguma, from ca. 410 to 360 Ma may result in the generation of a northeast-trending Early basin into which Horton Group rocks were deposited. Late Carboniferous dismemberment and deformation related to dextral strike-slip motion was associated with collision of Laurentia and Gondwana and the amalgamation of Pangea.

A detailed investigation of stream morphology and the impact of in-stream remediation structures on Mill Brook, Kings County, Nova Scotia

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In the summer of 1995, a hydrogeological study was conducted on Mill Brook, a tributary of the Cornwallis River. Mill Brook is about 10 km long and draws from a watershed of 45 km^2. The brook has an average flow of 5 cm/s, cross-channel width of 8.5 m and can be characterized as a free-stone creek with a traction load clast size-range of silt (< 0.1 cm) to cobble (20 cm) size. The natural channel morphology of Mill Brook has been altered significantly, resulting in loss of the salmon and trout spawning habitat. In-stream structures (digger logs and deflectors) were installed in July and August 1995 in an effort to re-establish the original channel pattern of the river.

Research focused on a detailed examination of the impact on stream morphology of the in-stream structures. It was found that the ability of the in-stream structure to alter river bed morphology is dependent on the dimensions and orientation of the structure itself, the bed composition of the river (bedrock, freestone or sand) and flow velocity and

depth. Stream bed monitoring stations were installed at three of the modification structures. Within one month of installation the development of a subtle thalweg was observed and sand- and silt-sized sediment was absent from the bed load. These observations were made while the stream was at low stage indicating that further re-organization of the stream bed can be expected. These changes occurred during low water conditions indicating that the structures have the potential to transport larger substrate at higher rates. The effectiveness of in-stream structures is dependent on a detailed understanding of the system in which they are to be employed. The information collected in this study will serve to guide further remediation efforts.

Glacial dispersal of massive sulphide boulders, Grandroy area, Bathurst Mining Camp, New Brunswick - EXTECH-II

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During 1995, Noranda Mining and Exploration uncovered high grade massive sulphide boulders in trenches on their Grandroy property, 5 km south of the Brunswick No.12 Mine, as a result of following up EM anomalies in Tetagouche Group felsic volcanic and sedimentary rocks. To locate the bedrock source of these boulders, a compilation of regional ice-flow indicators was done in conjunction with detailed surficial mapping of the Grandroy area. Physiographically, the Grandroy property is located near the boundary between the Miramichi Highlands (location of the Bathurst Mining Camp) to the west and the New Brunswick Lowlands (Carboniferous Platform) to the east, an area influenced by eastward- to northeastward-flowing ice (050°-090°) and younger northerly-flowing ice, reflecting the influence of the northward-trending Curventon-Bathurst Valley. Since the trenches are in an area between the two major ice-flow domains, it is possible that there was some remobilization of the older glacial deposits.

The Grandroy property is covered by 2 to 4 m of compact basal till, which is overlain in the western part of the area by a variable thickness of fine glaciofluvial silt and sand, deposited in meltwater channels on an outwash plain. The two units are generally separated by a thin layer of glaciofluvial outwash gravel, which is more continuous across the trenched area than the sand and silt layer. In the eastern part of the area, the clayey basal till is overlain by 1 to 1.5 m of patchy ablation till. A silty reddish soil overlies the glacial deposits and is commonly overlain by up to 1.5 m of cobbly colluvium. Striations were mapped at 4 sites approximately 1 km west-northwest of the trenches. They indicate eastward- (081°-100°) followed by northeastward- (059°-070°) flowing ice. This supports the 057° ice-flow indicated by the till fabric (orientation and imbrication of the clasts and sulphide cobbles and boulders) in the "discovery chamber" of Trench 3. Basal till at the base of this section is relatively unaltered compared to the till higher in the section containing the sulphide material. This yellowish coloured deformation till, containing mostly locally derived material, and having distinguishing textural characteristics, is present directly over sulphide deposits in other parts of the Camp, and is a potential prospecting tool. The abundance of massive sulphide cobbles and boulders higher in the section, the decreasing amount in Trench 2, and the stringer nature of the sulphides in Trench 4 indicate a very local bedrock source for the massive sulphide material, between Trenches 3 and 4 (up-ice from Trench 3). Subsequent trenching and diamond drilling have discovered this to be the case.

Quaternary geology and till geochemistry, Bathurst Mining Camp, New Brunswick

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The objectives of the EXTECH-II Quaternary mapping and sampling project in the Bathurst Mining Camp are: (1) conduct detailed till sampling and glacial dispersal studies, defining the relative chronology of ice flow, the direction of glacial transport and dilution rate down-ice from known massive sulphide deposits, and (2) complete the 1:50 000 scale Quaternary geology mapping.

Work during 1995 involved: (1) detailed sampling of till, pebbles from till, B-horizon soil, humus, and balsam fir twigs carried out at the Restigouche deposit (102 sites); (2) till sampling conducted at the Willett mineral occurrence (22 sites along a 160 m trench), to investigate variations in geochemical signatures of till over different rock types), the Stratmat deposit (29 sites + 79 archived samples, extending 3 km down-ice), and the Spruce Lake Road area (46 sites around outcrops of gossanous slates and mafic volcanic rocks); (3) regional and trench-scale surficial mapping; and (4) a study of clast provenance in till at 32 bulk-till sample sites.

Geochemical analyses (ICP-ES and ICP-MS) of trace elements in the fine fraction (<63 μm) of 419 basal-till samples collected in 1994 around the Halfmile Lake and Restigouche deposits are complete. The deposits are located in the Miramichi Highlands of north-central New Brunswick and are stratigraphically underlain by sedimentary and volcanic rocks of the Ordovician Tetagouche Group. Local topography is rugged and characterized by angular ridges and deeply incised V-shaped valleys. The main ice-flow direction was eastward (080°-110°), followed by northeastward flowing ice. Boulder erratics transported from the Mount Elizabeth Intrusive Complex deposited near the Halfmile Lake deposit confirm the east-northeast transport direction.

At Halfmile Lake, the highest concentrations of Cu-Pb-Zn and some other elements occur in a series of sites oriented along an east-west fault, paralleling the direction of glacial flow. At the western extremity, the zone of anomalous values overlies known mineralization and gossan (Upper AB Zone). However, there is a negative Zn till anomaly directly over the gossan at the Upper AB Zone and the gossan itself contains very low Zn values. A second anomalous zone is located 300 m to the east and may be associated with underlying mineralization or glacial dispersal from the Upper AB Zone. Results from a 250 m grid survey at the Restigouche deposit indicate strong Cu, Pb, Zn and Sn values in the immediate vicinity of the deposit and a stronger anomaly in similar rocks (Mount Brittain volcanics of the Ordovician Tetagouche Group) that are structurally repeated 1 km to the north of the Restigouche deposit.

Fluorescence of apatite: a fast method for discrimination of Cl/F compositional types

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Many recent studies have made it apparent that it is necessary to incorporate the effects of apatite composition (i.e., F and Cl content) into the determination of fission track ages and track length studies. This is because fluorapatites anneal at lower temperatures than chlorapatites, and disregard of this fact may lead to erroneous time-temperature paths. Therefore it has become important to distinguish different populations of apatite crystals in every sample processed. When an apatite grain is exposed to shortwave ultraviolet light, it radiates in the visible spectrum, giving the resultant, signature colour. It is the structure of apatite, which is dependent upon the ratio of Cl to F, that is the primary cause of the fluorescence. For example, chlorapatite generally fluoresces a deep orange. REE abundance plays a less important role in the fluorescence of apatite.

Samples of apatite from a sample from the Sverdrup Basin, NWT, contained two populations; one fluoresced a faint orange, the other not at all. Microprobe analyses of the two populations confirmed that the former, orange fluorescing apatite, is Cl-rich, whereas the latter is F-rich. Therefore, the colour that an apatite fluoresces can be used as a fast, efficient and nondestructive screening method for fingerprinting chlorine-rich apatite in a sample.

Development of cordierite in medium to high grade metamorphic rocks in southwestern Nova Scotia

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Large porphyroblasts of andalusite, staurolite, and cordierite are associated with low-pressure regional metamorphism of the Meguma Group in southwestern Nova Scotia. The metamorphism was contemporaneous with the intrusion of the spatially associated Barrington Passage, Shelburne, and Port Mouton plutons at 377 to 366 Ma (U-Pb zircon and $^{40}Ar/^{39}Ar$ ages). However, it is not clear whether there was a direct relationship between the plutonism and the regional metamorphism.

The origin of the porphyroblastic cordierite has been controversial because of the patchy distribution of the mineral, its presence in rocks from biotite to sillimanite grade, and the large number of phases in the cordierite-grade rocks (e.g., andalusite-staurolite-cordierite-garnet-biotite-muscovite-plagioclase-quartz). Cordierite also exists as smaller grains in the migmatite zone surrounding the Barrington Passage Pluton.

TWEEQU multi-equilibrium thermobarometry was applied to cordierite-bearing rocks from throughout the area and indicates that these rocks had attained equilibrium. Pressure-temperature conditions range from 2500 to 4100 bars and 420 to 680°C. Isotherms are generally concentric around the plutons, except where they crosscut the eastern side of the Shelburne Pluton; this suggests a direct relationship between plutonism and regional metamorphism.

Thermobarometry, petrography and mineral chemistry indicate three mechanisms by which cordierite formed. Below ~520°C, idioblastic cordierite formed from matrix minerals. From ~520 to ~600°C, xenoblastic cordierite formed at the expense of andalusite and staurolite. Above ~600°C, migmatitic cordierite formed at the expense of sillimanite. The rarity of sector trilling in cordierite in the area, including in the migmatites, attests to the slow heating rate of the metamorphism and long thermal history.

The patchy distribution of cordierite cannot be explained by pressure-temperature conditions, nor can it be explained by water pressure, as calculations indicate that $P_{H2O}=P_{TOTAL}$ in some cordierite-bearing rocks, and $P_{H2O}<P_{TOTAL}$ in others. The main controls on cordierite formation in the area are therefore whole-rock Fe/Fe+Mg ratios and f_{O2}.

Surficial geology of the Caledonia Highlands, exploration geochemistry and land use applications

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The 1:50 000 scale surficial mapping and till geochemistry project that covers most of the (1:250 000) 21 H map area (Amherst) is progressing at the rate of approximately 1 map sheet per year. The mineral potential of the area has long been recognized, and recently gold mineralization has been found in the Belleisle Bay area along the Taylor Brook and Wheaton Brook faults. However, till geochemical results for that area are not yet available. The Caledonia Highlands area is also the subject of several land use related studies: the Kennebecasis drainage basin study (DOE); the Fundy Model Forest research project (ForCan, DNRE Forest Management); and Ecological Land Classification (DNRE Stewardship Branch). Data that have been collected using standard surficial geology mapping methodology have been used for baseline data in all of these studies.

Glacial erosion, mixing, dispersal, and deposition are determined using glacial striae and landforms, till fabric analyses and pebble and boulder dispersal patterns. Material is mostly of local derivation, but transport of up to 30 km can be identified. Some lithologies are particularly useful tracers of glacial dispersal, as are certain chemical elements. Gross dispersal patterns not only have exploration significance, but also have land use implications. The combination of source rocks, mixing, and glacial abrasion determines many of the soil parent material properties. These, in combination with relief, which is also largely controlled by geological factors, and climate, determine land use potential.

Evaluation of the nutrient dynamics of an Atlantic coast beach, Nova Scotia

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In the last two decades, there have been several major oil spill incidents in different parts of the world, some of them affecting Canadian coastlines. As a consequence, research has been focused on the development of oil spill countermeasures for coastal systems. Of the new technologies, bioremediation (based on the addition of substances to accelerate natural biodegradative processes) has been proven to be effective. Previous field trials on low-energy coastal environments including salt marshes and sand beaches, as well as on cobble beaches following the Exxon Valdez oil spill incident, have conclusively demonstrated that the optimal biodegradation rates of oil may be limited by the availability of nutrients (N and P). The addition of nutrients, accelerated both the natural rate and the extent of oil degradation.

A total of forty six field trials are now being conducted to develop operational guidelines for bioremediation. However, highly variable rates of natural oil degradation have been observed following nutrient enrichment, both between and within the same study sites. Possible explanations include both the physical loss of the added nutrients or the presence of natural nutrient sources. As part of a baseline study prior to future field trials, geological expertise is being applied to define the hydrogeological and stratigraphical parameters influencing nutrient concentrations at two low-energy beach sites on the eastern shore of Nova Scotia.

The first site is a pocket beach limited by rocky headlands and has a stepped intertidal profile. The second site is morphologically similar to the first except for the presence of a tidal channel and a flatter profile. Both sites are backed by low dunes which separate standing water bodies from the beach. At the first site, the dunes completely isolate a freshwater lagoon whereas, at the second site, the tidal channel allows saltwater to intrude at high tide so that the lagoon water has a salinity close to or higher than that of the ambient seawater. These water bodies generate a positive hydraulic gradient which results in ground water flow through the beach at low tide.

The preliminary results of the chemical analysis show that the nutrient concentrations in seawater and freshwater from the lagoon at the first site are both relatively low compared to concentrations found in pore water from the beach. The pattern of along-profile nutrient concentrations in the beach porewater was found to be coherent between tidal cycles, but difficult to explain in detail. The presence of high nutrient concentrations in the beach pore water suggests the presence of one or more sources of these nutrients within the beach sediments. A possible source could be nutrient regeneration from the degradation of buried organic matter (e.g., seaweed); however, the results could be influenced by other factors such as rainfall and evaporation.

Pyrrhotite composition and its relationship to acid drainage from the Halifax Formation, Meguma Group, Nova Scotia

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Acid drainage from the Halifax Formation has been recognized at least since the early 1960s when it formed as a result of construction activities at the Halifax International Airport. Mitigation efforts at the airport site have been ongoing and continue to the present day. In addition to the airport site, acid drainage has adversely affected various other areas throughout southwestern Nova Scotia, all underlain by the Halifax Formation. In general, acid drainage is attributed to sulphide mineralization within the host bedrock. In the past, little attention has been paid to the sulphide mineralogy, texture, distribution and mode of occurrence. In recent years, however, it has been recognized that the type of sulphide is an important factor. One reason for this is that iron-sulphide minerals contain different molar proportions of Fe and S, and therefore oxidize to form different amounts of H^+ ions. As an example, the overall oxidation of pyrite by oxygen can be shown by the general formula:

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

This leads to the formation of 2 moles of H^+ ions for each mole of pyrite oxidized. On the other hand, the overall oxidation of pyrrhotite by oxygen can be shown by the general formula:

$$Fe_{(1-x)}S + (2-x/2)\ O_2 + (x)\ H_2O = (1-x)\ Fe^{2+} + SO_4^{2-} + (2x)\ H^+ \qquad (2)$$

where x can vary from 0.0 to 0.125. At the end-member where x = 0 (FeS), no H^+ ions are produced. However, the end-member where x = 0.125 (Fe_7S_8), leads to the maximum amount of H^+ ions produced. In this case, 1 mole of Fe_7S_8 leads to 0.25 moles of H^+ ions produced. Therefore for pyrrhotite, the amount of H^+ ions released into solution is dependent upon its composition. Although quantitatively less H^+ ions are produced for pyrrhotite than for pyrite, previous studies have shown that pyrrhotite oxidizes substantially faster than pyrite. This could result in a "sudden pulse" of acidity in the surrounding environment.

Microprobe data from pyrrhotites in drill core samples from the Halifax International Airport give an average stoichiometry of $Fe_{7.058}S_{8.000}$. XRD studies give typical double peak d-spacings near 2.057 and 2.047. These data indicate the pyrrhotite is 4C monoclinic. For comparison, samples were taken from four other areas including: (1) immediate vicinity of Halifax - contact metamorphic, (2) highway 101 near Mount Uniacke (25 km northwest of Halifax) - contact metamorphic, (3) Beaverbank road (25 km north of Halifax) - regional greenschist facies (biotite grade), (4) drill core from the Eastville zinc-lead deposit (40 km southeast of Truro) - regional greenschist facies (biotite grade). Preliminary data collected to date suggest the pyrrhotite composition is consistent and homogeneous regardless of geological environment and is of the 4C monoclinic type. This study shows that pyrrhotite compositions in the Halifax Formation will lead to the maximum amount of H^+ ions produced for that mineral. We have a worst case scenario for sulphide mineralization, composition, and the development of acid drainage in the Halifax Formation.

Distribution and origin of felsic volcanic rocks, Tetagouche Group, Bathurst Mining Camp

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The Middle Ordovician Tetagouche Group felsic volcanic rocks have been subdivided into four formations, intrusive units, and later comendites based on detailed petrology and geochemistry. Felsic volcanism commenced early in the depositional history of the Tetagouche Group and is represented by the Spruce Lake and Nepisiguit Falls formations. The Spruce Lake Formation occurs in a number of thrust sheets and consists of chemically distinct feldspar-phyric dacites to rhyodacites. These rocks were deposited at discrete volcanic centres. The Nepisiguit Falls Formation mostly consists of pyroclastic quartz-feldspar porphyries that occur stratigraphically immediately below the Brunswick No. 12 massive sulphide deposit. These two formations are overlain by the predominately aphyric ignimbrites and rhyolite flows of the Flat Landing Brook Formation. A region of coarse volcanic breccias in this formation is interpreted to be the remnants of a caldera. All three formations originated in response to partial melting of thinned and heated heterogeneous basement rocks. The youngest felsic volcanic rocks are comendites that are likely the extreme fractionates of alkalic basalts and occur as a minor component of the Boucher Brook Formation, which overlies the Flat Landing Brook Formation.

Geology of the Carboniferous Hopewell and Cumberland groups, southeastern New Brunswick

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The northwestern depositional margin of the Cumberland Subbasin in New Brunswick exposes a Carboniferous sequence of poorly dated predominantly red bed continental clastics that have in whole, or in part, been previously assigned to the Hopewell Group. These red beds are conformably underlain by the mainly marine middle Viséan Windsor Group and overlain by the terrestrial late Namurian to Westphalian Cumberland Group.

Previously defined problems of Hopewell Group stratigraphy have in part been resolved. For example, along the basin margin, between the regional Harvey-Hopewell and Shepody faults, the Hopewell red beds are now interpreted to comprise two laterally separate facies of alluvial fan conglomerates. Clast content and transport vectors indicate that both conglomerate facies were derived from the adjacent Caledonia Uplift to the northwest. The present study has identified an unconformity near Alma between the locally derived Hopewell conglomerates and the distally derived red quartz-clast conglomerate, sandstone and mudrocks of the overlying Enragé Formation of the Cumberland Group. The unconformity suggests that a significant part of the Namurian section is missing here.

Southeast of the Shepody Fault, the Hopewell Group comprises a basin-axis succession comprising red fine grained sandstone and mudrocks of the Maringouin Formation and overlying grey and minor red quartzose sandstone, mudrocks and conglomerate of the Shepody Formation. The contact between the Maringouin and Shepody is conformable and gradational. Miospore assemblages across the boundary suggest a middle Viséan (AT Zone) age. The Shepody Formation is tentatively assigned a middle Viséan to early Namurian age. Miospore assemblages from the Shepody are somewhat confusing and are still being studied.

The contact between the Shepody Formation and the overlying Enragé Formation is not well exposed, but is here interpreted as a disconformity. This is based on the time gap between the early Namurian Shepody and the late Namurian Enragé strata. The relatively thin Enragé Formation underlies and is regionally conformable with the well-dated late Namurian to Westphalian A Boss Point Formation. Thus, the lithostratigraphic and palynologic data indicate a significant Namurian hiatus exists not only along the northwestern margin, but also in the axial part of the Cumberland Subbasin.

Flocculation and fine grained turbidites

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A simple conceptual model of the depositional environment of fine grained turbidites using a "floc limit" interpretation is presented. The grain size for which the residence time of particles in suspension equals the aggregation time is called the "floc limit", because it marks the boundary between floc-deposited and single-grain-deposited sediments. Grains smaller than the floc limit arrive at the seabed in flocs; grains larger than the floc limit arrive as single grains.

There are two principal controlling factors in the deposition of fine grained sediments, gravitational settling and flocculation. Flocculation, or particle aggregation, is the process in which small, slowly sinking particles collide and adhere with other particles in suspension, thus forming larger, faster sinking aggregate particles or flocs. The principal control in aggregation is the collision rate of particles, which is most strongly influenced by the particle concentration.

Fine grained turbidites are among the most abundant sediment types recovered from the Deep Sea Drilling Project. They form thick sequences on prodelta slopes, deep sea fans, continental rises and abyssal plains. Fine grained turbidites are gravity-current deposits. Turbidity flow competence is generally determined by the density (or particle number concentration) differences between the ambient sea water and the suspension. Describing the proximal to distal trends in the floc limit of turbidites serves two purposes. First, a comparison of the observed and predicted trends in the floc limit will demonstrate the potential and limitations of the concept for the interpretation of depositional environments of fine grained sediments. Second, the observed trends in the floc limit will clarify which variables play the greatest role in setting its value. The model predictions are compared to the observed floc limit trends of Wisconsinan fine grained turbidites from selected cores of the Laurentian Fan and Sohm Abyssal Plain.

Till stratigraphy at the Dead Creek Pb-Zn-quartz float occurrence, southwestern New Brunswick: indications for a local source

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The Dead Creek float occurrence comprises several dozen angular, mineralized quartz boulders concentrated in a surface area of only a few hundred square metres. One, collected by prospector Don Ward in 1994, contained 47% Pb, 7.24% Zn, and 0.028 oz./ton Au. Since the float occurs in association with boulders of Oak Mountain Formation volcanics and Benton Granodiorite (outcropping ~7.5 and 11 km to the north of the occurrence, respectively), the source was considered as most probably local.

To better understand the depositional processes in the area, a pit was hand dug to bedrock adjacent to one of the mineralized boulders. The pit exposed ~1 m of dense, silty basal till containing 4% quartz pebbles, overlying 0.6 m of moderately dense, gravelly deformation till containing 29% quartz or quartz-metasediment pebbles. Three mineralized quartz cobbles and three pyritiferous metasediment cobbles were also recovered from the deformation till. The deformation till is anomalous in Au, As, Cu, Pb, Zn, Co, Sb, Sc, and Eu, and threshold in Ni, Mn, W, Lu, and Sm. The underlying bedrock, vertically-dipping weathered siltstone, is anomalous in Pb, Zn, Sc, and threshold in Co, Cr, and Ni. The presence of mineralized clasts in the deformation till and anomalous Pb and Zn in the bedrock strongly suggest that the mineralized float is of local origin. The probable source area is beneath the large bog immediately to the north-northeast.

Late glacial sedimentary records from three lakes on the North Mountain, northwestern Nova Scotia: preliminary results

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A late-glacial cold period (Younger Dryas) has been recognized throughout Nova Scotia, in part through detailed analysis of pollen assemblages preserved in lake sediment cores. Many of these cores also record a sedimentary record of this oscillation. There is uncertainty at many sites as to whether this shift in sedimentation style is related to the instability of the local soil cover associated with climate deterioration or rejuvenation or regeneration of local ice masses. In northwestern Nova Scotia sedimentary records of late-glacial climate oscillation are sporadic and, in many cases, equivocal. Young Lake, Long Lake, and Sandy Lake in Annapolis County were cored in order to determine if a sedimentary record of the late glacial climate oscillation existed at these sites.

All lakes were cored in winter using the Reasoner coring system; at Young Lake 3 m of continuous sediment core was obtained. All sediment cores were stratified and exhibited a sharp contact between a basal diamict (LOI about 5%) and overlying organic sediment (LOI about 30%). Consistently high LOI values (ca. 35%) are maintained throughout the core above this contact. At the Sandy Lake site the basal diamict was dense, contained angular, striated allochthonous gravel clasts which were suspended in a sandy silt matrix; and 60 cm of basal diamict was recovered. At the Young Lake site the basal diamict itself was similar to that observed at Sandy Lake but also contained thin layers of sorted sand and gravel. At the Long Lake site the diamict contained angular basaltic clasts.

The basal inorganic sediment is interpreted as till, which at Young Lake is overlain by a thin veneer of outwash sediment. The overlying organic sediment was deposited, as vegetation invaded the region following deglaciation. There is no sedimentary evidence at these sites of climate oscillation. These data indicate that either the basal diamict in each core post-dates the climatic oscillation or geological conditions were not suitable for deposition or preservation of a sedimentary record of the oscillation at these sites.

Gravity and magnetic prospecting for massive sulphide deposits

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Sulphide bodies have physical properties that generally contrast sharply with those of host rocks. Thus, they have considerable potential to generate significant anomalies, which are prime targets for exploration. In favourable circumstances, for example, where the bodies are close to the surface, of moderate dimensions and in a relatively homogeneous geological setting, such anomalies will be easily recognizable. Unfavourable conditions can make recognition difficult. Aside from outlining possible ore-related anomalies, gravity and magnetic data play two other important roles in mineral exploration: (1) they can be processed in a variety of ways to produce map images that assist lithological and structural mapping, and (2) they can be analyzed quantitatively to yield size and shape information in the third dimension. The short course will include an overview of the gravity and magnetic techniques in general, and a more specific examination of their roles in massive sulphide exploration. The following topics will be touched upon: map presentation of data, effects of data distribution and contouring interval, Bouguer and isostatic gravity maps, horizontal and vertical gradient maps, shaded relief maps, reduction to the magnetic pole, geological contact mapping, separation of regional and local anomalies, maximum depth formulae, mineralogical controls on gravity and magnetic anomalies, rock densities, magnetic susceptibilities, susceptibility and density mapping, induced and natural remanent magnetizations, gravity-magnetic signatures of ore bodies, estimation of ore reserves, development of magnetite in the ore-forming (massive sulphide) environment, magnetic properties of pyrrhotite, magnetic expression of alteration zones, magnetic signatures of subvolcanic sills. The course will present also an interactive demonstration of a 2½-dimensional gravity-magnetic modelling program, executable on a desktop computer. Gravity and magnetic anomalies will be modelled in real time to outline fundamental steps in developing a crustal section using available constraints, such as surface geology, borehole intersections and rock properties. Aspects of modelling relating to ambiguity and depth of burial will be examined.

Results of gravity and magnetic analyses applied to mineral exploration, Bathurst Mining Camp

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New gravity surveys, some detailed, have been completed within and/or around the Willett, Canoe Landing Lake, Key Anacon and Half Mile Lake properties. On the Willett property, very small positive anomalies (~0.08 mGal amplitude) were defined on deposit-bearing horizons. Because of their small size and possible extraneous gravity effects, their significance in terms of buried sulphide bodies is equivocal. At Canoe Landing Lake property, no positive signatures were identified in gravity traverses crossing the known sulphide deposit and several VLF conductors, suggesting that the deposit thins near-surface and conductors reflect graphitic sources. In an area north and west of the Heath Steele deposit, more than 50% of 40 plus mineral deposits occur on the flanks, or within, magnetic highs related to mafic intrusive and volcanic units. Given the significant role that subvolcanic sills are believed to play in the production of sulphide deposits, such magnetic highs may provide an invaluable guide to exploration.

Chemosynthetic tube worms concentrated around hydrothermal mounds over volcanic rocks, Gays River Formation, basal Windsor Group, Ingonish Island, Cape Breton

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The Gays River Formation outcrops on the north side of Ingonish Island as a 3 m thick dark coloured, thinly stratified, bituminous, gastropodal limestone. It contains metre-wide, single and compound mounds over which surrounding strata are draped. Mound cores consist of popcorn-like, multigenerational, botryoidal biocementstone. Around and over the mounds are concentrations of straight to gently curved, hollow, fossil tube worms. These fossils are up to 3 cm wide and up to 20 cm long, round to slightly compressed, and only partially filled with calcite. Wall structure is well preserved beneath pustular microbial crusts. These tubers are identical in form and stratigraphic position to those we have found on the Cape Breton mainland at Burke Head, Warren Lake and Young Point, in western Newfoundland on the Port au Port Peninsula, and in southern New Brunswick.

The biocementstone mounds are similar in geologic setting, textures, structures, and fauna to calcite tufa mounds in saline lakes of the Great Valley. These localities include Mono and Pyramid lakes in California and Nevada, respectively. There, hot springs feed and concentrate bacteria that precipitate calcite tufa with matching textures and structures to those of the lowest Windsor Group mounds. In all cases, monospecific gastropods graze bacterial mats between the mounds.

The Ingonish Island exposure is the best locality for tube worms and associated mounds yet found in the Gays River Formation of Nova Scotia. The underlying volcanic basement of the island is a possible heat and chemical source for chemosynthesis. The Dalhousie University Ar/Ar lab is attempting to obtain a better radiometric age of the volcanism. An Imperial Oil Limited University Research Grant and the Royal Ontario Museum Foundation funded this research.

Carbonate tufa sheets draping plutonic basement in the basal Windsor Group at St. Anns Bay (Englishtown), Cape Breton

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Limestones of the basal Windsor Group occur along the shore of St. Anns Bay, 5 km north of Englishtown. The limestones drape underlying plutonic basement that has rugged relief. Feldspathic sandstone floors some depressions and contains spheroids of partially decomposed diorite. Attitudes of the base of the sheet closely follow the rugged relief and vary from horizontal to overturned, with some narrow but deep synclines. The carbonate is up to 3 m in thickness and has two main units. The basal unit consists of laminated crystalline calcite with scattered fine grained peloids, and intercalated brachiopod coquina. Structures vary from flat-beds to asymmetric lobes. The upper layer is a marly peloidal laminite similar to earthy facies of the Macumber Formation.

Attitudes appear to be depositional. Lobes in the basal limestone layer resemble laterally linked, cyanobacterial stromatolites. They are not stromatolites because: (1) depositional dips vary from horizontal to overturned; (2) these dips decrease upward to horizontal; (3) axes of lobes strike down-dip; (4) the lobes sag downward from a drawn-out neck; and (5) the texture is crystalline, not detrital, and the calcite crystals in places are perpendicular to the laminae. The sheet resembles flowstone; however, intervening brachiopod coquinas indicate subaqueous precipitation in marine water. The upper limestone unit is typical Macumber, a deep-water precipitate.

The carbonate sheet is analogous to those in mounds within Great Basin saline lakes, as at Pyramid Lake, Nevada. There, hot springs feed and concentrate bacteria that precipitate calcite tufa as vertical to overhanging towers up to 100 m high. The textural varieties of tufa includer a bulbous, laminated crystalline crust, with downward-sagging lobes. All textures and structure are duplicated in basal Windsor mounds.

We conclude that the basal Windsor limestone at Englishtown is the result of bacterial precipitation over a plutonic basement. We thank Drs. Sandra Barr, Peter Giles, and Ms. Lynn Baechler for instigation. An Imperial Oil Limited University Research Grant and the Royal Ontario Museum Foundation funded this research.

Preliminary investigation of the Wedge Mine, NTS 21 O/8E

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The Wedge Mine is located on the north bank of the Nepisiguit River 40 km southwest of the city of Bathurst, NTS 21 O/8E. This Cu-rich massive sulphide deposit had a lifetime production totalling 1,503,500 tonnes grading 2.88% Cu, 1.61% Zn, 0.65% Pb, and 20.6 g/t Ag. Detection and subsequent drilling (total 20,000') of an EM anomaly in 1957-1958 by Cominco resulted in the discovery of the deposit.

Previous interpretations placed this deposit at the contact between felsic volcanic rocks of the Flat Landing Brook Formation (unit OFLB) and sedimentary rocks of the Patrick Brook Formation (unit OP). Results of this study would suggest that the position of this deposit is stratigraphically lower and similar to that of the Brunswick deposits. The rhyolite, quartz-feldspar porphyry (QFP), felsic tuffs and related sedimentary rocks in the footwall should be assigned to the Nepisiguit Falls Formation (ONF). Rhyolite in the deep footwall (ONF or older) are problematic since they display REE profiles similar to unit OFLB but appear to be stratigraphically below rocks assigned to unit ONF. Feldspar-phyric to aphyric rhyolite east of Forty Mile Brook are dissimilar to those in the footwall of the deposit and are tentatively assigned to the Spruce Lake Formation. The hanging wall sequence is in tectonic contact with the massive sulphides and comprises intercalated slate, wacke and mafic volcanic rocks of the Boucher Brook Formation (OBB).

According to Douglas, Cu is concentrated in coarser grained pyrite in the thicker parts of the deposit to the west, and along the north side of the lens adjacent to the rhyolite/QFP contact. Fine grained pyrite and narrow bands of sphalerite and galena are associated with the south side of the ore lens and in the eastern end of the deposit. The Cu to Pb+Zn metal zonation coupled with a discordant stringer-zone, sericitic, silicic, and chloritic alteration on the north side of the deposit suggest a southward-younging sequence.

The structural geology in the area of the Wedge deposit is complicated. The earliest fabric, an S_0/S_1 layer parallel foliation, distinguished by differential layering, was produced during D_1 thrusting. The second deformation (D_2) is responsible for the distribution of rock units and is characterized by the development of tight, upright to east-plunging F_2 folds. The F_2 folding event reoriented earlier S_0/S_1 so that it strikes 060°-075° and is vertical to steeply north-dipping at surface. At the 300' level the structure becomes horizontal and then dips 065° south. As the D_2 event progressed, thrusting brought rhyolite of the Spruce Lake Formation over the Footwall sequence from the east. Subsequent oblique movement along a northeast-striking fault caused dextral south-side-down offset of the orebody.

Post-rhyolite shale-hosted massive sulphide deposits in the central Bathurst Camp, northern New Brunswick

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The central part of the Bathurst Camp contains several shale-hosted, massive sulphide deposits including Willett, Canoe Landing Lake, and the Wedge Mine. These deposits occur in Tetagouche Group rocks and are hosted by black shales of the Middle to Late Ordovician Boucher Brook Formation, with felsic volcanic rocks in the immediate to deep footwall. The quartz- to quartz-feldspar-phyric rhyolites in the footwall belong to either the Nepisiguit Falls or Spruce Lake formations. These felsic volcanic rocks have lower HFSE contents and steeper LREE/HREE profiles than rhyolites of the Flat Landing Brook Formation that occur higher in the camp stratigraphy. The black shales are compositionally similar to Boucher Brook black shales elsewhere in the camp with high Mn, Fe, Fe/Mn, V and Co, reflecting the moderately oxidized environment in which they formed and a volcanic allochemical source based on immobile element contents.

Remote sensing and GIS for terrane boundary assessment

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The Meguma and Avalon terrane boundary is defined by the Minas Fault system along which the St. Mary's Basin resides. The basin is composed of Horton Group sedimentary rocks characteristic of a strike-slip basin. The southern flank of the basin is in fault contact to the east and rests unconformably over the Meguma Terrane in the west. The Cobequid-Chedabucto fault system defines the northern boundary of the basin with the Avalon Terrane. An assessment of the basin and terrane boundary relationships has been carried out for the last two years utilizing field mapping and various digital datasets including: satellite imagery (optical and radar), geophysical (elevation, magnetics, radiometrics and gravity) and geology maps of various scales. The scale of the digital geophysical datasets for the region is ideal for terrane evaluation purposes. The variety of images provide insights into the tectonic history of different levels of the crust.

Hybrid "image maps" were used in combination with field observations to interpret the tectonic history of the terrane boundary. Results of this interpretation include the Late Paleozoic collision of the Meguma Terrane with Avalon, followed by the initiation and dextral motion on the Cobequid-Chedabucto fault system (middle Carboniferous). The northern section of the basin was tectonically removed with continued east-west dextral motion, and may occur north of Guysborough Harbour. Sinistral motion on northwest-trending strike-slip faults in the Meguma Terrane resulted in a "mega-kink" in the boundary faults causing a restraining bend to form. With continued dextral motion between Meguma and Avalon a positive flower structure developed in the Guysborough area. Two northeast-trending lineaments are evident at the western end of the basin in the Salmon and Stewiacke River area. These lineaments parallel an axial planar cleavage trace and appear to rotate to a north-south trend in their southern limits. The rotation of these structures are interpreted as interference patterns associated with faulting in the Shubenacadie and Kennecook basins. A set of northwest-trending fractures occur throughout the basin and are interpreted to be Mesozoic transfer faults related to the opening of the Atlantic Ocean.

Geology education in grades 1-12: you reap what you sow

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The shrinking number of job opportunities for geologists in the last decade has been the major reason for the negative attitude pervading the profession and for reduced involvement in extracurricular activities. One possible spinoff has been the relatively minor role of the Atlantic Geoscience Society in providing support to teachers. There have been some worthy projects and some committed individuals but the overall impact has not been as great as originally perceived. Should we let matters continue in this direction, perhaps with the continued low key production of highway maps, videos and video guides? Or do we need to do more?

Here are some of the initiatives that seem to hold promise if we wish to enhance the role of geology in general education. Several geologists are becoming directly involved with education in our schools by working with the teachers. This involvement may be through classroom visits, talks,

demonstrations, or field trips. It may be through organization of workshops for teachers. It may be through the development of Internet and WWW services. Or it may be the unique Resident Scientist program.

Whatever we do demands familiarity with existing curricula and willingness to provide support when asked. There is a need to encourage students to continue their scientific education, to appreciate the role of the earth sciences in everyday life and to be better equipped to address environmental concerns. By becoming involved, and passing on the process on some of our knowledge, we can rekindle our own enthusiasm and make geology as exciting to the children as it is to us. We should share our experiences so that we can benefit from our successes and learn from our failures. But, most importantly, let's reverse the charge on our negative attitudes so that we have a positive and lasting effect on geological education in schools.

Scanning electron microscope studies of dinoflagellates: an illuminating experience

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The increasingly sophisticated understanding of dinoflagellate cyst morphology has led to a revolution in the phylogenetic classification of this group of organisms. Elucidation of some of the subtle variations using the light microscope is becoming increasingly difficult. Fortunately, the Scanning Electron Microscope (SEM) is providing some of the answers. The advantage of the SEM is that it allows instant differentiation of the two surfaces of a dinoflagellate cyst, so that previously unsuspected tabulations are now revealed. An example is the species *Samlandia chlamydophora*, whose tabulation can be conclusively demonstrated as cribroperidinioidean, a subfamily of the gonyaulacaleans. Other studies are providing new insights into details of surface ornamentation and the excystment aperture, commonly termed the archeopyle. SEM studies of one group of Paleogene dinoflagellates, the wetzelielloideans, has helped in the development of a morphostratigraphy divorced from the previous subjective classification. This approach provides more reliable, detailed biostratigraphic control in the Eocene-Oligocene and, hence, leads to a more concise delineation of the sequence stratigraphy of offshore eastern Canada. Thus, rather than being a piece of esoteric equipment, the SEM is becoming an essential asset in the continuing utilization of dinoflagellates for detailed biostratigraphic and palaeoecological interpretations.

Framboidal copper sulphides associated with bitumen: implications to the genesis of the El Soldado copper deposit, Chile

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Bitumen (solid petroleum) has been recognized in the ores from the Cretaceous El Soldado copper deposit, central Chile. In association with this bitumen, copper ores contain abundant sulphide framboidal and spheroidal aggregates made of bornite-chalcocite-chalcopyrite, as well as the common pyrite. Paragenetic relationships suggest at least two generations of primary spheroidal sulphide aggregates, one pre-ore and another related to copper mineralization, which also occurred with the pseudomorphic replacement of pre-ore spheroids. Successive stages of development of these spheroidal aggregates lead to the formation of massive copper-sulphide ore.

Textural evidence suggests three separate stages of sulphide formation: (1) initial disseminated pyrite and arsenopyrite was formed at the time of deposition of the host volcanic sequence; (2) burial of the volcanic sequence was associated with the formation of early (north-south) faults followed by oil migration into the fault zones and permeable horizons: this second stage was associated with biological and thermal degradation of petroleum and the formation of framboidal pyrite, sphalerite and chalcopyrite; and (3) early (north-south) fault reactivation and development of new (northeast-southwest) faults provided a focus for copper mineralization; bitumen was solid when copper mineralization occurred, and was veined and replaced by copper sulphides.

Copper mineralization occurred after destruction (biological-thermal) of a pre-existing petroleum reservoir. It is suggested that the stage of sulphide formation associated with the petroleum (now preserved as bitumen) provided a reductant and a source of S which controlled the later episode of copper mineralization.

Geochemistry and petrogenesis of felsic volcanic rocks from contrasting structural/stratigraphic settings in the Big Bald Mountain area, Bathurst Mining Camp

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The east-west-trending Moose Lake-Tomogonops (MLT) shear zone divides the Bathurst Mining Camp into northern and southern structural and stratigraphic domains in the Big Bald Mountain area. In each domain, felsic volcanic rocks of the Tetagouche Group overlie dark grey siltstones and shales of the Miramichi Group, and are overlain by alkalic basalts, shales and wackes of the Boucher Brook Formation. In the north, Tetagouche felsic volcanic rocks are assigned to the Nepisiguit Falls and Flat Landing Brook formations; in the south, the Clearwater Stream and Sevogle River formations are the respective stratigraphic equivalents.

The Flat Landing Brook Formation is chemically distinguished from the Nepisiguit Falls Formation by greater abundances of high-field-strength elements (HFSE) and rare-earth elements (REE), as well as by steeper slopes (higher La/Yb ratios) and a less prominent negative Eu anomaly (higher Eu/Sm ratios) on REE distribution profiles. However, considerable variation exists within the Flat Landing Brook Formation, and some compositional overlap with the Nepisiguit Falls Formation is locally evident. HFSE ratios of the two units suggest a common lower crustal source, although the higher HFSE and REE abundances in the Flat Landing Brook Formation likely reflect a second stage of partial melting. The crystal-rich pyroclastic rocks of the Nepisiguit Falls Formation are interpreted to have been generated under lower temperatures and higher water fugacities than the crystal-poor lavas of the Flat Landing Brook Formation.

South of the MLT Fault, the Clearwater Stream Formation is dominantly dacitic, whereas the overlying Sevogle River Formation is dominantly rhyolitic; again, some compositional overlap is noted among samples collected near the interpreted contact. Despite differences in major element chemistry, HFSE and REE abundances in the two units are comparable, and, in general, are higher than in felsic units north of the MLT Fault. Trace-element ratios are also very similar except for those that involve Ti, V, Sc, or Cr; the greater abundance of these elements in the Clearwater Stream Formation reflect its more intermediate composition. On REE distribution profiles, the Clearwater Stream Formation shows higher La/Yb and Eu/Sm ratios than the younger Sevogle River Formation (in contrast with REE profiles of felsic units north of the MLT Fault, where the older rocks (Nepisiguit Falls Formation) feature the lower La/Yb and Eu/Sm ratios).

REE systematics suggest that the Sevogle River Formation may be related to the Clearwater Stream Formation by fractional crystallization. Models that attempt to derive major-element Sevogle River geochemistry by fractional crystallization of a Clearwater Stream-like parent must take into account their similar trace element contents; the simplest scenario involves tapping of a Clearwater Stream-type magma before significant differentiation occurred, followed by a prolonged period of fractionation, producing a zoned chamber with an Sevogle River-type melt at the top.

Fission track analysis applied to mineral deposits and exploration

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Apatite fission track (FT) analysis is a rock-dating technique that, in addition to an age, provides a time-temperature cooling history for the rocks sampled. The technique is particularly sensitive and well-calibrated between 60°C and 120°C, which coincides with the range of temperatures of carbonate hosted base metal deposits, some epithermal precious metal deposits, active geothermal fields, and thermal halos around unexposed intrusions and salt structures. This is also the domain of rocks approaching the surface of the earth during exhumation due to tectonic processes such as crustal thickening, thrusting, block faulting and continental rifting, or to lowering of the base level. Fission track dating of minerals with suitable uranium in solid solution, such as zircon (blocking temperature ca. 200°C), epidote (ca. 200-400°C), titanite (ca. 300°C), promise applications in the realm of epithermal to mesothermal ore deposits.

The Gays River zinc-lead deposit, Nova Scotia, and similar deposits, hosted in Mississippian carbonates, were formed in the late Pennsylvanian-Early Permian during rapid basin dewatering of hot overpressured fluids (ca. 300 Ma), coinciding with FT dates on zircon, but apatite FT dates are much younger (ca. 200 Ma) representing post-ore exhumation through the 100°C isotherm in the Mesozoic.

In the Central Andes, apatite FT analyses in the giant Eocene-Oligocene Chuquicamata porphyry copper deposit and surrounding basement rocks indicate that the mineralized porphyries were intruded immediately following a period of rapid exhumation, that cooling of the intrusions was fairly rapid indicating shallow emplacement, and that post-ore exhumation proceeded at a pace conducive to optimal supergene enrichment and concentration of exotic copper ores.

It is probable that northern Labrador has seen significant post-Precambrian exhumation into the Mesozoic, possibly related to rifting of the margin. Apatite FT analysis will be used to test whether there has been differential uplift and exhumation in distinct tectonic blocks. Kimberlite or lamproite complexes may exist in Labrador; for the diamondiferous tops of these complexes to be preserved, erosion must be limited after their emplacement. If the uplands erosion surface (and gossans over sulphide bodies) developed during deep lateritic weathering in the mid-Cretaceous warm event, as we propose, any younger kimberlite/lamproite complexes have a chance of being preserved.