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ABSTRACTS

1995 COLLOQUIUM AND ANNUAL GENERAL MEETING

ANTIGONISH, NOVA SCOTIA

The 1995 Colloquium of the Atlantic Geoscience Society was held in Antigonish, Nova Scotia, on February 3 to 4, 1995. On behalf of the Society, we thank Alan Anderson, Mike Melchin, Brendan Murphy, and all others involved in the organization of this excellent meeting.

In the following pages we publish the abstracts of talks and poster sessions given at the Colloquium which included special sessions on "The Geological Evolution of the Magdalen Basin: A Natmap Project" and "Energy and Environmental Research in the Atlantic Provinces", as well as contributions of a more general aspect.

The Editors

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A study of carbonate rocks from the late Visean to Namurian Mabou Group, Cape Breton Island, Nova Scotia

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The Mabou Group, attaining a maximum thickness of 7620 m, lies conformably above the marine Windsor Group and unconformably below the fluviatile Cumberland Group. It comprises a lower grey lacustrine facies and an upper red fluviatile facies. The grey lacustrine facies consists predominantly of grey siltstones and shales with interbedded sandstones, gypsum, and carbonate rocks. The red fluviatile facies contains red with minor green and grey sandstones, siltstones, shales, and pedogenic carbonates. Together these rocks record lacustrine and marginal lacustrine sedimentation in an arid to semi-arid environment. Strata of the Mabou Group, previously assigned to the Canso Group, can be traced throughout the western portion of Cape Breton Island and within the Sydney and Loch Lomond basins of eastern Cape Breton Island. From west to east there appears to be a decrease in the overall thickness of the Mabou Group, notably the red facies, although the basic lithology remains the same.

Carbonate rocks, although not plentiful, are important constituents of the lower Mabou Group. The types of carbonate rocks present include laminated lime boundstones (stromatolites), floatstones, and grainstones. The stromatolites occur predominantly as planar laminated stratiform types and as laterally linked hemispheroids, some having a third order crenate microstructure. Flat-pebble conglomerates, or floatstones, containing fragments of neighbouring stromatolites, are often found associated with the stromatolites. Grainstones present contain ooids, serpulids, coated grains, and algal debris, or stromatolite fragments, as major constituents. The carbonate rocks and their relationship with associated lithofacies of the lower Mabou Group provide important indicators suggesting deposition in a shallow, agitated, subaqueous environment undergoing periods of subaerial exposure. Due to lateral discontinuity of the carbonate rocks, they are not good tools for local lithostratigraphic correlation. Their ubiquitous presence in the lower part of the Mabou Group is, however, a useful indicator of stratigraphic position.

Devonian - Carboniferous volcanic and gabbroic rocks in Guysborough County and Cape Breton Island, Nova Scotia

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On-going studies of Devonian to Carboniferous volcanic and associated sedimentary and gabbroic rocks in the Guysborough area of northern mainland Nova Scotia and in central and southern Cape Breton Island are leading to better understanding of their distribution and age, and hence (ultimately) their regional significance. In Guysborough County, basalt and minor rhyolite of the Sunnyville Formation are overlain conformably(?) by red conglomerate and sandstone of the Glenkeen Formation, and quartz wacke and siltstone members of the Clam Harbour River Formation. A mid-Devonian age for these units is indicated by a U-Pb (zircon) date of 389 ± 2 Ma from rhyolite in the Sunnyville Formation. In contrast, a rhyolite flow located near the top of the Fisset Brook Formation in the Gillanders Mountain area east of Lake Ainslie in Cape Breton Island has yielded a U-Pb (zircon) age of *ca.* 375 Ma, indicating that the Fisset Brook Formation (at least in that area) is of mid- to late Devonian age, and hence significantly younger than the Sunnyville Formation. In contrast to these Devonian volcanic rocks, the St. Peters Canal gabbro has yielded an early Carboniferous U-Pb (zircon and baddeleyite) age of 339 ± 2 Ma. This work resolves long-standing uncertainty about the age of the St. Peters gabbros, previous interpretations of which ranged from Precambrian to Mesozoic. Similar gabbros in the Creignish Hills and Guysborough areas may also be of Carboniferous age. All of these igneous units have petrological features consistent with origin in a within-plate continental extensional setting.

Re-mapping of the McAdam Lake Formation in the Boisdale Peninsula shows that, contrary to previous reports, the formation lacks volcanic rocks, but has been intruded by rare fine-grained hornblende-bearing lamproite (spessartite) dykes and sills of uncertain age.

The earth sciences: new resources for teachers

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Specialization in the sciences and the rapidity of technical development is making it increasingly difficult for educators to be aware of the latest concepts and resources. To encourage updates in the earth sciences, the EdGeo Committee of the Canadian Geoscience Council funds workshops for elementary and junior high-school teachers. The motivation, organization and hosting of a workshop, however, is the responsibility of regional groups. EdGeo workshops in Nova Scotia have had an intermittent history, the most recent prior to 1994 being in 1983. This situation is changing, as witnessed by the success of the workshop, "The Earth Sciences: New Resources for Teachers", held in Halifax-Dartmouth, last August 21 and 22. This was hosted by the Atlantic Geoscience Society EdGeo Committee. The main intent of the workshop was to update teachers on such recent developments as: the Scientists and Innovators in the Schools program; the Nova Scotia Museum geology kits, including the new Mining Kit; "Earth Science Resources", a project of the Atlantic Geoscience Society Education Committee; rock kits (each teacher was given one); Internet services such as "Geology in the Classroom"; and the Atlantic Geoscience Society video series and guides. An essential part of the workshop was the half-day field trip. Because of the encouraging response of the teachers attending, the Committee plans similar workshops throughout Nova Scotia, with the next scheduled for Sydney in August 1995. Each workshop will have a local flavour, especially the field trip. And if these workshops are also successful, we intend to explore new directions, both in subject matter and participation.

The Fundy Basin story

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

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

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

Geophysical and outcrop evidence for extensive Carboniferous salt tectonics, Gulf of St. George, Nova Scotia

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Recent re-examination of geophysical data from the Gulf of St. George and the west coast of Cape Breton has revealed the presence of spectacular salt structures, ranging from embryonic salt pillows to salt walls and diapirs. These salt structures can be traced from seismic sections to onshore outcrops. Salt diapirs and their associated deformation of Carboniferous strata are exposed in coastal outcrops and can be traced inland from drill cores and as karst topography. The geometry and deformation of syn-halokinetic sediments suggests that salt withdrawal and subsequent diapirism was initiated during the early Westphalian (Port Hood Formation equivalent) and continued until the halokinesis had a fundamental effect upon the development of the sedimentary architecture of Carboniferous sediments within the Gulf of St. George and the west coast of Cape Breton.

Trace element geochemistry and environmental implications in sediments from Halifax Harbour

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Contamination of surficial sediments in Halifax Harbour is evident in the distribution of anomalous metal concentrations (Cu, Zn, Pb, Hg, Cd), especially near major sewer outfalls, industrial sites, and old landfill sites. More than 50% of the total Cu, Pb and Zn in the sediments is potentially reactive as reducible or oxidizable metal. Five types of sediments have been identified based on geochemical characteristics; each type of sediment is indicative of specific sources of contamination such as primary contamination from sewers, secondary contamination from landfill sites, surface drainage, diagenetic remobilization, and biogenetic carbonates. Contaminants have been accumulating in sediments of Halifax Harbour for more than 100 years, with maximum concentrations of most metals being obtained in the decades between 1950 and 1980. Enrichments by metal contamination over background is about three times for Cu and Zn, ten times for Hg, and twenty times for Pb. Historical trends in changing contamination reflect changes in industrial activity, urban growth, changes in the use of metals in paints, domestic and industrial chemicals, and in the use of combustion fuels.

Tetrapod trackways in a fossil *Walchia* forest: a new discovery from the early Permian of Nova Scotia

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The discovery by Cory and Howard van Allen of an exceptional *Walchia* forest tetrapod habitat at Brule, in the Cumberland Basin of Nova Scotia, opens a window on early Permian ecology. The 500 m^2 site occurs within horizontal redbeds of the Cape John Formation, Pictou Group. The monotypic, mixed age stand of the conifer *Walchia* comprises casts of 41 trees *in situ*, foliar litter, cones and prostrate trees up to 20 m long, some with lateral branches. This is the first report of *Walchia* from Nova Scotia. The site provides a rare opportunity to reconstruct *Walchia* forest density and tetrapod ecology. At least 6 tetrapod ichnogenera are represented, provisionally ascribed to pelycosaurs, cotylosaurs and possibly, lepidosaurs; trackway analysis is in progress. At least 7 subparallel trackways (range = 25), consistent either with seymouriamorphs (cf. *Amphisauropus latus*) or edaphosauriomorphs (cf. *Ichniotherium cottae*), occur on three successive bedding surfaces, indicative of non-random passage of the Brule tetrapods along a preferred route and suggestive of group behaviour. Herding, unknown to us in the Paleozoic, can neither be conclusively demonstrated nor ruled out, although we note that parallel trackways on a given bedding surface are spatially separated and not overprinted. Sedimentological evidence suggests that these trackways were imprinted over a short time interval on at least two occasions. The tracks are preserved in successive, mud-cracked, thin (5-10 mm) red silty sandstone beds with mud drapes, belying ephemeral (?seasonal) floods inferred to have been generated under a semiarid climate by the developing megamonsoon of Permian Pangea. Replicating the Brule trackways has called for a measure of ingenuity, given their problematic location in a briefly exposed intertidal zone.

Geological mapping in the Stellarton Gap (NTS 11E/7,9,10,15), a status report

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The Stellarton Gap is underlain mainly by Carboniferous rocks. Stratigraphic units vary markedly in thickness across the area. In the north they are gently folded and unmetamorphosed. In the south the terrain is divided into blocks in a broadly east-west dextral strike-slip fault system. Deformation and induration in the blocks is unrelated to age and very varied.

The Windsor Group apart, Devono-Carboniferous rocks in the gap are non-marine. The Fountain Lake, McAras Brook, Falls, Hollow and Claremont formations formed in alluvial fans adjacent to basement source highlands. The red sandstone to conglomeratic New Glasgow Formation constitutes an upward-coarsening, calcrete-bearing alluvial fan sequence related to strike-slip faulting. Clast size trends indicate northward transport. Possibly correlative conglomerate south of the Hollow fault may have been offset to the west by dextral fault movement. The more extensive sandy lower member is traceable northeastward to the centre of Merigomish Harbour, northward to Pictou Island in drill core and northwestward to the River John at longitude 63°2.5' and latitude 45°41.5'. The Canso Group and Parrsboro Formation are mainly drab and lacustrine.

Late Devonian to early Carboniferous climate in Nova Scotia was tropical and relatively dry (calcrete, evaporites). Earliest evidence of monsoonal conditions (vertisols) was found in Namurian rocks. The Westphalian began with a pronounced wet phase, succeeded by seasonal climate of varied dryness. Evidence includes fluvial sandstones of the early Westphalian Boss Point and late Westphalian Malagash formations. In the former, channel and overbank deposits are drab and organic-rich. The latter is distinguished by generally red overbank deposits with vertisols and calcrete. Regionally, the wet phase produced leached soils and widespread drab, organic-rich, pyritic sandstone and quartz-pebble conglomerate (Boss Point, Silver Mine, Port Hood formations) which host a number of base metal deposits and prospects with metal type related to the underlying unit; e.g., Dorchester (Cu) on red, mafic-bearing conglomerate, Meadowville (Pb) on granitic conglomerate, Terra Nova (Zn) on hornblende granodiorite and Yava (Pb) on lead-rich felsic porphyry.

Late Devonian mafic-felsic magmatism in the Meguma Zone

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The Meguma Zone of southern Nova Scotia is the most outboard lithotectonic terrane of the northeastern Appalachians. Peraluminous granitoid plutons dominate a late Devonian episode of magmatic activity, but minor mafic intrusive bodies of roughly the same age also occur in the Meguma Terrane. We propose to classify the granitoid plutons as: (i) Central Plutons, including the South Mountain Batholith, which are *ca.* 372 my old, late- to post-tectonic, predominantly unfoliated, emplaced into low-grade metamorphic host rocks, generally not spatially associated with mafic intrusions, exclusively peraluminous with polymetallic Sn-W-Mo-U greisen- and vein-dominated mineral deposits, and entirely crustally-derived (sub-Meguma Group source rocks and Meguma Group contamination), that probably owe their origin to crustal thickening associated with the collision of the Meguma terrane against the Avalon terrane; and (ii) Peripheral Plutons, at the northeastern and southwestern extremities of the Meguma Zone, which may be slightly older (≥376 my old), late-tectonic, moderately foliated, emplaced into higher-grade metamorphic host rocks, spatially associated with late Devonian mafic intrusions (LDMIs), mostly peraluminous with only limited Be-pegmatite mineralization, and of mixed derivation (sub-Meguma Group source rocks and mantle-derived mafic magmas), that probably owe their origin to the lower to mid-crustal emplacement of subduction-related mafic magmas intruded prior to the final emplacement of the Meguma terrane.

This integration and synthesis of the field relations, geochronology, petrology, geochemistry, and mineralization for the felsic and mafic magmatism represents a new petrogenetic and tectonic paradigm for the Meguma Zone in the late Devonian.

Chemical composition of detrital apatite as an indicator of sedimentary provenance and as a modifier of fission track age: Sverdrup Basin, Canadian Arctic archipelago

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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-Paleozoic and late Paleozoic to early Cenozoic, and deformed and uplifted by the Ellesmerian and Eurekan orogenies. Detrital apatite samples have been obtained from nine wells and eight field locations representing both of the above sequences. The analysis of fission tracks in apatite grains can yield information on burial, cooling and exhumation events in sedimentary rocks. Fission track data from the southern Sverdrup Basin constrain the cooling history and exhumation events in the Triassic in the southern Sverdrup Basin and in the Tertiary in the northern 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 affects both the thermal annealing of fission tracks, and their etching behavior, therefore affecting the fission track models for cooling and exhumation that can be computed from them; and (2) The composition of detrital apatite, including the contents of halogens and REE, may characterize certain suites of igneous and metamorphic rocks, thus providing provenance data for the sediments in the basin.

Analysis of landsat thematic mapper imagery of the Framboise/Mira region, Cape Breton Island, Nova Scotia: drumlin and till classification and distribution

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Both drumlin orientation and till distribution are important components in drift prospecting programs. Landsat Thematic Mapper (TM) imagery (bands 3, 4 and 7) was used to delineate the distribution and form of drumlins in the Framboise/ Mira Map sheet, Cape Breton Island, Nova Scotia. A 400 km^2 drumlin field located west of the Mira River contains spindle, parabolic and transverse asymmetrical forms. These features are best resolved on Band 4 TM imagery (range of 0.76 - 0.9 μm) in which the contrast has been stretched. The imagery was obtained on September 9, 1994 following a summer of significantly reduced rainfall. The high reflectance of the drumlins with respect to the surrounding land surface may be due to the relatively low soil moisture content and vegetation stress on these positive relief features.

The same TM imagery also shows promise for delineating different till types. Both a thick silty till and a thinner sandy till occur at the study site. The silty till exhibits higher reflectance values than the sandy till that can be enhanced with contrast stretching. These relationships are most likely a result of differences in the vegetation cover, vegetation stress and the moisture content of the two tills. Classifications produced from the TM imagery correlate well with previously published till distribution maps.

Gaining knowledge, changing perceptions and creating awareness - the results of earth science education

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All of us in the field of earth science would like to be appreciated for the value that we bring to society. After all it is we who investigate the earth, describe earth history and find the needed mineral resources for use in our society. Geologists know about the importance of their work; others, such as decision makers in government and the private sector, planners, the public, and schools, do not seem to be aware of the mutiple uses of geological information. Some governments and societies are trying to bridge this gap of understanding by helping people to gain knowledge, change their perceptions and create more awareness of earth science and its uses. Such groups as the Atlantic Geoscience Society Education Committee, Scientists and Innovators in the Schools (SITS) and the Nova Scotia Musuem and Department of Natural Resources have created active programs to facilitate change. Much of this energy targets schools and especially teachers. With fewer resources, schools need more help than ever. Earth scientists, their societies, and other NGO groups such as SITS, can form effective partnerships with government to promote knowledge about and awareness of earth science. Helping people change their perceptions, gain knowledge and create awareness about earth science helps our science and society.

Occurrence and mobility of petroleum hydrocarbons in groundwater

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The investigation and design of efficient site remediation measures for petroleum contaminated sites depends on thorough site characterization with particular attention to spatial variation in geology and hydraulic conductivity, and careful consideration of the physical and chemical characteristics of both the site geology, and the chemical compounds of concern.

This presentation briefly outlines the procedures involved in contaminated site characterization, and factors influencing the distribution and mobility of petroleum hydrocarbons in the groundwater system. A general overview of the partitioning, fate and mobility of petroleum hydrocarbons in the subsurface is presented. Methods and limitations for estimating free product and contaminated soil volumes, monitoring clean-up progress, and groundwater sampling will be briefly addressed.

Acid drainage from black slates of the Halifax Formation: is there need for further work?

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Sulphidic, black slates of the Halifax Formation have been recognized for some time as a source for acid drainage in parts of Nova Scotia. At the Halifax International Airport (HIA), disruption of the black slates during construction activities has resulted in high acid run off causing fish kills and a decrease in water quality in nearby streams.

In the past, acid production from the black slates has been attributed to pyrite. However, our studies indicate pyrrhotite is the predominant sulphide mineral at the HIA whereas pyrite and marcasite are less abundant. The predominance of pyrrhotite also has been confirmed in other areas of Nova Scotia underlain by the Halifax Formation. Oxidation tests on mineral samples from the HIA concur with results from the literature in that the oxidation rate of pyrrhotite is substantially faster than pyrite (with and without the presence of *Thiobacillus* bacteria). Therefore, initial short-term acid drainage may be higher than expected when pyrrhotite-rich, rather than pyrite-rich slate, is disturbed. Obviously then, it is important to outline pyrrhotite-rich areas within the Halifax Formation, an aspect that has been overlooked in the past.

Since pyrrhotite is a magnetic mineral, we are using magnetic susceptibility of rocks to assess the relative potential for acid drainage. Detailed magnetic susceptibility measurements on drill core, field samples and powders have been conducted and the data show a useful correlation with chemical analyses and mineralogical observations.

Geology of the Slacks Lake area, Bathurst Camp, New Brunswick

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The Slacks Lake area is underlain by sedimentary, volcanic and hypabyssal intrusive rocks of the Ordovician Tetagouche Group, and by granitoid rocks of the Siluro-Devonian Miramichi and North Pole Stream plutons. Stratigraphic mapping is complicated by numerous sub-parallel faults and associated splays of the broad Pringle Brook-Moose Lake dextral fault system, which transects the survey area in an east-west direction and dissects the central part of the area into a series of narrow slices. This fault system represents a major tectonic break, as Tetagouche Group stratigraphic nomenclature defined for the northern part of the Bathurst Camp is not, in some cases, approriate south of the fault zone. Hence, rocks to the north of the Pringle Brook-Moose Lake fault system can be assigned (from oldest to youngest) to the Patrick Brook, Nepisiguit Falls, Flat Landing Brook, and Boucher Brook formations, whereas south of the fault zone, the Clearwater Stream Formation and Stony Brook volcano-plutonic complex have been identified as the stratigraphic equivalents of the Nepisiguit Falls and Flat Landing Brook formations, respectively.

The Patrick Brook Formation consists of dark grey shales, slaty siltstones, and fine-grained quartzites. The Nepisiguit Falls Formation consists of light greyish green to greyish brown quartz-feldspar-phyric felsic volcanic rocks that, compared to most Nepisiguit Falls Formation rocks elsewhere, are notably crystal-poor, and commonly resemble fine-grained flows. The Flat Landing Brook Formation comprises light greyish green to greyish brown, typically feldspar-phyric felsic volcanic flows and related flow-margin breccias (hyaloclastites). The Clearwater Stream Formation consists of medium greyish green, chlorite and/or sericite-rich, schistose, feldspar-phyric, felsic pyroclastic rocks. The Stony Brook felsic complex includes: light greyish green to greyish pink, aphyric or feldspar-phyric, massive to schistose felsic volcanic rocks; greyish pink to greyish brown, massive, porphyritic hypabyssal intrusive rocks typically containing large euhedral to subhedral phenocrysts of K-feldspar; and minor dark grey shale. The Boucher Brook Formation consists mainly of dark green mafic volcanic rocks, with lesser sedimentary rocks and felsic hypabyssal intrusions. Sedimentary rocks include dark grey shale and siltstone, black carbonaceous shales and cherts, and (intercalated with the mafic volcanic rocks) local thin beds of dark grey ironstone and red-maroon shale or chert. Local olive green, massive, trachytic, hypabyssal intrusive rocks in the east-central part of the area have also been assigned to the Boucher Brook Formation.

Late Devonian and Carboniferous history of western Cape Breton Island

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Post-Acadian sedimentation in western Cape Breton Island records, in a single map-area, many tectono-stratigraphic features typical of the onshore Maritimes Basin. Bimodal volcanic rocks of the latest Devonian Fisset Brook Formation record initial deposition in a continental rift setting. Succeeding sedimentary rocks of the Horton Group (Tournaisian) were also deposited in a rift environment but are more laterally extensive than the Fisset Brook volcanic rocks. The early Visean was a period of local uplift with consequent tilting of Horton strata, and has no sedimentary record in western Cape Breton. Marine invasion of the area during the middle and late Visean resulted in widespread deposition of cyclic marine and non-marine rocks of the Windsor Group which pass transitionally upwards into fine-grained lacustrine and fluviatile siliciclastics of the Mabou Group. The Mabou ranges in age from late Visean to Namurian C. Previous workers have suggested that the change in depositional and tectonic setting between late Devonian and late Visean time represents a fundamental change in Maritimes Basin architecture. Movement on the Margaree Shear Zone, an extensional detachment cutting the Fisset Brook Formation, may explain the more regional Visean and Namurian basin development following an initial (and independent ?) rifting event in the late Devonian and Tournaisian. Within the western Cape Breton map-area, the Port Hood Formation (basal Cumberland Group) lies unconformably on the Mabou Group, but may also overly latest Mabou strata without apparent stratigraphic omission. Strata of the Windsor and Mabou groups and Port Hood Formation were folded into upright and/or south-verging structures prior to deposition of the Inverness Formation. The latter (upper Cumberland Group) is unconformable on all older rock units, overstepping Carboniferous rocks to lie directly on the pre-Carboniferous of the Mabou Highlands. The Cumberland Group thus records two additional phases of basin subsidence, separated by an episode of significant fold deformation, uplift and erosion.

Down-to-the-basin movement on the Ainslie Detachment provides a plausible mechanism to accommodate the early Westphalian phase of Carboniferous subsidence in western Cape Breton. The detachment model fails, however, to rationalize the mid-Cumberland Group unconformity which clearly postdates the Ainslie Detachment. The latter unconformity, and that separating the Horton and Windsor groups can be recognized in widely separated areas such as the Horton-Windsor type-area and in the Sydney Basin. Local fault movements cannot explain these major tectono-stratigraphic features.

Thermoluminescence dating of ceramic technology at St. Croix, Nova Scotia

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We report here the first direct dates for six ceramic artifacts recovered from BfDa-1, a prehistoric archaeological site located in Hants County, southcentral Nova Scotia. Thanks to excavations in 1990 and 1993, this shallow site has produced sherd fragments from which over 100 vessels have been inferred. Normally, local and regional culture histories are interpreted on the basis of existing chronological sequences which are constructed on the basis of design changes in prehistoric ceramics. Such stylistic chronologies are underpinned by a limited number of absolute radiocarbon dates. The thermoluminescence (TL) technique is much preferred over relative typological dating for ceramic chronology. First, it provides a date for the firing of each vessel. Secondly, it may allow the discovery and chronological attribution of local stylistic variants or rapid stylistic changes which may not be recognizable in an existing typology. The six sherds from the St. Croix site yielded absolute ages of 1.6 ± 0.2 ka to 3.1 ± 0.3 ka. They thus confirm the interpretation, based on stylistic attributes, that the site's occupation period spanned the greater portion of the Ceramic period (*ca.* 1050 B.C. to 1500 A.D.).

Transpressive D_2 thrusting in the Hartts Lake-Murray Brook area, Bathurst Camp, northern New Brunswick

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The Hartts Lake-Murray Brook area, located in the northwest part of the Bathurst Camp, is underlain by sedimentary and volcanic rocks of the Tetagouche and Miramichi groups and intruded by the syn-tectonic Popple Depot granite. The northwest-trending Forty Four Mile Brook Thrust has been recognized as a major tectonic contact that subdivides the area into eastern and western structural domains. East of the thrust, steeply dipping felsic volcanic rocks of the Flat Landing Brook Formation and mafic volcanic and sedimentary rocks of the Boucher Brook Formation are folded into tight, north/south-trending, doubly plunging F_2 folds. Quartz-feldspar volcaniclastic rocks of the Nepisiguit Falls Formation occur in the far northeastern part of the map area where a thin sedimentary unit marks the contact with the overlying Flat Landing Brook Formation. The area west of the thrust is characterized by a well-developed flat cleavage (S_3) and recumbent folding (flat belt). In this area, interference between F_2, F_3 and F_4 folds has created a complex outcrop pattern between quartz-feldspar, crystal-rich Nepisiguit Falls Formation rocks and aphyric to sparsely feldspar (± quartz) phyric volcanic rocks of the Flat Landing Brook Formation. Black phyllite, considered to be laterally equivalent to the Brunswick Horizon, occurs locally near the top of the Nepisiguit Falls Formation. The Devils Elbow and Mount Fronsac deposits as well as three new mineral occurrences are found at this horizon. Tectonic and structural relationships observed in the map area suggest that the thrusting was associated with D_2 sinistral transpression and that it played a major role in the development of the flat belt in the western part of the Bathurst Camp.

Coalbed methane potential, Gulf of St. Lawrence region, eastern Canada

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A seismic facies related to Upper Carboniferous Coal Measures has been mapped over an area of more than 60,000 km^2 in the Gulf of St. Lawrence Region of Atlantic Canada, including central and eastern Prince Edward Island. The Coal Measures generally are too deep to mine, but the volume of coal indicated by the extent of this facies could contain several hundred trillion ft^3 (TCF) of coalbed methane. The Coal Measures also may have charged deeper and shallower reservoirs with this natural gas. Beneath central Prince Edward Island, the Coal Measures are in the depth range from which coalbed methane is being exploited in the United States. With the present forecast that gas will be a principal fuel of the 21st Century, this indicated resource presents a potentially rewarding challange to determine how it can be recovered and used.

Preliminary geophysical interpretations of the Antigonish-Mabou subbasin

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The Hollow Fault Zone separates the Antigonish-Mabou Carboniferous subbasin from the main Magdalen Basin. Some parts of the Magdalen Basin are deformed in a similar manner to the St. Georges Bay area, while other areas are not deformed and are much different. Geophysical correlations between these basins suggest a difference in sediment thickness and varying seismic stratigraphy across the Hollow Fault Zone. Seismic reflection data immediately north of the Hollow Fault Zone record 2000 to 4000 m of strata, locally folded and faulted. Seismic profiles across the Hollow Fault Zone suggest at least 2000 m of down-to-the-south movement on the fault. Several negative gravity anomalies observed on land in the Antigonish-Mabou subbasin coincide with evaporite deposits, confirmed by drilling. At least six similiar anomalies are interpreted from the gravity and seismic data as low density, evaporite structures beneath St. Georges Bay. The distribution of sediments around these salt cored structures suggests salt flowage coeval with sedimentation. The catalyst for salt movement appears to be unknown, external, tectonic forces. Faults, of uncertain age, offset the base Windsor Group reflection and suggest that low angle, reverse faulting has occurred beneath St. Georges Bay. The base of Windsor Group time structure map indicates the basin is deepest (6000 m) in the northeast and thinning of the sediments and/or evaporites occurs in the northwest and south parts of St. Georges Bay. Computer modelling of gravity anomalies, incorporating interpretations from deep reflection data, is continuing in an effort to better understand overall basin structure and the mechanics of the formation of evaporite structures.

Detrital and metamorphic ages from the Meguma Group, Mahone Bay area: $^{40}Ar/^{39}Ar$ data from muscovite separates and whole rock samples

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Cambrian-Ordovician metasediments of the Meguma Group underlie most of southwestern Nova Scotia and host numerous (mainly) Devonian peraluminous granitoid plutons. Metamorphic grade ranges from lower greenschist facies (locally subgreenschist facies) to upper amphibolite facies. One problem in interpreting the geologic history of the Meguma Group is the apparent inconsistency between discordant $^{40}Ar/^{39}Ar$ whole rock ages suggesting metamorphism at *ca.* 405 Ma, and related regional structures affecting rocks as young as *ca.* 385 Ma.

Petrographic examination shows the existence of several generations and morphologies of muscovite in the sandstones and slates of the Goldenville and Halifax formations. These include fine-grained matrix sericite, long detrital grains preserved in the sandy units of the Goldenville Formation, and in the slatier units of the Halifax Formation, small grains that define the regional metamorphic cleavage.

Six muscovite separates and a whole rock analysis gave maximum ages of 600 and 560 Ma for detrital grains and ages of 395 to 391 Ma for regional metamorphism. A whole rock sample with muscovite randomly overgrowing a strong cleavage gives an age of 388 Ma, interpreted as the lower limit (with respect to muscovite closure temperature) for regional metamorphism in this area. Spectra from detrital muscovites are disturbed with evidence of argon loss, presumably due to regional metamorphism. Samples with abundant cleavage-parallel muscovite produced spectra ranging from a virtual plateau to a disturbed spectrum showing the effects of detrital muscovite partially reset to a metamorphic age. A seventh muscovite separate produced a flat spectrum with an age of 376 Ma.

These data are generally consistent with previous results from detrital and metamorphic minerals, but provide additional constraints of the thermal history of the lowest grade part of the Meguma Group.

Time domain reflectometry analysis of surface crown pillar deformation over abandoned underground mine openings at Goldenville, Nova Scotia

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The Goldenville monitoring site lies on the southern limb of a major anticline in an area where extensive underground mining has taken place since the late 1800s. Abandoned stopes excavated in stratiform gold-bearing quartz veins are tabular in shape, strike east-west and generally dip steeply to the south. Surface crown pillars are typically 1 to 2 m wide and as little as 1 to 3 m thick. The near-surface bedrock is characterized by tabular to wedge-shaped decimetre-scale blocks.

Rock masses in and around surface crown pillars were monitored in eight boreholes by time domain reflectometry between 1991 and 1993. The time domain reflectometry data indicate that the bedrock is deforming by pervasive shear and extension along numerous discrete discontinuities. These data imply that the wallrocks and crown pillars are undergoing progressive gravity-controlled degradation. Such degradation, if it continues, must lead to eventual failure and surface caving. Although surface subsidence is evident above several of these stopes and has been increasing in magnitude for the last few years, a direct causal relationship between crown pillar failure and subsidence has not been established.

The technique of monitoring rock deformation by time domain reflectometry is currently being used to assess highwall stability at the National Gypsum Mine in Milford, Nova Scotia. This project will continue until late 1995, and is supported by quantitative laboratory evaluation of induced voltage reflections.

Gravity measurements in Pictou County, Nova Scotia

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A Bouguer Gravity contour map has been constructed using gravity data measured by the Nova Scotia Research Foundation Corporation (NSRFC). Approximately 300 gravity stations from eleven different NSRFC gravity surveys, carried out between 1958 and 1982, have been reprocessed for this study. Natural Resources Canada (NRC) gravity stations in the area, numbering about 200, have also been included in the dataset. The area covered by the gravity map includes the Carboniferous basins of Pictou County, Nova Scotia, and the adjacent areas.

The dominant anomaly is a large, positive feature with an east-west to northeast-southwest trend produced by the higher density Hadrynian, Cambrian, Silurian and Devonian rocks of the Cobequid Highlands. The eastern termination of the Cobequid Highlands is clearly delineated on the gravity map. To the east is part of a second positive anomaly resulting from the higher density basement rocks of the Antigonish Highlands. Between these two large positive anomalies is a narrow, east-west trending negative (-7 mGals) anomaly which results from the lower density, Upper Carboniferous sediments of the Stellarton graben. The Stellarton graben anomaly lies at the head of a gravity embayment extending southwards from the large area of more negative gravity values in the north of the map area. These negative anomalies result from the thickening Carboniferous and younger sediments of that part of the Magadalen basin which underlies the Northumberland Strait.

To the south of the Stellarton graben anomaly are a series of low amplitude positive anomalies which form a sinuous east-west to north-south pattern. These anomalies may reflect higher density rocks within, or underlying, the Carboniferous sediments together with higher density, older volcanic and sedimentary rocks to the east.

Two other negative anomalies are of significance: the first coincides with mainly Hadrynian and Cambrian strata, Cambrian volcanics and isolated granitoid rock outcrops (Hadrynian, Cambrian and Devonian) in the Moose River area. It is suggested that this -7 mGal anomaly is due to a lower density, granitic complex beneath a thin veneer of sedimentary strata. The second negative anomaly (-5 mGals) in the Kemptown area is presently interpreted to result from thickening of lower density Carboniferous strata.

First and second vertical derivative and horizontal derivative maps have been generated from the Bouguer gravity data. These enhance the higher frequency content and delineate previously mapped fault trends, and indicate the continuation of some faults and the presence of previously unmapped structures.

The regional and residual Bouguer gravity maps are to be used for more detailed interpretation and modelling of specific anomalies.

Mineral deposit and glacial dispersal investigations, Willett Showing, northern New Brunswick

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A comprehensive project involving bedrock and surficial mapping, mineral deposit and glacial dispersal studies of the Willett massive sulphide showing, located 35 km southwest of Bathurst, New Brunswick began in 1994. High grade massive sulphide boulders were originally discovered by prospecting in 1975 by Claude Willett. Although a bedrock source was known for the boulders, several companies have worked the property over the years, with little success. Recently, Freewest Resources re-established old grids and trenched the area of the original discovery, uncovering a lens of massive sulphides (approximately 1 m thick and 10 m in length) with grades up to 13.17% Cu, 12.83% Pb, 9.78% Zn, 473.83 g/t Ag and 4.1g/t Au. The sulphide lens is hosted by a sedimentary melange that contains blocks of strongly sericitized and pyritized rhyolite (10 cm to 5 m in length) in a matrix of black slate and wacke. Within this unit an east-west trending horizon characterized by abundant rhyolite blocks can be traced for 700 m. The sulphide lens and host rocks have undergone at least three phases of deformation that are distinguished by three distinctive penetrative fabrics. The first and second deformational events resulted in the development of east-west and northwest trending fabrics respectively. These are offset by north-south striking sinistral faults associated with the third deformation. Extensions of the lens have been found to the west and northeast. Outlining the sulphide zone at depth and along strike will be the focus of future exploration. A detailed structural interpretation and lithogeochemical survey is ongoing.

The property lies in an area of flat to gently rolling topography of the Eastern Miramichi Highlands. Regional surficial mapping indicates that ice movement affecting the area was eastward (080°-110°) followed by northeastward and southeastward flowing ice off the central Highlands. Detailed mapping of ice-flow indicators in the new trench supports this chronology. Fine-coarse, sandy-clayey-loamy basal till is very thin (generally <1 m), but several old trenches contain thicknesses exceeding 3 m. Regional till geochemistry and till pebble lithologies suggest glacial dispersal was very local (<500 m-1 km). Closely spaced sampling (45 samples [basal till and pebbles from till] on 250 m spacing) and detailed surficial mapping, is underway to firmly define the glacial dispersal of sulphide material and till geochemical anomalies down-ice from the Willett Showing. It should be noted that several boulder erratics from the Mount Elizabeth Intrusive Complex, located approximately 20 km up-ice, were found on surface in the area of the showing.

Preliminary geological investigation of Upper Carboniferous strata in southeastern New Brunswick

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Upper Carboniferous rocks in southeastern New Brunswick are comprised of red and grey, fluviatile strata which were deposited during late Namurian to Stephanian time. In ascending order they are referred to as the Boss Point, Salisbury, Richibucto and Tormentine formations. The succession is gently folded into a broad regional anticline which plunges shallowly to the east (Westmorland Anticline).

The relationship between the Salisbury and Richibucto formations is considered to be diachronous (facies equivalent), based on their laterally adjacent stratigraphic position and overlapping spore ages. The contact with the overlying Tormentine Formation is not exposed but is assumed to be conformable based on similarities in lithology, bedding style, bedding relationships and the presence of overlapping spore assemblages. Field observations to date tentatively suggest the contact between the Boss Point and overlying Salisbury formations is concordant and locally appears to be interbedded; however, results from continuing field work and palynological studies in progress are needed before this can be stated with certainty.

A disconformity between the Boss Point and overlying strata elsewhere in southern New Brunswick (Moncton sub-basin) has been implied by palynological studies which have failed to record strata of late Westphalian A to mid Westphalian B age. In Nova Scotia strata of this age, assigned to the Cumberland Group, conformably overlie Boss Point rocks in the Cumberland sub-basin.

Fluid inclusion studies of carbonate-hosted mineral deposits in the basal Windsor Group of Nova Scotia: generation of high-temperature, high-salinity fluids as a consequence of an anomalous geothermal gradient or dewatering of a sedimentary basin

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The basal part of the marine Windsor Group of the Maritimes Basin is host to Pb-Zn-Ba-Cu-Ag mineralization which replaces the carbonate rocks or infills primary and secondary porosity. The regionally extensive basal Windsor Group of Visean age (Macumber and Gays River formations), the local host, overlies either terrestial clastics of the late Devonian Horton Group (conformably) or metaturbidites of the Cambro-Ordovician Meguma Group (unconformably) and is overlain by evaporites of the Carrolls Corner Formation. Three of the most significant mineral deposits from separate Carboniferous sub-basins in Nova Scotia have been studied in detail and herein we report results of fluid inclusion studies and interpret the data in the context of additional geological and geochemical information. The Gays River deposit (Musquodoboit-Shubenacadie sub-basin; 2.4 Mt 8.6% Zn and 6.3% Pb) is located within a dolomitized carbonate bank, whereas at the Jubilee deposit (River Denys sub-basin; 0.9 Mt 5.2% Zn and 1.4% Pb) mineralized zones are hosted by brecciated calc-mylonite, and at Walton (Kennetcook sub-basin; former producer Ba-Pb-Zn-Cu-Ag) mineralized zones replace sideritized limestone. At Gays River and Jubilee, galena and Fe-poor sphalerite dominate with traces of other sulphides and calcite as the major gangue, whereas at Walton a greater variety of sulphides occur, including Fe-poor sphalerite, along with arsenides and Ag-bearing phases and abundant barite.

Fluid inclusions have been studied in pre-ore (dolomite, calcite, quartz (?); Gays River and Jubilee), syn-ore (sphalerite, calcite, barite; all deposits) and post-ore (calcite, barite, fluorite; all deposits) phases. Inclusion types include: (1) aqueous L-V ± Halite; (2) CH_4; (3) H_2O-CO_2 (Gays River); and (4) petroleum. Aqueous-type inclusions dominate, but petroleum types are abundant at Jubilee (pre-, syn- and post-ore) and Walton (syn- and post-ore). Homogenization temperatures (T_H) of aqueous inclusions for the three deposits range from <100°C to 300°C, with pre-ore phases having T_H of <160° at Gays River and <100°C at Jubilee. Salinities (eq. wt. % NaCl) of aqueous inclusions for all deposits range from 10 to 30 wt. % with most in the 20 to 25 wt. % range; low first-melting temperatures indicate H_2O-NaCl-$CaCl_2$ fluid composition and ice-hydrohalite melting suggests variable $CaCl_2$/NaCl ratios. At Walton and Gays River, low-salinity inclusions (0-5 wt. %) are commonly associated with high-salinity types. Type 2 inclusions (CH_4) homogenize to the vapor phase at -85° to -74°C. Petroleum inclusions homogenize to the liquid phase with T_H = 90-280°C at Walton and 30-200°C at Jubilee. Analyses (GC) of gases liberated from inclusions hosted by sphalerite and calcite at Gays River confirm the presence of CO_2, CH_4 and hydrocarbons.

The high temperatures of T_H for syn-mineralization phases contrast with the relatively lower temperatures of pre-ore phases and temperatures generally associated with MVT-style mineralization. Results from examination of clay mineralogy and organic maturation at Gays River also suggest a high-temperature anomaly compared to the local sub-basin. Thus, collectively the data indicate that the regional, saline brines generated within the basins either mixed with or were flushed out by higher-temperature fluids, perhaps focused along structural zones, to produce mineralization. A third fluid, which post-dates mineralization, is suggested by mixing trends in T_H-salinity plots and by the presence of low-salinity inclusions. Generation of petroleum is related to local cracking of organic matter (Horton or Windsor group rocks) within the fluid pathway; rapid transport and trapping of the petroleum is essential to its preservation.

Developing a mass balance around an electrical generating plant burning Nova Scotia coal

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Increasing concern over the potential negative effects of priority substances, has led some governments to introduce legislation design to control their emissions. This emphasis has been the motivator for coal burning electric utilities to undertake programs to investigate the emissions coming from their power plants.

While priority substances quantification and control studies have been reported in the literature, much of the early work is disjointed and lacks focus and is therefore of limited value in drawing generalized conclusions about specific coals and combustion processes. Adding to the difficulties are the coal and process specific nature of the studies and the lack of standardized sampling, analytical and data reporting protocols.

In 1993, Nova Scotia Power, as part of a Canadian Electrical Association (CEA) Advisory Panel, carried out comprehensive emissions tests at its Lingan coal fired generating station. The study followed product streams from the mine, through the wash plant and furnace to the ultimate disposition as bottom ash, fly ash and stack gas. During the program, the sampling and analytical protocols recommended by the CEA Advisory Panel were evaluated. This paper describes the study, comments on the applicability of protocols and presents some of the data.

Clues to the structural evolution of the Bathurst Mining Camp from a rotated garnet porphyroblast

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Rocks underlying the Bathurst Mining Camp (BMC) represent part of the New Brunswick segment of the Central Mobile Belt of the northern Appalachians. The area has undergone four main phases of deformation (D_1 - D_4) and five phases of folding (F_1-F_5). The first phase of deformation (D_1) is related to underplating in an accretionary wedge complex that developed during closure of a back-arc basin. With continued convergence and obduction, D_2 folding reoriented earlier fabrics into near-vertical attitudes. Two major shear-zones, associated with late D_2 sinistral shear, transect the BMC, and in places, e.g., the Forty Four Mile Brook area, have evolved into transpressional thrust zones that separate D_3-related flat and steep structural belts in the camp. The flat belts have developed where recumbent F_3 folds have reoriented earlier fabric elements into near-horizontal attitudes. The D_4 phase reoriented earlier structures by rotating them into the camp-scale Z-shaped Tetagouche Antiform/Nine Mile Synform pair.

The present geometry of the camp as seen on a geological map of New Brunswick is broadly circular and has morphological similarities to a clockwise-rotated garnet porphyroblast. A rolled garnet is typically situated within a relatively undeformed area that is bracketed by cleavage planes or septae along which much of the shear component of deformation has taken place. Correspondingly, the BMC is bracketed by the Rocky Brook-Millstream Fault to the north, which shows at least 50 km of dextral offset (shear), and the Catamaran Fault to the south. Both faults transect the Miramichi Anticlinorium and have a prolonged movement history. The latest ductile movements on the Rocky Brook-Millstream Fault were associated with the development of the Tetagouche Antiform and Nine Mile Synform and caused a later clockwise rotation of the Tetagouche Antiform. The main planar fabric element in the camp, a composite S_1/S_2 foliation that outlines the Tetagouche Antiform/Nine Mile Synform pair, is comparable to the inclusion trails in a clockwise-spiralling garnet. The rotated-garnet analogy is useful for demonstrating the development of the D_4 macro-structures and the late-tectonic evolution of the Bathurst Mining Camp.

Early Carboniferous (Visean) carbonate breccias in the Windsor Group: multiple origins and metallogenic significance

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Marine sedimentation in the Magdalen Basin is restricted to the early Carboniferous Windsor Group. The stratigraphy of the group is dominated by evaporites and siliciclastics. Carbonates are only significant at the base of the group; the Macumber Formation was deposited downslope to the reefoid mounds of the Gays River Formation. Both units are sometimes mineralized (Pb-Zn-Cu-Ba). In the Macumber, the ore is associated with carbonate breccias.

Three types of breccia are present. Synsedimentary rotational slide (slump) breccias occur in m-thick predictive rock patterns. The breccias are characterized by concave shear failure planes, monocompositional nature of the sometimes rounded clasts and a mud matrix derived from background sedimentation. Late tectonic breccias are typified by angular monocompositional clasts with a puzzle-like texture, cement matrix and were formed following lithification and chemical compaction, but prior to hydrocarbon migration, mineralization, secondary dissolution of carbonates, and syn-ore to post-ore calcite cementation. Finally, late solution collapse karstic breccias are characterized by their heterolithic nature, presence of early breccia fragments, red siliciclastic infills in dissolution voids, gravitational calcite cements and formation following burial of the host rock.

Distinction between the various breccias is critical to base metal exploration because the tectonic breccia is the only one responsible for creation of significant secondary porosity. For the Jubilee deposit, brecciation played a key role in controlling pathways for mineralizing fluids in the early Carboniferous Basin.

In the vicinity of the Jubilee deposit, regional distribution of the $\delta^{18}O$-$\delta^{13}C$-$^{87}Sr/^{86}Sr$ (relatively heavy O-C ratios and non-radiogenic Sr) suggests that the Macumber stabilized under warm burial conditions, in equilibrium with marine like waters and ^{18}O-rich evaporative fluids. These fluids have also affected the host-rocks at the deposit where breccia porosity is filled by fibrous pre-ore calcite, sphalerite-galena and anhedral syn- to post-ore calcite. The carbonate cements show similar ^{13}C-depleted carbon ratios (average -25‰), but distinct $\delta^{18}O$ fields: a cluster around -6.0‰ and an interval ranging from -5.0 to -12.0‰, respectively. The data suggest that fluids responsible for cementation of the tectonic breccia were hydrocarbons and hydrothermal fluids which mixed during mineralization.

Geological setting and characteristics of Siluro-Devonian porphyry-related Cu-Au skarn deposits in northern New Brunswick

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Numerous contact metasomatic Cu-Au skarn deposits occur in proximity to small Siluro-Devonian intermediate to felsic stocks and/or dikes throughout northern New Brunswick, and the adjacent Gaspé Peninsula of Québec. One of the best examples and the only producing porphyry-skarn deposit is in Murdochville, Québec (Mines Gaspé). The skarns at Mines Gaspé contain(ed) approximately 60 Mt averaging 1.3% Cu (A-B-C zones) and 8.9 Mt grading 3.16% Cu (E zone), both of which are spatially associated with the Copper Mountain Porphyry that contain(ed) 200 Mt grading 0.4% Cu and 0.2% Mo.

In northern New Brunswick, the skarn occurrences are principally hosted within the late Ordovician to early Silurian Matapédia Group, which consists of thin-bedded, dark grey argillaceous limestone and calcareous siltstone. In northeastern New Brunswick, the Upsalquitch (calcareous slate and sandstone) and La Vieille (nodular limestone) formations of the early Silurian Chaleurs Group and the Elmtree Formation of the Tetagouche Group also host several major skarn occurrences. The subalkaline, peraluminous intrusions that intrude these sequences are syn-tectonic to post-tectonic with respect to the Acadian orogeny and range in composition from granodiorite to granite. The larger, younger plutons, i.e., Nicholas Dénys Granodiorite and Antinouri Lake Granite, seem to be somewhat independent of obvious late fault structures. However, the late Silurian stocks and dike swarms found in the north-central part of the Province form en echelon arrays that suggest that their distribution is, to some extent, fault controlled. A protracted intrusive history, which is evident from cross-cutting relationships, produces variable intensities of deuteric and endoskarn alteration within these intrusions. Similarly, the distribution of mineralized skarns is usually closely related to complex brittle structures (e.g., McKenzie Gulch faults and Rocky Brook-Millstream Fault Zone). These structures acted as conduits for high-temperature fluids that evolved from the intrusions during crystallization. The chalcopyrite-bearing exoskarns are commonly related to the high-temperature prograde skarns that consist of moderately oxidized-proximal (Fe-Mg diopside-intermediate andradite-magnetite-pyrite) to reduced-distal (hedenbergite-grossularite-pyrite) skarn assemblages. The locally siliceous chlorite-carbonate-rich arsenopyrite, base-metal, and Au-bearing vein systems, which are spatially related to the skarns, crosscut the prograde assemblages and occur distal to them as well. The complex fault-control, base-metal zoning, porphyry dike/stock association, and argillaceous carbonate-bearing lithotypes for skarn and vein mineralization are very similar to porphyry-related Cu-Au systems in the Basin and Range Province of the southwestern United States.

Supergene and hypogene covellite, 4,500N section, Chuquicamata Porphyry Copper Deposit, Chile

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The presence of covellite (CuS) in drill core has been used operationally as an index mineral for supergene (secondary) mineralization within the Chuquicamata porphyry copper deposit. Supergene enrichment is a major factor in the relatively high Cu grades (by a factor of 2 to >10 over hypogene or primary grades) of the Chilean deposit, and supergene mineral assemblages dictate adjustments in the metallurgical treatment of the ores. We document the occurrence of coarse-grained covellite as part of the hypogene (primary) assemblage with digenite, bornite, and chalcopyrite in the presence of anhydrite in the 4,500N cross-section. Continuing research characterizing the differences between supergene and hypogene covellite is currently focussed on detailed description of assemblages and sulphide mineral chemistry in selected drill core in the 4,500N cross-section. Preliminary results indicate that there is a significantly greater Fe content in the hypogene covellite and that in the supergene setting the covellite is relatively Fe-free.

Regional structures outlined from Natmap 1:250 000 compilation of Cape Breton Island (11F, 11K)

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A primary objective of the Magdalen Basin NATMAP program is the digital compilation of new and existing geological maps encompassing northern Nova Scotia and southeastern New Brunswick, for the production of the first 1:250 000 scale maps of this region. Broad stratigraphic correlations are effectively outlined at this scale, and the large scale nature of important structures becomes evident, while many of the details established at 1:50 000 are still preserved. On Cape Breton Island (11F, 11K) four new regional scale structures are now recognized which are responsible for a range of tectonic features which characterize pre-Acadian, Acadian, and post-Acadian orogenic events and subsequent Carboniferous basin evolution: (1) an

extensive late Silurian thrust system extends from the Cheticamp area in northwestern Cape Breton down to the Mabou and Middle River areas, and features imbrication of Cambrian-Precambrian basement rocks of Gondwana derivation with Ordovician-Silurian volcanic arc cover sequences, including the Sarach Brook volcanics and correlative units. High grade metamorphism and thick mylonite zones indicate significant tectonic burial and crustal thickening during south-directed transport; (2) early Devonian contraction features the thrust emplacement of the Cabot nappe along the Highland Shear Zone (HSZ) which rims the south, east, and west margins of the Cape Breton Highlands separating gneissic and non-gneissic domains. The HSZ is a deeply rooted crustal-scale fault characterized by the juxtaposition of highly contrasting metamorphic assemblages, with the thrust emplacement of the main gneissic nappe resulting in dynamothermal metamorphism of footwall rocks and regional development of inverted isograds. Units within the nappe include Precambrian marble, quartzite, and amphibolite, as well as large granitic, dioritic, and tonalitic intrusions and Silurian to Devonian orthogneiss of the Belle Cote and Pleasant bay complexes. The Cabot nappe is overprinted by folding and is preserved as a broad klippe within a regional synclinorium; (3) late Devonian extensional denudation of the Cabot nappe was in part accommodated in the footwall of the low-angle Margaree Shear Zone during the initiation of the Maritimes Basin. The Margaree Shear Zone is a large scale retrogressive extensional mylonite zone which is now mapped along and adjacent to the western and southern margins of the Cabot nappe, and occurs immediately beneath Late Devonian volcanic units at the base of the Maritimes Basin; and (4) within the Visean Windsor Group, the Ainslie Detachment is a bedding-parallel extensional fault occurring at the evaporite-carbonate interface at the top of the Macumber limestone. The Ainslie Detachment is responsible for significant stratigraphic gaps within the Windsor Group and appears to have controlled early Westphalian clastic sedimentation in association with listric faulting.

Coalbed methane - a new energy source for Nova Scotia?

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Coalbed methane, or more properly "coal gas" as it is referenced under the legislation which governs its activity, may finally have its day as a new resource for the province of Nova Scotia. Recent initiatives by both the government and the private sector have set the stage for current and future development activities for this clean energy resource.

Ever since commercial coal mining began in this province in 1720, coalbed methane has long been the bane of coal miners. Fire damp or "that damn gas" has plagued mining efforts for centuries. Driven by a need for mining safety and the realization that the methane could be a readily available cheap energy source, technology and techniques have evolved after some 15 years of development activity principally in the United States.

Response to provincial government requests for proposals has resulted in two of the three major coal basins of the province being held by industry for exploratory and development work. Private sector drilling this past year and work planned for next several years will continue the evaluation efforts. The government has funded several research projects aimed at enhancing the understanding and improving the data base for coalbed methane efforts. The federal government as well has undertaken studies relating to the methane potential of the region. In a province where some 67% of its energy needs are meet by imported foreign crude oil, development of an indigenous source of clean burning fuel such as methane would be a benefit to all.

Tetrapod from Joggins, Nova Scotia

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This special fossil is a tetrapod vertebrate from the Upper Carboniferous Period, or more simply, a four-legged animal with a spinal cord who lived 300 to 325 million years ago. Back then, the lands of Nova Scotia lay close to the equator and were mainly warm swamps and river flood plains where the large fern-like trees of Joggins grew. The tetrapod roamed these swamps in search of food and eventually died at the edge of the water. This can be observed because the tetrapod exposed skull and upper body have little distortion as the gentle burial by sand and clay particles entombed the body to help create the beautifully preserved fossil.

Ancient amphibians and some modern reptiles retain bony scales in a ventral armour of v-shaped rows along the belly, a structure of use in protecting the low-slung body while travelling over rough ground as can be seen in this specimen.

Re-processing of seismic reflection data in the Cumberland Basin

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To better understand the geology and the resource potential of the Cumberland Basin, northern Nova Scotia, and to establish linkages with offshore sedimentary basins, we have initiated a compilation of seismic reflection data acquired mainly by the oil industry. Some of the data, gathered in the early 1970s for Anschutz Exploration (Canada) and Gulf Oil Canada Limited, need to be re-processed to better image stratigraphic and structural features. Here we report on the re-reprocessing and preliminary interpretation of about 500 km of seismic profiles.

Re-processing was conducted by Pulsonic Geophysical Limited. The selection of the critical processing parameters was made in close collaboration between the company and ourselves in order to meet specific objectives. These included better imaging the upper part of the seismic sections, recovery of meaningful data beyond the original limit of four seconds, and continuity of data quality from top to bottom of the section. Processing operators such as statics corrections, deconvolution and migration were found to offer the greatest improvement in the section quality which is far superior in the re-processed profiles.

The re-processed data together with other seismic sections allow us to pick a few seismic horizons basin wide and to identify the main stratigraphic units. Major structural features within the basin are identified and mapped. For example, the data indicate that the basin is subdivided into two distinct structural domains, separated by the east-west striking Beckwith Fault. To the north of the fault, the strata are horizontal, whereas to the south their structure is more complex and their thickness varies greatly. In the Athol Syncline, the sediments thicken up to 2.8 s two-way travel time (about 5 km). To the south and to the southeast, the basin is bounded by the Cobequid Highlands and by the Scotsburn Anticline. There is evidence for north-directed thrusting along the northern margin of the anticline.

The data indicate that several structural features observed in the basin including the Beckwith Fault, and the Malagash and Scotsburn anticlines extend offshore to the northeast. This suggests that the on land Cumberland Basin is part of a much larger basin that stretches under the eastern Northumberland Strait and eastern Prince Edward Island.

Application of organic petrology and organic geochemistry in characterizing the pollution in recent sediments - an example from the Halifax Harbour, Nova Scotia

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Selected organic-rich recent sediments (depth: 0-15 cm from the top sediment surface) from Halifax Harbour were chosen to characterize various natural and anthropogenic organic components by using organic geochemical parameters which are normally used for the study of coal, petroleum source rock and crude oil.

The analyzed samples have more than 3% total organic carbon. More than 75% of this carbon is not derived from a natural source and can easily be traced back for its anthropogenic source which pollutes the recent shallow marine environment at the Halifax Harbour. Organic petrology (maceral composition, reflectance, and spectral fluorescence) and biomarker geochemistry (triterpane, sterane and PAH's) revealed the presence of spilled crude oil (presently biodegraded), refinery products (diesel oil), dumped Nova Scotian bituminous coal, carbonization residues (fly ash and coke) from a power plant and coke oven plant, other factory dumped PAH's, and human fecal products. Both land plants (especially cellulose-rich barks, lignin-rich stems, charcoal, and pollens) and marine algae are the common constituents for natural carbon source. Abundant algal growth is possibly related to nutrient-rich (nitrogen compounds) human waste in the harbour water. Nonmarine plants which are being transported by rivers into the harbour, are converted to gelified huminite macerals.

Geology of the St. Mary's Basin, Nova Scotia

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The St. Mary's Basin, central mainland Nova Scotia, is underlain by a latest Devonian-early Carboniferous (Tournaisean) intra-continental fluviatile to lacustrine basin-fill sequence of clastic sedimentary rocks that are assigned to the Horton Group. The basin occupies the boundary between the Meguma and Avalon Composite terranes. The contact with the Avalon Terrane is tectonic, but along the southern flank of the basin Horton Group rocks unconformably overly the Meguma Terrane, implying that a portion of the basin is underlain by Meguma basement. Facies relationships indicate deposition along the southern flank of the basin was influenced by coeval faulting. In the southwestern portion of the basin, the rocks are overlain, presumably unconformably, by the Windsor Group. Most Horton Group units defined in the eastern portion of the basin can be mapped westwards where they form part of a thick sequence with that generally strikes northeast to east-northeast, faces southeast, coarsens upward, thickens towards the southeastern basin of the margin and contain clasts of Meguma derivation. However, in the northwest portion of the basin, the clastic rocks have a mixed Avalonian-Meguma provenance confirming the status of the Horton Group as a post-Acadian overstep sequence. The details of this area are still unclear and are the focus of ongoing mapping.

The character of the basin-fill rocks does not vary with proximity to the Chedabucto fault, suggesting that this fault does not constitute the original margin of the basin, and that an unknown portion of the basin has been tectonically removed and may be found north of the fault. Although it can be demonstrated that least some of the basin-fill rocks overlie a basement composed of Meguma Terrane rocks, the existence of Avalonian basement rocks cannot be confirmed. Strike-slip motion along the Cobeqequid-Chedabucto fault system has resulted in heterogenuous deformation characterized by a variety of dextral kinematic indicators. In the western basin, the zone of intense deformation transects the basin in an northeast-southwest direction, where it produces a relatively intense, narrow (*ca.* 2 km) zone characterized by small-scale and regional tight to isoclinal folds, associated faults in the hinges of these folds and locally developed mylonitic fabrics. In the eastern basin, deformation is relatively mild. Regional factors suggest that this deformation reflects Late Paleozoic dextral relative motion between Avalonian and Meguma terranes, and between Laurentia and Gondwana.

Thermochronologic evolution of the Cobequid Highlands, Nova Scotia

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The Cobequid Highlands of northern Nova Scotia occupy an east-west trending belt (*ca.* 160 km long, 10-20 km wide), forming the eastern component of a major tectonic element, the Cobequid-Chedabucto fault zone. Recent $^{40}Ar/^{39}Ar$ geochronology of diorites, granodiorites, granites, and mafic dykes, has produced an increased understanding of igneous and tectonic activity for this region. It is now known that the majority of latest Devonian-early Carboniferous granitic magmatism is confined to a very small window of time. This was followed by mafic-magmatic activity and ductile deformation within an active fault system. Direct observations derived from these new data indicate changing patterns of tectonic activity within the Cobequid Highland belt, occurring throughout the early Carboniferous.

Present $^{40}Ar/^{39}Ar$ dating with existing U/Pb data of granitic lithologies indicates the majority of igneous-felsic activity was confined to the Tournaisian epoch. The presence of granitic lithologies reflects trapping of mafic magma producing significant crustal melting. The $^{40}Ar/^{39}Ar$ dating of mafic lithologies indicate that mafic magmatism spanned the Tournaisian, Visean and early Namurian epochs, suggesting persistent activity. The presence of mafic lithologies (tholeiitic diorite, gabbro, and lamprophyric dykes) suggests the presence of easy pathways associated with rifting. The large volume of Visean mafic products in the eastern Cobequid belt is contemporaneous with compressional features located in extreme western regions of the belt. Regionally, this early to middle Visean activity is correlated with the change in tectonic style between the Horton (clastic) and Windsor (chemical) groups within the Magdalen Basin, suggesting extension and compression within the belt were associated with the early evolution of the basin. Further $^{40}Ar/^{39}Ar$ dating of secondary minerals implies that high temperature Na-metasomatism occurred shortly after the emplacement of some granitic plutons. Pervasive potassic alteration along the entire Cobequid fault is of early Namurian age, correlated with the intrusion of lamprophyric dykes.

Quaternary geology and glacial dispersal studies, Bathurst Mining Camp, northern New Brunswick - an overview of Extech II

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The EXTECH II project, designed to develop methods and improve the existing geoscience database involved in the exploration for massive sulphide deposits in the Bathurst Mining Camp (BMC), started in 1994. One aspect of the project involves surficial mapping and the study of glacial dispersion around massive sulphide deposits in the BMC. Since more than 80% of the area is covered by glacial deposits, the study of glacial dispersal is an important complementary mineral exploration technique. This study will concentrate on both the dispersion of pebbles in the till and on the dispersion of the trace elements in the till matrix. The results will aid in the interpretation of data collected in other EXTECH II projects, including lead isotopes in till, geochemistry of soils and stream-sediments, hydrochemistry of ground and surface waters, biogeochemistry, and radiometric surveys.

Surficial mapping at 1:50 000 scale and basal till sampling on an approximate 2 km grid has been carried out over much of the BMC in recent years. Regional mapping, in conjunction with the data acquired during several detailed surveys, has provided the background necessary to determine optimum mapping scales and sample spacing for the EXTECH II project areas. Generally in the BMC, basal till is thin (<1-2 m thick); glacial dispersal is short (<500 m to a maximum of 1 km); till clasts reflect local underlying bedrock (<10% transported from up-ice); and striations, pebble lithologies and location of boulder erratics indicate a dominate eastward ice movement (070°-110°). In 1994, Quaternary mapping and collection of basal till, and pebbles from basal till was completed around selected deposits in the BMC. Detailed studies of the Half Mile Lake (315 sample sites on 30 and 120 m spacing) and Restigouche (126 sample sites on a 250 m grid) massive sulphide deposits and an initial study of the Willett mineral occurrence (45 samples on 250 m spacing) was carried out. At Half Mile Lake, a 120 m trench and 20 pits (1.5-3.5 m depth) were excavated in the 3 km^2 area around the Upper AB Zone to study and compare the vertical variation in till geochemistry and Pb isotopic signatures of till (a total of 205 samples taken at 10 cm vertical intervals). Detailed Quaternary mapping, and till geochemical, till clast and till mineralogical studies will serve to define: (1) the distribution and character of surficial materials, (2) the relative chronology of ice flow, and (3) the direction of glacial transport and dilution rate down-ice from massive sulphide deposits. Results from these case studies can be applied to other sites in the area.

Monitoring of environmental pollutants using dental enamel

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Dental enamel remains essentially inert after its initial formation. Thus, it can provide a permanent and cumulative record of elements in the environment to which the tooth was exposed. This record includes the concentrations of trace elements incorporated into the crystal structure of enamel during its formation. For humans, calcification of teeth begins 4 months in utero and continues for the first 2 decades of life. In addition, there is a record of those elements absorbed by dental enamel, through its microscopic porosity, during the lifetime of the individual.

There is intrinsic scientific value in having the concentrations of trace elements in dental enamel updated by modern techniques. There is also a practical value, however, in that the relationship between environmental pollutants and diseases can be better studied if this updated data is available. For example, such data would facilitate the investigation of any link between the presence of geologically derived elements, such as uranium and the heavy metals, and the incidence of multiple sclerosis. Presently, elemental analyses are underway in this laboratory using fission track analysis, neutron activation, electron microprobe analysis, and inductively coupled plasma atomic emission spectroscopy.

Of all living tissues in the body only dental enamel retains indefinitely the history of its radiation exposure. The effect of radiation on the crystalline hydroxyapatite in dental enamel is to produce free electrons that become trapped indefinitely in defects within the crystal lattice. These free radicals can be detected using electron spin resonance (ESR). A similar technique is used in geological dating.

Knowledge of the cumulative absorbed radiation dose in the general population, and in populations suspected of having been exposed to large doses of ionizing radiation, can lead to a direct measure of radiation risk. Also, for acute radiation accidents dosimetry using dental enamel can provide a means of triage, or it can be of forensic value in post-mortem investigations. ESR in dental enamel has been successfully used to study doses absorbed by victims of acute radiation exposures such as that resulting from the Chernobyl nuclear disaster and the participation in atomic bomb tests. Further, a means of separating contributions to the overall dose to a tooth from diagnostic and background radiation has been developed.

The ESR technique utilizes dental enamel obtained from teeth extracted in the normal course of dental treatment. A lack of sensitivity, and formidable problems in miniaturization of the large laboratory equipment used for the measurement, makes in-vivo ESR measurements of dental enamel unattainable at present. Even with existing limitations, teeth provide unique advantages for both concurrent and retrospective monitoring of pollutants.

Acid mine drainage and the Cape Breton coal industry

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Acid Mine Drainage (AMD) from mine waste and coal refuse spoil piles has long been recognized as an environmental liability for mine operators, property owners and the public in general. A vast amount of research has been completed within the mining community to understand the dynamics of the generation of acid water and to develop and implement ways to mitigate or eliminate the problem.

Current methods for control of acid water generation include water cover or flooding in the creation of wetlands; sealing the material with impermeable covers using organic mate-

rial, soils, cement or limestone sludge generated during the treatment of acid water, interlayering waste material with limestone or other buffers; and neutralizing the acid water using lime, limestone or other chemicals in a water treatment facility built at the site.

The Cape Breton Development Corporation (DEVCO) has numerous programs which are currently in place to control or eliminate the AMD problem in existing mine waste and coal spoil piles. This presentation discusses a recently initiated project of AMD remediation at a DEVCO site.

Fission track dating of natural and man-made glasses: calibration and problems

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Some of the early work on fission track dating was done on natural glasses, and some pioneering work on mid-ocean ridge basalts was done at Dalhousie by F. Aumento two decades ago. Fission track dating is the method of determining the age of geological materials using the natural property of the ^{238}U isotope to decay by spontaneous fission. This action produces damage in the solid surrounding the uranium (contained in solid solution), called a fission track, which can be made visible by etching a polished surface of the solid. Much smaller tracks are formed by alpha radiation (alpha tracks), and their counting has been used effectively in environmental and exploration studies, but are not generally used for dating. Natural glasses do often contain sufficient amounts of uranium (about 20μg/g) to be countable and thus yield an age. Therefore, fission track dating has found applications in Archaeology and Quaternary Geology, generally through dating tephra or some man-made glasses (a uranium-glass date of 150 years is reported in the literature), but more often by dating other minerals (e.g., zircon) in the sample as well. Unfortunately, tracks in natural and man-made glass are unstable and undergo annealing (fading) over geological time, even at relatively low temperatures, and despite new methods devised to correct ages for this effect, fission track dates of glass alone must be considered minimum ages. Another problem encountered is a very low uranium concentration which has produced very few tracks over the age of the sample (normal man-made glass has concentrations of 1μg/g).

This project attempts to evaluate different glasses of varied compositions and ages for their suitability for fission track dating. Image analysis is used to decrease to some extent the time and the subjectivity involved in counting samples with very low density of tracks. Progress in counting, etching, calibration and imaging are presented.

Late Devonian - Early Carboniferous evolution of the Cobequid Highlands

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We present tentative synthesis of the evolution of the Cobequid Highlands during the early stages of development of the Magdalen Basin. This is based on geophysical data and field mapping, but takes into account recent geochronology.

The earliest basin sedimentation and volcanism in the eastern Cobequid Highlands comprises thick volcanic rocks (Fountain Lake Group: ?late Devonian) and mid-Devonian clastic sediments. The main phase of gabbro and granite pluton emplacement is latest Devonian in age (six U/Pb zircon ages from 361-365 Ma). Magnetic data show three domains of pluton emplacement. (1) West of Parrsboro, predominantly granitic magmas were emplaced along major east-west faults. (2) Between Parrsboro and Portapique, pluton emplacement is more widespread and shows east-west trends. In this domain, pluton margins show northward thrusting, and Neoproterozoic-Silurian country rocks host gabbro and rhyolite sheets along analogous thrust faults. (3) East of Portapique, magnetic data suggest that west-northwest-striking lineaments predominate. These lineaments post-date the main phase of pluton emplacement, which was associated with the rise of magma along the Rockland Brook fault and widespread northward thrusting. Small fault-bounded basins associated with this thrusting contain lacustrine, fluvial and alluvial fan sediments of the Nuttby Formation, locally containing Tournaisian palynomorphs. Some sediments include plutonic clasts and are cut my marginal granite phases, suggesting that uplift accompanying pluton emplacement was rapid.

The youngest igneous phase in the plutons comprises diabase dykes associated with east-west extension and irregular gabbro sills and pods. Similar dykes cut Tournaisian, but not Visean, strata south of the plutons and probably correlate with abundant gabbro intrusions in Guysborough Company and southern Cape Breton, dated at 339 Ma by U/Pb. Early Namurian K/Ar ages on secondary biotite and hornblende from mylonite in the Cape Chignecto pluton have been recently confirmed by $^{39}Ar/^{40}Ar$ dating. These point to a phase of dextral strike-slip on the Cobequid fault system that probably correlates with Namurian uplift inferred from sediment dispersal and marginal unconformities in adjacent basins.

ODP Leg 155 on the Amazon deep-sea fan: amazingly like the Meguma Group

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Leg 155 of the Ocean Drilling Program drilled 34 shallow holes (to 500 mbsf) on the Amazon deep-sea fan, in levees, channels, depositional lobes and monstrous mass flow deposits. Stratigraphic correlation was provided principally by seismic reflection profiling and rare highstand nanno-foram clays. Four glacial-interglacial cycles were penetrated. Maximum sedimentation rates on levees were 25 m per thousand years. The recovered core can be precisely related to depositional environment by the use of seismic reflection profiles.

The Amazon Fan has a thickness of many kilometres and dimensions of hundreds of kilometres. In water depths of less than 4000 m, the fan consists almost entirely of overbank muds and silts, traversed by narrow channels that deliver coarse sand to a sandy lower fan that has little interbedded mud. Many of the facies drilled on Leg 155 resemble those seen in the Meguma Group. These new observations support previous suggestions that the Goldenville-Halifax transition could represent a major facies change.

The environmental aspects of oil and gas development on the Scotian Shelf

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The successful development of oil and gas deposits on Canada's East Coast, specifically the Scotian Shelf, will require the right prices and markets, an efficient regulatory framework and appropriate environmental planning and review.

This environmental planning must take into consideration the historical and potential future uses of the Shelf area. Experience to date, using the Cohasset/Panuke project as an example, indicates that this is possible. The early establishment of communication with the fishing community and other groups or individuals that may, or have the perception that they may be affected is important in lowering the anxiety levels in the community. This helps lead to a less confrontational Public Review.

The other aspect of environmental management is the preparation of an external analysis to determine the "100 year oceanographic and meteorological design criteria". The results of these studies and geophysical information gathered at the development site are used to select or design the facilities to the proper Codes. While the Scotian Shelf is part of the North Atlantic, the environmental conditions are such that conventional engineering and proper design can meet the requirements for a safe and environmentally acceptable project.

Earthquakes and tsunamis of eastern Canada: cause for concern?

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The known earthquake seismic source zones of most concern to the populated areas of eastern Canada are the Charlevoix, Passamaquoddy and offshore Laurentian Slope seismic zones where major earthquakes of magnitudes 7.0, 5.7 and 7.2 occurred in 1925, 1869 and 1929, respectively. The Passamaquoddy area experienced a 5.9 event in 1904 and the Charlevoix area a 6.0 event in 1988 with the Laurentian Slope having had about nine events 5.0 or greater since 1929 up to 1977; all nine may have been simply aftershocks.

Events greater than 5.0 were not known in the Passamaquoddy Seismic Zone when the Lepreau CANDU Nuclear Generating Station was designed in 1975 for a maximum magnitude 6.0 event 20 km from the site. There are some indications of a seismic zone offshore in the Gulf of Maine and the New Year's Eve 1882 event may yet prove to be a significant earthquake centred in the Gulf of Maine. The January 9, 1982 earthquake of 5.7 in the north-central part of New Brunswick has led to the realisation that this area along with the Moncton area (1817 - 5.2) are zones of lesser seismic concern.

Only the 1929 tsunami is known to have been fatal and it stands as Canada's most tragic earthquake with a death toll of 28; the loss of life has recently been lowered by one with the Cape Breton loss of John MacLeod (actually John Young) now disproved by oral history. Other less serious tsunamis have occurred in 1755, 1848, 1864 and 1914 with apparent tsunamis in 1813, 1843 and 1908.

November 18, 1929 tsunami-laid sand and pebble deposits on the Burin Peninsula, Newfoundland

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The 1993 discovery of a tsunami-laid sand at Taylor's Bay on the Burin Peninsula has been detailed with trenching, surveying and electronic leveling as well as ^{210}Pb dating along with analysis of the peat section by the Terrain Sciences Division of the Geological Survey of Canada. Both tsunami-laid sand and pebble deposits have been found in at least four locations along the south coast of the Burin. The ^{210}Pb dating has confirmed that the deposit at Taylor's Bay is from the 1929 tsunami. The peat below the tsunami-laid sand (t-ls) at Taylor's Bay shows a normal peat plant succession. The addition of the 3 to 6 cm thick t-ls appears to have altered the drainage and the peat immediately above the t-ls shows a dramatic change to much more grass. The grasses slowly revert to a normal peat succession upwards from the t-ls.

The ideal conditions to create and to capture a tsunami-laid deposit appear to require a very nearshore or beach source of sand or fine pebbles, a back-beach pond to capture storm overwash and a low, flat marsh or peat bog 'meadow' shoreward of the pond to trap the slurry of fine sediment swept in by the tsunami.

Geology of the northeastern end of the Indian Mountain uplift, New Brunswick

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A regional geological compilation, supplemented by local detailed field work, is in progress in a 900 km^2 area northeast of Havelock in the Indian Mountain uplift of southeastern New Brunswick. The purpose of the study is to resolve historically perplexing stratigraphic and structural problems in the lower Carboniferous Horton Group. Samples have been collected for miospores to provide much needed chronology in these highly faulted and largely undated strata.

The Indian Mountain uplift is characterized by small inliers of pre-Carboniferous "basement" granitoids unconformably overlain by a thick section of lower Carboniferous (Tournaisian) Horton Group continental clastic strata. The Horton rocks are unconformably overlain by Visean coarse red beds and marine limestone of the Windsor Group and Visean to Namurian fine to coarse red beds of the Hopewell Group. The Namurian and older rocks defining the uplift are in fault and unconformable contact to the north and south with late Westphalian B to Stephanian red and grey fluviatile beds of the Pictou Group.

New findings from the preliminary field work include evidence that: (1) the uplift comprises several major northeast-trending faults that have a long history of reverse and strike-slip displacements, (2) north-northwest- and northwest-trending cross faults are primarily dip-slip structures and in part post-date the northeast-trending faults, (3) the rocks between Berry Mills and Salisbury on the north side of the Berry Mills Fault are Horton Group and not Boss Point Formation or Pictou Group as previously mapped, and (4) the base of the Pictou Group is diachronous from late Westphalian B on the south side of the Indian Mountain Uplift to late Westphalian C on the north side.

Temperature, chemistry, water-rock interaction and mineralization processes around the Gays River and Jubilee Zn-Pb deposits, basal Windsor Group, Nova Scotia

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The Gays River deposit (2.4 Mt, 8.6% Zn and 6.3% Pb) and the Jubilee deposit (0.9 Mt, 5.2% Zn and 1.4% Pb) are hosted by basal marine carbonates of the Windsor Group (Carboniferous, Visean). The mineralized unit overlies meta-clastic rocks of the Meguma Group (Cambro-Ordovician) unconformably, or continental clastic rocks of the Horton Group (Devonian) conformably, and is covered by evaporites of the Carrolls Corner Formation. The two deposits show a number of differences; in order to compare their mineralizing systems, isotopes and fluid inclusions of the two deposits and their host-rocks were investigated regionally.

On mainland Nova Scotia, the Gays River deposit is hosted by biolithites that are entirely replaced by texture and porosity preserving, pre-ore, dolomites. The high-grade ore part of the deposit occurs as a replacement of the dolostone, whereas low-grade ore infills primary pores. Precipitation of sphalerite and galena is partly coeval with xenomorphic calcite. Isotopic data indicate that hot, metal-rich fluids interacted with radiogenic continental clastic and/or metasedimentary rocks.

On Cape Breton Island, brecciated fine-grained limestone hosts the Jubilee deposit. Brecciation created secondary porosity which facilitated hydrocarbon and metal-rich fluid migration. The metal-rich fluid was hot and characterized by low $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ due to interaction with non-radiogenic granite and granodiorite, and to oxidation of hydrocarbons.

Fluid inclusion investigations indicate that (1) the regional background temperature around the Jubilee deposit was lower than around the Gays River deposit; (2) hydrocarbons were abundant during mineralization at Jubilee, but rare at Gays River; and (3) both deposits show T_m-T_h trends typical of mixing of two or more fluids, among which, one was heated (≤250°C), saline (≤ 25-30 wt. % eq. NaCl) and had Na/(Na+Ca) ≥0.7-0.8. In both deposits, oxygen and strontium isotope co-variations, and $\delta^{34}S$ suggest mixing of two or more fluids and sulfur of marine affinities. The mineralizing fluids of the Jubilee and Gays River deposits could have had distinct heated sources and could have mixed with background basinal brines.

Geomorphic evolution of Nova Scotia since the Triassic - constraints from fission track analysis and vitrinite reflectance

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Triassic and Jurassic rifting during the break-up of Pangea and opening of the Atlantic Ocean were the last major tectonic events to have influenced Nova Scotia. Since that time, the landscape of Nova Scotia has evolved through processes of landscape denudation. Davisian evolutionary models were first proposed by geologists who envisioned a single Mesozoic cycle of erosion, peneplanation, deposition and rejuvenation. The caveat of an alternative equilibrium model is that present-day landscape relationships have been maintained since the Triassic. The test of these hypotheses is the presence or absence of extensive Mesozoic and Cenozoic cover.

Thermochronological and organic maturity data from Nova Scotia provide constraints on the post-Triassic cooling history of the region and thus have a direct bearing on models of landscape denudation. The maturity of lignite from Cretaceous outliers has been used to suggest prior burial to depths of about 1 km. Previous forward modelling of apatite fission track data from Meguma Group metasedimentary rocks suggested post-Cretaceous heating of rocks presently exposed at the surface to temperatures around *ca.* 60 to 80°C. These earlier suggestions have been confirmed by new apatite fission track data from the Maritimes region and by new vitrinite reflectance data from the Shubenacadie area.

Random search forward modeling of apatite fission track data from Triassic sandstones collected near the Bay of Fundy requires linear cooling below *ca.* 120°C beginning in the Triassic to near-surface temperatures in the Cretaceous, followed by heating to temperatures in the range 50 to 60°C in the Tertiary in order to provide an acceptable fit to the data. Vitrinite reflectance of lignite coals from inferred Cretaceous strata intersected by the Shub 94-5 drill core ranges from 0.31 to 0.48% over depths of *ca.* 100 to 150 m, respectively. This level of organic maturity indicates heating to temperatures up to *ca.* 80°C, as well as suggesting a very high geothermal gradient at the time of peak temperatures. Estimating a former depth of burial from the paleotemperture data is spectulative in the absence of an extensive vertical profile to evaluate, but at least 1 km of additional Cretaceous section is suggested for geothermal gradients typical of sedimentary basins (i.e., 20-40°C/km).

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Deglaciation of the inner Scotian Shelf, Nova Scotia: correlation of land-sea events

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The continental shelf off Nova Scotia, located between the deep ocean and the land, is a critical region for land-sea correlation. Glacial and nonglacial sediments of the last glacial cycle are preserved in eastern Canada across the land-deep sea boundary to the edge of the continental shelf. The inner shelf has been recently mapped and subdivided into five coast-parallel terrain zones which record glaciation, ice retreats and readvances, and sea-level rise and fall during the Late-glacial period.

A major morainal system termed the Scotian Shelf End Moraine Complex lies at the seaward margin of the inner Scotian Shelf. These moraines formed at the margin of the Scotian Ice Divide located across the axis of the Nova Scotia peninsula. The divide evolved in response to removal of ice from the Laurentian Channel and its associated feeder tributaries. Ice flow from the Scotian Ice Divide changed from northward, directed into the Lauentian Channel to northwestward into the Bay of Fundy as ice receded from the Gulf of Maine. The formation of the Scotian End Moraines is coeval with abundant iceberg production in the Emerald Basin to the southwest, dated between 17 and 15 (^{14}C) ka.

Landward of the end moraines is a linear depositional basin termed the Basin Zone. Seven sequences have been identified from acoustic profiles. A piston core (91018-53) from this basin was analyzed for foraminiferal content and grain size variations and was radiocarbon-dated. Core lithofacies and biofacies were correlated to the seismic sequences in the Basin Zone. Interpreted together, these records provide a unique history of Late-glacial climatic change. Core 91018-53 did not penetrate the lowest depositional sequences (1+2) within the Basin Zone. They are characterized by high amplitude, coherent reflections (Emerald Silt facies A) and are interpreted to be ice proximal sediment, deposited by overflow and interflow meltwater plumes emanating from a tidewater ice margin.

The Chedabucto Bay glacier in northern Mainland Nova Scotia evolved from the Scotian Ice Divide after landward retreat of this glacier out of the Basin Zone (*ca.* 14-13 ka). A readvanced *ca.* 13 ka formed terminal moraines on land and DeGeer moraines in the marine realm. Sequence 2 in the Basin Zone (Emerald Silt facies A) was deposited during this re-advance. From 14 to 13 ka, sea level dropped rapidly, due to general isostatic recovery. As the margin of the Chedabucto Bay glacier emerged above sea level, wave turbulence and meltwater plumes from the retreating, tidewater glacier suspended and transported very large amounts of sediment. Iceberg rafting was also an important sediment delivery mechanism. This sediment was carried out into the Basin Zone, forming Sequence 3, characterized by low amplitude reflections and dropstone diffractions (Emerald Silt facies B). Enhanced current erosion during a sea-level lowstand *ca.* 11.6 ka was recorded in the inner Scotian Shelf basins by erosional truncation of Sequence 3. After this erosional event sea level rose rapidly concomitant with climatic warming, as indicated by foraminiferal fauna within the Basin Zone and increase in spruce pollen in Nova Scotia terrestrial lake records. In the Basin Zone a seismic sequence characterized by indistinct, low amplitude reflections (Sequence 4) was deposited.

Sequence 5 was deposited during the period from 11 to 10.0 ka. It is characterized in the core by increased sand content and sandy layers and seismically by a return to high amplitude, coherent reflections (Emerald Silt facies A). Sequence 5 is correlative with the Younger Dryas clay layer in lakes and the glacigenic sediments that overlie peat in land sections. Both land and sea records demonstrate an oscillation from organic-rich sediments to an inorganic sedimentation event initiated at around 10.8 ka. Climatic cooling and snowfield/glacier buildup on land, with increased sea-ice/icebergs in the marine realm, are the principal causes of these sedimentation events. The land and ocean sedimentation events appear synchronous.

Carbonate microbial mounds, mineralized vents, periplatformal oozes, and slump domes in Macumber equivalents, eastern Cape Breton

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Coarse, fascicular-optic calcite comprises scores of mounds that range in diameter from decimetres to decametres in basal Windsor strata. They contain a restricted fauna of vertical microbial strands coating homomorphic corals and bryozoa, nests of almost monospecific brachiopods, shrimp-like arthropods, and probable vestimentiferan worm tubes. Surrounding strata are of two main lithologies: black, peloidal carbonate laminites with slump structures and complexly slumped, vuggy dolomudstones with large, discordant, mineralized pipes. Crystals of calcite, baryte, and galena partially fill the vugs and pipes.

The mounds grew in deep, saline, anoxic water as organic "oases" of chemosynthetic communities. Bacterial activity concentrated over methane and/or hydrogen sulfide vents may have supported the communities, induced carbonate precipitation, and promoted both sulfate and sulfide deposition. They are similar to deep-water, tufa towers in saline rift lakes of the Great Basin (U.S.A.) and Africa. Laminites are rhythmites related to sulphate-reducing bacteria in a deep-basin/deep-water meromictic, lacustrine-like rift basin. The dolomudstones were slumped, peri-platformal oozes injected from below by small and large volumes of fluids.

Deposition and deformation of the Stellarton Formation, Nova Scotia: strike-slip motion at the southern margin of the Magdalen Basin

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The Stellarton Formation is a thick succession of Wesphalian (B-D) coal-bearing sedimentary strata that fills a lozenge-shaped basin at the junction of the Cobequid and Hollow Fault systems. The basin fill displays major facies changes both laterally and vertically. The basin fill is asymmetric, with mainly coarser clastic facies concentrated along the southern edge. The northern margin is characterised by thicker, more numerous coal seams. The lower density sediments and coal seams within the basin produce a pronounced, negative (-7 mGals) gravity anomaly. Comparison of laterally equivalent sections suggests that subsidence was greatest near the basin centre, but that the subsidence history of the basin is overprinted by the effects of differential compaction in the basin-fill.

Outcrop-scale structures involve closely spaced listric normal faults striking predominantly north-south. The earliest faults are associated with load structures, and were probably formed while the sediment was still wet. Larger-scale normal faults are associated with 'roll-over' fault bend folds. These extensional structures are overprinted by a suite of structures indicating shortening of bedding. Small thrusts, marked by calcite veins in sideritic concretionary siltstone beds, locally account for between 5 and 10% shortening in an east-west direction. These thrusts cannot be traced into adjacent shale beds; they probably formed at a time when the siderite beds were well lithified but intervening muds were still plastic. Later thrusts cut all lithologies, locally reactivating the earlier extensional structures.

Deformation is most intense along the northwest basin margin. Sedimentary strata of the Stellarton Formation are folded about axes trending southwest-northeast, and cut by extensional faults trending northwest-southeast, consistent with an environment of dextral strike-slip motion. Adjacent to the basin, older Westpalian rocks (New Glasgow and Middle River Formations) are uplifted and overturned, facing northwest. Fault slices of Mabou Group (Namurian) with cover of Middle River Formation in this zone are interpreted as forming a positive flower structure.

The structure of the Stellarton basin is consistent with an overall history of dextral strike slip motion. Deposition probably occurred in a transtensional environment associated with a releasing bend in the Cobequid-Hollow fault system; subsequent transpression along the northwest margin was probably associated with a change in movement direction or fault geometry.

The Canoe Landing lake deposit, Bathurst Mining Camp: an example of a distal transported massive sulphide deposit

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The Canoe Landing Lake deposit has calculated geological reserves of 22.8 million tons grading 0.64% Pb, 1.82% Zn, 0.56% Cu, 0.94 oz/ton Ag and 0.034 oz/ton Au. The sulphides are hosted by grey to black graphitic slate of the Middle Ordovician Boucher Brook Formation at or near the contact with the mafic lavas, hyaloclastite, pyroclastic and epiclastic rocks of the conformably overlying Canoe Landing Lake Formation. The stratigraphic position of this deposit is atypical of other deposits along the Caribou Horizon, which usually occur lower in the Boucher Brook Formation, i.e., immediately above the contact with felsic volcanic rocks of the Flat Landing Brook Formation.

The sulphides form a semi-continuous sheet with a strike length of 1200 m. The sulphide sheet strikes 110° to 140° with dips between 60°N and 90°N, and has a down-dip length in excess of 925 m. The deposit varies in thickness between 2 m and 9 m and averages 5 m. Hanging wall contacts of the sulphide lens tend to be sharp. However, footwall contacts may be sharp or gradational into disseminated pyrite that appears to be, in part, diagenetic. Footwall alteration features and stringer zone mineralization normally associated with proximal VMS deposits are absent at the Canoe Landing Lake deposit. Intraformational conglomerates (10 cm - 2 m thick) containing clasts of grey and black slate, and locally sulphides, in a black slate matrix are numerous in the immediate footwall of the deposit. The slate fragments range in size between 1 mm to 3 cm and tend to be tabular and quite angular, whereas, the sulphide clasts tend to be rounded. In most drill intersections the sulphide sheet comprises zones of massive, disseminated and clastic sulphides interlayered with barren slate, indicating numerous depositional episodes. These clastic textures are similar to textures seen in the "Transported ores" of the Buchans deposits and are consistent with a transported depositional model. These observations suggest that the sulphides are distal to the original vent complex and were emplaced by a combination of down slope transport and brine pool mechanisms.

Preliminary geomatics analysis of the St. Mary's basin, Nova Scotia

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A GIS and Image database is currently being established for the St. Mary's basin, central Nova Scotia. The database will include satellite optical and radar imagery, geophysics, including magnetics, gravity, and radiometrics, geochemistry, and lithological and structural data from parallel field mapping. The goal of the project will be to use this technology in two modes: (1) to examine the strengths of correlations between known geology and the geomatics datasets, and (2) to assist in the delineation of lithologies and interpretation of the tectonic setting of the basin and surrounding terranes.

The St. Mary's basin is comprised of the Horton Group which appears to be locally derived from the Meguma Terrane to the south. The rocks were deposited in a tectonically active strike slip basin as is evident by the fanglomerates at the southern flank and alluvial deposits in the central basin. The northern portion of the basin has been tectonically removed by dextral motion along the Cobequid/Chedabucto fault system. The southern boundary is defined by fault contact in the east with the West St. Mary's fault and in the west by an unconformity with the Meguma Group. Both the northern and southern boundaries are visible on the image data.

Deformation in the basin is minor with the exception of

the northern boundary and a northeast-trending zone of intense folding in the Stewiacke River area. The basin is characterized by northwest-trending lineaments representing fracture planes associated with dextral motion between the Meguma and Avalon terranes. Some lineaments appear to continue from the Meguma Terrane through the basin and into the Avalon Terrane to the north.

Image processing of the radar, Landsat, and geophysical information will assist in defining structures and potential lithological contacts within and surrounding the basin. The integration of the lithological and structural data from parallel mapping will be used in combination with the imagery to define approximate contacts. Profile modelling of the geophysical data (magnetics and gravity) is planned to assist in determining the extent of the basement blocks beneath the basin. Digital 1:250 000 and 1:50 000 base maps will be merged with the imagery and field data to produce image maps depicting several layers of information on a single map. A lineament analysis will be performed on the original imagery and shaded relief products, and interpreted based on the local strike-slip tectonic regime. General characteristics of the signatures (land cover, topography, geophysics, geochemistry) between the Avalon Terrane, basin, and Meguma Terrane will be examined for some key areas. Stream geochemistry will be examined to identify areas of potential mineralization and possible correlations with the source materials. All of the information will be compiled and presented using desktop mapping software for display and query. Mineral resource potential will be examined and modelled within the study area using a GIS.

Hydrocarbon charge modelling in the Jeanne D'arc Basin: status, plans, results and implications

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Hydrocarbons are distributed throughout sedimentary basins in response to unique combinations of physical, chemical and geologic/tectonic processes. Semi-quantitative to quantitative reconstructions of such processes through basin modelling increases our understanding of these petroleum systems. This provides a powerful petroleum exploration method which finds maximum utility when used with other tools such as 3-D seismic interpretation. The level of sophistication of basin modelling ranges from relatively simple, single point (often a well) 1-D reconstructions of burial, thermal and maturity histories, to fully integrated, dynamic, multiphase migration models in 2-D. The Hydrocarbon Charge Modelling Project (HCMP) is tasked with developing genetic models of hydrocarbon occurrence within Canada's offshore east coast frontier basins. The program of research is executed through an association between the Geological Survey of Canada (Atlantic Geoscience Centre - AGC and Institute of Sedimentary and Petroleum Geology - ISPG), several petroleum exploration and production companies, Dalhousie University Department of Earth Sciences and NSERC. The development of genetic models of the generation, expulsion, migration and accumulation of petroleum will assist in efforts to assist the remaining undiscovered resource and define the major geological risks and uncertainties associated with further frontier exploration and production. Two-dimensional, multiphase fluid migration models are presented for test lines in the Jeanne D'Arc Basin and indicate several phases of expulsion/migration and accumulation.

Gas chromatographic analysis of organic molecules in fluid inclusions within sulphide ore minerals

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This paper outlines a method to analyze fluid inclusions in ore minerals for organic molecules by the direct crushing of host phases on-line to a gas chromatograph. This technique has rarely been performed on sulphide ore minerals and the sampling therefore considered a range of geological and ore depositional environments. Results show organic phases, most notably low molecular weight hydrocarbon gases, evident in varying proportions. High molecular weight hydrocarbons were also present but at lower levels. A negative correlation is inferred with the increase of formation temperature and the presence of CH_4. Therefore, organic phases are present in ore minerals and at the time of ore precipitation, although at this stage the effects of organic molecules interacting with inorganic species and minerals, directly or indirectly, is poorly constrained. A more integrated and detailed study is required to constrain these reactions and to clarify the effect of organic molecules in ore mineralisation systems.

Stratigraphic and petrochemical contrasts between the northern and southern parts of the Bathurst camp, New Brunswick: investigations in the Big Bald Mountain area

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The Big Bald Mountain area is underlain by siliciclastic sedimentary rocks of the Cambro-Ordovician Miramichi Group, volcanic and sedimentary rocks of the Middle Ordovician Tetagouche Group, and Ordovician to Siluro-Devonian granitoid rocks. A broad dextral shear zone (Pringle Brook Fault) strikes east-west through Tetagouche Group stratigraphy and divides the area into two domains characterized by contrasting volcanic rock lithology and petrochemistry. North of the shear zone, the Tetagouche Group comprises the Patrick Brook, Nepisiguit Falls, Flat Landing Brook, and Boucher Brook formations, whereas to the south, the Clearwater Stream Formation and Stony Brook volcano-plutonic complex occupy the stratigraphic positions of the Nepisiguit Falls and Flat Landing Brook formations, respectively. North of the Pringle Brook Fault, quartz-feldspar-phyric rocks ("porphyry") typical of the Nepisiguit Falls Formation locally host massive sulphide deposits and associated laterally-extensive iron formation. However, to the south of the Pringle Brook Fault, quartz phenocrysts are absent in the stratigraphically equivalent felsic pyroclastic rocks of the Clearwater Stream Formation, and massive sulphides (Chester deposit) lack an associated iron formation. Relict glassy textures and flow-margin hyaloclastic breccias typical of felsic volcanic rocks in the Flat Landing Brook Formation are absent in the Stony Brook Complex, which contains a large proportion of hypabyssal intrusive rocks. South of the fault, mafic volcanic rocks of the Boucher Brook Formation are almost exclusively massive, unlike the pillowed flows that dominate farther north.

All felsic volcanic rocks are subalkaline and range in composition from dacite to rhyolite on a SiO_2 vs. Zr/TiO_2 diagram. However, felsic volcanic rocks in the southern domain contain higher abundances of high field strength elements (HFSE) and rare-earth elements (REE), have higher Zr/TiO_2 ratios and more prominent negative Eu anomalies. North of the Pringle Brook Fault, felsic volcanic rocks of the Flat Landing Brook Formation can be distinguished from those of the Nepisiguit Falls Formation by higher abundances of HFSE (Ti, Th, Hf, Sc, Nb, Y, Zr) and REE. South of the fault, the Stony Brook Complex felsic rocks can be distinguished from the Clearwater Stream Formation mainly by their very high K_2O/Na_2O ratios, but also by higher REE and a larger negative Eu anomaly. Mafic volcanic rocks of the Boucher Brook Formation exhibit both alkalic and tholeiitic affinities. Alkalic basalts and trachyandesites have sloping REE profiles, whereas tholeiitic basalts that are locally interbedded with the alkalic variety, are characterized by flat, MORB-like REE profiles, as well as lower HFSE and REE, and higher V, Sc, and Cr than alkalic basalts.

Application of apatite fission track analysis to hydrocarbon research in the Atlantic Provinces

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Apatite fission track analysis is a rock-dating technique that also provides the temperature attained by the rocks in the geological past. The technique is particularly sensitive and well-calibrated in the temperature range 60 to 120°C, which coincides with the range of temperatures at which liquid petroleum is generated in organic-rich sedimentary rocks, migrates and (under the right conditions) accumulates to form reservoirs. The technique exploits the instability of fission tracks (damage trails) in the crystalline lattice of the mineral apatite [$Ca_5(PO_4)_3(F,Cl,OH)$], which occurs commonly among sand grains. Fission tracks are formed continuously through time from the spontaneous radioactive decay of ^{238}U, present in minute amounts in the structure of apatite. The number of tracks per unit area is a function of the uranium content, and of the time elapsed since the rocks cooled below about 120°C, and thus an age is obtained. But tracks (formed with a length of 16µm) are annealed (fade) as a function of time and temperature and following the laws of diffusion, therefore the measurement of the lengths of tracks within the mineral grain allow an assessment of the timing, magnitude, and style of cooling for rock samples that were hotter in the past. The development of predictive modelling techniques and fast computers have transformed apatite fission track analysis into a powerful tool in the study of the thermal history of sedimentary basins. Dalhousie's Fission Track Laboratory has recently been awarded an equipment grant from the Canada-Nova Scotia Offshore Development Fund, thanks to which the region has now this world class facility unique in Canada. Highly trained personnel, students and scientists and industry geologists from Canada and several other countries benefit from the research carried out in the lab.

Fission track analysis in the Maritimes Basin (located beneath the Gulf of St. Lawrence and adjacent low-lying areas of New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland), confirm that sedimentary rocks were heated to temperatures in excess of 100 to 150°C very soon after their deposition in the Carboniferous Period, probably leading to hydrocarbon generation and migration, and to the formation of significant coal deposits and coal bed methane. Since the Permian Period the area has been uplifted and up to 4 km of sedimentary cover has been removed by erosion from most of the Canadian margin.

Studies in the Scotian Basin offshore Nova Scotia, where

25 exploratory wells have dicovered hydrocarbons, show that samples from the Missisauga, Mic Mac and Verrill Canyon Formations of early Cretaceous age have apatite fission track ages younger than their stratigraphic ages, indicating partial to total annealing of fission tracks. The computer modelling of data for many samples indicates that some of the rocks have been hotter (up to 55°C) in the past (at some time between 100 and 40 million years ago) than at present.

The genesis of the Chuquicamata porphyry copper deposit in northern Chile in relation to Tertiary Andean tectonics

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The principal copper deposits of the Andes of northern Chile, of which Chuquicamata (*ca.* latitude 22°16.5'S/longitude 68°54'W) is the largest, are porphyry type deposits related genetically to the epizonal emplacement of late Eocene-early Oligocene (41-31 Ma) stocks. The large porphyry copper deposits are distributed preferentially within the domain of a regional north-south shear system, that roughly coincides with the western limit of a large uplifted block in the Pre-Cordillera, cored by Paleozoic crystalline rocks. The Paleozoic basement, which remained under the sea during the Jurassic and part of the early Cretaceous, has been uplifted to 4000 and 5000 m.a.s.l. Apatite samples from Paleozoic intrusive rocks of the Domeyko Cordillera give fission track (FT) ages ranging from 45 to 35 Ma. The ages show a regular variation with altitude, and track-length modelling indicates that the region underwent relatively fast cooling due to exhumation in the Late Eocene (Incaic tectonic phase) and that exhumation continued at a steady, but slower pace until a renewed faster episode in the Miocene (Quechua tectonic phase). Crustal thickening associated with the Incaic tectonic phase appears to have depressed the zone of magma generation into a homogenized, undepleted deep- or sub-crustal source, to form magmas with a restricted range of Sr, Pb, Nd, S and O isotopes, and steep REE patterns typical of Chilean porphyry coppers of Tertiary age.

Apatite FT ages from Chuquicamata are similar to $^{40}Ar/^{39}Ar$ dates on hydrothermal micas and K-feldspars, compatible with fast cooling and shallow emplacement of the ore system. FT data in the vicinity of the Falla Oeste, a large north-south neotectonic structure that truncates the orebody, indicates that part of it cooled for the last time under *ca.* 100°C in the Pliocene.

Our working model envisages Chuquicamata developing at the roots of an explosive volcanic complex such as a Cascades volcano. Mineralized porphyries would have been intruded at *ca.* 34 Ma, into a relatively deep, active, dextral, ductile shear related to oblique subduction. Potassic alteration, fracturing and low-grade (*ca.* 0.5% Cu) bornite-chalcopyrite mineralization ensued, dominated by magmatic fluids. Uplift and erosion followed, removing the epithermal domains of the hydrothermal system. A new pulse of porphyry intrusion, quartz-sericite alteration and renewed mineralization with a net input of Cu, Mo and As, occurred at *ca.* 31 Ma, controlled by brittle fractures at a shallower depth than the older potassic alteration, still responding to a dextral shear system. Continued exhumation in the Oligocene enhanced the wholesale supergene enrichment of the deposit into Miocene times, coinciding with a period of sinistral strike-slip movement of the Falla Oeste system.