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Résumé de l'article

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ATLANTIC GEOSCIENCE SOCIETY

ABSTRACTS

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1986 Colloquium

MARITIME SEDIMENTS AND ATLANTIC GEOLOGY

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Geological and fluid inclusion study of tin mineralization associated with the Wedgeport Pluton, Yarmouth County, Nova Scotia*

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Cassiterite and base metal sulphides occur in veinlets in the margin of the Wedgeport monzogranite, and vein and stratiform concentrations in metasediments which belong to the transition between the Goldenville and Halifax Formations (GHT) of the Meguma Group. The metasediments contain beds rich in calcareous concretions, metamorphosed to calc-silicate nodules.

Tin occurs in (1) rare detrital cassiterite grains, (2) stratiform sulphide-cassiterite replacement bodies in calcareous layers, (3) sulphide-cassiterite veinlets in metasediments with restricted chlorite alteration and (4) rare sulphide-cassiterite veinlets in greisenized monzogranite. The sulphide cassiterite veinlets exhibit a mineralogical zonation away from the pluton: Mo and W rich within 2 km of the pluton, Sn rich about 3 to 4 km away, to Pb and Zn rich about 4 to 7 km distant. Trace element background values of plutonic samples are lower than those usually associated with "specialized" tin-bearing granitoids. Alteration haloes around mineralization are limited, and therefore lithogeochemical exploration may be of limited use. Background trace element contents of metasediments are similar to or lower than the average values found in the host metasediments of Cornish tin deposits.

Primary fluid inclusions in fluorite and quartz in greisenized veinlets within the pluton have moderate salinities and homogenize at ca. 295°C and those in quartz veinlets associated with base metals as far as 5 km from the pluton, homogenize at a slightly lower temperature. Different populations of secondary fluid inclusions throughout the area homogenize below 200°C. This is compatible with emplacement of the cassiterite mineralization following emplacement of the pluton and contact metamorphism, at pressures of 1000-2000 bars and temperatures of 400-500°C. The secondary inclusions have developed during a protracted and complex post-mineralization structural history which involves shearing events, and the intrusion of dykes in Triassic-Jurassic times.

*Research supported by NSERC Grant A9036 and E.M.R.-G.S.C. Research Agreement 10614/81.

Indications of source area for Hibernia oil from Vitrinite Reflectance studies, Grand Banks of Newfoundland

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Vitrinite reflectance measurements have been made on ditch cutting samples from 13 wells in the Jeanne d'Arc Basin, located on the Grand Banks of Newfoundland. Maturation profiles based on these measurements yield estimates of organic maturity and indicate the depth and thickness of the present oil-generating interval ('oil window') at each well site. These profiles mimic the thermal gradient of the well and are an expression of them. The

thermal gradients in turn appear to reflect rock conductivity and basin structure.

The area of lowest thermal gradient, where the 'oil window' is thickest, lies in the central part of the basin adjacent to most of the significant oil discoveries including the giant Hibernia oil field. During the past 100 million years the 'oil window' moved upwards through the section containing Upper Jurassic oil source rocks. As it did so, it probably had a similar configuration to its present form. Because the greatest thickness of the 'oil window' is in the central area of the basin, the organic matter present there had the longest time to generate oil. If so, this would be a significant factor in the charging of the reservoirs at hibernia and nearby discoveries.

Tectonostratigraphic subdivisions of Cape Breton Island, Nova Scotia

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Cape Breton Island has traditionally been considered to be part of the Avalon Terrane but until recently scarcity of detailed field studies and radiometric age data made regional correlations difficult. A new geological map of Cape Breton Island now includes most of the pre-Carboniferous rocks, generally mapped on a scale of 1:20,000, and is supported by detailed studies of petrology, geochemistry, metamorphism, structure, and geochronology, thus providing a much clearer picture of the complex geology. The data suggest a division into four zones (Southeastern, Central, Highlands and Northern Highlands). Boundaries between the first three zones may be gradational, but major fault/mylonite zones separate the Northern Highlands and Highlands Zones. The entire island is much affected by major faulting and shearing of Devonian to Carboniferous age.

Southeastern Cape Breton Island is characterized by typical "Avalonian" geology - large epizonal dioritic to granitic intrusions of late Hadrynian to Early Cambrian age intruded into mainly calc-alkalic metavolcanic and metasedimentary rocks (Fourchu Group) of similar age, and overlain by essentially unmetamorphosed Cambro-Ordovician sedimentary and bimodal volcanic rocks. Crossing the Bras D'Or Lakes into the Central Zone, the Fourchu Group is replaced by the George River Group, a shelf sequence of mainly marble, quartzite, slate and other metasedimentary rocks, intruded by granitoid rocks similar in petrology and age to the southeast. To the north in the Highlands Zone, gneissic units are widespread and the metamorphic grade increases in other metasedimentary rocks. However, correlation between the George River Group and any of the various metasedimentary and metavolcanic units of the Highlands appears tenuous and, at best, marble and quartzite-bearing units in the Highlands may represent deeper water, more argillaceous equivalents of the George River group. A characteristic feature of the Highlands Zone is the abundance of granitoid rocks which cover more than two-thirds of the area and display a wide range in composition and age. Many are Devonian and Early Carboniferous, but Siluro-Ordovician and Late Hadrynian to Early Cambrian intrusions are also numerous. The Northern Highlands is underlain by the "Blair River complex", an assemblage of quartzo-feldspathic gneiss, syenitic gneiss and amphibolite, intruded by anorthosite, monzodiorite, and syenite.

Geological mapping of plutonic and metavolcanic rocks, Eastern Caledonian Highlands, New Brunswick

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Geological mapping in the eastern Caldedonian Highlands of southern New Brunswick during the summer of 1985 covered an area of approximately 160 km^2 centred on the Fortyfive River pluton north of Alma. The purpose of this study is to examine in detail the distribution, field relations, lithology and chemical composition of the plutonic rocks in the area, as well as their host metavolcanic rocks, in order to interpret their petrogenesis and tectonic setting, assess their economic potential and compare them to units inferred to be of similar age elsewhere in the region, especially southeastern Cape Breton Island.

Preliminary results indicate that the plutonic rocks are mainly hornblende-bearing diorite, quartz diorite, leucotonalite, granodiorite and minor granite. There is no evidence for more than one age of plutonism, and the intrusions are inferred to be comagmatic. Host metavolcanic rocks are mainly medium to fine-grained intermediate to felsic crystal tuffs, now metamorphosed to slate and phyllite. Primary textures are largely destroyed by development of metamorphic foliation and widespread pervasive cataclastic deformation which also affected the plutonic rocks. The Teahan Zn-Cu-Pb-Ag-Au prospect in the northern part of the map area is hosted by a felsic phyllitic unit. Similar units occur elsewhere in the map area and typically contain abundant pyrite. Pyritic quartz veins are also widespread. A major sedimentary unit (including arkose and conglomerate) may post-date the volcanic rocks, but has been deformed and metamorphosed with the older rocks. A less metamorphosed arkosic sedimentary unit with interlayered amygdaloidal basalt flows occurs in the southern part of the map area. It is interpreted to unconformably overlie the other rock units, and may be Cambrian (or younger).

Gravity modeling of a mafic, ultramafic association, Darvel Bay, East Sabah, N. Borneo

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The association of tertiary age mafic, ultramafic and sedimentary rocks exposed at Darval Bay, East Sabah, Malaysia is believed to be the best exposure of an apparently continuous arcuate line of ophiolite running along the Sulu archipelago and Palawan Island (Philippines). The exposures at Darvel Bay are interpreted by Huchison (1975) to be part of a large flake of upthrust oceanic or marginal basin lithosphere.

This area was the site of a gravity survey in 1975 conducted by Dr. P.J.C. Ryall. The results of the survey are summarized in a Bouguer contour map of the area which shows a positive gravity anomaly of 70 mgal associated with the mafic-ultramafic suite.

Based on preliminary results, subsurface interpretations by Huchison (1975) need to be modified in order to result in the production of a satisfactory structural model which can accommodate both the available geological and geophysical data.

Models produced to date indicate subsurface geometry of the mafic and ultramafic bodies consistent with post emplacement tectonic (folding and faulting) activity rather than thrusting associated with a Miocene emplacement.

Bromine stratigraphy of Windsor Group Major Cycle 1, A guide to depositional conditions, correlation and structural configuration

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The methodology of progressive bromine substitution for chloride in successive saline evaporites, including halite, sylvite and carnallite has been developed and applied to potash exploration and interpretation of many evaporite sequences. Distribution coefficients for bromine in chloride salts deposited from sea water are less than one. Therefore, residual brines depositing progressive evaporite sequences are enriched in bromine if the rate of evaporation equals or exceeds the rate of basin influx-reflux.

The Windsor Group comprises five major depositional cycles. Major Cycle 1 (MC1) is the basal, thickest and contains the greatest proportion of evaporites. MC1 facies in Nova Scotia, New Brunswick and Newfoundland are very similar lithologically, suggesting interrelated and probably nearly synchronous depositional histories in the Carboniferous Magdalen (Fundy) Basin. Major seaway connections with the proto-Atlantic(?), through the Nova Scotia Platform and parts of Cape Breton, allowed very rapid catastrophic invasion of a sub sea level intermontane basin complex. Physical and dynamic restriction in a highly evaporitic arid environment caused salinity increases from normal to hypersaline levels. This progression produced the classic marine evaporite suite of marine basal carbonate, anhydrite, halite and potash in a vertical sequence up to 600 metres thick. Although local variations are present, there is generally a regional lateral facies change with less saline facies to the southeast (Nova Scotia Platform) and more saline facies to the northwest (New Brunswick Platform).

Bromine profiles representing Br content of NaCl in several widely separated sections of MC1 in New Brunswick and Nova Scotia are similar to the increasing upward theoretical profile and actual profiles from world marine evaporite analogues. A distinctive peak in the lower half of the halite phase coincides with major potash deposition. Deviations and irregularities in the overall increasing upward trend reflect variation in depositional salinity, due in part to repeated freshening influx that produced numerous minor recessive cycles of anhydrite. Locally, Br profiles assist in the correlation of the anhydrite zones as well as confirming or detecting repetition by folding in sequences lacking distinctive marker units. Bromine stratigraphy is a powerful tool for identifying the conditions for potash deposition and consequently for assessing the potash potential of evaporite basins.

Contact metamorphic effects of the Liscomb Pluton on the Eastville lead-zinc deposit, Colchester County, Nova Scotia

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Mineral occurrences in the Cambro-Ordovician Meguma group have been found to be preferentially associated with the transition between the Goldenville and Halifax Formations (GHT, Zentilli and MacInnis, 1984). The Eastville Zn-Pb deposit is located between Eastville and Hattie Lake, Colchester County, Nova Scotia, and consists of a 10 km section of steeply dipping GHT striking to the northeast. The Liscomb Pluton, a Devonian-Carboniferous granodiorite-

monzogranite complex, intrudes the deposit, making this locality a unique place to study the interaction of granitoids with mineralized GHT.

At Eastville, significant quantities of Mn (between 6.9 and 8.6 weight %) predominantly contained in spessartine garnet, are found in finely laminated, locally calcareous, contorted beds (coticules) of the GHT. The protolith of this coticule appears to be Mn-carbonate, as demonstrated by Hingston (1985) at Lake Charlotte (another exposed section of the GHT), where spessartine garnet has grown at the expense of Mn-carbonate with increasing metamorphic grade. At Eastville, the rocks have undergone regional metamorphism to lower greenschist facies represented by assemblages of chlorite ± spessartine garnet ± muscovite ± quartz, indicating temperatures of between 370 and 445°C.

The presence of sphalerite in the cores of regional metamorphic spessartine garnet indicates an important Zn enrichment prior to deformation associated with the Acadian Orogeny (Cameron, 1985). This textural evidence poses constraints on possible genetic hypotheses for the base metal sulphides. Syngenetic-diagenetic models are favored.

Intrusion of the Liscomb Pluton changed Zn/Pb ratios in the deposit and produced a contact aureole of staurolite grade with garnet-biotite geothermometry suggesting a temperature of around 580°C for this episode. These temperatures are only tentative, because the presence of Mn makes these geothermometers of questionable validity. The Liscomb Pluton is similar to other granitoid plutons in the Meguma Zone. Granodiorite occurs in the western section of the pluton, while monzogranite forms the more eastern section. A limited geochemical study of the northwestern corner of the Liscomb Pluton does not reveal metal specialization. If not definite evidence, similar Pb-Zn ratios in the Meguma Group and the pluton, possible metamorphic garnets in the granodiorite, and rounded xenoliths are compatible with significant assimilation of Meguma rocks by the Liscomb Pluton.

Research supported by NSERC Grant A9036

Anhydrite distribution in the Pugwash Salt Mine - 830' Level

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The Canada Salt Company began producing salt at Pugwash, Nova Scotia in 1959 following the closure of the Malagash, Nova Scotia mine in the same year. Interpretation of the initial drilling at Pugwash suggested a simple flat-lying salt deposit. However, production work very quickly revealed that the deposit was a complex series of steeply dipping anhydrite units interstratified with halite. The anhydrite units are isolated in a matrix of halite by boudin development. Within the evaporite sequence, bedding dips from 30° ('flat lying') to sub-vertical.

Published geological reports on the Pugwash mine have been limited to the 630 foot level workings and have discussed the origin and lithology of the anhydrite, and the stratigraphy and geometry of what was interpreted to be a complex salt diapir. Subsequently, mining on the 630 foot level has been completed and production is now from the 830 and 730 foot levels. Investigations of the latter levels have not been attempted prior to this study.

Although the evaporites are structurally complex, individual anhydrites and ultimately the intervening halite units can be identified and correlated. There are two or possibly three lithologically distinct anhydrite members exposed in the 830 foot level workings. The two recognizable members (ranging 15-30 m in thickness) have been termed informally the main anhydrite and the borate anhydrite. There is possibly a third anhydrite member which does not exhibit internal markers. However, it is suspected that further detailed investigations will identify the currently unnamed anhydrite units as fragments of one of the above. The potash (carnallite and sylvite)-bearing halite and mudstone present on the 830 foot level probably occur within an upper stratigraphic portion of the evaporite sequence, as exposed in the present workings.

The Avalonian terrane around Saint John, New Brunswick and its relation to the evolution of the Appalachians

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The Saint John region exhibits basement of tonalitic gneiss (probably about 1700 Ma) veneered by a shelf-type metasedimentary sequence (marble-quartzite). These units are intruded and overlain by volcanic plutonic complexes of Late Precambrian age emplaced in three stages separated by significant deformation. The oldest stage (750-800 Ma) produced mafic to ultramafic plutons, accompanied by contemporaneous submarine slumps. The second stage produced major basalt-andesite-rhyolite units and cogenetic plutons, while the third (Eocambrian) stage produced bimodal rhyolite porphyry and basalt, with abundant volcanoclastic sediments. The latest Eocambrian stage passed with slight unconformity into Cambro-Ordovician sedimentation. Silurian rocks occur only as allochthonous slices, and Devonian rocks are absent. Abundant coarse clastics of Carboniferous and Triassic age accumulated in fault-bounded troughs.

Major structures, including folds overturned to the northwest and numerous transcurrent faults, appear to be mainly of Carboniferous age, but the movement history of the faults probably dates to Precambrian time. Significant deformation of Taconic (Ordovician) or Acadian (Devonian) age has nowhere been demonstrated in this terrane. Despite local spectacular thrust allochthons, deformation resulted mainly from transcurrent fault motion on curved faults. Local kinematic indicators suggest diverse movement senses which explain the observed segmentation of the terrane.

Comparison of the Saint John terrane with other Avalonian terranes suggests that much of the Avalon tectonostratigraphic zone in Canada is floored by Precambrian basement of Grenville aspect. The western side of this zone was strongly affected by Late Ordovician-Early Silurian magmatism and deformation which reflects the amalgamation of this zone with more westerly zones. These observations suggest a relatively local, rather than exotic, origin for Avalon terranes, and a history involving repeated break-up and re-welding of a continental edge.

The Deep Cove Pluton and associated Polymetallic Mineralization, Gabarus Bay, Cape Breton Island, Nova Scotia

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The Deep Cove Pluton and Fourchu Group rocks at Gabarus Bay, Cape Breton Island were studied in detail in the summer of 1985 as part of an Acadia University M.Sc. research program. The study included four weeks of field mapping at Gabarus Bay, and four weeks of logging drill core at the N.S.D.M.E. core library in Stellarton. Drill core from a total of 22 wells was logged. The holes were drilled in the pluton and in the adjacent country rock to delineate alteration zones containing polymetallic (Ag-Bi-Cu-Pb-Zn) mineralization.

The Deep Cove Pluton intruded into Late Precambrian rocks of the Fourchu Group, which consists of a complex sequence of mainly pyroclastic rocks of predominantly intermediate composition. Preliminary results of petrographic and geochemical studies indicate that the pluton is a variably altered porphyritic granite with phenocrysts of plagioclase in a fine grained granitic groundmass. Two other intrusive units are also identified; 1) a series of randomly oriented rhyolitic dykes ranging in width from less than 1 m to over 5 m and 2) a fine grained equigranular granite dyke of unknown dimensions (observed at a depth of approximately 270 m in a single drill core). Alteration within the pluton is complex, with zones up to 15 m wide of quartz-sericite-pyrite greisenization displaying complete destruction of original texture, separated by zones of less intense alteration where the principle alteration products include sericite, chlorite and potassium feldspar. Alteration generally decreases with depth and strongly altered zones occur as lenses rather than uniform horizons.

Mineralization is of two main types; 1) simple molybdenite occuring in quartz veins and as disseminations and, 2) polymetallic mineralization (pyrite, pyrrhotite, chalcopyrite, sphalerite, molydenite and bismuthinite) occuring as veins and fracture coatings. Polymetallic mineralization is associated with zones of stronger alteration.

Faulting and Deformational History of the Cobequid Highlands, Northern Nova Scotia

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The Cobequid Highlands region contains rocks that range in age from Early Hadrynian or older to Early Jurassic. The oldest Precambrian rocks, the Bass River and Mt. Thom complexes, a "basement" unit (Great Village River Gneiss) which was deformed and metamorphosed prior to c.940Ma. Younger "cover" rocks (Gamble Brook and Folly River Schists) were deposited, intruded, and deformed with the "basement" prior to c. 700Ma. These rocks contain folded mylonite zones which may represent ancient fault zone remnants. The younger Precambrian mafic volcanic rocks (Jeffers and Warwick Mountain formations) were deformed during the Cadomian Orogeny of approximately 600 ma. Dioritic and granitic plutonism followed the two periods of folding. No information exists about the Taconian Orogeny because no Cambrian or Early Ordovician rocks are preserved. The Acadian orogeny was heralded by the deposition of now exposed conglomerates at the top of the Silurian-Early Devonian section. The Acadian folding event began in Middle Devonian time. During the last part of the Devonian great volumes of felsic and mafic volcanic rocks were erupted. Much of this thickness was preserved by faults (perhaps contemporaneous in part) which downdropped or rotated the volcanic pile. Large volumes of diorite then granite were intruded in the Early to "Middle" Carboniferous during "Middle Carboniferous (Namurian) time. Some of the plutons were mylonitized and cut by E-W faults while others were intruded into the faults. Some of the faults had 20 to 100 km or more of probable dextral movement. The major fault movements constituted the "early" Alleghenian - Hercynian Orogeny. Stata and plutons of early Namurian age or older were penetratively deformed along

a narrow (20 to 50 km) zone parallel to the Minas Geofracture. Late Carboniferous rocks rest unconformably on the older strata and contain numerous conglomerates near the E-W faults. Graben formation began in Middle to Late Triassic time and produced fanglomerates and related fine-grained sedimentation. None of the Triassic or Early Jurassic strata were penetratively deformed.

Avalonian volcanic rocks of Nova Scotia

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The nature of Late Precambrian volcanic rocks in the Avalon Composite Terrane in Nova Scotia varies from one terrane to another: (i) in the Cape Breton Terrane, calc-alkaline basalts, andesites, rhyolites and pyroclastics characteristic of a cratonic volcanic arc are prevalent (Fourchu and Keppoch Formations) (ii) in the Antigonish Terrane, tholeiitic basalts (Chisholm Brook Formation) and oceanic island alkali basalts (Clydesdale Formation) occur in an interarc basin.

During transpression immediately following the accretion of these terranes into the Avalon Composite Terrane, bimodal alkali and tholeiitic, within-plate Cambrian volcanism occurred in small pull-apart rifts. Volcanism next occurred at the beginning of the Silurian with the eruption of bimodal, within-plate continental tholeiitic lavas associated with the minor rifting event preceding the Silurian transgression. Mid-late Devonian and earliest Carboniferous volcanism in the Avalon Composite Terrane is typically bimodal, alkali and tholeiitic, within-plate, and continental and formed in response to the rifting associated with the pull-apart Magdalen Basin produced during the Acadian Transpression Stage.

The Geological Structure of the Paleozoic Rocks on the Avalon Platform, Offshore Newfoundland, Canada

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Single channel seismic reflection profiles across the Avalon Platform have been analyzed for Paleozoic reflections and interpreted in conjunction with lithologic and biostratigraphic data. Formline mapping revealed a 4000m thick Ordovician-Silurian marine shale sequence that is gently folded about NNW-SSE axes, and is unconformably overlain by a synclinal inlier of ?Devonian red beds approximately 700m thick.

The Avalon Platform may represent a mildly deformed Acadian terrain, which is contiguous with onshore Avalonian sequences, or it may be part of a foreland zone adjacent to an overthrust belt.

Geological Highway Map of New Brunswick and Prince Edward Island

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The English version of the Geological Highway Map of New Brunswick and Prince Edward Island was published as A.G.S. Special Publication #2 on schedule and in time for the Annual Meetings of the Geological Association of Canada and the Mineralogical Association of Canada in Fredericton, N.B. in May 1985. The French version was published in November 1985 and was on display at the Review of Activities of the N.B. Department of Forests Mines and Energy in Fredericton. The map is thus the first geological highway map of any Canadian Province to be published in the two official languages. Translation into French was by Yvonne McLaughlin under the supervision of Jacques Thibault of the N.B. Department of Natural Resources.

The colour scheme is compatible with that of the Geological Highway Map of Nova Scotia (published as A.G.S. Special Publication #1 in 1980) and the scale is approximately the same so that the two maps may be used in juxtaposition to illustrate the geology of the entire Maritime Provinces.

Initial seed money for the project was kindly provided by the Canadian Society of Petroleum Geologists and the Canadian Geological Foundation. The bulk of the project was funded by the N.B. Department of Natural Resources with assistance from the N.B. Department of Tourism and the Government of Prince Edward Island.

Printing costs of both the French and English versions have been covered by the N.B. Department of Natural Resources and the Canada Department of Energy, Mines and Resources under the Canada-New Brunswick Subsidiary Agreement on Mineral Development, 1984.

The Stratigraphic Nomenclature of Atlantic Canada

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Volume 6 of the Lexicon of Canadian Stratigraphy, for the Atlantic Region, will be published in spring 1986. A database containing the names of all stratigraphic units in the region has also been prepared, and can be made available to any interested person. Unlike the Lexicon itself, which being a book cannot stay up-to-date, the database will be maintained as a current reference.

The comprehensiveness of the lexicon is due to the time and services of many volunteers. There are detailed write-ups of all the formal entries. The database should similarly be maintained through the interest of research workers. At present, it includes names, rank and status, locality, ages and a minimum of citation information. A particular attempt has been made to address the relationships of old and current names, and rank memberships and groupings. This information has been proofread against the lexicon. In future, it will be corrected and updated with the help of contributors around the Atlantic Region.

The Lexicon and database will be explained and demonstrated. Any interested persons are invited to suggest appropriate changes or improvements. Copies of the database will be made as printouts or on floppy discs for research workers.

Possible Avalon Basement in the Miramichi Terrane

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The Miramichi Terrane is characterized by the presence of volcanic rocks and associated iron formation of the Ordovician Tetagouche Group. The abundance of felsic volcanic rocks in northern New Brunswick, together with an underlying, thick, quartzose sedimentary sequence implies a Precambrian continental basement to the Miramichi Terrane; the felsic volcanics were presumably generated by partial melting and the quartzose substratum derived by erosion of a sialic protolith. Generally migmatitic rocks of the Trousers Lake Complex in central New Brunswick may represent surface exposures of this basement.

The Trousers Lake Complex forms a sequence of interlayered amphibolite, sillimanite-bearing schist, psammite and granitic gneiss that is quite unlike the greenschist-facies volcanic and sedimentary rocks of the Tetagouche Group. Rocks of the complex can be traced southward from Trousers Lake to the Catamaran Fault, but their eastward extent is not known with certainty. Similar rocks occur south of the Catamaran Fault in the Sisson Brook area where they appear to be in fault contact to the southeast with quartz wacke and phyllite of the Tetagouche Group.

The Miramichi Terrane, lying as it does to the south of the Ordovician Fournier ophiolitic suite of northeastern New Brunswick, can be considered as a continental fragment within the Avalon Composite Terrane. Southward-verging recumbent folding and high grade metamorphism affected the Miramichi Terrane during its collision with the Laurentian craton between the late Ordovician and early Silurian. Subsequent less intense deformation occurred as the Avalon Terrane (proper) collided with the Miramichi Terrane in the Mid-Devonian.

Geology Of The Lupin Gold Mine, N.W.T.

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In the Contwoyto Lake area of the N.W.T., gold is associated with Archean iron formations which occur in a thick, complexly interbedded succession of argillites and metagreywackes.

At the Lupin mine, high gold values are restricted to sulphide-rich iron formation which is interbedded with variable proportions of silicate-rich iron formation. The orebody is a Z-shaped structure which plunges steeply to the north, and occurs in an area that is marked by folds of greater than normal amplitude.

The sulphide iron formation is well banded on a millimetre scale. Laminations of hornblende, quartz and pyrrhotite alternate with bands of chert. Arsenopyrite and loellingite occur in the iron formation adjacent to quartz veins. Gold values in the quartz veins are low. Other minerals present in the sulphide iron formation in minor amounts include graphite, ilmenite, chalcopyrite and scheelite. The silicate iron formation is composed of various proportions of grunerite and hornblende, along with quartz and chlorite. Clastic rocks are interbedded throughout the iron formation.

Studies to date indicate that the major Z-shaped structure was produced by isoclinal folding during metamorphism and was further deformed by strike-slip faulting and subsequent granite intrusion in the late Kenoran.

Correlation of the late Precambrian Rocks of the Northern Appalachian Eastern Margin: How is "Avalon" Defined?

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The term "Avalon," as defined by the Late Precambrian-Early Paleozoic rocks of the Avalon Peninsula, Newfoundland describes a non-North American basement of the eastern margin of the Northern Appalachian orogen based on age and stratigraphy. Recent investigations have shown that a number of fault-bounded blocks in the eastern margin have sequences of late Precambrian-Early Paleozoic rocks with quite different thermo-tectonic histories.

Data are presented to show that the Boston Platform and Avalon Peninsula rocks are distinctive, and are the only true representatives of "Avalonia." In board from these blocks, and bounded on the north and west by the Lake Char-Campbell River-Nonesuch River-Norumbega fault system, the remaining eastern margin shows a more highly correlated and coherent tectonic and plutonic history. Although these inboard blocks have some similarities to the Avalon Peninsula, differences in stratigraphy, ages of Precambrian events and metamorphic and plutonic episodes are evidence for differences in geologic evolution.

We suggest the term "Avalon" be restricted to the Avalon Peninsula and Boston Platform sequences which define an outboard terrane, and that a new term be introduced to describe the other similar inboard blocks of the eastern margin (i.e.: Hope Valley - Cape Breton terrane).

Did Sulphur in Sydney Coal Come From the Windsor Group Evaporites?

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High sulphur contents in coals are normally explained by the proximity of the original peat to marine waters during deposition, as the sulphate ions in seawater provide an abundant source of sulphur. However coals of the Pennsylvanian Morien Group, which are rich in sulphur, are associated with a freshwater biota and alluvial sedimentary features, and no marine beds are known in the succession. Several workers have suggested that the sulphur was derived from dissolution of sulphate evaporites in the underlying Mississippian Windsor Group, rather than from Pennsylvanian seawater.

We set out to test this hypothesis using a geochemical model derived from studies of sulphur isotopes in modern peat swamps. During the anaerobic decomposition of plant material, the H_2S generated from groundwater sulphate is fixed as metal sulphides which are enriched in the lighter ^{32}S isotope by about 15 $^{o}/oo$. Sulphides formed chemically at higher temperature during burial will be much less fractionated. As Windsor sulphates on mainland Nova Scotia have $\delta^{34}S$ values of about +14 $^{o}/oo$, coal pyrite derived from a Windsor source should range from +14 to about -1 $^{o}/oo$, depending on the proportion of biologically and chemically precipitated pyrite in the coal.

Eight evaporite samples from the upper Windsor Group in the Sydney Basin gave $\delta^{34}S$ values of about +15 $^{o}/oo$. Eleven pyrite samples from four Morien coal seams ranged from +14.6 $^{o}/oo$ to -5 $^{o}/oo$. The pyrite values thus follow the pattern predicted for derivation from Windsor sulphates. The Gardiner Seam, the stratigraphically lowest studied, contains the most fractionated sulphur, suggesting that much of the sulphur came into the swamps from the Morien rivers and was fixed shortly after deposition. The Harbour, Hub and Point Aconi Seams, higher in the section, probably obtained much of their sulphur from groundwaters during burial.

Due to the similarity of $\delta^{34}S$ values for Mississippian and Pennsylvanian seawaters, the test does not preclude a marine source of sulphate during Morien times. The results, however, are consistent with a Windsor sulphate source. Our study has application, with further work, to the tracing of sulphur emissions from industrial plants.

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Geochemical Characterization of Rocks Comprising the Goldenville-Halifax Transition (GHT) of the Meguma Group. Southern Nova Scotia.*

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The transition between the sandy Goldenville and shaly Halifax Formations of the Cambro-Ordovician Meguma Group of Nova Scotia is a control for metallic mineral concentration. The stratigraphic interval straddling the Goldenville-Halifax transition (GHT) hosts a disproportionate number of the mineral occurrencees (e.g. Au, W, As, Sb, Pb, Zn, Mn) in the non-igneous portion of the Meguma Terrane.

This project attempts to understand the physical and chemical processes that have led to this enrichment. In order to characterize the rocks of the GHT in terms of lithogeochemistry, over 400 samples were collected with good stratigraphic control from units above, within and below what has been referred to as the Goldenville-Halifax contact by different workers in localities stretching from Guysborough to Yarmouth Counties.

Geochemical analyses show enrichment of Pb, Cu, Zn, Ba, and Au in a finely laminated, manganiferous, locally calcareous unit in the upper part of the Goldenville Formation. Similar rocks, often referred to as spessartine quartzites (coticules) occur within the GHT throughout southern mainland Nova Scotia and are locally associated with known metallic prospects. Besides its metallogenic purpose, this project provides baseline data for regional geochemical exploration and for water quality studies within the Meguma terrane.

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Prince Edward Island's Alkaline Igneous Rocks

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A late Permian? lamprophyric sill on George Island in Malpeque Bay represents the only known exposure of igneous rocks in Prince Edward Island. Geochemical modelling suggests that phlogopite and other Ti bearing phases in the source regions for many lamprophyres help control magma Rb and Ti concentrations but they had only a minor effect on the Malpeque Bay magma. The unimportance of these phases may be related to the nature of the metasomatic event which enriched the source (and resulting magma) by only small amounts in K, Rb and Cs. More substantial enrichment is shown by Sr, Ba and the light REE, but the high valency cations (e.g. Hf, Ta, U, Th, Zr, Nb) were increased the most. Geochemical comparison of the lamprophyre with other highly alkaline rocks suggests that the metasomatizing fluid (or magma) was CO_2 rich. It either carried K and Rb through the lamprophyre source region, leaving behind only high valency cations, or was incapable of carrying the former elements. The presence of spinel lherzolites as well as Fe-Mg-Ni relationships show that the lamprophyre represents a primary melt. Various geothermometers give low equilibration temperatures for the lherzolite xenoliths (~ 970 degrees C) and show that they cannot represent the magma's source.

The Character and Tectonic Implications of Cambrian Volcanism Over Avalonian Terrane: An Overview

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Cambrian basaltic rocks associated with Acado-Baltic sedimentary rocks in Newfoundland, New Brunswick, Nova Scotia, Norway and Poland show characteristics consistent with emplacement in a tensional tectonic setting. The basalts exhibit both alkaline and tholeiitic affinities with major and trace element compositions representative of continental, within-plate basalts. The small volume and bimodal (basalt-rhyolite) nature of the volcanic rocks at many localities in the Acado-Baltic province support a tensional tectonic environment. Their small volume and low frequency of eruption suggest that only small amounts of lithospheric extension took place. The extension may represent the final stage of a major tensional event prevalent during the late Precambrian. Volcanic activity was apparently most common during the Early and Middle Cambrian and least common during the Late Cambrian. Using volcanic activity as an indicator, it appears that the tension lasted throughout the Early and Middle Cambrian but waned in the Late Cambrian, possibly in direct or indirect response to processes that led to closing of the Iapetus Ocean.

The Hope Valley Shear Zone in Rhode Island

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The Hope Valley shear zone (HVSZ) is a major late Paleozoic structure separating two distinct Avalonian basement terranes in southeastern New England. The Esmond-Dedham terrane (eastern) is largely composed of variably deformed 620 Ma granitic rocks (tonalite to granite). These rocks are locally overlain by latest Precambrian to Cambrian marine sediments, intruded by Ordovician to Devonian anorogenic plutons, and overlain by Pennsylvanian nonmarine basins. The Hope Valley terrane (western) is largely composed of highly deformed, leucocratic granite gneisses of late Precambrian age (~ 600 Ma).

Rocks of the Esmond-Dedham terrane are weakly to moderately deformed except within 15-20 km of the HVSZ. Strong linear and/or planar fabrics are developed in late Precambrian and Devonian (370 Ma) rocks near the HVSZ, and one Devonian pluton is truncated by the shear zone. Lineation trends, asymmetric feldspar augen and quartz c-axis fabrics in highly deformed gneisses proximate to the HVSZ all indicate a major component of dextral shear.

The HVSZ is a major structure along which the Esmond-Dedham terrane was juxtaposed against the Hope Valley terrane during the Alleghanian orogeny. The accretion of the Esmond-Dedham terrane appears to be the cause of Alleghanian tectonism in southern and western Rhode Island and easternmost Connecticut. In contrast, the Hope Valley terrane was accreted to North America during the Ordovician or Devonian, and appears to underlie the Merrimack synclinorium. Along with other similar and related rocks, the granite gneisses of the Hope Valley terrane probably constituted the eastern basement block of the Acadian orogeny. The sequential accretion of "Avalonian" rocks in southeastern New England resolves some discrepancies among earlier tectonic models of the New England Appalachians. The tectonic interpretation of other eastern basement regions in the northern Appalachians might be approached in this context.

The Gulf of St. Lawrence Carboniferous Basin; The Largest Coalfield of Eastern Canada

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Two continuous coal zones occurring in a 2500 feet (762 m) thick section of the Upper Carboniferous Pictou Group (Westphalian C and D) have been encountered in five offshore wells drilled for oil and gas in the Gulf of St. Lawrence. They correlate, by means of fossil spores, with thick coals of the Mabou and Inverness coalfields situated at the eastern margin of the Basin. Therefore, the presence of a large submarine coalfield of at least 18,000 square miles (46,620 km^2) is indicated. This compares with an estimated size of 14,000 square miles (36,260 km^2) for the Sydney Coal Basin.

Accessibility is provided only by the small onshore parts of the Mabou and Inverness fields, because farther offshore the coals lie too deep to be mined (below 4,000 feet (1219 m)).

Two two near-shore coal exploration wells indicate that at Mabou Mines the younger Inverness coals occur at a mineable depth to at least 5 km from land. A structure contour map of this area shows a reserve of 125 million tons, in two Inverness equivalent seams that are 8.5 feet (2.6 m) and 4.5 feet (1.4 m) thick. The Mabou coals, however, reach too great a depth close to shore to possess mineable resources.

A structure contour map of the Inverness submarine area, based on mine data and one offshore seismic profile, indicates inferred mineable resources of 160 million tons, in two seams that are 7 feet (2.1 m) and 4.5 feet (1.4 m) thick. A detailed deep-seismic survey will be necessary to substantiate the structure and resource estimates.

Maceral and coal quality percentage diagrams of five column samples of these seams (the 7 Foot and 13 Foot Seams of Inverness Equivalents) show a bright banded coal, high in reactive macerals, which will produce a weak coke unsuitable for metallurgical purposes. A thermal coal with a rank of H.V. "B" Bituminous (0.64% Ro) is present, averaging 12,000 BTU/lb (6,660 KCAL/KG), 10% ash and 6% sulphur, of which 60-80% is derived from pyrite.

Microlithotype profiles of the major Mabou and Inverness coals show characteristic successions that can be used for seam identification and proved valuable for structural interpretations.

The time of faulting in the major fracture zone on the eastern margin of the Gulf of St. Lawrence Basin has been deduced from coal rank variations. It occurred in post-Permian, probably Early Triassic time.

Tectonic Subdivisions of the Avalon Zone in Southeastern New England, USA

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The eastern margin of the Appalachian orogen in Massachusetts and New Hampshire, east of the Siluro-Devonian rocks in the Kearsarge-Central Maine Synclinorium, is subdivided into three major fault-bounded blocks. Each has a distinctive geological and magmatic history.

The easternmost, the Boston block (Milford-Dedham zone of Zen et al., 1983), contains many of the features common to Avalonian terranes in the Northern Appalachians. These include a predominance of Late Proterozoic (580-650 m.y.) calc-alkaline granitic through dioritic plutonic rocks and associated volcanics, covered by a thin veneer of Upper Proterozoic to Lower Paleozoic platform sediments and fluviatile Carboniferous basin deposits. This terrane is itself potentially composite and can be further subdivided into three subzones on the basis of the character and age of igneous rocks, depth of burial, and style of deformation. More highly deformed mafic rocks, formed prior to the main Avalonian magmatic pulse, predominate along the western margin of this terrane. The principal metamorphism, generally assigned an Alleghanian age, is no higher than greenschist facies in the Boston area but locally increases to the upper amphibolite facies near the southern and southwestern terrane margins in Rhode Island.

To the west, across the prominent Bloody Bluff fault zone, the geologically different Nashoba block is a terrane largely underlain by mafic volcanics and volcanogenic sediments metamorphosed to the sillimanite and second sillimanite zones. These rocks are most likely Late Proterozoic to Early Paleozoic in age, with 730 m.y. gneisses (e.g., Fish Brook Gneiss) assumed to be basement.

During the Ordovician-Silurian, the Nashoba terrane was simultaneously intruded by pervasive peraluminous granites and a series of intermediate calc-alkaline plutons. The youngest granites (400-415 m.y.) likely formed

at least in part by local anatexis, give an upper age limit to the metamorphism.

West of the Nashoba block, across the Clinton-Newbury fault zone, lies another potential terrane, the Merrimack trough. It is underlain by a thick sequence of pre-Middle Ordovician flysch and calcareous flysch. These are assigned an age on the basis of dates on cross-cutting plutons. It is also believed that these plutons establish an upper limit for the ages of deformation and polymetamorphism. The sediments and at least some of the deformation and metamorphism could be as old as Late Precambrian.

Are the Nashoba block and Merrimack trough separate terranes, a composite terrane joined in the Late Precambrian-Early Paleozoic or part of a single terrane? And how do these terranes relate to the terrane containing more classic Avalonian geological features to the east? These are questions that still need to be resolved.

Role of Igneous Rocks in Terrane Analysis: Application to Geological Evolution of the New England Avalon

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In southeastern New England, the Avalon Zone contains the following terranes (from east to west): the (1) Fall River-Dedham terrane, (2) Esmond-Milford terrane, and (3) Hope Valley gneiss terrane. Within this composite zone, the study of igneous rocks provides insight into: (1) constraints on timing of terrane linkages, (2) mechanics of linkage and tectonics (i.e., subduction, strike-slip, flake tectonics, pull-apart regimes, (3) evolution of crustal sources through time, and (4) processes that may disturb such "normal" evolutionary trends.

The presence of widespread Paleozoic alkalic igneous rocks within the Fall River-Dedham and Esmond-Milford terranes indicates assembly prior to the mid-paleozoic, and possibly as early as the late Proterozoic. Juxtapositioning of the Hope Valley and Esmond-Milford terranes occurred between 370-275Ma as indicated by deformation of Devonian granite along the Hope Valley Shear Zone, and subsequent intrusion of Permian granite which locks together the two terranes. Arrival of the Hope Valley terrane to ancestral North America is poorly constrained, but most likely occurred during the Taconic or Acadian orogenies, although an Alleghanian arrival is not precluded.

In all three terranes, late Proterozoic magmatism is mainly calcalkaline, and consistent with processes of crustal thickening and accretion. The residual, relatively anhydrous crustal source material underwent periodic partial melting throughout the Paleozoic to produce episodic alkalic magmas that formed shallow A-type plutons accompanied by local bimodal volcanism. Such magmatism occurred within attenuated crust, probably accompanied by strike-slip faulting which ultimately caused late Paleozoic rift or pull-apart basins. A dramatic change in magmatic character occurred in the Permian, and is characterized by peraluminous, water-rich magmatism involving source material that contains a substantial component of Archean age. Apparently, anhydrous source material was mixed with old, hydrous material derived from the African craton by underplating during impingment of Gondwana with the North American continent during the closing of the Rheic Ocean.

Late Quaternary Depositional Environments of the Canadian Beaufort Shelf

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Seismic and borehole data have been studied from the Beaufort Shelf, east of Mackenzie Trough. Three acoustic sequences, separated by unconformities can be recognised from high resolution seismic records. Sequence 1 consists of complex horizontal and progradational reflectors, with variable acoustic penetration. It is bounded above by an unconformity on which two broad valleys are incised to a depth of 30 m. Sequence 2 has a wedge-like geometry at the margins of these valleys and consists predominantly of oblique progradational reflectors which become sigmoidal towards the centres of the valleys. A second unconformity marks the top of this sequence, although in intervalley areas, it is often impossible to distinguish from the lower unconformity.

Metallogenic Evolution and Migration of the Magmatic Front in the Chilean Andes Between 21° and 26° South*

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The segment of the Andes between 21° and 26° South is one of the richest in this copper-specialized metallogenic province and probably characterizes the most intense mineralizing processes related to subduction of oceanic lithosphere beneath continental South America.

The pre-Mesozoic basement is sparsely mineralized despite magmatic events in Ordovician-Silurian, and Late Carboniferous-Triassic times, the latter being associated with subordinate Cu, Mn, Ag and Pb hydrothermal deposits.

From Jurassic to Early Cretaceous times, plutonism and volcanism were apparently almost continuous, with pulses at 170-165 Ma, 145-140 Ma and 130-115 Ma, and the magmatic front was located near the present coast. Related to this metallogenic epoch are extensive volcanic-hosted stratabound Cu deposits and Cu veins hosted in Jurassic plutons. Minor veins with Au, Ag, Fe, Ni-Co and Mn were also formed. From Late Cretaceous to Paleocene times (78-24 Ma) the magmatic front had migrated about 80 km towards the continent, and although magmatic activity was almost continuous, radiometric dates show clusters at 70-60 Ma and 45-35 Ma. The major ore deposits of the region are related to the Oligocene pulse, which contains, among others, the super giant porphyry Cu deposit of Chuquicamata, and a number of epithermal Ag, Au, and Cu veins, polymetallic Cu-Au-Ag, Sb, and Co veins, as well as minor Cu, Mn and Fe stratabound deposits.

The youngest magmatic-metallogenic epoch is the Miocene to Quaternary event, during which the magmatic front migrated eastward up to 200 km, to form the present Andean high Cordillera and Altiplano of Chile-Bolivia-Argentina. The most significant mineralization associated with this phase consists of the large irregular magnetite flows (?) of EL Laco volcanic complex, minor Ag, Sb and Sn veins in the Nevados de Poquis area and numerous S deposits associated with volcanic vents.

The landward migration of the magmatic front appears to have taken place in discrete "jumps", preceded by deformational phases, and both seem to coincide with major reorganization of lithospheric plates, in Late Cretaceous and Miocene times.

The distribution and variable characteristics of metallic ore deposits in this region can be related to particular petrologic association, basement tectonics and the local level of erosion.

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Seismogram Modelling applied to Surficial Sediments

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During the past two decades, methods for dealing with seismological data have been refined to the extent that our understanding of the structure and mechanical properties of large features in the lithosphere have been considerably improved. These methods have not previously been carried over into the investigation of surficial sediments of the seabed, a field in which seismic investigation is usually restricted to the deployment (either high or low in the water column) of some type of normal-incidence subbottom profiler.

Such devices are widely used to reveal as 'reflectors' the position (in time) of discontinuities in the variation with depth of some mechanical property, but they are neither able to deal with a continuous variation of mechanical properties nor to determine seismic velocities.

The use of suitably designed multichannel seismic equipment allows observations to be made which are appropriate for analysis by the methods of modern seismology. An example from the Beaufort Sea shows that the results of this analysis may be quite different from those deduced by the application of conventional travel-time methods to the very same field data.

Contrasting Geology Across the Cradle Brook Thrusts; Subaerial vs Marine Precambrian Environments; Caledonia Highlands, New Brunswick

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The Cradle Brook fault zone in southern New Brunswick separates highly deformed Precambrian terranes reflecting radically different geological environments. The zone is comprised of major southward directed thrusts and is interpreted to represent, in part, the boundary between the Central and Eastern volcanic belts of the Caledonia Highlands.

The rocks north of the fault have been deposited in a subaerial and locally subaqueous environment. Periods of intense volcanic activity produced voluminous, unsorted felsic and mafic tuffaceous deposits, highly vesiculated mafic flows and extensive felsic flows. The felsic volcanic rocks are mostly oxidized and there is little evidence of reworking of volcanic debris. Isolated basins are represented by finely laminated and commonly normally graded fine- to medium-grained sedimentary rocks that occur as discontinuous units intercalated with the volcanic deposits. These sedimentary rocks contain variable amounts of locally derived volcanic debris. This stratigraphy has been traced to the Central Intrusive Belt north of the fault zone.

The rocks south of the fault zone have been deposited entirely in a marine environment. Periods of intense volcanic activity also produced voluminous felsic (commonly pyritiferous) and mafic tuffaceous deposits but these are generally finer-grained than those north of the fault and are commonly reworked producing well-sorted and laminated deposits. The volcanic flows are mafic and occur as vesiculated pillow lavas and hyaloclastites. During intermittent periods of quiescence, limestone, chert, quartzite, arkose and finely laminated, fine-grained sedimentary rocks were deposited. Some of these sedimentary units are quite extensive laterally. This stratigraphy has been traced east to Fundy National Park and correlatives exist throughout the Eastern Volcanic Belt. Equivalent rocks also exist in fault blocks north of the fault along the coast near Big Salmon River.

In addition to the differences in Precambrian stratigraphy, extensive areas south of the fault are underlain by small plugs and large bodies of felsic and mafic intrusive rocks, and by Cambrian rocks that rest unconformably on mafic pillow lavas of the Eastern Volcanic Belt. Based on a limited number of chemical analyses, the volcanic rocks north and south of the fault zone appear to possess calc-alkaline ensialic and tholeiitic-ensimatic affinities, respectively.

The structural and stratigraphic relationships imply that the subaerial rocks are older than the marine rocks and that the latter are probably near the top of the local Precambrian sequence. Limited chemical information and the abundance of intrusive rocks in the subaqueous sequence substantiate juxtaposition of very different geological regimes.

The Eastern St. George Batholith – Recent Advances in Interpretation

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The St. George Batholith, in southwestern New Brunswick, has been divided into Devonian (western) and Carboniferous (eastern-Mount Douglas) granitic segments and major phases in each have been partly delineated. Mineralization associated with the Carboniferous granites consists of endocontact Sn, W and Mo bearing greisens and veins, and a few exocontact base metal and possibly Au occurrences.

Recent investigations in the western part of the Mount Douglas granite has revealed three variably textured but mappable intrusive phases. These are the older medium- to coarse-grained seriate biotite granite, equigranular fine- to medium-grained biotite granite and younger (?) porphyritic microgranite with abundant associated aplite. Contacts between various phases are generally sharp and less commonly gradational indicating close temporal relationships. Miarolitic cavities, pegmatites and graphic textures are common in all but the equigranular granite.

Most of the equigranular granite occupies a northeast trending linear belt within the central part of the seriate unit which indicates that it represents the core of the system. The linear nature of this belt and the occurrence of an extensive porphyritic unit next to a dilatant shear zone along the northwestern granite – country rock contact indicates possible structural controls on emplacement of some younger phases.

The distinction between phases is substantiated to some extent by a limited number of chemical analyses. The western part of the equigranular belt, that is mapped as a separate unit, is least differentiated as shown by lower SiO_2 and Li, and higher TiO_2 contents. Rb/Sr ratios are also low.

The content of these elements in the eastern part of the equigranular belt, however, show reverse trends and are the most highly differentiated of the granites.

Greisen veining and intense alteration of the country rocks were probably generated by both younger phases. This is demonstrated by the development of greisen veins near the apices of aplitic and/or porphyritic microgranite cupolas throughout the area and by greisenization near and alteration of the country rocks along the northwestern contact. The disposition of the largest and economically most interesting greisen zones relative to the equigranular granites and the paucity of aplitic or porphyritic microgranite intrusions in these areas provide subtle evidence of another source for mineralizing fluids.

These relationships contrast markedly with the ground examined to date in the central part of the Mount Douglas granite. The distinction between seriate and porphyritic phases of intrusion cannot be made. The equigranular phases have not been found, there is a distinct lack of greisens and more than one phase of seriate granitic intrusion have been observed. Also, pegmatite pods and large masses of granophyre are much more abundant and minor amounts of country rock xenoliths are ubiquitous in some areas. These differences in texture and mode of occurrence may reflect magmas that were subjected to contrasting crystallization histories as a result of some external control of magmas that developed as separate intrusive phases.

Geological History of the Antigonish Highlands, Nova Scotia

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The Antigonish Highlands is bounded by major tectonic lineaments to the north and west (Hollow Fault) and to the south (Chedebucto Fault) and is unconformably overlain by Devonocarboniferous rocks to the east. The highlands are predominantly underlain by Precambrian rocks of the Georgeville Group with Cambro-Lr. Ordovician (Iron Brook (IB) and MacDonald Brook Group (MB)) and Upper Ordovician-Lower Devonian (Arisaig Group, AG) distributed at the margins of the highlands.

Precambrian rocks consist of subaerially deposited interlayered rhyolites, basalts and basaltic andesites overlain by a thick sequence of turbidites and minor basalts. The stratigraphic content and geochemistry of volcanic rocks suggests deposition in a basin in an extensional environment. Closure of the basin in the latest Precambrian resulted in polydeformation and greenschist facies metamorphism. Late Precambrian intrusive rocks are post-tectonic and consist of appinite (hornblende gabbro), alaskite, and mafic dyke swarms. The appinites are spatially associated with major faults.

Cambro-Lr. Ordovician rocks consist of fluviatile to shallow marine red clastics and fossiliferous limestones (IB) and a laterally equivalent sequence of bimodal volcanics (MB). These rocks unconformably overly the Georgeville Group. They were deposited in a small pull-apart basin which was formed in a period of transpression during the latest stages of the late Precambrian orogeny. These rocks were polydeformed probably in the middle Ordovician.

The Arisaig group consists of a bimodal volcanic sequence interlayed with red fluviatile conglomerates and oakoses and overlain by fossiliferous siliciclastics and minor rhyolites. The sequence records a marine transgression. The rocks were deposited in a extensional tectonic environment. The southern highlands was deformed by NW and NE trending conjugate shear zones and intruded by granite plutons in the middle Devonian. The deformation and plutonism may be attributed to the docking of the Meguma Terrane to the south along the Chedabucto Fault.

Variscan Tectonostratigraphy in the Avalon Terrane of Southern New Brunswick

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The basement-involved, Variscan fold-thrust belt of coastal southern New Brunswick can be attributed to dextral transpression associated with the regional strike-slip response to the Variscan event in Maritime Canada. Variscan deformation in the vicinity of Saint John, strongly influenced Westphalian sedimentation within the penecontemporaneous Mispec Group, and reflects sustained NW-SE shortening that coincides with a major compressive bend in the east-west Cobequid-Chedabucto fault system, on which there was significant right-lateral, Westphalian displacement.

Within the Mispec Group, purple to green lithic wackes and polymict conglomerates of the Balls Lake Formation are the product of alluvial fan sedimentation and display facies depicting deposition in proximal to mid-fan, mid-fan and distal settings. Grey lithic arenites of the Westphalian Lancaster formation are largely the product of a major meandering stream system but partially represent overbank sediments influenced by the distal fan. Fluctuations in relief of the fan source area produced interfingering and occasional lateral equivalency of these formations, while deformational fabrics within Balls Lake conglomerates suggest syntectonic sedimentation. Paleocurrents imply northwestward progradation of the Balls Lake fan into the basin drained by the Lancaster fluvial system in response to uplift of a southeasterly source.

The first deformation to affect the Mispec Group (D1), produced NW-directed, basement-involved thrust faults that structurally invert regional stratigraphy. Associated lower greenschist facies metamorphism accompanied the development of a widespread, SE-dipping fabric (S1), variably expressed as a slaty cleavage, protomylonitic solution cleavage and orthomylonitic foliation. The fabric locally contains a strong mineral lineation (L1) of variable orientation, and is axial planar to NW-vergent, isoclinal minor folds and regional overturned structures (F1) that plunge gently NE and SW. Continued compression was accompanied by renewed thrusting (D2) and backthrusting (D3) and produced fold trains coaxial with F1 that verge both NW (F2) and SE (F3) and are, in part, conjugate. Associated S2 and S3 axial planar crenulation cleavages overprint S1 and dip SE and NW respectively.

On-strike variations in deformational style and timing with respect to metamorphism, coupled with steeply-dipping, en echelon zones of intense deformation, suggest the fold-thrust belt is segmented by right-stepping convergent wrench faults synthetic to the Cobequid-Chedabucto fault system. These faults shallow into thrusts to form positive flower structures, and locally terminate into thrusts associated with anomalous NW-SE trends in D1 and D2. The regional deformational history is consequently attributed to Variscan transpression along downward-steepening, en echelon thrust faults that subparallel the present Fundy shore. Thrust uplift in response to initial transpression is proposed to account for the southeasterly source area of the syntectonic, Balls Lake alluvial fan. Continued displacement

and telescoping resulted in structural inversion of regional stratigraphy, and allowed deposition of the Mispec Group in advance of, and subsequent overriding by, an allochthonous Variscan terrain to the south.

Stratigraphy and Sedimentology of the Oil Shales and Associated Clastics of the Stellarton Group, Nova Scotia

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Oil shale units of the east half of the Stellarton Basin occur within the grey coal-bearing members of the Westphalian B-C aged Stellarton Group. The upper three members of the Stellarton Group (Thorburn, Coal Brook and Albion) contain over 40 oil shale units. Individual units, some as thick as 50 metres, are traceable laterally 1-5 kilometres.

Oil shales are typically silicate-rich (quartz and clays) with humic and algal organic matter comprising up to 50 per cent (by weight) of the rock.

Lithologies interbedded with the oil shales include: 1mm - 2 cm alternating siltstone and claystone couplets (F), siltstone with thin (1mm and less) parallel sandstone laminae (Fl), thinly interbedded flaser to lenticular siltstone and sandstone (Sl), rippled sandstone (Sr), discontinuous-crested ripples (Sr_1), weakly undulatory to straight-crested ripples (Sr_2), bifurcating ripples (Sr_3), high angle trough cross-bedded sandstone (St_1), low angle trough cross-bedded sandstone (St_2), horizontal tabular-bedded sandstone (Sh), massive and cross-stratified pebble to cobble conglomerate (Gc), coal (C) and coaly shale (Cs).

General depositional settings for the above lithologies include open lacustrine (oil shales, F), wave-influenced delta (Fl, Sl), distributary and wave-influenced delta front (Sr, Sr_2, Sr_3 and St_1), fluvial channel and levee (St_1 and Fm), alluvial fan - fan delta (Gc and ?Sh) and well- and poorly-drained swamps (C_s and C). The restricted nature of the Stellarton Basin allowed for widespread abrupt transgressions and regressions of these depositional environments. As a result, further lithostratigraphic subdivision of the Thorburn, Coal Brook and Albion members could prove difficult.

Stratigraphic and Petrochemical Evolution of Late Proterozoic Rocks in Southeastern Newfoundland

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Late Proterozoic rocks, which lie to the southeast of the Dover Fault in Newfoundland, display a stratigraphic, tectonic and magmatic evolution analogous to that of many Late Proterozoic belts of Gondwana, particularly Afro-Arabia. In Newfoundland, these rocks comprise the Avalon Zone or Avalon terrane, and are disposed in several northeast-trending fault blocks. Detailed stratigraphic and chemical data permit precise correlations across most faults; the major exception is the Paradise Sound Fault. The oldest dated rocks the Avalon Zone form a 760 Ma, ophiolitic volcanic - tholeiitic gabbro complex; its relationship to younger rocks is uncertain. Subsequent volcanicity (630 Ma - 580 Ma) is divisible into at least three volcanologically, petrologically and geochemically distinct intervals, locally separated by episodes of sedimentation. The first is characterized by the eruption of subaqueous and locally subaerial, basaltic, rarely andesitic and rhyodacitic-rhyolitic rocks of calc-alkaline to mild tholeiitic affinity and intrusion of calc-alkaline adamellite and granodiorite. A second interval is marked by extensive epiclastic volcanism and volcanogenic sedimentation together with the extrusion of rhyolite and flood basalt of mild alkaline affinity. A final interval of latest Proterozoic age (ca. 590-580) (possibly as young as Early Cambrian) resulted in peralkaline, bimodal volcanism and rare alkaline to peralkaline plutonism. This volcanism accompanied terrestrial sedimentation locally within fault-bounded basins that formed in response to strike-slip movements. The magmatic evolution is comparible to both Proterozoic and recent Phanerozoic orogenic areas such as the Hijaz Arc and the Basin and Range Province.

Hadrynian and Lower Palaeozoic Geology of the Western Cobequid Hills

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The Hadrynian Jeffers Formation is the oldest rock group in the western part of the Cobequid Hills. Several major east-west faults break up the succession into a number of discrete structural blocks. The lower part of the Formation consists of mafic flows, some intermediate and felsic flows and pyroclastics, and interbedded phyllites, mudstones and minor carbonates. The upper part comprises felsic pyroclastics and volcaniclastic sediments. Both felsic and mafic hypabyssal intrusions cut the Formation prior to the development of a flat lying cleavage associated with local recumbent folding. This cleavage is probably related to late Hadrynian strike-slip movement along an ancestral Cobequid Fault. The cleaved strata are cut by several granodiorite and minor granite intrusions, the largest of which (the Jeffers Brook pluton) has been dated by Donohoe and Wallace as latest Hadrynian. These plutons may be located along major strike-slip faults.

Silurian rocks consist of relatively undeformed fossiliferous mudstones and sandstones, and occupy only a very small area north of the Jeffers Brook Formation at the southern edge of the Cumberland Basin. The Devono-Carboniferous Fountain Lake Group is not widespread in the western Cobequids. Devono-Carboniferous plutons are localised along major strike-slip faults and appear to post date the main phase of motion on all but the main Cobequid Fault.

Large Mafic Intrusions in Devono-Carboniferous Granites Along the Cobequid Fault

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The Cobequid Fault was an active transform fault between the Meguma and Avalon terranes of Nova Scotia in the Devono-Carboniferous. Granite plutons

of probable Carboniferous age that are truncated by the western part of the Cobequid Fault have very abundant diabase sills and small diorite intrusions close to the fault. These mafic rocks become rare only a few kilometres north of the fault. Further east, granite plutons contain abundant mafic dykes of probable Carboniferous age. These mafic rocks largely predate final strikeslip motion on the Cobequid Fault, and are geochemically distinct from the younger Triassic volcanic rocks in the area. Some of the mafic rocks are alkaline in character, while others are olivine tholeiites. These mafic rocks were tapped from deep levels of the lithosphere by the Cobequid transform fault. They thus provide evidence for a gabbroic magma beneath the major Devono-Carboniferous plutons of the Avalon terrane.

Discordant Blocks of Prince Edward Island: Evidence for Seismic Activity in the Lower Permian?

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At Wood Islands, Prince Edward Island, disrupted bedding containing intraformational discordant blocks of sandstone and mudstone were encountered in the Permo-carboniferous redbeds. Similar discordant blocks were already known to be present at Prim Point in southeastern Prince Edward Island, and their common presence in the redbeds of this part of the Island poses an interesting problem as to their origin, facies and tectonic significance.

At Wood Islands a zone of chaotic bedding is laterally exposed over a distance of approximately 175 m. It ranges in thickness from a single surface to an interval of up to 1.5 m. This zone has a locally erosive lower contact and an upper contact that is conformable to the bedding above. The matrix of the bed is mudstone, a mixture of mudstone and sandstone, and/or pebbley sandstone. Well developed internal bedding is absent. Within the limits of exposure a total of ten discordant blocks are seen.

These discordant blocks can be readily identified in outcrop by their angular discordant relationships with the enclosing strata. Their maximum dimensions range from 0.5 m to 4 m, and the grain size within the blocks ranges from mudstone to medium grained sandstone.

The majority of discordant blocks have the following features in common:

1) Internal bedding and sedimentary structures including graded beds, ripple cross beds, porting lineation, load casts, and bioturbation features can be present.
2) Internal bedding of the blocks appears undistorted indicating that they represent blocks of sediment unaffected by disruption.
3) Smooth to irregularly shaped "flow markings" are common over the entire outer surfaces of the blocks.
4) Commonly present also on the bounding outer surfaces are thin "films" of mudstone.
5) A rounded convex surface suggesting a rotational slump origin commonly characterize these blocks.
6) The blocks appear confined to a single stratigraphic interval which may extend at least 20 km from Prim Point to Wood Islands, and possibly beyond.

Internal bedding of discordant blocks may be upright, inclined or even overturned with respect to the enclosing strata.

Features not necessarily associated directly with the discordant blocks but always found in close proximity to them are a variety of dewatering, sediment filtration and sediment intrusion structures.

Present hypotheses for the origin of these discordant blocks include:

1) mass flow transport
2) intrastratal disruption
3) local slumps into fluvial channels

from bank undercutting, and
4) "sand boulders" deposited in the fluvial regime during flood.

Based on the available evidence, a mass flow origin related to slumping is favoured here. The slumping may have been induced by earthquakes, tectonic or erosional oversteepening or a combination of these and other factors. Their presence in the redbeds of Prince Edward Island could have an important bearing on the understanding of the tectonic evolution of the basin during Early Permian times.

Geology and Mineralization of the Western Highlands Metavolcanic-Metasedimentary Complex, Cheticamp-Pleasant Bay Area, Cape Breton Island

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Geological mapping at a scale of 1:10,000 has been carried out in the western Highlands volcanic-sedimentary Complex and Pleasant Bay Complex (map sheets 11K/10, 11K/11 and 11K/15) in order to (1) define their depositional and structural stratigraphy in detail, (2) determine their relative and 'absolute' ages and (3) examine the nature of the contact between the complexes.

The western Highlands volcanic-sedimentary complex (WHVS Complex) consists of low-grade (greenschist) metavolcanic rocks and low-to-high-grade metasedimentary rocks. The metavolcanics are dominated by sheared, plagioclase, crystal metatuffs interlayered with metabasites, metafelsites and chlorite schists. A previously unrecognized pillow basalt sequence has also been mapped locally within the sequence. The metasedimentary lithologies have been divided into (1) a low grade package of interbedded pelites, semipelites and psammites (2) a medium grade, dominantly pelitic package, (3) a medium grade, dominantly semipelitic package and (4) a relatively higher grade prophyroblastic, pelitic package interbedded with semipelite. From west to east metamorphic grade changes through chlorite, biotite, garnet and staurolite (+ andalusite) grade.

The dominant lithologies of the Pleasant Bay Gneiss Complex are: (1) biotite-bearing schists and paragneisses, (2) amphibolite and granitic pegmatite, (3) felsic, muscovite-rich, garnet-bearing (ortho?) gneiss and (4) granodioritic orthogneiss, all of which are intruded by biotite granodiorite. Metamorphism to at least lower amphibolite grade is indicated by well preserved kyanite porphyroblasts in local, highly pelitic zones.

Field relations give no clear indication of the depositional age of the WHVS Complex. No evidence has been found for a geological discontinuity between the WHVS Complex and the Pleasant Bay Gneiss Complex suggesting that they may represent a continuous sequence. The nature of the transition zone between the complexes requires further investigation. Ar^{40}/Ar^{39} dating of mineral separates is currently in progress in order to gain some indication of metamorphic cooling ages for the complexes.

Lithoprobe East: Marine Deep Seismic Reflection Results Across the Appalachians North of Newfoundland

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Approximately 2600 km of 30-fold marine deep seismic reflection data, recorded to 15-20 seconds two-way travel time (approximately 50-60 km depth), have been gathered north of Newfoundland and across the adjacent continental shelves and basins since the fall of 1984. These data, which provide the critical third dimension needed for interpreting deep crustal tectonics, have profoundly influenced our interpretations of surface and near-surface geology. In particular, lines 84-1 and 84-2, which cross all of the major geological zones defined in Newfoundland, were positioned with the aim of relating deep crustal structure to surface geology. A preliminary geological interpretation of the seismic results is currently in press.

Our preliminary interpretation tentatively established: the under-thrust eastern limit of the stretched Grenville continental craton, which underlies the Humber and western Dunnage zones; the allochthonous nature of at least the western portion of the Dunnage zone; a tectonically disrupted Moho beneath the Humber zone; and the vertical nature of the Dover Fault, which separates the Gander and Avalon zones. The Baie Verte Lineament (boundary between the Humber and Dunnage zones) and the Gander River Ultramafic Belt (boundary between the Dunnage and Gander zones) have no deep crustal expression, suggesting that they are allochthonous features.

We have identified three seismically continuous lower crustal blocks beneath the Newfoundland Appalachians. (1) The Grenville craton, traced from surface exposures in Labrador, continues beneath the foreland basin and the Humber zone, and in fact extends 70 km eastward beneath the Dunnage zone. Beneath the Humber and Dunnage zones, the Grenville craton thins eastward, reflecting late Precambrian stretching and rifting. (2) A lower crustal block of uncertain affinity (continental?) underlies the eastern Dunnage and Gander zones. This "Gander" block appears to have a "collisional" relationship with the Grenville craton to the west. (3) Avalon lower crust exhibits a markedly different seismic character from the "Gander" block to the west, from which it is abruptly separated by the Dover Fault.

Tectonism of the Eastern Cape Breton Highlands Metamorphic Units, N.S.

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The eastern two-thirds of the Cape Breton Highlands are composed of a wide variety of deformed and metamorphosed stratified and plutonic rocks. Extending throughout much of the area is a sequence of metamorphosed clastic and mafic volcanic rocks, informally termed the Ingonish River sedimentary unit. Analysis of the structural elements indicates that these rocks have undergone a relatively simple deformation in the north, producing a tightly folded synclinorium which plunges gently to the southwest. In the south, the same units can be traced into an isoclinal near-vertically plunging fold, which may indicate some component of strike-slip tectonics. In the extreme northeastern Highlands, the rocks of the Money Point and Cape North

Groups which lie along the northwestern side of the Aspy Fault display similar lithologies, and have been deformed by two episodes of near-horizontal coaxial penetrative deformation.

Extensive areas of plutonic rocks have also undergone regional fabric-forming deformation. Plutons in the southeastern Highlands ranging in age from 752 to 386 Ma are tectonically foliated and are typically elongate parallel to the regional trends.

Metamorphic grade increases toward the centre of the Highlands from the south and east. Chlorite grade metavolcanic rocks are exposed in the extreme south and near Ingonish, but most of the stratified rocks have been metamorphosed to amphibolite facies. Bathozone 4 assemblages (sillimanite + staurolite) are preserved south of the Aspy Fault, bathozone 5 assemblages (kyanite + staurolite) have been identified north of the fault. Throughout the southern part of the area, extensive retrograde muscovite indicates prolonged lower amphibolite (Acadian?) metamorphism.

The central Highlands are underlain by gneisses which preserve porphyroblasts which indicate an earlier crenulation event before the main regional metamorphism. The northwestern Highlands display very complex foliation trends, indicating they may have been subjected to repeated deformation.

All areas have been affected by brittle Carboniferous deformation, which is best displayed in peripheral deposits of sedimentary rocks.

Geological Mapping of the North Mountain, Northern Cape Breton Highlands, Nova Scotia

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Geological mapping in the northernmost Highlands of Cape Breton Island during 1985 continued a project which involves mapping and petrologic studies of the Precambrian and Paleozoic crystalline rocks of the entire Highlands. The 1985 map area consists of two zones of contrasting lithologic character. The bulk of the area, west and north of major fault/mylonite zones, is underlain by the "western gneissic complex", a complex assemblage of quartzofeldspathic gneiss, amphibolite and syenitic gneiss. Anorthosite occurs in small plutons and dykes within the gneissic complex. Our mapping has redefined the distribution of previously mapped anorthosite, identified the presence of a major additional body, and established the intrusive relationship between anorthosite and the gneissic complex. Mappable bodies of monzodiorite occur in apparent close association with anorthosite in the southern part of the map area. These are intruded by abundant dykes and small plutons of syenite and granite. Syenite also forms a large intrusion in the northern part of the map area. This unit is particularly significant because the Meat Cove zinc deposit and other sulphide showings occur in association with marble xenoliths within the syenite.

The map area south and east of the major fault zones includes two major units of stratified rocks: the predominantly gneissic Cape North Group and the predominantly schistose Money Point Group. These groups were originally identified by previous workers on the Cape North Peninsula but can be traced south from the peninsula in a continuous belt for at least 15 km. The rocks of the Cape North Group include a wide variety of lithologies, but are characterized by the ubiquitous presence of gneissic semipelitic and pelitic lithologies. In addition, there are substantial amounts of amphibolitic rocks,

and smaller amounts of psammitic and calcareous lithologies. All of these lithologies are abundantly intruded by granitoid sheets and lenses. The Money Point Group consists of low to medium grade pelitic and semipelitic rocks with minor amounts of psammitic and mafic rocks. The predominantly volcanic sections of the Money Point area do not occur in the area to the south. All the rock types in the group are closely interbedded and it has not been further subdivided.

In addition to the lithologies described above, abundant granitic plutons and granitic and mafic dykes are found throughout the map area. Rhyolites and associated units of the Fisset Brook Formation occur locally around the periphery of the crystalline rocks.

Isotopic Constraints on the Genesis of the Gays River Pb-Zn Deposit*

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The Gays River deposit is the largest carbonate-hosted lead-zinc deposit known in the Mississippian Windsor Group of Atlantic Canada. Isotopic data pose constraints on the possible genetic models that can be applied to the basin and elsewhere.

Ore-stage calcites are characterized by very uniform $\delta^{18}O$ and $\delta^{13}C$ values. The $\delta^{18}O_{smow}$ of water in eqilibrium with these calcites at 170°C (the fluid inclusion homogenization temperature) was +3.3 °/oo. The oD of the fluid inclusion fluids is -39 °/oo. The fluid isotopic composition indicates a basinal brine very close to the field representing typical Mississippi Valley Type deposits.

The ore fluid was probably completely reduced at the depositional site by organic compounds present. The isotopic composition of carbon in ore-stage calcites suggests that the carbon budget was dominated by this organic material. As expected in a reducing environment, ore-stage sphalerite and galena have $\delta^{34}S$ values which mimic the nearby (assumed source) sulfate rocks (= +14 °/oo).

Strontium and lead isotopic analyses were done on gangue minerals and galena respectively. Cambro-Ordivician Meguma Group metasediments possibly mixed with Devonian granites, or derivatives of these - the Horton Group clastics, appear to be the likely source rock(s) on the basis of the strontium and lead data.

Our data so far suggest that the Gays River deposit formed epigenetically due to the influx of a hot sulfate bearing, Pb-Zn rich fluid from a clastic source, that was subject to reducing conditions of diminishing or fluctuating strength at the depositional site.

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Pre-Confederation Historical Seismicity of Nova Scotia With an Examination of Selected Later Events

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A recent four-month archival, contract research program for the Earth Physics Branch of the Canada Department of Energy, Mines and Resources has investigated the historical seismicity of Nova Scotia from 1752-1867. Long runs of all available issues of long-publishing Halifax newspapers were scanned for all earthquakes and tsunami.

All earthquake references were extracted to ascertain the usefulness of the newspaper and the degree to which the journal covered seismic events, or simply used them as fillers, if at all. The Halifax '<u>Royal Gazette</u>' was found not to detail local news or local earthquakes very well in the period of 1752 to 1813 when the Halifax <u>Acadian Recorder</u> became the local newspaper of record. The <u>Acadian Recorder</u> was found to be much better for the study. A twenty-year period of the Yarmouth <u>Herald</u> was also scanned from 1848 to 1867 to guage the comparative coverage and to sample the Province at the southwest end where more earthquakes appear to have been felt over the last 200 years. Some 450 references were extracted in the study.

Prior to this study, only three tsunami were known to have impinged on the shores of Newfoundland; now three newly-documented tsunami are known to have affected the shores of Nova Scotia at Liverpool, in the Yarmouth area and at Cape North. A fourth tsunami has been documented for Newfoundland.

Some eight newly-documented earthquakes have been defined for Nova Scotia; two or three 'ghost' or erroneous events have been defined. One seismic event that may be related to a meteorite has been found. Significant new data for some ten previously-known Nova Scotia events have been found. Similarly, about 16 apparently newly-documented events for New Brunswick, Maine and Upper Canada may have been found with new data on some 14 other previously-known events in these areas. Only three previously-known events failed to yield new data when event-specific newspaper searches were done.

Comparison of Auriferous Structures in New Brunswick and Their Relationship to Tectonostratigraphic Zone Boundaries

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Gold occurs in several distinct geologic environments in New Brunswick. These include Late Precambrian and Early Ordovician, auriferous volcanogenic stratiform base metal sulphide deposits, auriferous porphyry copper deposits and a great variety of auriferous veins and stockworks in rocks ranging in age from Late Precambrian to Carboniferous. Only the auriferous veins and stockworks are discussed in this paper. The greatest concentration of these deposits are along the faulted margins of the major tectonostratigraphic zone or terrane boundaries in the province. The characteristics of the various auriferous structures reflect the complex deformational histories of each of these tectonically active belts.

Numerous auriferous quartz ± carbonate ± sulphide veins and stockworks cutting rocks ranging in age from Ordovician to Devonian, have been reported in the northern Miramichi and Elmtree zones. The greatest concentration of these veins is between the northeast striking Rocky Brook - Millstream and northerly striking Antinouri Lake faults. Most veins in this area appear to fill northwest striking extension fractures associated with the Rocky Brook dextral wrench fault system, which separates the Miramichi and Elmtree zones. All the known auriferous veins in this area are in the contact aureoles of Devonian granitoid intrusions which were emplaced immediately after the Acadian orogeny.

Several recently discovered gold prospects of economic interest in northern New Brunswick occur in northeast striking, steeply dipping, dilatent shear zones that developed during the final stages or immediately after the Acadian orogeny. These occurrences include the Smith Prospect at Upsalquitch River, the deposit discovered by Lacana Mining Corporation near Alcida and the Hickey Showing north of Alcida. The Smith prospect is in a dilatent shear zone that cuts Silurian, intensely deformed siltstone and limestone and that is intruded by mafic dykes and sills. The mafic intrusions are associated with a prominent splay of the Rocky Brook - Millstream Fault. Gold is associated with disseminated pyrite and locally hematite-rich veins. The Lacana Deposit occurs along the intensely sheared unconformable contact of the Ordovician Elmtree Group and Silurian Chaleurs Group, in the Elmtree Zone. Sheared mafic intrusions are common in this area. The Lacana shear zone is cut by numerous quartz-carbonate veinlets and contains abundant disseminated pyrite, argentiferous galena, sphalerite and stibnite.

In the northwestern part of the Magaguadavic - St. Croix Zone, there are several distinct types of gold-bearing veins. Gold- and scheelite-bearing quartz-carbonate veins occur in the contact aureole of the Devonian Pokiok Batholith and its satellite plutons north and northeast of the Lake George Antimony Mine. Auriferous argillic alteration haloes with abundant arsenopyrite and bismuth minerals envelop northwest-striking, thin quartz veins that are cut by easterly-striking stibnite-bearing quartz veins in the Lake George Antimony Mine. The host-rocks for both these types of gold occurrences are tightly folded Silurian greywacke and slate.

Auriferous quartz-pyrite-chalcopyrite veins occur in prominent northeast striking, steeply dipping, dilatent shear zones in the Mascarene Peninsula along the southern margin of the Magaguadavic - St. Croix Zone. The host-rocks are Silurian mafic and felsic volcanic, and sedimentary rocks.

Auriferous quartz ± arsenopyrite veins are common in Early Ordovician pelitic metasediments along the southern margin of the Cookson Zone northeast of St. Stephen in southern New Brunswick. The veins occur in northeast striking, steeply dipping dilatent shear zones and in the crests of prominent steeply plunging cross folds associated with the shear zones.

A variety of gold-bearing veins and stockworks have been found along the southern margin of the Caledonia Zone, immediately north of the Cobequid - Chedabucto Fault. Northeast striking, steeply dipping quartz-hematite veins cut Late Precambrian polydeformed, rhyolite at Dipper Harbour, southwest of Saint John. Older folded quartz veins in these rocks are not auriferous. Auriferous quartz-carbonate ± base metal sulphide veins and stockworks occur in Carboniferous sandstone and conglomerate that unconformably overlie late Precambrian rhyolite at Little Dipper Harbour. The veins strike roughly perpendicular and parallel to the axes of easterly trending, gently plunging folds that are overturned to the north. In the Cape Spencer - Millican Lake area, east of Saint John, auriferous pyrite and locally hematite are associated with quartz veins and stockworks that occur mostly along the crests of gently north-northeast or south-southwest plunging D_2 folds that deform a gently dipping penetrative fabric (S_1) in Carboniferous and/or older argillitized and silicified arkosic sandstone and conglomerate. The arkose unconformably overlies Precambrian or younger granite and granodiorite. The D_2 folds are associated with easterly- and westerly-dipping thrust faults. In addition to veins along D_2 fold crests, there are others roughly perpendicular to D_2 fold axes.

Syndepositional Evaporite Diapirism and the Effects on Sedimentation in the Permo-Carboniferous Strata of the Northeastern Part of the Cumberland Basin of Nova Scotia

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The major structural features of the northeastern part of the Cumberland Basin trend east-west. The features include the Cobequid Highlands, the Tatamagouche Syncline, the Claremont-Malagash Anticline and the Wallace Syncline (Canfield Dome).

Within the northeastern part of the Cumberland Basin there are two styles of evaporite diapirism: (a) fault-related diapiric anticlines, i.e. Claremont-Malagash Anticline and (b) concentric evaporite domes, i.e. Canfield Creek.

A north-northwest paleocurrent direction is dominant in the Namurian to early Permian strata of the eastern part of the Tatamagouche Syncline. The paleocurrent data for the western part of the Syncline are bimodal with a division of flow at approximately the synclinal axis. The flow direction on the southern limb is to the north-northwest. However, on the northern limb the direction of flow is to the east-southeast. This indicates the influence of a possible topographic high developing to the northwest due to uplift in the vicinity of an evaporite diapir.

The southeastward flow directions are found in progressively older strata towards the west suggesting that diapirism of the Windsor Group evaporites initiated during the Westphalian B in the west but not until the Stephanian in the west. The divergent paleocurrents provide a useful indicator that Windsor Group evaporite diapirism migrated through time from west to east.

The unimodal distribution of paleocurrent determinations in the Canfield Creek dome area suggests diapirism postdated sedimentation of the surrounding Upper Carboniferous strata (Westphalian C).

Recent Developments in the Sedimentology and Stratigraphy of the Avalon of New England : The Boston Basin

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The Boston Basin is fault-bounded and similar in size to modern basins situated on the Antarctic shelf. It is similar to the late Hadrynian Avalon succession of Newfoundland and is floored by a late Precambrian calc-alkaline granite that records Avalonian deformation and is intrusive into older metamorphic/plutonic basement. This granite is disconformably overlain by late Precambrian bimodal vocanics that are conformably and disconformably succeeded by 3,000+ m of Precambrian-Cambrian conglomerates, diamictites, sandstones, siltstones, and shales collectively known as the Boston Bay Group. Overlying the Boston Bay Group are Cambrian sandstones, siltstones, and shales containing an Acado-Baltic trilobite fauna.

The existing stratigraphy of the Boston Basin is both confusing and cumbersome because original stratigraphic subdivisions of the Boston Bay Group are vaguely defined and difficult to discern in the field. Consequently, stratigraphic units have been subject to misidentification and, on occasion, structure has been invoked to account for stratigraphy. The sedimentological history of the Boston basin is consequently confused as evidenced by the

sheer volume and variety of interpretations in the literature. In addition, investigations have tended to concentrate on the upper part of the succession and were often short-lived.

Recent research on the stratigraphy and sedimentological history of the Boston Basin has centered around cataloguing what is present, identifying and mapping facies patterns and textures, compiling data on paleo-flow vectors, compiling petrographic and geochemical data to assess provenance and tectonic settings, and comparing the above information with similar data from other late Precambrian basins situated on "Avalon" terrain.

Our preliminary findings suggest that the Boston Basin formed during the breakup of a narrow, remnant passive margin shelf during a late Precambrian subduction event (Avalonian Orogeny). Rapid sedimentation of large volumes of volcanic, plutonic and sedimentary detritus from nearby highlands was largely by way of gravitational mechanisms. A rifting phase recorded by high sodium andesitic and/or basaltic dikes, sills, and flows was contemporaneous with and post-dated basin filling. Latter stages of basin filling were characterized by sandstones and siltstones, some of which contain late Precambrian acritarchs. The succession terminates with an Acado-Baltic, trilobite-bearing Cambrian sandstone-siltstone-shale sequence of shallow marine affinity, although the nature of the transition is not clear.

The geometry of the succession appears to be that of a fan which records either a continuous but noisy rise in eustatic sea level coupled with subsidence and/or pulses of sedimentation throughout the late Precambrian and Cambrian. From a sedimentological perspective there appears to be no requirement for the Avalon platform to have been exotic to North America.

Basis for Distinguishing Different Terranes Within "Avalonia" in Maine and New Brunswick

D.B. Stewart, National Center 959, U.S. Geological Survey
Reston, Va. 22092

Remnants of a non-North American continent form a composite terrane in New England and New Brunswick characterized by shelly Atlantic fauna (equivalent to the Baltic, Celtic, Acadian, or Rhenish faunas of various authors) in Paleozoic sedimentary cover sequences that were deposited upon one or more Precambrian basements. Within this composite terrane, at least two distinctive lithotectonic terranes were shuffled together before to or during accretion to the North American craton along strike-slip faults that were subsequently intruded by Acadian plutons.

Fragments of a terrane corresponding to the Avalon terrane of eastern Newfoundland occur in New Brunswick in long belts in the Caledonian Highlands and Kingston Peninsula. These belts consist of Late Proterozoic plutonic and bimodal volcanic rocks unconformably overlain by thin fossiliferous Cambrian and Ordovician rocks of shallow marine origin. No Silurian or Devonian cover rocks are present. This type of terrane is widespread in eastern Massachusetts and Rhode Island, but absent in Maine.

The second distinctive lithotectonic terrane occurs along the coast of Maine and extends northeast across southern New Brunswick. It consists of highly deformed and metamorphosed sialic Precambrian rocks overlain by poorly dated, but less deformed, Upper Proterozoic to Ordovician interbedded feldspathic and manganiferous sedimentary rocks and bimodal volcanic rocks that are metamorphosed to greenschist facies assemblages. These rocks are in turn overlain by thick sequences of weakly metamorphosed Lower Silurian to Lower Devonian bimodal volcanic rocks and shallow marine sedimentary rocks containing shelly Atlantic fauna.

Another possible lithotectonic terrane within the composite terrane consists of thick Ordovician black sulfidic slates and thin sandstones, but the shelly fossils obtained so far may not be diagnostic of Atlantic origin. The black slate lithotectonic terrane is located between terranes with typical North American or Atlantic faunas in both Maine and New Brunswick. Meguma is still another lithotectonic terrane of early Paleozoic age that might be considered a component of the composite terrane.

The boundary between Grenville basement of cratonic North America and other younger (?) basements "outboard" of the craton need not coincide with the boundary between North American and Atlantic faunas found in the lower Paleozoic cover sequences.

Regional Tectonic Implications of the Lithoprobe East Marine Deep Seismic Reflection Line Across the Northern Canadian Appalachians

G. Stockmal, Geological Survey of Canada, Atlantic Geoscience Centre, Bedford Institute of Oceanography, P.O. Box 1006 Dartmouth, Nova Scotia B2Y 4A2, and The Lithoprobe East Group

In the fall of 1984, as the initial stage of a presently ongoing program, over 450 km of marine deep seismic reflection data were recorded to 15 seconds two-way travel time across the Appalachian Orogen, northeast of Newfoundland. The seismic line, which crosses all of the major geological zones of the northern Canadian Appalachians, was positioned with the aim of relating deep crustal structure to surface geology. A preliminary geological interpretation of the seismic data is currently in press.

The preliminary interpretation, which tentatively established the underthrust eastern limit of the stretched Grenville continental craton, the allochthonous nature of at least part of the Dunnage zone, and a tectonically disrupted Moho, has major regional tectonic implications. In light of recent near surface geological interpretations, we have considered possible plate tectonic configurations for the evolution of the orogen, which will satisfy the seismic observations and simultaneously explain the major regional change in structural geometry and sense of vergence between Newfoundland and the Gaspe Peninsula as well as the development of the arcuate Anticosti foreland basin.

Our preferred interpretation involves initial continent/arc collision between the offset Grenville craton (Precambrian rifting is known to have produced a 300–400 km right-lateral offset in the margin, which is preserved as the Quebec Reentrant and the St. Lawrence Promontory) and a relatively straight eastward dipping subduction zone to produce the Taconian Orogeny. Acadian shortening in Newfoundland was then accommodated by lithospheric delamination of the lower lithosphere beneath the Grenville of the St. Lawrence Promontory with simultaneous tectonic wedging of the lower lithosphere which formerly underlaid the Dunnage back-arc basin. To the south, in New Brunswick and Quebec, further Acadian emplacement of the overthrust wedge onto the craton occurred. Major Acadian overthrusting in the northwestern Maritimes is supported by recent geological and geophysical observations, although the relative partitioning of Taconian versus Acadian shortening remains a problem.

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Preliminary seismic refraction and reflection results from the Southwest Newfoundland Transform Margin

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Predrift reconstructions of the North Atlantic show the southwestern edge of the Grand Banks as a sheared (transform) margin that developed during the Early Cretaceous with the separation of Iberia and North America. Mapping of the two-way time to basement shows a complex topography across the ocean-continent transition zone. Seismic refraction shows that this zone is about 30 km wide. The oceanic crust near the transition has a thickness of 6 km and is characterized by steep velocity gradients and the absence of a clear layer 3 arrival. The refraction data on the continental crust near the transition indicate a thickness of 30+ km. P-wave velocities of 7-8 km/sec are evident at depths of 15-20 km, which may correlate with crustal reflectors seen on preliminary versions of a Lithoprobe line across the Grand Banks. Little or no stretching of the continental crust occurred in the transition zone. Models and synthetic seismograms based on the refraction data are being refined.

Sediment Intrusion Phenomena in the Redbeds of Prince Edward Island. A Preliminary Classification of Pre-Collapse Structures

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Secondary sedimentary structures from physical diagenesis of the Stephanian-Lower Permian redbeds of Prince Edward Island can be broadly classified into two major groups:

1) those that reflect post depositional mud enrichment during compaction and
2) those that reflect post depositional mud enrichment and subsequent collapse of the sediments by surface and/or subsurface flow.

Field relationships of the structures suggest that initial mud enrichment and intrusion during compaction has led to a general lowering of the shear strength of the strata which in turn promoted collapse of the sediments during periods of induced shear. Overprinting of primary sedimentary features of the strata by the effects of the physical diagenesis is extremely common in the Prince Edward Island redbeds.

Attention is drawn here to a broad range of pre-collapse mud enrichment and intrusion phenomena, classifying them on the basis of increasing mud enrichment from diffuse matrix concentrations of mud, through mud plumes and mud replacement bodies by stoping to mud intrusion structures by forceful injection.

Both lateral and vertical components in the intrusion pathways are usually discernable, showing a combined overall angle of discordance of around 20^{o} to the enclosing strata. The cause for this prevailing angle of intrusion-discordance is not clear but it presumably represents a vector direction of least resistence reflecting a balance between upward mobility of the sediment from bouyancy related to density inversion and upward restriction of sediment mobility by the loss of permeability from compaction.

This presentation forms part of a long term continuing program of research on the nature, origin, effects, applicability and facies significance of physical diagenesis.

A Segment of the Hercynian Thrust Belt Between Saint John and Cape Spencer, Southern New Brunswick

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The segment of the Hercynian thrust belt which is exposed along the Bay of Fundy, southeast from Saint John to Cape Spencer, consists of polydeformed sedimentary sequences which in places host gold occurrences. Aside from a small Triassic graben, the coast exposes three distinct sedimentary packages, two of Carboniferous age and one of Carboniferous or older age. The Carboniferous or older sediments, including those referred to as the West Beach formation by Nance (1985), occur mainly along the coast to the southeast of Mispec Beach. The Carboniferous Balls Lake Formation occurs mainly to the northwest of Mispec Beach and the conformably overlying Lancaster Formation outcrops mostly inland.

The Carboniferous or older sedimentary rocks are thrust over the Balls Lake and Lancaster formations and consist mainly of fine-grained purple and greyish purple siltstone, slate, and sandstone with occasional thin limestone beds. Arkose and polymictic granite pebble conglomerate are locally abundant. The Balls Lake Formation consists of purple and red quartzose sandstone, siltstone, shale and quartz pebble conglomerate of probable fluvial origin. Local coarse polymictic paraconglomerates at Mispec Point appear to be debris flows. The conformably overlying Lancaster Formation consists dominantly of grey and brownish grey medium- and coarse-grained sandstone locally containing fossil tree trunks, discontinuous pebble conglomerates and minor thin grey shales. A finer-grained, possibly paralic sequence of Lancaster Formation is exposed near Saint John city.

At least three phases of deformation have affected these sequences. D_1 deformation produced a penetrative S_1 cleavage which is parallel or subparallel to bedding. No F_1 folds were discovered. It is possible that the S_1 cleavage formed by shearing (mainly bedding parallel) resulting from arching or bending during collision of the Avalon and Meguma terranes as suggested by Ruitenberg (1973) and Ruitenberg and McCutcheon (1982).

The D_2 phase deformation produced both southeast and northwest directed thrusting along with large northeast trending, thrust-related folds having either northwest or southeast dipping axial surface cleavages (S_2). A northwest dipping spaced S_2 cleavage is well developed in shaly units of the Balls Lake Formation. Gold mineralization clearly occurred along thrust-related folds of this deformation phase. A minor D_3 phase of deformation produced sporadic steeply dipping kink bands.

The D_2 thrusts are extremely important because they juxtapose the major rock sequences and they control the emplacement of gold deposits. The thrusts tend to follow the least competent units (shales, limestones). Many of the thrust surfaces contain thrust-parallel, layered quartz-chlorite veins a few centimeters thick but massive quartz veining up to two meters thick is found locally near gold occurrences. Extension veins of quartz ± calcite ± chlorite are often abundent in competent units near the thrusts. Folds commonly occur immediately above and/or below thrust surfaces. Alteration effects related to D_2 thrusting include reduction (green) of the original red beds adjacent to many thrusts and more intense buff alteration with pyrite and gold occurring in some thrust-related fold crests and below some thrust surfaces.

Late Carboniferous Tectonics and Sedimentation in Stellarton Gap, Nova Scotia

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Stellarton Gap lies between two Avalonian terranes, the Cobequid and Antigonish Highlands. The Carboniferous rocks which underlie it are cut by two major fault systems, the Cobequid and Hollow Faults. These respectively form the southern and northwestern boundaries of the Avalonian blocks. Upper Carboniferous sedimentation patterns are clearly related to these faults. The reddish New Glasgow Conglomerate (Westphalian B) was shed northward, away from them, into Stellarton Gap. Grey sandstones and reddish shales of the overlying "Merigomish Formation", the lowest unit of the Pictou Group (Westphalian C -D), were also shed northward. Grey and red shales and sandstones of the partly time-correlative Stellarton Formation (Westphalian B -C) were deposited in a graben bounded by the fault systems.

Knowing the sense, timing, and extent of movement on the Cobequid and Hollow Faults is critical to interpretation of the late Carboniferous stratigraphy. Observations of minor structures along the faults consistently indicate overall dextral displacement in response to regional northwest - southeast compression. Movement began in Westphalian B time (ca. 306 Ma) and probably ended in Westphalian D time (ca. 296 Ma). The offset of Devonian volcanics on the Cobequid Fault, and Silurian strata on the Hollow Fault, suggests about 20 km of displacement.

The New Glasgow Conglomerate represents a series of coalesced alluvial fans developed along the fault system. The Merigomish Formation is an alluvial plain sequence characterized by low sinuosity channels. An increase in suspended load deposits upsection suggests that braidplain conditions gave way to an anastomosing(?) regime. Thin oil shales and stromatolitic limestones in the lower part of the formation are lake deposits. The Stellarton Formation comprises mainly lacustrine and deltaic deposits. Scarcity of coarse clastics, except near the graben margins, suggests that subsidence was gradual, with relatively little relief developed. Red-bed members represent periods in which subsidence was relatively slow, or of dry climate and lower water table. The coal- and oil shale-bearing grey-bed members accumulated during episodes of more rapid subsidence, or of more wet climate and elevated water table. Interpretation of the fault-bounded basin, in which the Stellarton Formation was deposited, as a rhomb graben is supported by the orientation and sense of movement on second-order structures within the graben.

The observations outlined above may help to elucidate the relationship between tectonics and sedimentation in other late Carboniferous basins of the Maritimes.

Geology of the Chetwynd Gold Deposit, Newfoundland: A Progress Report*

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The Chetwynd gold deposit is located on Newfoundland's southwest coast, approximately 80 km east of Port aux Basques. It is hosted by the Georges Brook Formation of the middle-lower Ordovician La Poile Group, at the southwestern end of the Hermitage Flexure.

The immediate hosts to the deposit include a dark green, mafic volcano-sedimentary sequence to the southeast, comprising pelite, quartz-eye bearing greywacke, and quartz grit and mafic flows. Various dacitic, gabbroic, and ultramafic(?) sills intrude this sequence. To the northwest is a lighter coloured, predominantly sedimentary sequence of boulder and pebble conglomerates, and grits, with felsic and mafic tuffaceous rocks. At least three granitic sills of the upper Orodovician Hawks Nest Pond Porphyry intrude this sequence. All stratified units of the Chetwynd area exhibit remarkable along strike continuity and approximately constant thickness.

Disseminated gold mineralization occurs in a narrow, tabular body between the two sequences. Roughly constant in thickness, the silicified zone has been tectonically segmented, and intruded by a variety of mafic dykes. An associated alteration assemblage of quartz, muscovite, and pyrophyllite schist comprises its southern margin.

The upper Devonian Chetwynd Granite, a coarse grained, biotite/K-feldspar granite, truncates all units to the northeast.

All rocks in the area (except the Chetwynd Granite) have undergone at least one phase of penetrative regional deformation with associated(?) greenschist grade metamorphism. Typical metamorphic mineral assemblages of mafic dykes include quartz, plagioclase, epidote, actinolite, and chlorite. The dominant tectonic fabric in the area is a northeast-striking, steeply to moderately south-dipping penetrative foliation. This foliation is coincident with geological contacts and is axial planar to intrafolial, isoclinal folds, best exhibited in the pelitic rocks of the southeastern volcano-sedimentary sequence. A weak, north-trending crenulation cleavage is also observed. The isoclinal folds, along with other kinematic indicators (C-S fabrics, en echelon, quartz filled tension gashes) reveal a right lateral sense of shear for the area. The relationship between foliation, geological contacts and folding suggest some degree of tectonic modification of stratigraphy in the Chetwynd area.

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Gold Mineralization Related to the Evolution of a Miocene Volcanic Complex in the Southern Central Andes*

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Primary epithermal gold (and silver) deposits associated with subaerial calc-alkaline volcanism, both in high grade veins and low grade disseminations are becoming important exploration targets throughout the circum-Pacific region. Such deposits occur in the Neogene volcanic province of the Andes between latitudes 26° and 28°S. Volcan Coplapo is a large volcanic complex with more than a dozen discernable vents. Argon/argon geochronology indicates that volcanism persisted at Volcan Coplapo for almost 5 Ma. The oldest units (14-12 Ma) outcrop around the margins of the complex. Final volcanic activity (10-8.6 Ma) was focussed near the tall composite cone Azufre (6042 m). Azufre fills a preexisting caldera formed in a moderate eruption during which pyroclastic flows were emplaced. This

caldera-producing eruption capped important explosive activity of Volcan Copiapo, and was associated with hydrothermal activity. Eruption of lava, infilling of the caldera and construction of the Azufre cone dominated final volcanic activity. Besides late rhyolitic ignimbrites of uncertain source, volcanic rocks from Volcan Copiapo are all medium-to-high-K andesites and dacites. Plagioclase and hornblende (± biotite) are the most abundant phenocrysts in both andesites and dacites. In addition to economic sulphur deposits, low-grade disseminated gold mineralization occurs in several alteration zones controlled by roughly north-south trending fracture systems. In one major mineralized zone, alunite yields a K/Ar age of 12 Ma. Approaching the mineralization, the host rocks are altered to quartz ± alunite ± illite ± kaolinite ± montmorillonite ± jarosite ± chlorite assemblages. Altered rocks are generally enriched in H_2O, K_2O, Rb and S with respect to their fresh protoliths, whereas Ti and Zr behave as relatively immobile elements. Gold enrichment is accompanied by a significant increase in As, Pb, Sb and Mo in the rocks, but Ag values are low.

It would appear that background values of gold are high (ca. 10-20 ppb) in fresh, glassy, felsic volcanic rocks of this complex. This gold has been leached and concentrated in localized permeable areas where hydrothermal circulation was voluminous and sufficiently protracted in time.

*Research supported by NSERC Grant A9036, N.I.U., and SERNAGEOMIN, Chile.