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See table of contents

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Meetings

A meeting on the Natural Resources of Atlantic Canada was held by the Atlantic Geoscience Society at Acadia University, Wolfville in early 1976. Three general sessions based on Geological Background, Metallic Minerals and Fuels and Industrial Minerals formed the framework of the meeting. Abstracts of the papers presented at the meeting are given under the sessional headings.

THE BACKGROUND

NEWFOUNDLAND APPALACHIAN GEOLOGY AND RESOURCES

M.J. KENNEDY. Memorial University of Newfoundland, St. John's, Newfoundland

Several separate stages in the development of the Newfoundland Appalachian System by opening and closing of the Proto-Atlantic (Iapetus) ocean can be recognized. The System is poly-orogenic and no single simplistic model can account for the development as it is now known. Conflicting evidence for the initiation of separate stages is present in different parts of the System. Rifting, which led to initiation of the ocean, can be dated as latest Precambrian-earliest Cambrian in the west, although in the east rifting and possibly some spreading shown by dismembered ophiolitic rocks may be as old as mid-Hadrynian. Oceanic crust formed during drifting may be represented by the ophiolote complexes of central and west Newfoundland which are no younger than Lower Ordovician: alternatively they may have been formed in back-arc basins. Continental-rise deposits on both sides of the System are of Precambrian-early Ordovician age; again they seem to be older on the eastern side of the System. Island arc volcanic suites formed in association with closure of the ocean are well documented from the Ordovician, but older remnant Cambrian and possibly Precambrian suites suggest that the history of subduction was also protracted and complex. Multiple arcs and multiple polarity of subduction best fit the evidence available. Deformational episodes, also presumably related to consumption of oceanic crust, occurred in late Precambrian, late Cambrian-early Ordovician and mid-Devonian times.

Each separate stage is characterized by different deposits. The western carbonate bank hosted Pb/Zn sulphide deposits in the Ordovician which Cr, Fe and Cu mineralization is characteristic of the ophiolite complexes, and where alteration is intense chrysotile asbestos also occurs. Polymetallic massive and disseminated Fe, Cu, Zn, Ba with associated Ag and Au occur in the Ordovician and Silurian Island arc sequences, and are also present in the older arc sequences. On the southeast side of the system, where oceanic crust is postulated to have descended beneath continental crust at several stages of closure of the Iapetus ocean, mineralization is different. W, Sb, Ag, Au and F mineralization occurs. There is some evidence that the F may be of Carboniferous age. Although plate tectonic models may be of some help in evaluating mineral potential, erosion has probably removed many deposits that are common in Mesozoic-Tertiary arcs. However, some of these minerals may be concentrated in later sedimentary basins within the Appalachian region.

GEOLOGICAL MODELS OF NORTH APPALACHIAN STRUCTURE

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A series of geological models of North Appalachian structure have been proposed:

The earliest model is that of Hall and Dana, who defined and elaborated the geosynclinal theory. This model has had a prolonged vogue in geological literature and is perhaps one of the most commonly applied models. The geosynclinal theory led to a widespread conclusion that metallogenesis is associated with orogenic and post-orogenic activity often related to granitic plutons. The vast majority of the Northern Appalachian Plutons were related by Billings to Acadian Orogeny. The position of many deposits was claimed to be conditioned by tectonic deformational structures.

The next model in time was that proposed by Dewey and Bird, who suggested that the Northern Appalachian orogen consists of two structured parts of continental shelves; one, a part of the proto-Eurafrican continent if indeed proto-Eurafrica was a simple unit then. In terms of metallogenic deposits the emphasis shifted to oceanic layered deposition especially by Strong and others.

The third model is being developed at present and depends on the recognition of a complex sequence of orogenic events and the interplay of conditions including the *circa* 600 m.y. Avalonian-Cadomian event, the *circa* 400-380 m.y. Acadian event and lastly the Variscid-Alleghanian events. The detailed elucidation of such a complex history is important in metallogenic discussions of the future. But in view of red bed associations, as pointed out by Van de Poll, evaporitic types of metallogenesis are widespread if at present economically insignificant.

EAST COAST OFFSHORE OIL AND GAS POTENTIAL

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The East Coast offshore region, comprising the Atlantic continental margin of Canada, is more than four times the area of Alberta and includes the most extensive and voluminous sedimentary basin system in all of Canada.

Four separate sedimentary provinces are represented, the most important of which is the more or less continuous Tertiary-Mesozoic coastal margin basin beneath Georges Bank, Scotian Shelf, Grand Banks, northeast Newfoundland, Labrador and Baffin Shelves and adjacent slopes and rises, which represent the northern submerged extension of the Atlantic Coastal Plain Province. Four major phases from Triassic to Tertiary are reviewed for their history of deposition and structure and their stratigraphy relevant to the generation and entrapment of oil and gas.

Since petroleum industry exploration in the Canadian East Coast offshore region began in 1959, some 425 million acres in oil and gas permits have been issued, 350,000 miles of reflection seismic have been shot, and 113 exploratory wells drilled for a total industry expenditure of $440 million.

Results of exploration have, on the average, been disappointing, excepting in the Sable Island area of the Scotian Shelf where six small discoveries have been made, and on the Labrador Shelf, where there have been two confirmed finds and indications of a third. The elements controlling oil and gas distribution are analysed and forecasts made as to future potential and activity. The Labrador Shelf sector of the region in particular is considered to be one of the three Canadian frontier exploration regions which should eventually contribute at least in a moderate way to Canadian petroleum supply. However, no major hydrocarbon province equivalent to the North Sea in potential is indicated by exploration to date.

METALLIC MINERALS

GEOCHEMISTRY AND MINERAL EXPLORATION - SOME NEW APPROACHES IN NEW BRUNSWICK

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Dwindling near-surface reserves of many minerals emphasize the need for the development of exploration techniques capable of greater depth penetration. Because most of the deposits located at or near the earth's surface in much of the well prospected parts of the world, including New Brunswick, have already been located by conventional exploration techniques such as geophysics and soil and stream geochemistry in conjunction with geology, emphasis at the University of New Brunswick is now being placed on the development of geochemical techniques capable of detecting ore deposits subcropping below thick glacial cover and blind ore deposits located hundreds of metres below the rock surface.

The geochemical expression of an ore deposit covered by tens of metres of glacial material is being investigated by a combination of electrochemical and chemical methods. For example, the conductivity of a soil-water slurry has been used successfully to indicate sub-cropping mineralization below approximately 20 m of glacial till. Selective acid and water-extractable digestion procedures show equal promise in locating buried mineralization.

The geochemical expression expected for an ore deposit buried hundreds of metres below the earth's rock surface is being investigated with geochemical studies conducted at massive sulphide deposits in the Bathurst District, as well as in other parts of of Canada and in Turkey. From these studies extensive and intensive geochemically anomalous zones, resulting from a variety of primary and secondary processes, have been defined and outlined in the sedimentary and volcanic rocks associated with Brunswick No. 12, Heath Steele, and Key Anacon deposits in northern New Brunswick. The size of these hemispherically shaped zones (i.e., radius up to 600 m) suggests the application of rock geochemistry to the exploration for blind massive sulphide deposits in the Bathurst District, as well as elsewhere.

The successful application of rock and soil geochemistry to the exploration for deeply buried massive sulphide deposits requires an understanding of the primary and secondary processes affecting the distribution of elements. An appreciation of the controlling processes aids in differentiating between geochemical trends reflecting the presence of mineralization and geochemical trends unrelated to mineralization. Consequently, laboratory experimentation, in conjunction with field geochemical studies, has been conducted in an effort to understand the controlling processes both related, and unrelated to massive sulphide deposition.

A case history of a rock geochemical exploration technique recently employed in the Bathurst District outlines the various geochemical procedures used to locate an anomalous zone as well as to define a drilling target within the zone.

METALLOGENY AND PLATE TECTONICS IN NEWFOUNDLAND

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The Newfoundland Appalachians have been traditionally subdivided into three major divisions: the Western Platform, the Central Mobile Belt and the Avalon Platform. These three divisions can, with some redefinition of boundaries, be regarded as three distinct Paleozoic plates. Types of mineral deposits are distinctly different on each plate and can be explained in terms of plate interaction in the Paleozoic era.

Mineral deposits of the Western Platform are "Mississippi Valley Type" zinc sulphides in the Lower Ordovician shelf carbonate sequence and "Cyprus Type" copper sulphides in thrust slices of Paleozoic oceanic crust obducted from the Central Mobile Belt. The Central Mobile Belt is essentially an island arc sequence of volcanic and sedimentary rocks overlying oceanic crust. "Cyprus Type" copper deposits are common in the oceanic crust at the base of the sequence. "Kuroko Type" stratabound base metal sulphide deposits occur in the overlying island arc sequence. "Kuroko Type" deposits became more polymetallic with the progressive evolution of the island arc. The boundaries of the "Central Plate" contain asbestos deposits in serpentinized ultramafic rocks of the oceanic crust. Paleozoic sedimentary rocks of the Avalon Platform contain iron and manganese deposits.

Late Paleozoic rifting of the entire Newfoundland Appalachians resulted in fluorite and molybdenite deposits in alkaline granites on the Avalon Platform and various base metal sulphates and sulphides in carbonates within successor basins of the Western Platform.

THE PORPHYRY-TUNGSTEN DEPOSIT AT MT. PLEASANT, N.B.

J.V. TULLY and J.S. PARRISH. Brunswick Tin

The Mount Pleasant deposit of Brunswick Tin Mines Ltd. is an epithermal deposit derived from a late stage magmatic differentiate of a granite. The mineralized zone, as described, has many similarities to the porphyry copper deposits of B.C. and the molybdenum deposits of Climax Colorado. As such, it is probably best termed a porphyry tungsten deposit.

Mineralization occurs as pods, disseminated grains, fracture coatings, fillings and veinlets in highly fractured and brecciated silicified plugs. These plugs contain mineralized bodies of up to 30 million tons that grade .1% Mo., .2% W., .1% Bi. Within these bodies, vertical and horizontal zoning of the minerals produce higher grade portions of up to 3 million tons that grade .15% Mo., .35%., .12% Bi.

There is marked alteration in and around the plugs. The various alterations include chloritization, fluoritization, kaolinization, sericitization, hematitization and, most prominately, silicification.

The plugs intrude a volcanic pile of Mississippian quartz feldspar porphyry flows and overlie a microgranite of unknown age. The volcanic basin is bounded on the north by the main Pennsylvanian series, on the south by a Devonian granite, and on the east and west by Silurian-Devonian sediment.

STRATIGRAPHIC AND PALEOGEOGRAPHIC SETTING OF BASE METAL DEPOSITS IN THE WINDSOR GROUP

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Re-discovery of the Gays River zinc-lead deposit and the proving of economically significant base metal reserves, has provided tremendous incentive for base metal exploration in carbonate rocks of the Windsor Group throughout the Maritime region. Numerous carbonate banks similar to those hosting the Gays River deposit have been documented in southern Nova Scotia although little success has been achieved in discovering additional economic base metal concentrations. Comparison of these bank deposits to the Gays River Bank reveals that they are similar in all aspects considered except base metal content.

The Gays River carbonate can be shown to be the probable time (stratigraphic) equivalent of the Macumber-Pembroke limestone which hosts the Walton deposit. These two deposits, which are the only economically significant base metal accumulations currently known in the Windsor Group, contrast in almost every respect excepting the stratigraphic position of their host(s).

The apparent restriction of base metals to the lowermost carbonate of the Windsor Group may be in part attributed to the widespread, immediately overlying evaporite, up to 1,500 feet thick, which may have formed an impermeable barrier to upward-migrating metal-bearing fluids.

Paleogeographic control of carbonate lithofacies is apparent, although no evidence has yet been presented to suggest that metallization is preferentially controlled by lithofacies within the basal Windsor carbonate.

URANIUM RESOURCES OF ATLANTIC CANADA

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The Uranium Resources Evaluation Section of the Geological Survey of Canada with the cooperation of provincial departments of mines and of industry is responsible for the periodic assessment of uranium resources of Canada. The Geological Survey of Canada makes a broader contribution in the form of geological reports, and geophysical and geochemical data in its uranium program. This information is used in resource evaluation, which indicates the potential of specific areas, which in turn may lead to significant discoveries. In this regard, our work in Atlantic Canada is encouraging.

While no economic deposits of uranium are known in Atlantic Canada, the environment of the Maritime Permo-Carboniferous successor basin is demonstrably favourable for deposits in epiclastic and volcaniclastic strata where there are significant occurrences and anomalies. In particular in the Hoyt-Harvey area encouraging uranium showings occur in volcanic and sedimentary rock which with Mount Pleasant perhaps define a U-Mo area. In the Moncton and Pugwash areas uranium occurs in association with copper; these areas are encouraging in light of recent reconnaissance geochemical surveys. Other areas of potential are in dark Cambro-Ordovician shales in Cape Breton Island, and in Devonian granitic intrusions.

PRE-FOLDING ACADIAN EMPLACEMENT OF SOME GOLD-BEARING QUARTZ VEINS IN SOUTHERN NOVA SCOTIA

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Gold-bearing, "interbedded", quartz-carbonate-arsenopyrite veins occur in the greenschist-grade regionally-metamorphosed slates and greywackes of the Cambro-Ordovician Meguma Group. Arsenopyrite geothermometry and fluid inclusion geobarometry indicate temperatures of crystallization of 432° C ± 60° C and pressures of crystallization of 1.5 to 3.5 kilobars for the vein-mineral assemblages. These vein-mineral assemblages appear to have crystallized in equilibrium with the greenschist metamorphic assemblages of the surrounding country rock. The veins are folded in the same manner as the country rock and deflect slaty cleavage. Their formation thus appears to have taken place under the same general stress conditions that later resulted in upright, gentle to steep, large-scale folds and penetrative, slaty, axial-plane cleavage of the Acadian Orogeny <u>and</u> during regional greenschist grade regional metamorphism of the same orogenic episode. Later granitoid intrusions cut folds and slaty cleavage and their narrow contact

metamorphic aureoles are superimposed on greenschist-grade regional metamorphic assemblages and some quartz-carbonate-arsenopyrite vein groups.

THE STRATIGRAPHY, DIAGENESIS, AND POSSIBLE ORIGINS OF THE LOWER ORDOVICIAN ZINC DEPOSITS, DANIEL'S HARBOUR, NEWFOUNDLAND

C. DEARIN. Newfoundland Zinc Mines Limited

The Daniel's Harbour ore deposits occur as a cyclic series of thin, narrow but elongate en echelon ore beds in Lower Ordovician carbonates. The ore is typically a Mississippi Valley type deposit of the Tennessee Variety, having only zinc as an economically mineable metal.

Proven ore reserves stand at 5.3 million tons averaging 9.7% zinc from 11 ore zones while at least 3 more zones remain as possible ore. Overall, 14 ore zones exist in a 5.5 square-mile area.

Stratigraphically, the ore bodies occur about 250 feet below a regional disconformity separating the Table Head - St. George Formations in a gently dipping cyclic sequence of solution-eroded, strata-controlled dolosparites, locally called pseudo breccia. Each pseudo breccia bed is separated from the next by a massive, generally featureless dolomite bed. This relatively thick (50 to 175 feet) cyclic sequence can be traced laterally into a similarly cyclic sequence of biointrapelsparites and interbedded micrites. Present evidence indicates that the pseudo breccia and laterally time-equivalent biointrapelsparites were deposited in a supratidal to shallow-water environment, as strongly to weakly burrowed limestones and (or) dolomites followed by a deeper-water featureless limestone bed. Finally, a high porosity was developed in the strongly burrowed beds within zinc-bearing fluids being deposited prior to major dolomitization in the porous limestone beds, the ore contacts being determined to a large extent by paleodolomite fronts. Later remobilization of the ore via compaction and dolomitization may account for the coarsely crystalline nature of the strongly colloform ore.

The original theory of collapse breccias to explain the development of pseudo breccia and localization of the zinc ore is disputed.

In general, a supratidal to subaerial environment is proposed for the deposition and diagenesis of the pseudo breccia unit. Several possible origins for the ore are discussed.

FUELS AND INDUSTRIAL MINERALS

BIOSTRATIGRAPHY OF THE LABRADOR SHELF

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The Labrador Shelf covers approximately 90,000 square miles and is overlain by a seaward thickening sedimentary wedge, up to a maximum of 20,000 to 30,000 feet. Hydrocarbon exploration in this inhospitable region commenced in the late 1960's. To date nine wells have been drilled, two of which have been termed discoveries, and a further two may have encountered hydrocarbons. The wells discussed in the present paper are Tenneco *et al* Leif E-38 drilled in 1971 and suspended at 3567 feet, and Eastcan *et al* Leif M-48 and Bjarni H-81, drilled in 1973. The oldest sediments encountered in Leif E-38 are of apparently Early Miocene age. Leif M-48, located one mile away and with a TD of 6165 feet, bottoms in basalt dated as Early Cretaceous. Bjarni H-81, approximately 130 miles to the north of the two Leif wells has a TD of 8252 feet, also penetrating the Early Cretaceous basalt between 7400 and 8252 feet. Overlying the basalt in Bjarni H-81 is the porous "Bjarni Sandstone", which contains Early Cretaceous palynomorphs, and which has tested gas with small amount of condensate. The "Bjarni Sandstone" is overlain by marine Late Cretaceous (?Campanian to Maastrichtian) rocks, in turn followed by a Tertiary sequence. The oldest sedimentary rocks encountered in Leif M-48 are Late Cretaceous (Maastrichtian). These are succeeded by a more-or-less complete Tertiary sequence, although the Early Paleocene appears to be absent. The depositional environment has shown considerable fluctuations, from non-marine in the Early Cretaceous, to ?neritic in the Late Cretaceous-Paleocene, bathyal in the Eocene, neritic in the Oligocene-Miocene and littoral to non-marine in the Plio-Pleistocene. Reworked microfossils are common in the Plio-Pleistocene.

GEOLOGY NORTHEAST OF NEWFOUNDLAND

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Bathymetry, seismic, gravity, magnetic and drill-hole data collected in the marine area landward of a line between Belle Isle and Funk Island forms the basis for a preliminary geological map of the north-eastern Newfoundland Shelf. Preliminary analyses of drill cores have been disappointing because of poor preservation of palynomorphs. However, the magnetic and seismic data suggest that Carboniferous sediments are covering most of the area west of 54° W except within the confines of Notre Dame Bay, where Ordovician and Silurian units surrounding the bay are still exposed offshore, and in the vicinity of Hare Bay where Hadrynian-Cambrian and Ordovocian-Silurian volcanics comprise the bedrock. Salt-withdrawal features were observed within the Carboniferous units. High gravity and magnetic anomalies east of Hare Bay may be equivalent to those in the Notre Dame Bay region and therefore may represent the location of a possible relic source for the Hare Bay allochthon. Regional geophysical trends recognized in surveys farther seaward can now be definitively traced inshore to trends associated with the Gander to Avalon tectonic zones.

COAL RESOURCES OF ATLANTIC CANADA

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The coalfields of the Atlantic region can be assigned to different depositional basins. Three types of paralic and two types of limnic coal basins are

represented. Each is characterized by specific sedimentological features, which are reflected not only in the clastic rocks but also in the associated coals. In the latter this is revealed by overall seam development, petrographic composition and variations in the miospore assemblages.

The post-deformational aspect of coalification and its affect on coal quality will be discussed, the significance of this feature on thermal maturation levels of hydrocarbon also will be indicated.

Views on remaining coal resources in the Atlantic region will be dealt with also, in the broad context of this paper.

BITUMINOUS SHALES OF ATLANTIC CANADA

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Bituminous shales are known to occur in almost all of the Carboniferous Basins of Nova Scotia, New Brunswick and Newfoundland. Over the past 150 years, these shales have received attention as an alternate hydrocarbon source and as a possible source rock for accumulations of hydrocarbons elsewhere in the geologic record. Several areas have received detailed evaluations and mining and retorting facilities were established.

The current energy shortage has renewed interest in bituminous shales and an indicator of this is the work being conducted in New Brunswick and Nova Scotia on their deposits. Unfortunately, exploration on the shales in Newfoundland has offered little encouragement for development with todays economics. Private interests have acquired exploration permits over several areas in New Brunswick and are conducting an exploration program.

The Nova Scotia Department of Mines is completing an inventory of the known bituminous shale occurrences in that Province. Preliminary results in the Nova Scotia program suggest the deposits are larger and more extensive than previously thought.

Several European countries and western United States have developed new and exciting technology to allow economic extraction of this valuable energy source. These include several new commercial above ground retorts that would allow production of up to 500,000 bbls of shale oil per day as well as *in situ* retorting techniques now being pilot-tested in the Piceanee Creek Basin of Colorado.

SAND AND GRAVEL RESOURCES OF NEW BRUNSWICK

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Sand and gravel production in New Brunswick has climbed irregularly over the past years until present annual production rates have reached more than ten million tons. The bulk of these resources are distributed along stream valleys in the form of glacial outwash although outwash plains not directly associated with present-day stream valleys are important contributors to the granular budget of the province. Other important contributors include glaciofluvial ridge deposits and proglacial deposits.

The very nature of sand and gravel as low-priced commodities means that pit or quarry operations must be located near to their market-of-use area. This has resulted in many small and temporary operations being established in New Brunswick near sites of highway construction. The need for an inventory of granular resources surrounding regions of large population growth is strongly emphasized.

NEW DATA ON WINDSOR SALT, SHUBENACADIE - STEWIACKE AREA, NOVA SCOTIA

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A recent St. Joseph Explorations Limited - Noranda Mines Limited joint venture exploration program consisting of a gravity survey and drilling of 4 deep holes has provided new information on the distribution and character of Windsor-age salt and overlying sediments.

The beds overlying the main salt unit consist of a cyclical repetition of siltstone, carbonate and anhydrite on a relatively small scale. Salt was the final product in 6 cycles in one hold drilled at Stewiacke East. Visual correlation between holes is hampered by abundant partial cycles but gamma-ray-neutron logging provided sufficient diagnostic responses to allow a good correlation between 3 holes. A red-green mottled siltstone with 40 to 60% anhydrite nodules was the only distinctive stratigraphic marker found, occurring 150 to 200 feet above the main salt. No evidence of extensive folding was found.

The main salt bed was encountered at depths between 917 and 1895 feet and varied in thickness from 249 to 1034 feet. The salt is rather impure, containing abundant interbeds of anhydrite from a fraction of an inch to several feet in thickness, as well as some clastic material. The salt is typically grey to black, with white to clear salt being more abundant near the bottom of the sections. The abundance of anhydrite throughout the salt indicates regular dilution of the brine in the evaporite basin to the extent that the salinity at no point greatly exceeded that required for the first precipitation of halite. Trace contents of potassium were low, thus supporting this conclusion.