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ABSTRACTS

1993 SYMPOSIA

"TECTONICS OF THE MARITIMES BASIN"
"PRECIOUS METAL MINERALIZATION IN THE ATLANTIC REGION"
"NEW FRONTIERS IN OCEAN MAPPING"

1993 COLLOQUIUM

"CURRENT RESEARCH IN THE ATLANTIC PROVINCES"

HALIFAX, NOVA SCOTIA

The 1993 Symposia and Colloquium of the Atlantic Geoscience Society were held at the Citadel Inn, Halifax, Nova Scotia, on February 12 to 13, 1993. On behalf of the Society, we thank D.J. Kontak of the Nova Scotia Department of Natural Resources, and all others involved in the organization of this excellent meeting.

In the following pages we publish the abstracts of talks and poster sessions given at the Symposia and Colloquium.

The Editors

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The resolution and information content of EM100 and EM1000 multibeam imaging sonars

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With the recent introduction of shallow water multibeam sonars into Canada, their capabilities as geophysical investigative tools is only beginning to be realised. In order to use these tools, however, their resolving capability and information content need to be understood.

The EM100 sonar was designed primarily as a hydrographic tool capable of resolving features that have a height of as little as 1% of the water depth and spatial resolution of about 15% of the water depth. In order to meet these specifications, an excellent knowledge of both the horizontal position, tidal elevation and vessel motion is required. With differential GPS and synchronous tide gauges, the first two parameters are well constrained. At present, the third parameter, the vessel motion (particularly roll), is limiting the quality of the bathymetric data. For geophysical purposes, however, as long as the nature of the artifacts in the data is recognised, it can still be of use.

In addition to bathymetry, the EM100 is capable of providing information on the backscattering strength of the seafloor at the same spatial resolution as the sounding data. With additional non-standard processing, this image data can be manipulated into maps of seafloor backscatter, of use in remote sediment classification.

The EM1000 sonar provides similar hydrographic data quality although extending over a wider swath. The wider data is, however, even more sensitive to roll and refraction artifacts. In shallow water this does provide up to three times the swath width of the EM100.

The EM1000 was specifically designed to provide imagery comparable to sidescan sonars with the added advantage of full topographic control and higher acquisition speeds (up to 18 knots). The imagery has a theoretical resolution of 15 cm. Operationally, only targets of 2 m or greater can be resolved with confidence.

Examples of the quality and imaging capabilities of both sonars will be presented.

National seismic digital library: Husky digital data library

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An extensive digital geophysical database has been donated to the Geological Survey of Canada by Husky Oil and Petro-Canada. Primarily, but not exclusively covering the eastern frontier basins, this material consists of approximately 50 000 magnetic tapes having an estimated acquisition cost greater than $100 million. Both raw and processed seismic reflection and refraction, gravity and magnetic surveys make up the database collected between the late 1960s and the mid 1980s. This information was previously available only in hard copy from the federal-provincial regulatory agencies and the companies were concerned that the scientific value of the digital data may be lost if not made accessible to Canadian researchers. To ensure the continuous development of new ideas and the data's integrity, agreements for the non-commercial rights to the data were made. The Geological Survey of Canada gains a unique data library putting it on an equal technological foundation with industry.

New frontiers in ocean mapping

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Requirements for better information about the seafloor, due to the intensified use of the oceans and their increasing strategic importance, have resulted in renewed interest in high resolution ocean mapping. Our ability to respond to these demands has been made possible by the convergence of a number of technological advances: (1) accurate positioning using satellites; (2) complete bottom coverage and high resolution using multibeam sounders; (3) increased power of shipboard computing; and (4) advances in digital data processing and image presentation.

In 1992, as part of the ongoing CHS/AGC ocean mapping program, a multiparameter survey employing these new technologies on board the CSS Matthew was conducted on the inner Scotian Shelf just south of Halifax. The data collected included bathymetry (100% coverage), pseudo imagery, magnetics and gravity. During 2 months with 31 days of data collection an area of 1000 km^2 was covered, including 11 400 km of bathymetry, 10 600 km of magnetics and 8020 km of gravity data.

Differential GPS (DGPS) positioning was used, providing 10 m accuracy; a shore based station transmitted in real time differential corrections to the ship's GPS receiver. The Simrad EM100 multibeam sounder provided 100% bottom coverage and pseudo imagery of the sea floor. The bottom coverage is 1.7 times water depth across track (80° angle), with 32 narrow beams, each about 2.5°. It operates at 95 Khz and has a depth range from 10 to 600 m. Spatial resolution (footprint of a single beam) is a function of depth; for this survey it averaged about 5 m.

Depths in the work area ranged from 50 to 200 m. Survey lines were planned to achieve at least 10% sidelap between adjacent lines, resulting in 100 m line spacing for the whole area and then interlining to 50 m in the shallower areas. Checklines, spaced at 4 km were run orthogonal to the regular lines and were used to determine the consistency of the data. A calibration procedure called a "Patch Test" was completed at regular intervals to detect and correct misalignment errors between the various sensors (transducer, motion sensor and GPS). The ship's motion (heave, roll, pitch and gyro) were continuously measured and these corrections were applied to the EM100 data. Sound velocity profiles were collected regularly and used to correct the data for speed of sound and refraction. The sounder ping rate varies with depth, but averaged about every 0.75 seconds. This meant about 2 Mb of raw data per hour; about 40 Mb per day; and about 1.2 Gb for the whole survey or about 100 million soundings. This raw data expands about ten times during processing.

During processing the raw data are corrected for sensor offsets (translations and rotations) and tides and then "cleaned". During cleaning within the HIPS processing package erroneous navigation and depth data are flagged using automatic and interactive software tools. The data set is then ready for further visualization and image presentation or for loading into a database. There are several software packages available that accept XYZ data points, then grid or bin the data and generate two- or three-dimensional images enhanced with colour or grey shading and illumination algorithms. By varying these parameters we can generate any number of images for interpretation that enhance particular features of the data set.

Presently, accurate measurement of the ship's motion, especially roll, is the limiting factor in realizing the full accuracy potential of these multibeam sounders.

CSS Matthew is a small ship and thus not ideal for gravity measurements in the open ocean since considerable vessel accelerations are produced in even moderate seas (State 3 and 4). The close line spacing on this survey allowed for considerable redundancy so that the disturbed portions of the records could be deleted and still maintain reasonable coverage. Frequent returns to the home port allowed good harbour calibrations. Ship acceleration may not be the only limitation on the quality and accuracy of gravity data. We have noticed correlation between crossover discrepancies on adjacent tracks which may indicate a vertical acceleration due to long period internal waves.

Special attention was paid to the magnetic measurements with the objective of a survey accuracy of 2 to 3 nT, an order of magnitude improvement over the previous practice. This is achievable by carefully monitoring and correcting for temporal changes of the magnetic field (diurnal variation and other disturbances), the position of the towed sensor relative to the fix reference position on the ship, depth of the sensor as a function of the speed, etc. Preliminary data processing has shown that by applying the above corrections, the RMS crossover error can be reduced to a half (from 21 nT to 12 nT).

The application of new technologies is a part of a larger initiative involving the private sector along with government and university labs. The goal of these strategic alliances is to achieve common objectives and develop competitive products that position Canada at the forefront of ocean mapping technology internationally while responding to domestic needs.

High resolution images of bathymetry offshore of Halifax

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A region of the inner Scotian Shelf near Halifax was surveyed in May and June 1992 from the CSS Matthew using the Simrad EM100 multibeam sounder. Over 80 million point measurements of depth were collected during this cruise, comprising 20 Gb of information. The data were corrected for navigation errors, sensor offsets, and tides, projected into a UTM projection, gridded at 10 m horizontal intervals and integrated into a raster-based GIS system. Shaded relief maps of this area show a diverse and varied bathymetry revealing a complex, faulted basement structure and a sedimentary record of glacial retreat. Three-dimensional imaging techniques help highlight aspects of this exceptional data set.

A series of repeated passes over the British Freedom, an oil tanker sunk off Halifax in 1944, permits a finer spatial resolution of bottom features. Three-dimensional shaded relief maps of the ship, at a 2 m grid spacing, resolve the general shape of the vessel and sediment scouring around the hull, but it is unlikely that the ship could be recognized on the basis of bathymetry alone. Coherence is lost when the bathymetric data are gridded at a finer horizontal resolution.

The bathymetric data are integrated with existing conventional geological maps and magnetic data within the GIS system. The correlation between the data sets aids the identification of offshore geological structure.

Multiparameter study of the geology of the inner shelf south of Halifax

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A full colour, 1:50 000 scale map sheet of detailed swath bathymetry from a region of the inner Scotian Shelf near Halifax shows the integration of a shaded relief map of the seafloor with onshore geology, derived from a 1:500 000 provincial geological map. This map reveals a diverse and varied bathymetry, highlighting a complex, faulted basement structure intruded by granitic plutons and a detailed sedimentary record of glacial retreat. A grey-scale version of this map enhances the textural features of the bathymetry.

A set of four 1:250 000 map sheets from this area demonstrates the integration of the swath bathymetry with published maps of onshore geology and the total magnetic field. An integrated map of geology and bathymetry, shaded by the relief of the magnetic field, facilitates the extension of onshore geologic units to the area of offshore bathymetric mapping. A synthesis map, based on these techniques, extends the Nova Scotia bedrock geologic map offshore.

These sheets complement an oral presentation given by the authors in this conference. It is hoped that these maps will be available as GSC open file reports by the time of the AGS conference.

Structural elements and sedimentation patterns in the Magdalen Basin

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We compiled a large amount of industry seismic reflection data together with Lithoprobe deep seismic reflection data to study the main structural elements in the Magdalen Basin. Pre-Horton Group basement rocks in the western part of the basin can be subdivided into three upper crustal blocks. Structures in the Laurent and Bradelle blocks appear to be the southeastward extension of structures observed in Gaspé. The northeast trending structures in the Shediac block appear to be parallel to the offshore extension of faults occurring in New Brunswick: the Belleisle, Fredericton and Catamaran faults.

In the central part of the Magdalen Basin, we identified a large unit beneath extensive salt intrusions that we call the sub-salt high. The sub-salt high has a complex structure as revealed by generally poorly defined seismic reflections with highly variable dips. The nature and the origin of the sub-salt high are unknown; however, Horton Group rocks, overlying Mississipian or older volcanic rocks, were drilled at the top of the sub-salt high.

In the Cabot Strait between Cape Breton Island and Newfoundland, a complex northeast striking fault system affects both basement and sediments.

A series of maps summarize the main sedimentation patterns in the Magdalen Basin. An isopach map shows that the Horton Group was deposited in small elongated half-grabens. An isopach of the Windsor and Canso (Mabou) groups combined indicates uniform deposition in a broad subsiding trough. We interpret the isopach maps in terms of two distinct tectonic environments, a crustal extension phase followed by thermal relaxation.

Distribution of Horton Group subbasins in the Gulf of St. Lawrence from seismic reflection data; implications for the early tectonic development of the Magdalen Basin

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The Late Devonian-Early Carboniferous Horton Group includes some of the oldest sediments in the mainly Carboniferous Maritimes Basin and records the earliest geologic history of this post-Acadian successor basin. To better understand the early development of the basin, we have interpreted an extensive amount of industry seismic reflection data in the Gulf of St. Lawrence. Time structure and isopach maps show that the Horton Group was deposited both locally in many small subbasins and regionally as a widespread veneer overlying basement. The subbasins, many of which are half grabens, can be as deep as 7 km. Regionally flat lying strata are 0 to 1 km thick. The Horton Group subbasins occur along two main trends parallel to basement structures (NW-SE and NE-SW), and their distribution forms an X-pattern reminiscent of a system of synthetic and antithetic faults occurring in strike-slip environments.

These observations, which indicate a Late Devonian-Early Carboniferous crustal extension phase, can be interpreted in terms of both an orthogonal or a transtensional rift. Although we do not observe mid-crustal detachments on the seismic reflection data, as predicted in a post-orogenic collapse model, we cannot totally discount this possibility.

A comparision of swath bathymetric data and sidescan sonograms from the inner Scotian Shelf off Halifax

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During 1991, a cruise of CSS Dawson collected a grid of high-resolution seismic reflection and sidescan sonar data, together with cores, surficial grab samples and bottom photographs in an area of the inner Scotian Shelf off Halifax. The area was surveyed in 1992 by the Canadian Hydrographic Service with a SIMRAD EM100, multibeam sounder system from the CSS Matthew. The multibeam bathymetric mapping provides 100% coverage of the seabed, presenting images similar to aerial photographs on land. In contrast, regional seismic and sidescan survey tracks are normally spaced from a few to tens of kilometres. The conventional sidescan sonar provides textural information on the composition of seafloor materials as well as information on surface morphology. A comparison of the two data sets provides a test of the capabilities and limitations of different imaging systems for seabed mapping. The resolution of these remote sensing systems must be understood and carefully compared.

Sidescan sonar and seismic reflection systems provide information not available from the swath bathymetry data alone. Areas of the swath bathymetric map that appear flat and featureless can exhibit a wide range of varying sediment textural distributions, dynamic features and microtopographic relief on sidescan sonograms. These include areas with complex distributions of starved megaripples, gravel and sand patches often with boulders, and exposed bedrock with broad flat unconformities developed across outcropping beds. Terrains that appear to represent outcropping bedrock on the swath bathymetric data, can appear on sidescan sonar imagery as boulder mantled till. Seismic reflection data indicate that this seabed relief arises from a mimicking of the subsurface morphology of the buried bedrock surface. A large shipwreck appears on the bathymetric data as two isolated topographic highs and would not be interpreted as a shipwreck from the bathymetric data alone. Sidescan sonar imagery shows details of the shipwreck including rails, deck flow lines, and superstructure elements including stacks and masts. Scour depressions in the seabed around the hull show on both data sets.

The geological interpretation of the swath bathymetric images must be carefully integrated with information on seabed sediments and bedrock provided by seismic reflection, sidescan sonar data and samples. The 100% seabed coverage of the swath bathymetry provides the essential data for correlation of geological characteristics between survey tracks and a continuity capability never before attainable. As such, the swath bathymetric mapping is a new and important tool to be added to the existing methods for seabed mapping.

Dinoflagellates: a new look at old bugs

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Dinoflagellates are planktonic organisms that have left a fossil record of cysts since the Late Triassic. Like foraminifera, their great abundance in certain rocks and their small size have led to their use in subsurface stratigraphic studies, especially in relation to hydrocarbon exploration. This has resulted in an explosion of data in recent years, too much for any individual paleontologist to cope with. The development of databases such as PALYLIT (developed by several oil companies and the Geological Survey of Canada) has not only simplified organization of the data, but has also provided the impetus for refining biostratigraphic correlations and for pursuing some new and exciting research directions. PALYLIT contains information from more than 17 000 publications and is by far the largest paleontological database used to establish diversity curves. Our plots of dinoflagellate species occurrences (diversities) through time are based on more than 52 000 biostratigraphic records retrieved from PALYLIT. We interpret the appearance and rapid diversification of dinoflagellate cysts in the Late Triassic to Middle Jurassic as representing a successful adaptive radiation for the group. Maximum diversities of cysts were attained in the Maastrichtian and Eocene with about 700 known species.

There was a significant decline between the Maastrichtian and Paleocene and a dramatic decline from Eocene to Recent times. Correlation of the diversity curves with the published sea-level curves indicate some striking similarities. Initial comparison with other data sets such as extinction plots of other groups of organisms and paleotemperature curves show promise for further avenues of research.

Geochemistry of Early Paleozoic black shales in the northeastern Appalachians

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Samples of Late Cambrian to Early Ordovician black shale were collected in a transect extending across the Canadian Appalachians from the Humber Zone in Quebec, the Gander and Avalon zones in New Brunswick, to the Meguma Zone in Nova Scotia. The samples were analyzed for 40 elements including rare earths in order to test established plate tectonic models of the region. The chemical data provide information on provenance and depositional environments of sediments that are too fine-grained for more traditional mineralogical and sedimentological studies.

Generally high Al_2O_3 contents, high Al/Ti ratios and steep rare-earth-element (REE) distribution patterns are consistent with a continental margin depositional setting for shales from the Humber and Meguma zones on opposite sides of the Iapetus Ocean. Generally higher K_2O contents, lower La/Th ratios and lower absolute REE abundances distinguish shale of the Humber Zone deposited on the Laurentian margin from that deposited in the Meguma Zone on the Gondwanan margin. High La/Th ratios indicate a similar Gondwanan source for shale from both the Meguma and Avalon zones. Shale from the Gander Zone contains less Al_2O_3 at increasing distances from its boundary with the Avalon Zone. Low Al/Ti and less fractioned REE distribution patterns suggest a greater component of volcanic detritus in shale of the Avalon and Gander zones. The presence of distinctive Balto-Scandian signatures (high U, V, and Mo) in shale of the Avalon and northwestern Gander zones are related to deposition in isolated peri-Gondwanan back-arc basins during a high stand of sea level.

Late Carboniferous sea-level changes in the Sydney Coalfield: cyclothems, valley incision and regional correlation

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Late Carboniferous cyclothems are repeated stratal packages that cover areas of >500 000 km^2 in midcontinental North America. Carbonate-dominated cyclothems are widely believed to reflect Gondwanan glaciation which caused eustatic fluctuations of 50 to 100 m, in the Milankovitch band. However, terrigenous cyclothems are widely inferred to have formed by local channel and delta-lobe switching (autogenic processes).

Recent work at Sydney has shown that the Emery to Point Aconi Seam interval includes eleven alluvio-deltaic cyclothems, 20 to 70 m thick, that show alternation of widespread coal (coastal) and red mudstone (alluvial) strata. Recently discovered agglutinated foraminifera indicate a marine influence, and the fossil assemblages are, remarkably, co-generic with modern coastal assemblages. Mean cyclothem duration was 200 000 years. The long duration and evidence for widespread transgression and regression preclude an autogenic origin and are consistent with a glacioeustatic origin for the cyclothems.

Most cyclothems show stacked alluvial-channel bodies 20 to 30 m thick that fill paleovalleys incised through marine strata during sea-level fall. Thick red paleosols in adjacent "interfluves" indicate minimal sedimentation during sea-level lows. Seatearths and roof rocks of the economic coals yield foraminifera, suggesting that the peats formed on a drowned coastal plain during stillstands near the peak of marine transgression.

Coals and, probably, cyclothems coeval with those at Sydney underlie the southern Gulf of St. Lawrence, giving a combined area of ca. 80 000 km^2. Approximately coeval cyclothemic intervals in the Illinois and Appalachian basins include some of North America's major coals (Herrin No. 6, Springfield No. 5, Freeport, Kittanning). Biostratigraphic zonation should permit correlation of some cyclothems between Nova Scotia and the mid-continent, a distance of at least 2000 km.

Bedding-parallel faults, breccia zones, large-scale recumbent folds and basin evolution: the case for extensional tectonics in the onshore Magdalen Basin in Nova Scotia

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Fault breccia up to 100 m in thickness occurs a few metres above the Horton-Windsor contact in the Windsor Group type-area, the Antigonish Basin and central and western Cape Breton Island. It marks the trace of a regional fault surface which we term the Ainslie Detachment. This essentially stratiform breccia zone may in places have little apparent effect on Windsor Group internal stratigraphic order. More commonly, it represents a zone of significant stratigraphic omission, juxtaposing Upper Windsor and post-Windsor rock units on basal Windsor lithosomes. In the hanging wall of the detachment, boudinage is common within breccia zones. Boudins of maximum dimensions of more than 10 m are rotated, which may provide a useful kinematic indicator. Where rheologic factors were appropriate, large scale, tight, recumbent folds are typical of hanging wall sequences. In the subsurface, flat–lying, overturned beds, in continuous stratigraphic succession exceeding 300 m in thickness, attest to large scale folds in this tectono–stratigraphic position. Smaller–scale folds in outcrop record movement towards the north and northwest, i.e., downwards towards the Magdalen Basin. Rotation of pea–sized augen shows a similar, regionally consistent tectonic transport direction. Key stratigraphic omissions across the detachment surface and the down–to–the–basin movement sense clearly document extension on the Ainslie Detachment. The regional extent of the detachment suggests a probable role in the late–stage evolution of the Magdalen Basin, particularly relevant to basin–wide subsidence and to the accumulation of thick Westphalian coal measures.

Sea–floor bedrock geology, Inner Scotian Shelf south of Halifax interpreted from EM100 swath bathymetry and magnetics

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High resolution sea–floor bathymetry is as useful for bedrock mapping beneath the ocean as air–photo or satellite imagery on land. Within our test area south of Halifax, marked contrasts in local relief and bottom roughness can be used for geological interpretation. Two principal sedimentary bedrock domains are distinguished, both characterized by sets of closely parallel bedding plane ridges. The inshore domain east of Ketch Harbour and south of Pennant comprises relatively thinly stratified and tightly folded rocks, cut by minor faults and fractures, interpreted as interbedded slates and wackes typical of the younger parts of the Meguma Group. In the offshore domain in the southeastern part of the survey area, similar bottom features are more widely spaced and individual ridges are less continuous. This is interpreted as the expression of a thickly bedded, greywacke–dominated Meguma Group.

An area of approximately 80 km^2 lying 10 to 20 km south of Sambro defines a third bedrock domain. Bathymetric data show a rough pattern of intersecting sub–linear relief elements; the parallel ridges characteristic of the other domains are absent. Both magnetic and bathymetric data show that this domain cross–cuts structures in the Meguma rocks. Magnetic data show a body of low magnetisation, a feature typical of granitoid intrusions in the Meguma Terrane. Magnetic data delineate the boundaries of major slate units with remarkable precision in onshore areas and, by inference, in this contiguous marine survey. Thus the combination of magnetic and bathymetric data can be used to map major structures and to tentatively distinguish between major slate and greywacke units. With this technology, geological mapping of the inner continental shelf is feasible.

The East Milford Mastodon, its discovery and excavation

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On October 22, 1991, Stanley McMullin, an equipment operator for National Gypsum Canada, encountered the partial remains of a *Mammut americanus* while conducting a stripping operation at the mine. The museum was contacted to identify the unusual find of "a tusk and big teeth". The authors responded immediately. Upon arrival at the site,

identification was immediate, based on the distinctive molars of the maxilla.

The overburden which is composed of glacial and non-glacial sediments is removed prior to mining. There is a well-developed paleo-karst topography which has in some instances been infilled with Late Wisconsinan non-glacial sediments (Mott *et al.*, 1982). These infills have been encountered several times since mining began in 1954 (Stea *et al.*, 1992).

The mastodon was situated half-way up the exposed 'mud-wall' of a partially excavated sinkhole. It was decided to recover all visible bones in the mud-wall and from the pile of previously removed material. However, because of possible slumping of the site, it was later decided to work through the winter under temporary shelter. Careful stabilization (Kozera and Grantham, 1993A), collection and documentation of the stratigraphy provided the opportunity for sampling by other researchers. The excavation continued into the summer and proceeded until all the bones had been removed. The last bones were removed at the end of August 1992, and the shelter was dismantled in November.

As well as mastodon; there were bones of birds, frogs, and turtles; teeth of fish and muskrat; several species of wood, seeds, cones, leaves and mosses; and several species of insects and mollusks.

The Mastodon bones and other samples taken are in storage at the Nova Scotia Museum. Conservation of the mastodon is expected to take over three years (Kozera and Grantham, 1993B). It is estimated that there is approximately 60% of the mastodon recovered.

Kozera, K.A. and Grantham, R.G. 1993A. Field Stabilization of In-Situ Wet Bones of the East Milford Mastodon. Abstract, Atlantic Geoscience Society Annual Meeting, February 12 and 13, 1993, Citadel Inn, Halifax.

——— 1993B. Proposed Wet Bone Conservation Method for the East Milford Mastodon. Abstract, Atlantic Geoscience Society Annual Meeting, February 12 and 13, 1993, Citadel Inn, Halifax.

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A fuzzy logic approach for detecting fractured zones with conventional well logs

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Conventional well logs, such as resistivity, porosity, density correction, and caliper logs, often exhibit abnormal values in response to fractured zones within a borehole. However, no single log response is completely diagnostic of fracturing since each log responds to a number of formation properties and borehole conditions. Furthermore, for a specific log, it is difficult to define quantitatively what response might be expected in the presence of a fracture. For instance, a fracture occurring in sandstone typically generates a much different caliper log response than a fracture occurring in shale.

To overcome these difficulties, we are developing a statistical–fuzzy logic approach using conventional, digital well logs. The technique first uses statistical methods (e.g., regression and population distribution analysis) on individual or combined log responses from intervals of similar lithology, based on cutting sample information. These results are then used to construct fuzzy logic membership functions. Each membership function provides a quantitative basis for evaluating whether an individual log response, or combination of responses, is related to fracturing. The product of the vector of membership function values with a user–defined, weight vector (whose summation equals one) gives an indication of fracture probability. This approach, iterated down the length of the borehole, produces a curve of fracture probability (0 = low probability of fracturing, 1 = high probability of fracturing).

Although well logs have recently been developed specifically for fracture identification, our statistical–fuzzy logic approach provides a method of fracture identification using the vast database of existing, conventional well logs.

Geology and geochronology of the Fowle Lake area: evidence for Late Cambrian volcanism in southern New Brunswick

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The Fowle Lake area, located 50 km west of Saint John and 5 km northwest of the Belleisle Fault, contains the western-most exposures of Avalon in New Brunswick. It comprises Late Precambrian granitoids and mafic volcanic rocks, Silurian sedimentary rocks and a newly recognized succession of felsic and minor mafic volcanic, volcaniclastic and epiclastic rocks named the Mosquito Lake Road volcanics (MLRV).

A U-Pb (zircon) date from rhyolite within the MLRV gives an unambiguous age of 515 +3-2 Ma (Late Cambrian). The rhyolite is conformably to disconformably overlain by the Matthews Lake beds (new name) comprising polymictic to quartzite-pebble conglomerate, thick-bedded quartzarenite and fine-grained sedimentary rocks. The Matthews Lake beds continue along strike to the Long Reach area, over 40 km to the northeast.

The MLRV and overlying Matthews Lake beds are in structural contact with Silurian sedimentary rocks to the north, along the ductile-brittle Wheaton Brook Fault. To the south they are in fault contact with granitoid rocks of the Ragged Falls Pluton, which yield an age of 555 ± 2 Ma in the map area based on U-Pb dating of zircon. This confirms a similar, previously published date for the pluton 6 km to the northeast.

Early and Middle Cambrian rift-related volcanic rocks in the Long Reach and Beaver Harbour areas form part of an extensive linear belt bound to the northwest and southeast by the Wheaton Brook and Belleisle faults respectively. The MLRV which are situated within this belt, provides evidence for a protracted history of Cambrian volcanism in this part of the Avalon Composite Terrane.

Nonmarine invertebrate ichnocoenoses from the Carboniferous of western Cape Breton Island, eastern Canada

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A relatively diverse assemblage of trace fossils has been identified from mid–Carboniferous strata (Hastings, Pomquet, and Port Hood formations) of the western Cape Breton subbasin in Nova Scotia. They can be grouped into numerous associations (ichnocoenoses) representing the work of particular benthic communities within various fluvio–lacustrine to fluvio–deltaic sub–environments.

At least six ichnocoenoses are recognised. In the older Hastings and Pomquet formations, they include the Rusophycus ichnocoenosis, a low–diversity suite of trace fossils from the lower portions of ephemeral channels comprising *Rusophycus carbonarius*, *Cruziana problematica*, *Helminthopsis* isp. and *Didymaulichnus* isp., and the Circulichnis ichnocoenosis which contains a more diverse ichnofauna of *Circulichnis montanus*, *Rusophycus carbonarius*, *Kouphichnium* isp., *Monomorphichnus* isp., ?*Beaconichnus*, surface trails, arthropod tracks and arthropod resting traces characteristic of probable thin, distal sheetfloods emptying into shallow lakes. *Ophiomorpha irregulaire*, *Taenidium* cf. *geniculata*, *Skolithos* isp., *Rusophycus carbonarius*, *Diplichnites* ispp., *Stiaria intermedia*, *Gordia marina*, arthropod tracks, U–burrows and ?vertical burrows are encountered in thin, non–channelised, ripple cross–laminated fine–grained sandstones of shoreline to shallow–water lacustrine origin. They are grouped together under the Diplichnites ichnocoenosis, although more than one discrete association may ultimately be represented. *Rusophycus carbonarius* and *Lockeia amygdaloides* are representative of more offshore, deeper lacustrine environments and are included within the Lockeia ichnocoenosis.

In younger strata (Port Hood Formation), trace fossils are much less common. However, the Cochlichnus ichnocoenosis, a unique suite consisting of *Cochlichnus anguineus*, *Cochlichnus* isp., *Undichna consulca*, and ?*Margaritichnus*, occurs in a thin shallow–water ?crevasse–splay deposit; and *Taenidium barretti*, Planolites isp. and branched burrows representing the Planolites ichnocoenosis, are present in several coarse–grained fluvial–bar sandstones.

Late Paleozoic tectonic models for the northern Appalachians: implications for the development of the Maritimes Basin

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Sinistral accretion of the Avalon Composite Terrane with Laurentia took place in the Late Ordovician-Early Silurian during collision between North and South America. In early Late Silurian times (ca. 425-415 Ma) sinistral accretionary deformation switched to dextral transpression that continued throughout the Late Paleozoic culminating with the collision between North America and Africa. The major foreland basin in the southern Appalachians is replaced at the 41°N oroclinal bend by fragmented Late Paleozoic retro-arc basins in the northern Appalachians that may be related to a reversal of subduction polarity. In this context, the four tectonic models that have been proposed for the Maritimes Basin: rift, wrench/pull-apart, foreland/retro-arc basin, and extensional collapse, may be assessed using the geological record. The Late Paleozoic rocks may be subdivided into four megasequences: Late Silurian to Middle Devonian, Late Devonian to Early Namurian, Late Namurian to Westphalian A, and Westphalian B to Early Permian. These megasequences are generally upward-fining and, except for the last one, start with bimodal, continental, intra-plate volcanism. The source region changed from proximal to distal with time. The onset of these megasequences appears to coincide with periods of more active deformation. It is possible that following collision in the Late Ordovician-Middle Silurian, crustal thickening might lead to delamination of the mantle lithosphere causing upwelling, partial melting, gravitational collapse and basin formation. However, the spatial concentration of Siluro-Devonian magmatism in the reentrants, rather than in the promontories, suggests NW extensional zones parallel to the middle limb of Z-shaped bends in the Appalachian Orogen formed in response to dextral transpression. Progressive dextral transpression that rotates the rift clockwise is documented by the 20° clockwise rotation recorded by paleomagnetic data. Periodic pulses of similar dextral deformation, bimodal intra-plate volcanism, and upward-fining megasequences suggest intermittent tectonic activity in a similar tectonic setting. A change from dextral transpresson to dextral, oblique collision is expressed in the change of principal dextral shear on NE-SW to E-W faults in the Late Devonian. Thus, it is concluded that the Maritimes Basin is a pull-apart basin within the regional northern Appalachian retro-arc basin setting.

Geological, geochemical, isotopic and fluid inclusion studies at the Gays River Zn-Pb deposit: carbonate-hosted base metal mineralization in the basal Windsor Group of Nova Scotia

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The Gays River Zn-Pb deposit (2.4 MT 8.63% Zn, 6.33% Pb) is one of several mineralized (Zn, Pb, Ba, F) centres hosted by Viséan age (ca. 330 Ma) carbonates of the Windsor Group which form part of the large Maritimes Basin of Eastern Canada. The Gays River deposit is generally considered to represent Mississippi Valley Type (MVT) mineralization and ore formation is estimated at ca. 300 Ma. The local stratigraphy includes basement rocks of the Meguma Group (psammites, pelites), an apron of breccia (Meguma Group clasts in limestone matrix) and an overlying reef complex (buildup) with onlapping evaporites; the entire area is overlain by glacial debris and a sediment-filled trench of Cretaceous age incises along the evaporite-limestone contact. The limestones have been pervasively dolomitized via constant volume replacement. Mineralization (Fe-poor sphalerite, Ag-poor galena) consists of massive replacement ore (MRO) and disseminated ore (DO) that forms a quasi-continuous, corrugated sheet of ca. 4 km strike length (E-W to NE-SW) with a 60 to 80 m vertical dimension. The MRO is confined to the forereef along the dolostone-evaporite contact; geochemical (REE) and textural data favour constant volume replacement of the dolostone as its origin. The DO occurs both as infilling of primary porosity and also replacement of dolostone; it forms the footwall to the MRO and gradually pinches out up dip and along the width of the reef. The Pb:Zn ratio of the ore increases down dip (i.e., basinwards towards the fluid source). $\delta^{34}S$ for galena and sphalerite (MRO and DO) are similar at +9 to +14‰ and reflect a sulfur source within the Windsor Group stratigraphy (i.e., $\delta^{34}S_{evaporites}$ = +13 to +16‰). $\delta^{13}C_{PDB}$ and $\delta^{18}O_{SMOW}$ data for calcites define a continuum with limiting values of -5‰, +25‰ and +3‰, +13‰, respectively, and indicate at least two reservoirs are involved. $^{87}Sr/^{86}Sr$ (Sr_i) for calcite ranges from 0.70817 to 0.71202 with the most radiogenic values from MRO samples. In $\delta^{18}O$-Sr_i space the Gays River trend sensibly overlaps that for the regional basin. REE data (bulk and laser ablation ICP-MS analyses) indicate large inter- and intra-sample ranges for ΣREE and $(La/Lu)_N$ for sparry calcites, but limited variation for calcite in the basal breccia and MRO. Fluid inclusion (calcite, fluorite, sphalerite) types are generally two phase (L+V) aqueous types ±halite; GC analyses indicate minor (<1 mole %) carbonic species are present. Thermometric measurements indicate T_H = 70 to >250°C, T_E = -70 to -50°C, and salinities = 23 to 35 wt. % equivalent NaCl. Thus, the above data indicate that while the carbonate bank experienced the same physio-chemical evolution as the regional Carboniferous basin (e.g., Shubenacadie), something unique must have occurred at Gays River to generate the deposit. Potential solutions are currently being addressed and will be discussed.

An overview of Meguma gold deposits in the Meguma Terrane of southern Nova Scotia: geology, geochronology, isotopes, fluid inclusions and geofantasy

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The Lower Paleozoic Meguma Group of southern Nova Scotia, composed of a basal sandstone- (Goldenville Formation) and overlying shale-dominant (Halifax Formation) stratigraphy, is host to numerous gold deposits. The Meguma Group was deformed (generally upright, open to closed folds) and metamorphosed (greenschist to amphibolite) during the regional Acadian Orogeny of ca. 400 Ma. The gold deposits occur throughout the Goldenville Formation, but generally in those parts rich in graphitic shales, and appear to have no affinity for metamorphic grade (e.g., Forest Hill vs. Tangier deposits). Deposits can be subdivided into (i) quartz-rich and (ii) quartz-poor (i.e., veins absent). The first type occur in antiformal structures with limb areas being most favourable, especially where secondary structures occur. These deposits can be further subdivided into two groups based on associated mineralogy: (ia) Ca-rich plag-bt-amph-grt-ep-tour-chl-ms-carb; and (ib) ab-chl-carb-ms. The former group are also distinguished by the higher-grade mineral assemblage of the host rocks. Type (ii) deposits, as represented by the Touquoy Zone at Moose River, have only been discovered in relatively recent times and occur in carbonatized and sulfidized graphitic pelites and psammites. The extent and potential for these newer deposits remains unknown. Gold mineralization, as native gold (>900 finess; rare electrum and alloys), varies from coarse nuggets to micron-size disseminated grains and based on textural relationships is assigned a late-stage paragenesis. Associated sulfides include gal, sph, cpy, py, aspy, po and Bi-Te compounds, and there is a general positive correlation of Au with some of these pathfinder elements (Bi, Zn, Te, Pb).

Petrofabric analyses of the gold deposits indicate consistent relationships between structures in the wall rocks, alteration minerals and vein deformation. In all deposits examined vein emplacement was accompanied by ductile-brittle deformation which post-dated regional deformation. Vein emplacement reflects periods of hydraulic fracturing ($P_{fluid}>P_{lithostatic}$), similar to the seimic pump model of Sibson *et al.* (1988). Fluid inclusions (quartz host) are remarkably uniform and indicate the vein fluid was a low salinity (<6 wt. % equiv. NaCl), non-boiling, H_2O-CO_2-CH_4 (X_{CO2}=0.15) type; P_{fluid} is estimated at 2 to 3 kbars. Geochronological studies ($^{40}Ar/^{39}Ar$, Rb/Sr: bt, ms, amph, chl, carb, wr) indicate similar ages of ca. 370 Ma regardless of geographic setting or vein mineralogy. These ages are considered to approximate the time of vein formation rather than reflect slow cooling and/or resetting. We note the coincidence of these ages with widespread mafic and felsic magmatism within the Meguma Terrane. Isotopic data (S, C, O, Sr, Pb) for vein minerals (sulfides, carbonates, silicates) indicate regional variations and mixing of source reservoirs. The light stable isotopic signatures, particularly C and S, reflect variable amounts of Meguma Group contamination, but the radiogeneic isotopes (Sr, Pb) clearly indicate a non Meguma Group source for the fluids. Using the average $\delta^{18}O_{quartz}$ from 5 deposits and T=300-400°C, $\delta^{18}O_{fluid}$ is estimated at +6-12‰; the only deviation is for the West Gore deposit where values of +12-16‰ are calculated. Similar $\delta^{18}O_{fluid}$ values are calculated using +12 to +16‰ isotopic data for carbonates.

The Meguma gold deposits are considered to reflect the influence of widespread generation of mafic and felsic magmas during the Late Devonian. The high temperatures attending this event resulted in devolitization of the lower crust and generation of a CO_2-bearing fluid. This fluid either was derived from or interacted with rocks of similar isotopic (Pb, Sr) composition as the Liscomb gneisses which were emplaced post 400 Ma and pre 380 Ma, thus satisfying the geochronological constraints. The fluids were subsequently focused along Acadian structures, perhaps reactivated hinge zones, during periods of excessive fluid pressure. Gold precipitation occurred as a result of fluid:wallrock interaction and decreasing pressure.

Field stabilization and field jacketing of *in situ* wet bones of the East Milford Mastodon

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During excavation of the East Milford Mastodon, (Grantham and Kozera, 1993) the bones were found to be in less than ideal condition. The majority were either broken, cracked or abraded. Because the bones were not fossilized, the collagen and hydroxyapatite had reacted with the clays and percolating ground water, causing decomposition. The mucopolysaccharides, holding both the collagen and the hydroxyapatite together also weakened, causing damaged areas to deteriorate to a fine powder.

To ensure safe removal and subsequent transportation of the bones, *in situ* stabilization had to be performed on the damaged areas. The clay surrounding the bones was removed to reveal any areas that needed stabilization, leaving the bone on a pedestal of clay. All of the *in situ* stabilization and field jacketing procedures described here are creations of the authors except for the use of Rhoplex AC-33 as the consolidant which is based on Stone *et al.* (1993) work. The best stabilization results were obtained by initially brushing the

broken or damaged area with a soft, dry paint brush, in order to remove any bone powder on the surface that could not be stabilized. A solution of ethanol (45%) and water (55%) was used to clean the damaged areas. The ethanol solution was allowed to dry for about a day so that it would not weaken the concentration of the consolidant solution which consisted of Rhoplex AC-33 (15%) (Trademark of Rohm and Haas, Limited) ethanol (40%) and water (45%). The damaged area was then injected with the consolidant solution and a halogen light was used to speed the drying of the consolidant; making sure that the undamaged areas of the bone were protected so they did not dry out. The damaged areas were injected with consolidant until stabilized. This is the first use and publication of this formulation for *in situ* wet bone conservation.

Once stabilized, the bones were then ready for removal. They were wrapped in a layer of plastic food wrap to provide a release surface. The area surrounding the bones was fenced with 3/8 inch polyfoam, which was then pinned to the supporting clay with nails. The specimen was then covered with spray foam insulation. After a few days, when the insulation expanded and hardened, the underlying pedestal of clay was sliced and the specimens lifted out as one package, and at that point loaded for transport to the Nova Scotia Museum.

GRANTHAM, R.G. and KOZERA, KA. 1993. The East Milford Mastodon, its Discovery and Excavation. Abstract, Atlantic Geoscience Society Annual Meeting, February 12 and 13, 1993, Citadel Inn, Halifax.

STONE, T.T., DICKEL, D.N., and DORAN, G.H. 1990. The Preservation and Conservation of Waterlogged Bone from the Windover Site, Florida: A Comparison of Methods. Journal of Field Archaeology, 17, pp. 177-186.

Proposed wet bone conservation method for the East Milford Mastodon

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Upon arrival at the Nova Scotia Museum, the bones of the East Milford Mastodon (Grantham and Kozera, 1993) were placed in temporary storage between two layers of polyethylene sheeting, creating a cocoon. This was to ensure they were kept as humid as possible while awaiting conservation.

A simple washing facility has been set up in the Nova Scotia Museum's Natural History lab which is equipped with running water and a silt trap. Because of a severe fungal problem, several precautions have to be taken, such as use of respirators and disposable clothing. The cleaning of the bones will take place in two stages. The first stage will be an overall cleaning of the bones which should remove about 90% of the enclosing clays and other material. The second stage, involving a more detailed cleaning, should remove most of the remaining material.

Once the bones have been cleaned, they will be placed in humidity chambers. The humidity in these chambers will be kept as high as possible, maintaining at least 90%, while the bones await conservation.

The bones will in turn be placed in stainless steel tanks, which will be filled with a consolidating solution of Acrysol WS-24 (15%)(Trademark of Rohm and Haas, Limited) (as recommended by the Nova Scotia Museum conservator Chris Lavergne), ethanol (40%) and water (45%). This is the first use and publication of this formula and these procedures for wet bone conservation. Soaking will take from one week to one month, or longer, depending on the size of the bone.

The bones will then be placed on a wheeled rack inside the first of a series of six drying chambers, each with a controlled relative humidity. The first chamber to receive bones will have a humidity of approximately 80 to 90%. The bones will be weighed on a daily basis to note the weight loss while drying. When there is no further weight loss the bones will be transferred to the second chamber, which will have a relative humidity of approximately 70 to 80%, and so on until the last chamber is reached having a relative humidity of 30 to 40%. In order to minimize handling of the bones, the walls of the humidity chambers will be removable and the rolling racks will be easily moved into the next chamber. This procedure will continue through to the last drying chamber with the lowest relative humidity, at which time the bones will be dried and conserved. At present it is estimated the conservation of the mastodon bones will take over three years.

GRANTHAM, R.G. and KROZERA, K.A. 1993. The East Milford Mastodon, its Discovery and Excavation. Abstract, Atlantic Geoscience Society Annual Meeting, February 12 and 13, 1993, Citadel Inn, Halifax.

Examples of Carboniferous structural styles determined from seismic data in the Cabot Strait

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Four main structural features, apart from the dominant northeast-trending strike-slip faults, have been identified within Carboniferous sedimentary rocks of the Cabot Strait, which forms the northeastern extent of the Maritimes Basin. Conventional reflection seismic lines from this area can be described in terms of these four features or styles, which are as follows: thrusts and detachments, basin inversion structures, east-trending faults and salt-related tectonics. Thrust and detachment faults are localized at the base of the Windsor-Codroy, where salt acts as a lubricating layer, and perhaps within shale layers in the Horton-Anguille. Inversion structures suggest contraction of small linear troughs which parallel the major faults, thereby ejecting sedimentary fill. East-trending faults are identified on the basis of seismic, potential field and onshore geological data. These, in combination with the dominant northeast-trending strike-slip faults, subdivide the area into blocks with characteristic structural styles. Finally, salt-related tectonics involves structures actually formed by movement of salt itself, such as ridges, swells and pillars, and asssociated deformed sediments.

Upper Paleozoic strike-slip tectonics in the Cabot Strait: seismic studies at an old plate boundary

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Conventional reflection seismic constituted the principal database for a study of the fault patterns, basin evolution and tectonic history associated with late Paleozoic strike-slip movement along the Cabot Fault, and associated faults, which trend northeastward under the Cabot Strait. The Carboniferous subbasins in the Cabot Strait area can be viewed as a master fault and wrench borderland system, modified and complicated by east-west faults associated with pre-Carboniferous structural trends, and by salt tectonics and basin inversion. Regional offset may have been accommodated along individual strands of the master fault system at different times in the late Paleozoic, creating "stepovers" and associated *en échelon* structures, such as sags and push-up ranges.

The identification of unconformities/sequence boundaries from seismic data in the Cabot Strait have enabled an assessment of the main periods of deformation associated with the regional fault system. These are (1) a fault-controlled, top Horton-Anguille unconformity, (2) a regional, angular Namurian-Westphalian unconformity, and (3) a localized, fault-controlled early Stephanian unconformity.

In the Cabot Strait, the study of thin-skinned Carboniferous basin formation, deformation and regional fault patterns can be integrated with other geologic approaches, brought together under Lithoprobe East, to help interpret the ancient Laurasia-Gondwana plate boundary. These include an assessment of the relationship between shallow basin-forming and deeper crustal processes (using Lithoprobe marine and on-land data), the study of fault systems in Newfoundland and Cape Breton Island and the correlation of tectonostratigraphic zone boundaries between them, and evaluation of the tectonic overprint of Taconian and Acadian by Hercynian structures.

Precious metal distribution in the Epigenetic Stringer Sulphide Zone at the Brunswick No. 12 deposit, Bathurst, New Brunswick

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There has been little published information on the occurrence, distribution, and abundance of gold in massive sulphide deposits of the Bathurst Mining Camp although it is extracted as a byproduct during the smelting of both the Cu and Pb concentrates (4.1 and 0.9 g/t, respectively) from the Brunswick No. 12 deposit, with a total annual production of 280 to 310 kg representing a 12% recovery. Gold is commonly enriched in the hydrothermal feeder system (stringer sulphides) to the exhalative sulphide ores. Therefore, as part of a larger study of alteration around the deposit, drill hole A1 was selected for a detailed analysis of Au and trace element analyses because this hole transgresses the hanging wall into the footwall sedimentary and volcanic rocks that hosts the main stringer sulphide mineralization. Native gold, electrum, arsenopyrite, and arsenian pyrite are the principal Au-bearing phases, and tetrahedrite, galena, pyrargyrite are the principle Ag-bearing phases in the Brunswick No. 12 deposit. Anomalous Au (200 to 600 ppb) with low but variable Ag/Au (10 to 50) occur in portions of the stringer sulphide mineralization that exhibits intense silicic alteration. The typical massive sulphide ore grade is 0.55 to 0.72 g/t Au, although the secondary Pb-oxide-bearing ore contains up to 2.25 g/t Au resulting in a high Ag/Au (140) ratio. The As/S ratio is high (0.02 to 0.2) but irregular in the stringer mineralization compared to 0.01 for the typical ore. This is consistent with the pronounced decrease in As solubility as arsenopyrite with decreasing temperatures and increasing oxygen fugacity. Within the sequence sampled ($n = 47$), there is a strong positive correlation between Au and As (0.84) and S (0.69) whereas Ag correlates with Zn (0.76), In (0.74), and Sb (0.66). The correlations may be explained mineralogically (i.e., Ag substitution in tetrahedrite or Au substitution in arsenopyrite or arsenian pyrites). However, the enrichment of Au is probably related to the destabilization of Au complexes (chloride, thioarsenide, or bisulphide) within the near-surface silica-rich stringer sulphide vein system.

Character, distribution, and origin of hydrothermal alteration associated with the Brunswick No. 12 deposit, Bathurst, New Brunswick

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At the Brunswick No. 12 massive sulphide deposit, four alteration zones have been recognized. The most distal alteration facies (zone 4) is characterized by the replacement of K-feldspar phenoclasts in the crystal-rich tuffs by chessboard albite, phengite, Mg chlorite, and quartz. These rocks are slightly enriched in Na, Fe, Mn, S, CO_2, base metals, and possibly Mg, and depleted in K, Ca, Ba, and Sr. Zone 3 alteration (proximal-distal) is characterized by the replacement of albite by Fe-Mg chlorite, phengite, and quartz. This zone is enriched in Fe, Mn, S, CO_2, and base metals and depletion of Na, Ca, K, Ba, Rb, Sr, and La. The Fe/(Fe+Mg) ratio, chlorite abundance, and sulphide veins/disseminations increases toward the vent facies alteration zone (zone 2). Pervasive, Fe-rich chloritic and heterogeneous silicic alteration is intimately associated with the sulphide stringer zone (vent-proximal; zone 1). The sulphide vein networks are well preserved in the silicified zones, which behaved more competently than other footwall rocks during deformation. The various types of alteration reflect the interaction of buoyant, high-temperature, weakly-acidic, Fe-rich fluids with the keratophyrically-altered footwall felsic volcaniclastic rocks.

High-resolution magnetic mapping as a component of multi-parameter surveys

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The 1992 survey of CSS Matthew represents a new approach to ocean mapping in terms of precision and resolution of survey parameters. Advances in navigation using satellites have been refined with the Differential Global Positioning System (DGPS) so that the position of the ship can be fixed continuously (at intervals of 1 to 2 s) with an accuracy of 5 m. The multibeam sounding method requires a spacing of survey lines no greater than twice the water depth for 100% coverage of the seafloor. On inner continental shelf this means line spacing of 50 to 100 m. To achieve full resolution, geophysical parameters (magnetics and gravity) are measured at 20 m along track (i.e., every 4 s).

The magnetic data must be corrected for the position of the sensor astern the ship (which depends on the cable length, ships speed, constancy of heading and cross currents); temporal changes in the magnetic field (diurnal, magnetic pulsation and storm-type disturbances); ship's heading and depth of the sensor below the surface. If these corrections are applied successfully, an accuracy of 2 to 5 nT in contours (based on 25 m gridded data) may be possible.

The quality control is assured by presenting the results as shadowgrams which are sensitive to any systematic level changes along a single survey line. Shadowgrams are also a powerful tool for revealing subtle changes in the underlying geology.

A survey over the shipwreck of the tanker "British Freedom" off Chebucto Head illustrates recent advances in our survey methodology.

The Ainslie detachment – field and geophysical evidence of Carboniferous low–angle extensional faulting in Nova Scotia

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Regionally extensive shear with fault breccia occurs near the base of the Lower Carboniferous Windsor Group in western Cape Breton Island and in central Nova Scotia, forming a broad detachment with underlying strata and basement. The shear zone is characterized by the development of planar lamination, carbonate dissolution, and the inclusion of boudinaged bedding segments as rotated augen. Sheath folds are locally abundant, and late–stage kink bands overprint the laminated fabric. Thick zones of fault breccia straddle portions of the detachment and contain blocks of underlying units as well as sheared limestone. Significant stratigraphic omissions across fault splays in the overlying Windsor Group suggest that low–angle faulting occurred within an extensional regime. Recumbent folds affecting the Windsor Group indicate that the basin is partly allochthonous above the detachment. Younger unconformable terrigenous clastic sediments of Westphalian age were deposited during listric normal faulting above the detachment. Shallow–dipping seismic reflectors are interpreted to be the geophysical manifestation of low–angle extensional faults.

Petrographic and geochemical variations in aplite dykes from an outcrop in the Halifax Pluton, Nova Scotia

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A suite of samples were collected from nine aplite dykes (10-200 cm wide) in a single biotite-cordierite monzogranite outcrop (200 x 400 m) near the northeastern margin of the zoned Halifax Pluton. The dykes display a wide range in AFM mineral assemblages but for this study have been classified as: Group I) biotite-dominated series including Bt≥Ms and Bt>Ms≥Cdt; and Group II) muscovite-dominated series including Ms>Bt≥Cdt and Ms=Cdt≥Grt>>Bt. No distinction can be made between the two groups on the basis of orientation with strikes and dips for all dykes ranging from NW-NE and 25 to 70° respectively.

Microprobe analyses indicate that Fe/(Fe+Mg) for biotite in Group I mostly range from 0.640 to 0.680, i.e., similar to values in the host Bt monzogranite, whereas values in Group II are much higher (0.730-0.780) and resemble the levels in the more chemically evolved Ms-Bt leucomonzogranitic rocks. Similarly, plagioclase compositions for Group I (An_{3-20}) are similar to compositions in the host Bt monzogranite whereas Group II compositions (An_{1-10}) are similar to evolved leucomonzogranite.

Concentrations of HFS and other "compatible" elements are higher in Group I (e.g., Ba 294-646; Sr 51-117; Ti 720-1740; Zr 57-141; La 12-36; Sc 2.8-4.9; Th 4.3-12.0 ppm) than Group II (Ba 58-248; Sr 19-50; Ti 0-720; Zr 34-70; La 3-14; Sc 0.6-3.4; Th 1.7-6.3). Conversely, the concentrations of LIL and other "incompatible" elements in Group I (e.g., Rb 230-300; Ta <0.5-1.4; Li 25-64; F 160-350; Sn 4-21 ppm) are similar to the levels in Group II (Rb 230-320; Ta <0.5-2.1; Li 37-68; F 50-273; Sn 14-22). The observed variation for HFS and "compatible" elements in Groups I and II are similar to, or exceed, the elemental ranges for average biotite granodiorite to muscovite±topaz leucogranite from the entire South Mountain Batholith. Conversely, concentrations of LIL and "incompatible" elements in both groups are similar to, or lower than, the least evolved biotite granodiorite of the batholith.

This study has revealed large mineralogical and chemical diversities for aplite dykes from a single outcrop. Therefore, caution should be used when making inferences regarding the evolution of granite bodies based solely on aplite/host compositions.

Structure of the crust in the Canadian Appalachians; Implications for the development of the Maritimes Basin

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The scale of the Late Paleozoic Maritimes Basin indicates that the basin formed as a result of tectonic events involving the entire lithosphere. As a result, the crust, which was affected in various ways by these events, contains clues for the formation of the basin.

Recent deep seismic reflection and refraction studies carried out as part of the Frontier Geoscience Program and Lithoprobe East have revealed the structure of the crust in the northern Appalachians. The reflection data suggest that the lower crust can be subdivided into three zones: the margin of the Grenville craton to the west, a zone associated with the Avalon Province to the east, and, between these two, a central zone of unknown affinity. The Maritimes Basin developed over the three zones, but its thickest part (up to 12 km) occurs in the Magdalen Basin over the thinned Grenville margin.

Seismic and gravity data interpreted jointly indicate an unusually thick crust (43 km) under the Magdalen Basin with a high density/high velocity layer in its lowermost part. This has been interpreted in terms of mafic and ultramafic rocks which intruded the lower crust, presumably as a result of decompressional melting in the upper mantle. Modelling studies indicate that the presence of hot material in the crust controls the rate of sedimentation.

The sedimentation patterns in the Magdalen Basin indicating an initial crustal extension (Late Devonian–Early Carboniferous) followed by thermal relaxation over a long period of time (Carboniferous to Permian) are consistent with such studies.

Measurement of compressional–wave velocity gradients in seabed materials – examples from the Beaufort Sea and the Sea of Japan

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The normal–incidence seismic profiling method which is widely used for the investigation of seabed sediments relies on the detection of discontinuities in the acoustic impedance of sediment layers. A continuous variation in acoustic velocity with depth is not detected by the method although this type of variation can occur in seabed materials as a result of the processes of consolidation or, in some instances, where pore fluids change state such as in bonding by ice or gas–hydrate. Observation of the reflected seismic wavefield at many incidence angles does allow the detection of these continuous variations. The character of the reflected wavefield at angles beyond critical is sensitive particularly to vertical gradients in compressional–wave velocity.

It is insufficient to use travel–time methods to analyse the observed reflected wavefield. Dynamic modelling of its amplitude and phase characteristics must be carried out, and may lead to quite different conclusions about the sediment column than a travel–time analysis of the same data.

Examples from the Beaufort Sea and from the Japan Sea show how the results of seismic investigation of surficial sediments carried out by this approach are in better accord with drillhole or other direct testing methods.

Although the term "Haggis–ponder" has been suggested by Raytheon Corporation, we prefer, in accordance with the long–accepted practice in Canadian academic archival journals of allowing trademark words ending in "–tec" to identify techniques giving even marginal advance in seismic investigation, that "Haggis–tec" be used in future as a name for our method which offers a significant step forward.

Tenth International Marine Geology Conference, Gelendzhik, Russia, and first impressions of research conditions in that country in October 1992

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The Shirshov Institute of Oceanology in Moscow has organised biennial conferences on Marine Geology at Gelendzhik, a resort on the Black Sea coast, since the early 1970s. Normally these meetings attracted researchers from all corners of the Soviet Union and during the mid to late 1980s, attendance was about 800, but at the meeting held in October 1992, this had declined to about 150, reflecting the severe difficulties experienced by Russians in raising even the seemingly modest sums of money needed to attend. In spite of their hardships, the Shirshov Institute invited around ten foreigners to attend and graciously paid all of our expenses inside Russia for the duration of the meeting and for the travel between Moscow and the Black Sea. The scope of the meeting was very wide. The proportion of review papers seemed to reflect the increasing difficulties which researchers have in finding funds for doing marine fieldwork, but new results were presented on such topics as environmental conditions in the basin of the Lena (found to be about the least polluted river in the world) and minutely detailed vulcanology in the Kuriles as well as in more conventionally marine or lacustrine work in areas like Lake Baikal, the Arctic and the Black Sea.

Although rapidly varying exchange rates and rampant inflation make comparisons hard and of fleeting validity, prices seem to be about one tenth of those in North America and wages about one hundredth. The Shirshov Institute is following an increasingly common practice of forming entrepreneurial service and manufacturing companies in a quest for survival. Haggis Geophysics acquired a graphic recorder from the acoustics group to demonstrate in Canada, Hong Kong and Japan. It was the first they had seen go out of the country and they said they were grateful for the experience it gave them with filling out the necessary export documents.

My thanks to Professor Alexander Lisitzin and his colleagues.

Southern New Brunswick compilation and correlation project by the New Brunswick Department of Natural Resources and Energy

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The first phase of the geological compilation and correlation project, which is jointly funded by the Canada-New Brunswick Cooperation Agreement on Mineral Development and the New Brunswick Department of Natural Resources and Energy, is nearing completion. By mid 1993, two coloured geological maps at a scale of 1:250 000 covering New Brunswick south of latitude 46° 00' will be published. Twenty-seven preliminary geological maps at a scale of 1:50 000 will also be published.

Field and laboratory work for the project during 1992 has revealed the following noteworthy points: (1) The Paleozoic rocks on Grand Manan and surrounding islands comprise three main sequences that can be correlated directly with units on mainland New Brunswick. The mafic volcanics and interbedded cherts on White Head Island and parts of Ross Island are identical to those in fault-bound slices that occur along the Fundy shore near Martin Head in the Avalon Zone. These rocks are likely Late Hadrynian to Early Cambrian in age. Sedimentary sequences comprised of quartzite, conglomerate, arenaceous sandstone and siltstone and carbonaceous shale, which occur on the northern part of Ross Island and on Grand Manan, are similar to Cambro-Ordovician units in the Avalon Zone north and west of Saint John. A unit composed of volcanogenic sandstone interbedded with siliceous siltstone occurs on the southern part of Grand Manan and forms the western-most Paleozoic package to the north-east. These rocks have likely correlatives with the Queen Brook Formation that crops out north of Saint John along the Avalon Zone/Dunnage-Gander Zone boundary. (2) A Silurian age for the bulk of the Kingston Dyke Complex has been confirmed by radiometric dating. A U-Pb (zircon) date from granite that forms a large part of the complex on the Kingston Penninsula yields a date of ca. 438 Ma (T. Krogh, written communication). (3) Volcanic rocks in the Castine area in Maine, which contain the Harborside base metal deposit, have been successfully correlated with similar rocks in the Annidale Group in New Brunswick. The correlation of the schists in the Ellsworth area in Maine with the Queen Brook Formation in New Brunswick has been confirmed. The Ellsworth hosts a large base metal deposit at Blue Hill. The economic potential of units in southern New Brunswick has, therefore, been greatly enhanced by these correlations.

Grenvillian inlier in the Appalachian Orogen: U-Pb ages from the Blair River Complex, northern Cape Breton Island, Nova Scotia

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The Blair River Complex (BRC) forms the surficial expression of the southeastern part of a promontory on the proto-Atlantic continental margin. In the northern Appalachian Orogen this margin, represented by the Humber Zone, is characterized by Grenvillian basement overlain by a Cambro-Ordovician, passive-margin sedimentary sequence. The BRC lacks these sedimentary rocks, but has granulite-facies gneiss, syenite, anorthosite, and granitoid orthogneiss, rock types suggestive of Grenvillian basement.

U-Pb dating of zircons from the BRC suggest that the igneous protolith of the Sailor Brook gneiss is no younger than 1217 Ma, and that metamorphism of this unit occurred at 1035 +12/-10 Ma. Zircon from the Lowland Brook Syenite indicates an igneous age of 1080 +5/-3 Ma. Zircon from a compositionally layered unit of the Red River Anorthosite Complex indicates metamorphism, perhaps accompanied by injection of minor foreign melt, at 996 +6/-5 Ma. The biotite-rich, garnet-bearing, granitoid Otter Brook orthogneiss yielded an igneous age of 978 +6/-5 Ma. Comparable ages occur throughout the North American Grenville Province.

The effect of a major thermal overprint on the BRC is demonstrated by titanite from seven widely distributed samples, which gave metamorphic ages of ca. 425 Ma. Rutile from the anorthosite complex yielded an age of 410 +2/-3 Ma and likely represents post-metamorphic cooling through 430 to 380°C.

Comparisons of rock types and ages best support a Grenvillian origin for the BRC, and the intense, widespread Silurian metamorphism indicates significant involvement in Appalachian orogenesis. These data support inclusion of the BRC in the Humber Zone.

Investigations of ancient and modern placer gold in the Meguma Terrane, onshore and offshore southern Nova Scotia

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Terrestrial placer environments in Nova Scotia are diverse, but most are intimately affiliated with glacial dispersion in one form or another. One of the best areas to research ancient (paleo) placers in Nova Scotia is the eastern Meguma Terrane because it has a history of successful gold production in several districts. Although a great deal of research and investigation has been done on the genesis and distribution of lode gold in host rocks, surprisingly little has been done to scientifically compile, document and evaluate the placer potential. Placer mining and development in Nova Scotia has historically been small scale, but relatively profitable. Most of these placers were never scientifically evaluated as they were exploited, and the possibility still exists that there are placer deposits in the province that may be economically viable as small operations. The 1992 field season saw the investigation of Nova Scotian placer concentrations and potential in a Horton Group basal conglomerate at Coldstream, in a Pleistocene buried meltwater channel and related glaciolacustrine delta at Beaver Dam, and in the specialized lagoon environments at Wine Harbour. The Wine Harbour lagoon is of particular interest, as it also presents a unique opportunity to develop an exploration model for the investigation of glaciated (ocean interface) placer concentrations. This modelling has implications for placer potential in submarine environments on the inner shelf that developed as estuarine and marine shorelines changed during Pleistocene sea level rise.

Characterization and maturation of selected Cretaceous and Jurassic source rocks and condensate/crude oil from Scotian Shelf Wells

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Selected organic-rich rocks and light oil and condensate samples from various Jurassic and Cretaceous formations were examined by organic petrography, Rock-Eval pyrolysis, liquid chromatography, gas chromatography, stable carbon isotope and GC-MS of the aromatic fraction.

An organic facies and source rock characterization was made, based on more than 250 cuttings and core samples, which suggests the presence of multiple condensate and/or gas-bearing source rocks (Types IIB-III and III) which are associated with minor local oil-prone clastic source rocks (Types IIA and IIA-IIB). Vitrinite reflectance and fluorescence data suggest the possible presence of deeper condensate in the basin and indicate the possible timing of overpressuring.

The GC-MS data of the aromatic fraction of both extract and light oil and condensate samples, when compared with stable carbon isotope, GC of both light and C_{12}+ hydrocarbons and liquid chromatography, reveal the following: Cohasset-Panuke-Sable Island oils belong to a non-thiophenic (low-sulphur) group possibly derived from lacustrine algal Type I or Type IIA source rock and the South Venture/Glenelg condensates belong to a moderately thiophenic group derived from a marine Type II or Type II-III source rock. Based on the Methylphenanthrene Index and the ratio of chrysene to benzo (α) anthracene, Cohasset-Panuke oils are less mature than Venture condensate which are formed within the "oil window". The stable carbon isotope and liquid chromatography data indicate the light oils and condensates can be grouped into three families. Cohasset source rock extracts are correlatable to some of the Cohasset oils.

Sm-Nd and U-Pb isotopic compositions of felsic volcanic rocks in the Antigonish Highlands: tectonic implications

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The age and nature of the continental basement to various parts of the Avalon Composite Terrane is of critical importance to Appalachian tectonic syntheses. In the Antigonish Highlands, geochemical data indicate that the Late Proterozoic volcanic rocks (ca. 618 Ma, U-Pb concordant monazite) were extruded in a rifted volcanic arc, whereas the Palaeozoic volcanic rocks (dated palaeontologically) were developed in within-plate rift environments. The felsic volcanic rocks are mainly the product of anatexis of continental crust melted by the heat generated by rising mafic magmas. Therefore neodymium isotopic compositions of felsic rocks yield information on their basement sources. εNd values, corrected for the extrusive age of each unit, are generally positive (0 to +5), reflecting moderately to strongly depleted sources. The recurrence of T_{DM} ages between 955 and 1000 Ma in each volcanic suite and in 9 of the 12 samples is remarkable. The simplest explanation for this data is that the Avalonian continental basement was the main source of the felsic magma and melted during successive anatectic events. The data could reflect either a ca. 1.0 Ga tectonothermal event affecting Avalonian basement or a source with a mean crustal-residence age of 1.0 Ga.

Correlation of swath bathymetric images with metrics derived from seismic and sidescan data

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Multibeam EM100 swath bathymetry maps provide a means for identifying regional patterns in seabed morphology. It is hoped that these patterns can be related unambiguously to surficial geology by correlating topography with a number of independently derived parameters, including potential field data and metrics calculated from high resolution reflection seismic and sidescan sonar data. A Geographic Information System is used to perform the correlation.

Metrics derived from reflection seismic data include reflectivity coefficients R1 and R2, and trace-to-trace coherence. The first of these measures the acoustic impedance contrast across the water-seabed interface, and is proportional to the "hardness" of the bottom. R2 measures the energy in the seismic signal following the initial bottom reflection. R2 tends to increase with scattering resulting from significant unresolved seabed roughness (or, microtopography) and with variation in the geometry and lithology of sediments just below the seabed. Coherence is a frequency-dependent quantity which measures the similarity of seismic signals returned from adjacent areas of the seabed. Coherence is strongly sensitive to microtopography.

Metrics similar to the above, but derived from sidescan sonar signals, are also diagnostic of sediment type over the entire sonar swath. These metrics may be used to constrain the interpretation of topographic features, for example, by helping distinguish bedrock outcrop from glacial moraines. The tasks of preparing metrics, correlation and interpretation are forms of feature classification. A number of simple neural networks have been implemented to assist in the process.

Deformation and igneous intrusion in the Cobequid Highlands: relation to extension of the Magdalen Basin

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The Cobequid Highlands occupy a pivotal position with respect to some of the major structures controlling Devono–Carboniferous sedimentation. The geology of the highlands is dominated by east–west faults parallel to the Cobequid–Chedabucto fault. These may have acted at times as transfer faults for major extensional structures in the Magdalen Basin including the Margaree Shear Zone. Distribution patterns and sequences of igneous rocks in the Cobequid Highlands provide information on sequential styles of deformation at this time. The age of the igneous rocks is only broadly constrained, but new dating is being carried out by Nearing at Dalhousie.

New mapping and aeromagnetic data show that the major diorite plutons have orthogonal outlines, suggesting that they occupy pull–apart space controlled by the major east–west faults. Diorites both cut and are cut by granite plutons, with magma intermingling relationships suggesting approximately co–existing magmas. All the plutonism is probably broadly synchronous based on Rb/Sr isochrons; recent U/Pb dating of zircons by Doig and Murphy suggests ages close to the Devonian–Carboniferous boundary. Biostratigraphic and Rb/Sr isochron evidence for a Devonian age for the Fountain Lake Group volcanism in the eastern Cobequids suggests that these volcanics predate the major plutonic phase.

The stretching lineation observed in the Cape Chignecto pluton appears to be partly syn–magmatic. This deformation culminated in the Namurian uplift event that caused thrusting of the Fountain Lake Group near Squally Point. Evidence of strike–slip synmagmatic deformation is also seen in the Hart Lake–Byers Lake pluton near the Rockland Brook fault. Further evidence for synchronous deformation and igneous activity is provided by undeformed dykes cutting deformed dykes, plutons, and the thrust faults in the Fountain Lake volcanics at Squally Point. Detailed mapping by Pass shows that late dykes are associated with east–west pull–apart.

The latest intrusive phase appears to be pods on the scale of hundreds of metres of gabbro with feldspar megacrysts: these are particularly abundant in the eastern Cobequids. The age of the youngest igneous activity is uncertain, but is probably post–Namurian.

A mechanism for high-heat-flow metamorphism and widespread metasomatism in the Meguma Terrane, Nova Scotia

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High–heat–flow regional metamorphism has affected two areas in the on–land part of the Meguma Terrane. Sillimanite–muscovite–grade assemblages have been developed in the Canso area, and sillimanite–cordierite migmatites occur in the Shelburne–Barrington Passage area. These very high–grade assemblages are indicative of localized temperatures exceeding 600 to 650°C, but in both areas are part of larger, regional, metamorphic culminations, in which andalusite–grade conditions extend up to 50 km away from the highest grade zones. Kyanite has not been found, but staurolite is common at lower grades--thus constraining metamorphism to between 250 and 400 MPa, and implying a geothermal gradient of over 50°C per km.

An unusual texture which is commonly preserved in staurolite– and higher grade metapelites of the Meguma Group is the abundant development of large porphyroblasts of staurolite. Textural investigations indicate these grew during static metamorphism with a one–for–one replacement of matrix muscovite, feldspar and earlier–formed biotite porphyroblasts. Quartz, garnet and magnetite were not involved. Such a replacement requires the introduction of Al and the removal of K from the reaction site, without disturbing the texture of the matrix.

The observations of high–heat–flow metamorphism and K–Al metasomatism can best be explained by the movement of large volumes of fluid which caused advective heat transfer, and extensive K–Al–metasomatism. The most likely sources for these fluids are the abundant granitic(?) plutons known, and inferred from recent aeromagnetic data, throughout the Shelburne and Canso metamorphic culminations.

The Athol Syncline: tectonic evolution of a Westphalian B-C depocenter in the Maritimes Basin, Nova Scotia

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High resolution seismic reflection profiles of the western Cumberland Basin, Nova Scotia, reveal considerable thickening of Westphalian B-C strata towards the axis of the Athol Syncline. This suggests that development of the syncline coincided with that of the depocenter in contrast with the stratigraphic relations typical of the Maritimes Basin where the general absence of Westphalian B-C strata indicates regional, Late Carboniferous uplift and erosion.

Seismically revealed post-depositional structural complications within the Athol Syncline include truncation of its southern limb by a near-vertical east-west zone of strike-slip faulting. This zone, the Athol-Sand Cove Fault Zone (ASCFZ), has been correlated to the west with a complex zone of faulting exposed on the coast of Chignecto Bay where numerous normal, reverse and oblique-slip displacements suggest predominantly brittle deformation and changes in the sense of strike slip. To the east, the ASCFZ splays north into the Springhill coalfield where it is responsible for complex patterns of normal, reverse and strike-slip faulting within Westphalian B coal measures.

Major Late Carboniferous strike-slip faults adjacent to the Athol Syncline record dextral motion south of the Cumberland Basin (on the E-W Cobequid Fault) and sinistral motion along the basin's northwestern margin (on the NE-SW Harvey-Hopewell Fault). These faults are respectively interpreted to be synthetic and antithetic structures related to a regional dextral shear regime in which the ENE-WSW Athol Syncline and associated depocenter formed in response to the direction of local compression during basin development. However, kinematic analyses indicate that post-depositional motion on the ASCFZ was predominantly sinistral. Development of the Athol Syncline is therefore interpreted to have been controlled by dextral, syndepositional transpression during the Late Carboniferous, whereas the later, post-depositional ASCFZ records predominantly sinistral transtension and may be related to the opening of the Fundy Basin which reversed the sense of regional shear during the Middle Triassic.

Nature and timing of mesothermal gold mineralization in western Newfoundland

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Epigenetic gold deposits and prospects in western Newfoundland occur in a variety of settings. The Stog'er Tight and Hammer Down prospects of the Baie Verte area are examples of structurally controlled mesothermal gold occurrences associated with major structural zones in accreted terranes of the Dunnage Zone.

The Stog'er Tight prospect is located near the Scrape Thrust, a secondary structure off the Baie Verte Line. It is hosted by Early Ordovician gabbro in the cover sequence of the Point Rousse Ophiolite Complex. Broad, distinct zones of hydrothermal alteration characterized by chlorite, calcite, ankerite, sericite, magnetite, albite, and pyrite accompany the mineralization. Gold was precipitated by fluid reaction with Fe-rich phases of the gabbro. Alteration involved progressive enrichment in CO_2, S, and K, as well as LILE, REE, HFSE, and Th. Hydrothermal zircon from the prospect has a Silurian U-Pb age.

The Hammer Down prospect, near the Green Bay Fault on the Springdale Peninsula, is hosted by early Silurian felsic porphyry dykes that intrude early Ordovician basalt, andesite, and tuff of the Catcher's Pond Group. Based on age and chemical composition, the felsic dykes are correlated with the Burlington Granodiorite of the eastern Baie Verte Peninsula. Most gold mineralization at Hammer Down is confined to a series of quartz veins that are locally rich in pyrite, sphalerite, and chalcopyrite, with narrow or absent wallrock alteration zones.

Values of $\delta^{18}O$ for quartz from both prospects range from +11 to +13‰, and are comparable to those from other mesothermal gold districts. Oxygen isotope thermometry indicates temperatures of mineralization between 250 and 400°C. Hydrogen and oxygen isotopic compositions of the ore-forming solutions imply a mixed fluid provenance.

Geochemical and geochronologic results indicate that the fluids responsible for mineralization in the Stog'er Tight and Hammer Down prospects are analogous to those of typical Archean (and Phanerozoic) mesothermal gold deposits in accretionary tectonic settings. The hydrothermal processes were related to magmatism and metamorphism during Silurian orogenesis and advection along crustal-scale structures.

October 3-4, 1884 telegraph cable breaks on the Tail of the Banks: the earliest recorded historical turbidity current?

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"There is no sound, no echo of sound, in the deserts of the deep or the great grey level plains of ooze where the shell-burred cables creep".

Rudyard Kipling, who wrote these words in the 19th century, knew nothing about turbidity currents. Recent research supported by the Atlantic Geoscience Centre has confirmed that the 1897 paper by the pioneer seismologist, John Milne, is essentially correct in reporting three near-simultaneous telegraph cable breaks at the foot of the continental slope south of the Tail of the Banks. Milne attributed the breaks to bradyseismic action...represented by secular folding, thrust or crush.

The 1884 breaks occurred over about an eleven-hour period, and the breaks in the three closely-spaced cables apparently lay in a straight line. The opinion was expressed at the time "that all three of these breaks has been caused by a landslide". Despite these observations and the traumatic experience of the twelve major cable breaks after the November 18, 1929 Grand Banks earthquake, geologists were not to realize that turbidity currents were responsible until the classic papers of Heezen and Ewing, Ericson, and that of Kuenen in 1952. The 1884 breaks are believed to be the result of a turbidity current, though we have been unable to establish any reports of a felt earthquake. The 1884 breaks were in two cases not repaired till the summer of 1885.

Pre-, syn-, and post-accretion gold deposits in the New Brunswick Appalachians

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Pre-accretion gold deposits in New Brunswick include Ordovician auriferous massive sulphide deposits and porphyry copper deposits in the Miramichi Terrane. Gold production in the province was initiated by cyanide heap leaching of gossan caps overlying some of the Ordovician massive sulphide deposits.

Middle Silurian-Early Devonian (Acadian) syn-accretion deposits are associated with extensive transpressive shear zones that are mostly close to the boundaries of tectonostratigraphic terranes and/or cover sequences. All these deposits occur north of or along the northern margin of the Avalon Composite Terrane. Syn-accretion deposits include quartz-carbonate veins and stockworks, polymetallic veins, contact metasomatic and porphyry-copper-molybdenum deposits.

Auriferous quartz-carbonate veins and stockworks, and some contact metasomatic deposits are locally associated with post-accretion Middle to Late Devonian granitic intrusions. These deposits occur in the same mineral belts as the syn-accretion deposits and could reflect reactivation of these earlier deposits.

The largest epigenetic gold deposits discovered to date in New Brunswick are associated with major Carboniferous (Hercynian) thrust fault systems along the southern margin of the Avalon Composite Terrane. No intrusions are associated with these deposits.

Allocyclic and thermochronological constraints on the evolution of the Maritimes Basin of eastern Canada

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The Maritimes Basin is made up of up to 7 km of primarily continental clastic strata that presently cover a large area of onshore and offshore Atlantic Canada. This study integrates three separate, but interdependent components: (1) stratigraphy and tectonically induced sedimentary allocycles, (2) a detailed thermochronological study including apatite fission track analysis, and (3) a study of the structure of the basin based primarily on the Cumberland Basin.

The stratigraphy of the Devono–Carboniferous basin–fill units can be divided into three megasequences or allocycles: (1) Late Devonian to Visean, (2) Namurian to Earliest Westphalian, and (3) Early–mid Westphalian to Permian. Each allocycle comprises a series of rocks which are gradational from basin–margin fanglomerates and time equivalent basinal lacustrine deposits (with or without associated volcanics) at the base, to regionally extensive units which onlap older basin–fill and the basement rocks at the top of each allocycle. It is interpreted that each of the allocycles represents a shift from local rapid subsidence associated with net dip–slip movement along strike–slip faults to regional subsidence associated with flexure due to terrane convergence.

Quantitative thermochronological evidence from this study suggests that an additional 1 to 3 km of strata were deposited throughout the Maritimes Basin and subsequently eroded. These sediments accumulated to a maximum thickness in the Permian (ca. 280 Ma), and were eroded during an exhumation that preceded the Triassic/Jurassic rifting of the Atlantic margin (ca. 200 Ma). The Maritimes Basin therefore represents only an erosional remnant of a much larger basin of deposition. Paleogeothermal gradients estimated from the thermochronological modelling were consistent with a continental origin for the basin.

The most significant structural components of the Maritimes Basin are the east–west strike–slip faults and the associated westerly directed thrusts. The Maritimes Basin lies at the northern edge of the Appalachian Orogen and the basin–fill is derived from the Mauritanides and Appalachians Mountains in the south. Detritus eroded from these mountains was transported longitudinally between the mountain ranges to the Maritimes Basin which acted as a receiving basin. The basin developed because of the gradient break created by the numerous strike–slip faults in the area. The basin can be classified as a continental wrench basin analogous to the more recent Malay Basin and related basins developed near the South China Sea.

Maritimes Basin evolution: key geologic and seismic evidence from the Moncton Subbasin of New Brunswick

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The Maritimes Basin is a composite large (148 000 km^2) post–Acadian internal successor basin. It comprises several early NE– to E–trending relatively deep isolated subbasins which are covered by mainly regionally derived and widely distributed fluviatile sequences. The early basin fill in the Moncton Subbasin of southeastern New Brunswick is seen from stratigraphic and seismic reflection evidence to comprise two depositional sequences (tectonic cyclothems) which are separated by a basin-wide unconformity. The basal cyclothem, the Horton Group, is a 3 to 5 km thick coarse–fine–coarse (alluvial–lacustrine–alluvial) cycle. The medial lacustrine interval implies a period of rapid subsidence. The unconformably overlying cyclothem, recorded by the Windsor and Hopewell groups, is a coarse–fine–coarse (alluvial–marine–alluvial) cycle. The marine Windsor Group indicates a medial period of tectonic(?) subsidence.

The depositional history of the Moncton Subbasin *sensu stricto* ended following Hopewell time when the subbasin was inverted via late Namurian deformation. The Hopewell and older basin fill is unconformably overlain by Westphalian mature fluviatile sandstones with associated inter–channel mudstones and paludal deposits of the regionally distributed Cumberland Group. Cumberland rocks are succeeded by late Westphalian/Permian high sinuosity fluviatile strata of the Pictou Group. A locally documented angular discordance between Cumberland and Pictou strata implies a period of uplift or regional tilting.

The tectonism that initiated and terminated the early cyclothems and which is recorded by unconformities following Horton and Hopewell deposition is seen from structural data and seismic reflection profiles to have resulted from dextral transpression. Evidence includes a network of basin–parallel NE–trending anastomosing faults (many with shallowly pitching slickensides), associated en échelon folds, and geologically and seismically identified positive flower structures. An interpretation of early Maritimes Basin evolution in a wrench setting is consistent with the many NE–trending terrane boundary faults in the underlying basement and with most recently published evidence throughout the Appalachians suggesting dextral oblique Acadian and Hercynian (Alleghenian) collisions.

Bulk mineable gold potential in Nova Scotia: a new discovery

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Until the mid 1980s all historical gold production in Nova Scotia (1.2 million ounces) came from high grade, quartz vein type, lode gold deposits hosted in Cambro-Ordovician Meguma Group turbidites; the deposits have many similarities with the richer and more productive Victoria gold fields in the Bendigo area of southern Australia. However, in 1986 a Nova Scotia company (Seabright Resources, Incorporated), determined to make gold mining profitable in this region, undertook a feasibility study of the Touquoy Zone (Moose River Gold District) utilizing a bulk sample collected from an open pit. Gold mineralization in this zone occurs on the north limb of the Moose River anticline in carbonitized argillite that is devoid of quartz veining. The ore zone is bounded on three sides by steep, intersecting faults but remains open along its eastern extension. Mineralization occurs as: (1) disseminations throughout the argillite; (2) along microfractures in the argillite (including cleavage planes); and (3) in sulphides (aspy, py, po, cpy). Bulk test mill recovery (2.2 g/t) of fine-grained to micron-sized gold, using straight gravity, gave excellent recoveries. Present reserves in the main part of the ore body are 1.2 million tonnes of 1.2 g/t Au with additional potential known along strike. In addition to argillite-hosted gold mineralization in Nova Scotia, there have been numerous reports of gold occurring in greywacke (sulphide hosted) although no significant production has occurred. However, a recent discovery in the western Meguma Terrane of native gold in association with Au-Pb-Ag-Cu metal alloys containing trace amounts of Ge-Sb-As-Cr-Zn-Sn and hosted exclusively in strongly carbonitized greywacke suggest that potential new mineable reserves may be uncovered. Trenching has revealed mineralization is a 70 m thick section for 100 m along strike and diamond drilling indicates mineralization continues below 50 m. Drill core assays of this sulphide-poor greywacke indicate Au grades as high as 6.9 g/t in sludge samples and 9.6 g/t in core samples. Company drilling further suggests that this unit is not unique to the property. Surface grab samples from outside the mineralized greywacke returned values of 0.32 g/t. Texturally, these native gold and gold-alloy grains differ from low Ag-bearing native gold encountered at other Meguma Group gold deposits. Many of these grains have a botryoidal, colloform type appearance while others are completely spherical. Cellular type textures with concentric, or semi-circular zonation, is manifest by exotic, native metal alloy mineralogy, possibly in solid solution. Similarly altered strata at the Caribou district (Hard Light Zone) are the only other greywackes in Nova Scotia to have returned ore grade gold analyses. This mineralization occurs adjacent to a crosscutting quartz-chlorite-carbonate stockwork-quartz vein system (No. 1 Flexure). Examination of heavy mineral concentrates from this zone indicate the presence of Pb-Au alloy mineralogy with similar spherical textures to those described above. Similar textures and compositions to those reported here are not documented from other lode-gold deposits, however, sulphide droplet textures observed in volcanogenic sulphide deposits do hold similarities. The recognition of these alloys and their close spatial association to pervasive, hydrothermal, carbonate alteration in greywackes adjacent to crosscutting fissure systems, demands a closer inspection of many other areas (particularly former gold districts) throughout the province. The recognition of this mineralogy further indicates that no lithology in the Meguma Terrane should be overlooked for its gold potential and that encouraging potential for large, bulk mineable deposits exists in this region.

Ichnology of the Late Ordovician Georgian Bay Formation of southern Ontario

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The Late Ordovician Georgian Bay Formation of southern Ontario comprises between 127 and 177 m of alternating blue, green and grey shales and grey calcareous sandstones, the unit being divided into upper and lower members based on the relative abundance of these two components. The succession is interpreted as a storm–dominated shelf sequence, individual sandstone–shale couplets displaying all or part of a characteristic internal sequence encompassing a basal lag zone overlain by hummocky cross–stratification overlain by horizontal–laminated and cross–laminated deposits, all overlain by shale.

Very little attention has been paid in the past to the ichnology of the Georgian Bay Formation, the majority of workers concentrating on its stratigraphy and sedimentology. Work undertaken in the lower member has revealed the presence of a rich, well-preserved ichnofauna characterised by the ichnogenera *Arthraria*, *Aulichnites*, *Chondrites*, *Cochlichnus*, *Cruziana*, *Curvolithus*, *Didymaulichnus*, *Diplocraterion*, *Fustiglyphus*, *Gordia*, *Gyrochorte*, *Helminthopsis*, *Lingulichnus*, *Lockeia*, *Micatuba*, *Monomorphichnus*, *Paleodictyon*, *Palaeophycus*, *Phycodes*, *Planolites*, *Rusophycus*, *Skolithos*, and *Trichophycus*. This association of ichnotaxa is characteristic of the *Cruziana* ichnofacies, indicative of a subtidal environment below fair–weather wave base, but above storm wave base.

Morphology and depositional facies, Inner Scotian Shelf near Halifax Harbour: Implications for Late-Glacial sea-level

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Distinct zones of erosional and depositional landforms occur on the inner Scotian Shelf. These "zones" or "acoustic landforms" can be defined by unique acoustic surface morphology and internal seismic sequences related to water depth. In the approaches to Halifax Harbour two major zones can be recognized: (1) outcrop zone and (2) truncation zone. The outcrop zone can be characterized as a broad area of acoustic basement with high relief that is largely devoid of surficial sediments. It extends from 70 to 120 m water depth. The truncation zone, extending from 70 m to the present shoreline, is defined by muted topography and a planar, erosional surface truncating bedrock and surficial cover. Sediment-infilled valleys within the truncation zone are often characterized by seismic facies with a ponded style of deposition planed by the sea surface or by erosional unconformities near the surface. Near Halifax, two depositional sub-zones within the truncation zone are noteworthy, Unit "C" and the "Sambro Delta". Unit C is an incoherent seismic facies that forms a flat blanket over the acoustic basement. Chaotic reflections are sometimes resolved within Unit C. These are truncated by the sea surface at depths between 50 and 70 m. The surface of Unit C is relatively flat. Side scan sonograms show a hard, cobbly and bouldery surface. Grab samples revealed a stony, sandy diamicton with rounded pebbles. Unit C is interpreted as a diamicton and bedded deposit of glacial origin that has been reworked in the shoreface zone during transgression that followed post-glacial sea-level fall. The progradational feature termed the Sambro delta is interpreted as a delta primarily because of oblique terminations of clinoform reflections and its location at the head of a southwest-trending valley. A core was obtained from the delta front at 73 m water depth. The top 70 cm of the core reveals a grey, medium to coarse sand capped by a lag surface of well-rounded cobbles. Abundant mussel (*Mytilus edulis*) valve fragments were found at 70 cm. One of these fragments was radiocarbon dated and produced an age of 11,650 ± 110 B.P.

A series of parallel ribbed moraines occur in water depths greater than 70 m south of Sambro and Sheet Harbour, Nova Scotia. They are part of the Morainal Zone. Near Sambro these moraines are superimposed on drumlins. The surface of these drumlins appears truncated at 70 m water depth. From the morphology and depositional facies of the inner shelf near Halifax we conclude that sea-level was 70 m lower than present at the end of the last glaciation.

Petrogenesis of the Weekend dykes, a suite of Late Devonian spessartite lamprophyres in the Meguma Zone of Nova Scotia

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Post-tectonic, Late Devonian (ca. 370 Ma) peraluminous granitoid plutons, and a suite of contemporaneous calc-alkaline mafic intrusions, intrude the southern and eastern Meguma Zone. Ten spessartite (amphibole and plagioclase dominant) lamprophyre dykes, known informally as the Weekend dykes, constitute a subset of this mafic intrusive activity. All dykes exhibit characteristic panidiomorphic textures, with seriate phenocrysts of amphibole, rare biotite, and clinopyroxene. Plagioclase, K-feldspar, quartz, and primary calcite and epidote occur only in the groundmass. Restricted major element variations (SiO_2 54–56 wt. %, MgO 6–13 wt. %, Al_2O_3 13–17 wt. %, and total alkalies 2.3–5.8 wt. %) reflect changes in mafic phenocryst abundance, and high Mg-numbers (0.6–0.8), Cr (278–1500 ppm), Ni (75–349 ppm), and LOI (1.7–4.3 wt. %) indicate the primitive and volatile-rich nature of these rocks. Enrichments of LILE (e.g., Sr, Rb, Ba – 270–835 ppm) relative to HFSE (e.g., Nb, Ta, Y – 4–30 ppm), and of LREEs relative to HREEs (La/Lu - 41–82) are typical of calc-alkaline lamprophyres. The textural and compositional consistency among dyke members suggests that they are cogenetic.

Models for the origin of such primitive, incompatible element enriched, hydrous magmas involve metasomatized lithospheric or asthenospheric mantle sources, with or without crustal contamination. HREE fractionation suggests derivation from a garnet-bearing asthenospheric source. Negative Ta–Nb–Ti anomalies, and geochemical similarities with modern subduction-related basalts, imply that fluids derived from subducted oceanic lithosphere promoted mantle metasomatism, generating lamprophyric parental melts. Combined low pressure fractionation, assimilation of crustal lithologies, and/or parent magma heterogeneity can account for geochemical differences between individual dykes.

Tectonically transported basement and platform units in the Stephenville area, western Newfoundland

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The Humber Zone of western Newfoundland represents a Cambrian to Middle Ordovician passive continental margin above which the Humber Arm Allochthon was emplaced in Middle Ordovician ('Taconian') time. In the Stephenville area, Lithoprobe deep seismic profiles show sub–horizontal reflectors extending beneath outcrop of Grenville age basement rocks in the Indian Head Range. These observations indicate that the outcropping passive margin sedimentary successions and their basement represent a later assemblage of thrust sheets here termed the Port au Port Allochthon. Cambro–Ordovician platform successions are exposed at Table Mountain, and in the Phillips Brook and North Brook anticlinoria. Platform strata at Table Mountain are affected by west and east vergent thrusts and reverse faults. Structural repetitions occur within platform rocks along the western edge of the Phillip's Brook Anticlinorium. Platform rocks are thrust over the Taconian Humber Arm Allochthon in this area. East–dipping thrusts occur on the western edge of the Indian Head massif, placing Grenville gneisses above Cambrian sedimentary rocks. Thrust–related structures are cut by steep faults associated with steeply plunging folds indicating dextral strike–slip movement. All these structures are overlain by sub–horizontal Carboniferous strata. These observations imply that both the Grenville basement rocks of the Indian Head Range and their Cambro–Ordovician cover have been tectonically transported. Observations farther west, where latest Silurian rocks are deformed at the thrust front on Port au Port Peninsula, imply that this deformation is of broadly Acadian age. Shortening was apparently followed by dextral strike–slip motion, suggesting an overall Acadian history of dextral transpression.

Revised stratigraphy and paleogeography of Siluro-Devonian rocks adjacent to the Ordovician Elmtree Inlier, northern New Brunswick

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Siluro-Devonian rocks surround the Elmtree Inlier (EI) and the northern end of the Miramichi Highlands (MH) in northern New Brunswick and comprise the Chaleurs and Dalhousie groups. These rocks occur in four structurally and stratigraphically distinct zones namely: (1) The east-west trending Nigadoo River Synclinorium (NRS) that separates the southern edge of the EI from the MH. (2) The north-south trending Jacquet River Syncline (JRS) that borders the western margin of the EI. (3) The Hendry Brook Syncline (HBS) that lies on the northern margin of the EI. (4) The Black point Anticline (BPA) that borders the JRS to the northwest and is separated from the JRS by the north-south trending, Black Point-Jacquet River Fault.

The Silurian to Lower Devonian Chaleurs Group rests unconformably on Ordovician basement in all four zones. Ten formations constitute this group; these are: Clemville, Armstrong Brook, Upsalquitch, La Vieille, Simpsons Field, Bryant Point, South Charlo, LaPlante, Free Grant and Benjamin (423 ± 3 Ma). The Armstrong Brook and La Vieille formations outcrop in all four zones. The volcanic members of this group (South Charlo, Bryant Point and Benjamin formations) are restricted to JRS and HBS. The Clemville, Simpsons Field, LaPlante and Free Grant formations are restricted to the NRS whereas the Upsalquitch Formation is restricted to the BPA.

The Lower Devonian Dalhousie Group conformably to disconformably overlies the Chaleurs Group and is restricted to the JRS. Five formations constitute this revised group as follows in ascending order: Mitchell Settlement (newly defined and comprises siltstone, mafic volcanic rocks and minor red beds), Jacquet River (sandstone, siltstone and minor mafic volcanic rocks), Archibald Settlement (felsic volcanic rocks), Sunnyside (mafic volcanic rocks) and Big Hole Brook (new name, sandstone and siltstone.)

In Early Llandovery the EI and MH did not exist as uplands, i.e., were not above sea level. By Middle Llandovery these uplands, which were separated by the incipient NRS, were the source area for conglomerates of the Armstrong Brook Formation. In the west, shallow marine clastic rocks of the Upsalquitch Formation were being deposited at the same time. In the Late Llandovery the La Vieille limestone was deposited around both uplands and to the west. By Wenlock time the Elmtree Upland began to subside whereas the Tetagouche Upland began to rise, as shown by the Simpsons Field conglomerate that coarsens upward on the southern margin of the NRS and fines upward on the northern margin of the NRS. At the same time in the west, subaerial mafic and felsic volcanic rocks of the Bryant Point and Benjamin formations were erupted. Laterally equivalent volcaniclastic conglomerates of the South Charlo Formation were deposited on the western edge of the Elmtree Upland. In Pridolian time the Elmtree and Tetagouche uplands were decoupled along the dextral Rocky Brook-Millstream Fault. Tectonic instability (uplift and strike-slip movement) caused large

blocks of LaPlante limestone to slide down slope into the NRS. By Early Devonian time, tectonic transport of the Elmtree block created a frontal trough in which the shallow marine Dalhousie Group was deposited. Continued westward transport deformed these rocks and caused their present day spatial distribution.

Late Carboniferous agglutinated foraminifera and thecamoebians from Nova Scotian coal-bearing strata: paleogeographic, paleoenvironmental and paleoecological implications

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Agglutinated foraminifera and arcellaceans ("thecamoebians") are documented from Late Westphalian–Stephanian cyclothems in the Sydney Basin of Nova Scotia. Assemblages from the eastern part of the basin are dominated by *Ammobaculites* and *Ammotium*, indicating low marsh/estuarine paleoenvironments. Mixed assemblages dominated by *Trochammina*, *Ammotium* and *Ammobaculites* occur in both the east and western parts of the basin and indicate vegetated substrates, equivalent to modern low marsh environments, flanked the estuarine system. *Trochammina* assemblages found underlying coal seams in the western part of the basin indicate substrates analogous to modern high marsh facies. Alternation of the *Trochammina* assemblages with encysted thecamoebians indicates short lived freshwater paleoenvironments.

Paleoecological interpretations based on comparisons with faunal associations occurring in modern coastal wetlands are supported by sedimentological features. Samples from a shale immediately below a sandstone containing trace fossils and reworked ripples in the Cumberland Basin (Joggins section) contain a foraminiferal assemblage indicative of estuarine conditions. This find represents the first evidence of marine influence during deposition of the Cumberland Basin. Laminated mudstones and sandstones, identified as tidal deposits from the Brazil Formation (Lower Carboniferous) of Indiana, also contain mixed foraminiferal assemblages indicative of estuarine depositional environments.

Hydrocarbon charge models of east coast basins: a report on a joint industry, government and university project

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Accumulations of oil and gas are a result of the dynamic interaction of a complex sequence of physical and chemical processes operating within the framework of a basin's geodynamic evolution and sediment infill/structural history. The last ten years has seen the development of numerically based basin analysis methods, of varying sophistication, that aim to reduce these complexities to a set of more easily imaged concepts and models. The Hydrocarbon Charge Modelling Project, an initiative coordinated through the Atlantic Geoscience Centre, is tasked to develop such models for the Sable and Jeanne d'Arc Basins offshore eastern Canada. The project, which is maturing into a truly collaborative, multidisciplinary effort, has attracted scientific and funding contributions from the Petroleum Industry, Academic and Government sectors. The underpinning science activities encompassed by this project are discussed with reference to their impact on planned, integrated products. The latter will be discussed in terms of their utility in the reduction of geological uncertainty and risk.

Stratigraphic relationships and mineralized horizons in the Heath Steele–Half Mile Lake area, Bathurst Camp, New Brunswick

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The Heath Steele–Half Mile Lake area is underlain by volcanic and sedimentary units of the Middle Ordovician Tetagouche Group, including, from oldest to youngest, the Patrick Brook, Nepisiguit Falls, Flat Landing Brook and Boucher Brook formations. The Patrick Brook Formation consists of dark grey to black quartz wackes and slates that underlie relatively small areas south and west of Half Mile Lake. The Nepisiguit Falls Formation is divided into two members comprising mainly volcanic and mainly sedimentary rocks, respectively. The volcanic member consists primarily of quartz–feldspar crystal tuffs that exhibit characteristics of both lavas and pyroclastic rocks, suggesting unusual

circumstances of eruption and emplacement. The Flat Landing Brook Formation consists mainly of aphyric or feldspar–phyric felsic flows and domes, plus local felsic hyaloclastites, quartz–feldspar crystal tuff, mafic to intermediate flows, tuffs and agglomerates, mafic intrusive rocks and minor sedimentary rocks. Flat Landing Brook rhyolites are chemically distinct from the Nepisiguit Falls "porphyries", and contain higher abundances of Nb, Y, Zr, Hf, Sc, and ΣREE. The Boucher Brook Formation consists mainly of alkalic basalts and dark grey to black shales and wackes; the relative proportion of mafic volcanic and sedimentary rocks varies widely however. The transition from the Flat Landing Brook Formation to the Boucher Brook Formation is similarly characterized by different depositional histories in different places. Units of quartz–feldspar crystal tuff, basalt and iron formation may occur in variable proportions and thicknesses; locally, any or all of these may be absent from the succession.

Economic mineralization is found at three distinct stratigraphic levels characterized by well–defined lithologic associations. The Heath Steele (Brunswick) horizon includes the Heath Steele and Half Mile Lake deposits and is located within the Nepisiguit Falls Formation, typically at the contact between the volcanic and sedimentary members. The Stratmat horizon lies within the Flat Landing Brook Formation, hosted by sedimentary rocks that are enveloped by felsic fragmental rocks and feldspar–phyric or aphyric rhyolites. The Caribou horizon occurs at or near the contact between the Flat Landing Brook Formation and Boucher Brook Formation; host rocks and associated lithotypes vary from one deposit to another, and may include mafic volcanic rocks, crystal tuffs, rhyolites, or sedimentary rocks. The Wedge and Nepisiguit deposits are included in this group.