

# ATLANTIC GEOSCIENCE SOCIETY

## ABSTRACTS

### 1989 COLLOQUIUM

### AMHERST, NOVA SCOTIA

**The 1989 Colloquium of the Atlantic Geoscience Society was held at the Wandlyn Inn, Amherst, Nova Scotia on February 3-4, 1989. On behalf of the Society we thank Laing Ferguson of Mount Allison University and all others involved in the organization of the meeting.**

**In the following pages we publish the abstracts of talks and poster sessions given at the meeting.**

### Physical volcanology of an Early Devonian volcanic sequence, Passamaquoddy Bay, southwestern New Brunswick

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The Early Devonian Eastport Formation comprises the northeast part of the coastal volcanic belt near St. Andrews, southwestern New Brunswick. Field and petrologic studies were used to establish the detailed stratigraphy and physical volcanology of the westernmost part of this bimodal volcanic sequence.

The mafic units occur as subaerial lava flows, lapilli tuff and numerous diabasic plugs, dykes and sills. The felsic units include parallel-laminated crystal tuff, heterolithic volcanic breccia, and two flow-banded rhyolite lava units. These are interpreted as an airfall deposit, pyroclastic flow, lava flow and intrusive dome, respectively. Flow-banded andesite, in the southern part of the sandy area, is interpreted as an extrusive volcanic dome.

Interbedded red sandstone and siltstone blankets the western part of the study area. The thinly bedded, parallel-laminated

sequences locally contain cross-bedding, bioturbation and ripple marks, and were probably deposited in a shallow water, littoral environment, with local deposition in a fluvial environment. The increase in sedimentary rocks in the study area, compared to the area to the east, may reflect either a downwarping or subsidence of the volcanic tract with time, or the positioning of the study area on the flanks of the volcanic edifice. Paucity of reworked volcanoclastic material poses some problems with the latter, unless explained by poor exposure.

Major-, trace- and rare-earth-element geochemical studies, now underway, will establish variations between and within flow units and help constrain the tectonic setting of the coastal volcanic belt.

### Late Hadrynian to Cambrian(?) sedimentary and volcanic rocks in southeastern Cape Breton Island, Nova Scotia

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Recent geological mapping in southeastern Cape Breton Island has defined a distinctive assemblage of sedimentary and volcanic rocks informally termed the Main a Dieu sequence. These rocks occur mainly in the northern and western parts of the Coastal Belt of the late Precambrian Fourchu Group and were included in the Fourchu Group by previous workers. However, the Main a Dieu sequence differs from other parts of the Coastal Belt in that sedimentary rocks (coarse redbeds, laminated siltstones, and cherts) and re-worked volcanogenic rocks are the dominant components, in contrast to the rest of the belt where such lithologies are rare. Crystal tuffs and lithic-crystal tuffs, which are the major components of the rest of the belt, are minor in the Main a Dieu sequence. Cleavage is weakly developed in

the Main a Dieu rocks compared to the Fourchu Group. Basaltic flows, tuffs, and breccia are widespread, and gabbros appear to be associated with the sequence. The Main a Dieu sequence shows some similarities to rocks of the Stirling Belt of southeastern Cape Breton Island, which hosts the Mindamar Zn-Pb-Cu-Ag-Au deposit.

The Main a Dieu sequence is inferred to be younger than the rest of the Coastal Belt, and probably late Hadrynian to Cambrian in age. It may be correlative with dominantly sedimentary rocks of this age in the Avalon Terrane in eastern Newfoundland, and in the Caledonian Highlands of southern New Brunswick. The latter area, in particular, has similar distinctive lithologic units, including an association with gabbros.

### Carbonate buildups in the Lower Carboniferous Horton and Windsor groups (Late Tournaisian - Visean) of Nova Scotia

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Carbonate buildups have been identified in most Carboniferous basins in an area extending 350 km from Mahone Bay to Sydney. They occur as marine bioherms, reef mounds or banks in the Windsor Group (70 localities), and as a lacustrine algal-caliche lithoherm in the underlying, nonmarine Horton Group. The buildup distribution and composition reflects the many factors linked with basin development, i.e., depositional environments, paleogeography and biota. The most numerous (40 localities), thickest and most laterally extensive buildups are

banks of the Gays River Formation at the base of the Windsor Group (Major Cycle 1). These were strongly influenced by paleotopography and are localized near unconformities on basin margins. Younger buildups in Major Cycle 2 (25 loc.) and Major Cycles 3-5 (5 loc.) are less numerous but have an expanded distribution into a basinal setting, without any apparent substrate or paleotopographic control. The distribution pattern partly reflects the smoothed paleotopography accompanying basin infilling by MC-1 evaporites, and continued onlap of basin mar-

gins. An isolated mound form (10-50 m thick) with a thin, off-mound facies (1-5m) is characteristic of MC-1 and 2 buildups. This contrasts with MC-3 and 5 buildups (20 m), which are enveloped within the normal carbonate facies of similar thickness.

Although volumetrically subordinate to the regionally extensive carbonate members, the buildups are: (1) major sources of high grade limestone and dolostone for industry and agriculture, (2) hosts for base metal and celestite deposits, and (3) potential hydrocarbon reservoirs.

### Origin of the Sable Island sand body

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The Quaternary Sable Island sand body lies on the outer Scotian Shelf, 225 km offshore from Halifax. It is up to 55 m thick, covers an area of over 12000 km<sup>2</sup> and contains 238 km<sup>3</sup> of sediment. Of this, 117 km<sup>3</sup> is Pleistocene in age and was deposited in ice marginal and proglacial environments. The remaining 121 km<sup>3</sup> is Holocene in age and was deposited in marine shelf and coastal environments. Holocene sands were derived from transgressive reworking of the underlying Pleistocene glacial sediments. The maximum Late Wisconsinan (Stage 2) ice margin lay NE-SW across Sable Island Bank. Subglacial tunnels incised older glacial and Tertiary sediments on the Bank and debouched at the ice margin, depositing a fine- to coarse-grained, silty sand in ice-contact and proglacial facies. The locus of ice-contact deposition occupied a NE-SW linear belt including Sable Island, Northern Spur and possibly extending NE across Banquereau and SW across Western Bank to Georges Bank and Cape

Cod. The age of the latest Wisconsinan glacial sequence is poorly constrained on Sable Island Bank, but appears to occupy the interval between 30 and 11 kybp. Following glaciation, relative sea level rose at 55 cm/100 yrs from below 49 mbsi at 11 kybp to 13.5 mbsi at 4.5 kybp. From 4.5 kybp to present, relative sea level rise slowed to 29 cm/100 yrs. This Holocene transgression converged from the bank margins towards the present position of Sable Island. Ahead of the transgression eolian environments predominated, combined with freshwater peat deposition in restricted lowland swamps. At the shoreline coastal barriers developed and separated extensive lagoons from the newly created continental shelf. Reworking on this shelf generated shoreface ridge fields oriented obliquely to the shoreline. Sediment generated by shoreline and ridge erosion and by shoreface retreat was primarily transported NE to accumulate in marine sand bodies at East Bar, West Bar and Northern Spur.

### The Turtle Creek Earthquake of April 24th, 1988 and its significance to the seismicity of the Moncton region of New Brunswick

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On April 24th, 1988, an earthquake of  $m_N = 3.7$  occurred near Turtle Creek, about 12 km SW of Moncton, New Brunswick. An earthquake of similar magnitude,  $m_N = 3.6$ , had previously occurred in the same area on September 23rd, 1984. An analysis of seismograms recorded at stations of the Eastern Canada Telemetered Network (ECTN) shows that the epicentres of the two earthquakes were separated by 6.4 km along a WSW-trending line. The presence of a weak Rg phase on the seismograms recorded at station KLN suggests shallow depths for the earthquakes, probably in the depth range 3 to 5 km. Interpretation of seismic-reflection-record sections for the area show a number of SW-trending thrust faults that might be possible sources for the earthquake movement. However, focal mechanism studies of the

two events yield different solutions: the "best solution" for the 1984 event suggests strike slip/thrust motion in response to NE compression along a strike direction of 121° and the "best solution" for the 1988 event suggests thrust faulting in response to NE compression on N- or NW-trending planes.

An intensity survey was conducted for the 1988 event and showed that the earthquake was felt over an area of approximately 4900 sq. km. Magnitude - felt area relationships yield magnitude estimates of 3.6 to 3.7, which compares favorably with the instrumentally determined magnitude. This latter result increases the confidence in applying the same relationships to historical earthquakes in the Moncton region.

### The Paradox of coal in an active depocenter: The Westphalian of the Cumberland Basin

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During the Westphalian B, the Cumberland Basin was the major depocenter of the Maritimes Basin. The high rate of sedimentation and the proximity of coals to both marginal alluvial-fan and major channel-belt deposits is seemingly at odds with prevailing theories that thick, low-ash ("economic") coals could not have formed temporally or spatially near such active deposystems. The >1 km-thick basin-fill sequence, comprising the coal-bearing Springhill Mines Formation and underlying, conglomeratic Polly Brook Formation, records a decelerating rate of subsidence. The formation of major peat-forming ecosystems (mires) was possible only during an optimal subsidence window coincident with alluvial-fan maturity and multi-storying of fluvial-sandstone bodies. The distribution of the peat mires was determined by groundwater systems, largely a tectono-geographic function and an allogenic control. Of primary importance was the recharge supplied to the piedmont by the mature coalesced fans at the southern basin margin, upon which the mires become increasingly dependent as basin infilling proceeded and regional groundwater levels declined.

The No. 3 seam of the Springhill coalfield has been studied in the context of a peat-forming ecosystem, using an interdisciplinary approach incorporating coal petrography, sedimentology, palynology and geochemistry. The seam developed as a groundwater influenced (rheotrophic), nutrient-rich peatland. A high degree of biochemical gelification, corrosion of miospores and formation of pyritic sulphur resulted from the high pH of the mire. The peat mire evolved by two distinct autogenic mechanisms: terrestrialization and palludification. The former resulted in an upward succession of mire types from limnic --? floating swamp --> forest swamp --> fen --> bog forest as the mire tended toward more ombrotrophic (rainfall-sourced) conditions. The latter mechanism occurred at the piedmont (southern) margin, where ephemeral sheetflow from distal alluvial fans was dispersed, dammed and invaded by the forest swamp vegetation, resulting in lateral accretion toward the piedmont. Within the allowable subsidence window, rheotrophic peatlands of the southern Cumberland Basin developed largely through these autogenic processes.

### Stratigraphic drilling of the Windsor Group: the Alton Gas occurrence

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The Alton (ALT-87-1) drillhole was located to examine the stratigraphy and structure of the Windsor Group evaporites in the north-central portion of the Shubenacadie Basin. The hole was spudded in Watering Brook Formation of the Canso Group and the oldest strata penetrated was the A Subzone, Carrole Corner Formation of the Windsor Group. Top-of-salt (base-of-dissolution) was intersected at 404.87 m. The drillhole was terminated at 683.05 m, due to an uncontrolled flow of natural gas into the well-bore.

The gas flow was controlled by an annular blow-out preventer (BOP) and killed with a treated and weighted cement. This represents the first time that a hydrocarbon flow has been controlled and killed with this type of equipment on a diamond drill in eastern Canada and procedures developed are specific to this type of equipment.

The gas flow characteristics were evaluated, within the limits of the wireline-coring equipment, prior to the kill operation.

### Cyclic, bimodal volcanism in a Siluro-Devonian continental volcanic zone: the Eastport Formation, southwestern New Brunswick

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The Siluro-Devonian Eastport Formation in southwestern New Brunswick comprises a continental, bimodal volcanic sequence with intercalated littoral to subaerial sedimentary rocks. Mafic-felsic volcanism occurs in three to four cycles through the represented stratigraphy of the complex. The complex is intruded by the Saint George Batholith as well as smaller rhyolitic, andesitic and gabbroic bodies and is overlain unconformably by the Late Devonian Perry Formation.

Mafic volcanic rocks are less abundant than the felsic units in each cycle. In the final cycle, however, the mafic to felsic ratio increases with mafic flows and littoral to subaerial sedimentary rocks being intruded by small felsic bodies. This cycle may represent the waning stages of volcanism.

The extrusive volcanic rocks are bimodal with a SiO<sub>2</sub> gap between 58% and 69% SiO<sub>2</sub>. The mafic rocks are tholeiitic and have a within-plate tectonic affinity. The three lower mafic units

plot as distinct groups for most immobile trace elements but as a whole lie along a single trend. The lowermost mafic unit contains the most-evolved composition with high abundances of Y, Nb, Zr and SiO<sub>2</sub> and low Cr and Ni. Y, Nb, Zr and SiO<sub>2</sub> decrease upward through the succession while Ni and Cr abundances increase.

Major element plots of the felsic rocks suggest they are calc-alkalic; however, the abundances of the immobile trace elements Y, Nb and Zr are comparable with those of alkalic to peralkalic rhyolites. The tectonic affinity of the felsic rocks is ambiguous.

### **Stratigraphy and sediment dispersal patterns of the Cumberland Group strata in the western Cumberland Basin**

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The Cumberland Group Westphalian A-C strata in the western Cumberland Basin comprise a 4000 m thick sequence of continental clastic sedimentary rocks. The Group can be divided into five formations: (1) Polly Brook, (2) Joggins, (3) Springhill Mines, (4) Ragged Reef and (5) Malagash. The Polly Brook Formation is a sequence of conglomerates and coarse sandstones that are laterally equivalent to the fluvial-lacustrine coal-bearing beds of the Joggins Formation. These formations are succeeded by the grey coal-bearing strata of the Springhill Mines Formation. The Springhill Mines Formation is overlain by the coarse-

grained sandstones, conglomerates and thin mudstones of the Ragged Reef Formation. Locally the finer-grained interbeds of this formation contain thin coal seams (e.g., Spicers Cove). The uppermost formation of the Cumberland Group is the Malagash Formation which is transitional in character with the overlying redbeds of the Pictou Group.

Sediment dispersal patterns in the western part of the basin indicate that the Athol Syncline formed a depositional trough with its axis approximately coincident with the present day structural axis.

### **Offshore extension of structural trends into the western Gulf of St. Lawrence**

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A compilation of industry reflection data and the 1986 deep seismic reflection data enabled us to delineate structural trends in the Gulf of St. Lawrence. These structures can be linked to the onshore geology of New Brunswick and the Gaspé Peninsula using seismic, gravity and magnetic data.

In the southwestern part of the Gulf a series of structural highs and lows, separated by northeast-southwest-oriented faults, are identified. Two significant fault zones, bounding a pre-Windsor Group basin, are mapped and interpreted to be extensions of the Fredericton and Belleisle faults. These structural trends are abruptly truncated by a NW-SE-oriented structural boundary passing through the southern part of the Magdalen Islands. East of Miramichi Bay another pre-Windsor Group basin is terminated to the north by the same NW-SE structural boundary. The boundary is characterized by a change in struc-

tural style on the seismic sections and by an elongate positive gravity anomaly. The boundary may correspond to the location of the newly postulated "Canso Fault" (McCutcheon and Robinson, 1987; and others).

North of the boundary is a region generally lacking basement reflections. Basement reflections are identified further north, where high amplitude reflections dip to the northeast from about 3 to more than 4 seconds, two-way-travel time. The data suggest that these reflections can be interpreted as a detachment between the reflection-poor basement and another basement block to the north. The trace of the detachment parallels the Appalachian Structural Front, suggesting that it is related to Taconic or Acadian thrusting of sediments of the ancient North American continental margin.

**Magmatic epidote- and high-Aluminum hornblende-bearing diorites and tonalites of the southeastern Cape Breton Highlands, Nova Scotia**

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Six late Precambrian (560 Ma) dioritic and tonalitic plutons occur in the Bras d'Or Terrane of the Cape Breton Highlands. Three of these, Ingonish River Tonalite (IRT), Gisborne Flowage Quartz Diorite (GFQD), and Kathy Road Dioritic Suite (KRDS), contain a high-pressure igneous mineral assemblage that includes epidote and high-Al edenitic and ferrogan pargasitic hornblende. The major mineral assemblage is hornblende + plagioclase (An<sub>30-55</sub>) ± quartz ± biotite, with rare K-feldspar. Hornblende compositions are consistent with pressures of crystallization of 500-700 MPa for the IRT, 650-800 for the GFQD, and 700-900 MPa for the KRDS. The presence of magmatic epidote (pistacite component = 23-30%) within tonalitic and locally quartz dioritic portions of the plutons limits their mini-

um pressure of consolidation to >600MPa. Fractionation trends on trace-element variation diagrams indicate that the plutons have undergone a combination of plagioclase and hornblende fractionation. All display flat HREE patterns and slightly negative Eu anomalies, consistent with plagioclase and hornblende fractionation. High LREE content of the GFQD is interpreted as the result of abundant sphene and allanite crystallization in a magma that has undergone more efficient crystal-melt separation than the IRT or the KRDS. Tectonic setting is considered to have been a volcanic arc where melting of inhomogeneous amphibolitic source rocks resulted in emplacement of plutons at depths of more than 20 km.

**The effects of metamorphism upon the Fournier oceanic fragment, New Brunswick**

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The Fournier oceanic fragment comprises a predominantly basic igneous suite with minor trondhjemite. All lithologies associated with the complex are metamorphosed. The lowest exposed unit is gabbroic (cpx + plag) that has been statically metamorphosed to greenschist facies. Locally, relatively high-grade (sheared igneous through to amphibolite facies) shear zones occur in the gabbros. At some localities, trondhjemitic (plag + Qtz ± allanite) dykes and sills are also affected by shearing, but in some places cross-cut and post-date the shear zones. These trondhjemitic pods, when not affected by the shear zones, have been statically metamorphosed along with their host gabbros. Mafic dykes that cross-cut both the trondhjemites and

the gabbros have been metamorphosed to greenschist facies. Pillow lavas display mineralogies consistent with lower greenschist and sub-greenschist facies metamorphism.

With the exception of the shear zones, the metamorphic gradient could be attributed to the effects of hydrothermal metamorphism at a spreading centre. The field relationships suggest that the emplacement of the acidic rocks took place during and just after intrusion and deformation of the host basic rocks, presumably in close proximity to a magma source. It therefore appears that the lithologies of the Fournier oceanic fragment predominantly document syn-magmatic deformation and metamorphism and not post-emplacement regional overprinting.

**Tectonic significance of Ordovician basalts in the St. Croix Terrane, coastal Maine and New Brunswick**

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The St. Croix Terrane of coastal Maine and adjacent New Brunswick is characterized by Ordovician carbonaceous pelites

that are locally interbedded with mafic volcanic rocks. These mafic rocks are moderately to highly evolved basalts (Mg'

ranging from 54 to 41) that have trace-element abundances similar to intraplate tholeiites. Their La/Nb ratios of 1.3 to 1.9 and absolute REE concentrations of 30 times chondrite in the more evolved basalts are features common to many continental flood basalts. The lack of depletion in high field-strength elements relative to MORB readily distinguishes them from island-arc tholeiites.

Deposition of carbonaceous pelites coincided with the widespread development of back-arc basins along the southeastern margin of an early Paleozoic ocean. The trace-element and REE patterns from basalts interbedded with pelites of the St. Croix Terrane suggest eruption into an aborted marginal ensialic basin remote from the influence of any consuming plate margin.

#### **Arsenic and mercury in tailings, Oldham Gold District, Nova Scotia**

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The mercury content of the tailings in the Oldham Gold District is high and consistent at 4 ppm on average and commonly greater than 10 ppm. Mercury distribution is controlled by (a) grain size (finer tailings are more Hg-rich), (b) Au grade (tailings associated with higher grade areas are more Hg-rich), and (c) the amount of fine-grained organic matter (more organic rich samples tend to be more Hg-rich).

Arsenic concentration and distribution are controlled by arsenopyrite distribution. Redistribution into the fine organic or clay fraction is less important than for Hg.

The groundwater has anomalous concentrations of As, Fe, and Mn, but little free Hg. The tailings contribute enough As to Black Brook to increase downstream concentrations beyond safe

limits; however, the tailings buffer the acid surface drainage entering the tailing from upstream.

Vegetation is composed of genotypes of common species capable of tolerating high concentrations of both As and Hg. Aquatic species accumulate high concentrations of both metals, which may reflect both active metal uptake and passive absorption of As and Hg onto their surfaces.

As and Hg concentrations have little influence on the distribution of tailings plant communities. Depth to water table and the thickness of the surface organic layer are the most important physical features affecting the distribution of the seven plant communities found on the tailings site.

#### **Economic geology and development of the Jubilee Pb-Zn Deposit, Cape Breton Island, Nova Scotia**

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Adits were driven in the early 1930's and 115 exploration holes totalling over 12,000 m were drilled by nine different operators from 1937 to 1979 near the Jubilee showing on Cape Breton Island. Probable reserves of 500,000 t >6% Zn-Pb mineralization occur in thin basal Windsor limestone beneath thick evaporites. The host limestone breccia is better developed, thicker, and more mineralized in a narrow zone parallel to the

Jubilee Fault. This growth fault has controlled local sedimentation as well as a fluid migration history. A model of ore formation associated with growth faults over thick Horton clastics opens much of the Horton/Windsor surface for potential mineralization. Post-ore karst controls the present geomorphology and the distribution of the gypsum being mined above the deposit.

Ore minerals are sphalerite and galena. Though Ag is cited

in reports on the deposit, no assays have shown detectable silver. Chalcopyrite is common in the footwall clastics but only in trace amounts. The paragenetic sequence is pyrite-sphalerite-galena-barite with calcite throughout. Hydrocarbons are common in present-day porosity and in ore-stage solid and fluid inclusions.

Despite adits driven on the property underground assessment has been inadequate. Possible extensions to known mineralization are untested and continuity of tonnage and grade would require infill drilling.

### **Silicate control of Noble Metal behaviour during magma evolution: evidence from ODP LEG 115 hot-spot basalts**

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Suites of variably evolved tholeiitic basalts were recovered from four sunken oceanic islands along the Reunion hot-spot trace during Ocean Drilling Program (ODP) Leg 115 in the Indian Ocean. Comagmatic suites of rocks show that noble metal abundances (Au, Pd, Pt, Rh, Ru, Ir) decrease with magma evolution. The compatible-element behaviour may be related to precipitation of chromite, Ir-Os-based alloys, sulphides, and/or silicates in some combination but the simplest explanation is that silicates controlled behaviour of the platinum group elements

(PGE = Pt, Pd, Rh, Ru, Ir). Partitioning coefficients for precipitating silicate phases were numerically derived from the noble metal data assuming Rayleigh fractionation. The partitioning coefficient estimates suggest that olivine has an affinity for Ir, Rh and Ru and can fractionate these metals from Pt and Pd. Clinopyroxene displays an affinity for all the metals but cannot fractionate the PGE. Plagioclase has little affinity for the PGE. Gold concentrations show no relationship with the percentage of silicates precipitated during magma evolution.

### **The wanderings of *Donsexinis* Stach, 1957, alias *Densosporites* S.W. & B., 1944 in the North Atlantic Ocean: a forensic geology investigation**

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*Donsexinis* Stach, 1957 refers to an "Anschliff" (polished section) microspore exine present in Carboniferous coals, but occurs also in coals of Early Cretaceous age. This has caused stratigraphic confusion and provenance complications and has led to the writing of this paper as a geological detective story.

This story involves tracing the provenance of ocean bottom sediments from properties of contained detrital particles of coal. These include maceral composition, coal rank as determined by vitrinite reflectance and palynological age determinations.

Material from three localities in the North Atlantic Ocean are

discussed. One locality, located 760 km east of Bermuda contains Carboniferous coal debris that can be traced to the Sydney coalfield of Nova Scotia. Of the other two, one is from the Labrador Sea and the other is from Davis Strait. Both contain Early Cretaceous coaly particles that likely were derived from onshore coal deposits in northern Baffin Island.

From the provenance determinations, conclusions regarding turbidity flow and paleocurrent direction of Arctic waters can be drawn.

### **The mineralogy, petrology and geochemistry of the Halfway Cove-Queensport Pluton, Nova Scotia, Canada**

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The Halfway Cove-Queensport pluton (HCQP) of eastern Nova Scotia is a moderately deformed, post-Acadian granitoid intrusion that was emplaced into Meguma Group metasedimentary rocks by passive stopping, with some degree of forceful

emplacement. Deformation features (C-S fabrics) occur in the northern and southern parts of the body. The peraluminous pluton is composed primarily of monzogranite with minor granodiorite. Five rock units are recognized by textural and minera-



logical characteristics (HCQP1, HCQP1A, HCQP2, HCQP3, HCQP4). There are minor late-stage intrusions of aplite, pegmatite and leucogranite.

All rocks, except the late-stage intrusions, contain quartz, alkali feldspar, plagioclase, muscovite and biotite. Garnet and apatite occur in trace amounts. Cordierite is not present, contrasting with other peraluminous granitoid bodies of the Meguma Zone where cordierite is common. The presence of garnet and muscovite, both of presumed magmatic origin, constrains the pressure of crystallization to between 3 and 4 kbars (10.5-14 km).

Major element compositions resemble those of other granitoid plutons of central and eastern Nova Scotia, with lower FeO, TiO<sub>2</sub> and higher Al<sub>2</sub>O<sub>3</sub>, F<sub>2</sub>O<sub>3</sub> and normative corundum than the

South Mountain Batholith (SMB). The least evolved units of the HCQP, however, are chemically more similar to rocks of the SMB. A well-defined chemical break between the two least evolved units (HCQP1 and HCQP1A) and the three more evolved units (HCQP2, HCQP3 and HCQP4) suggests that processes such as fractional crystallization, assimilation and melting of heterogeneous sources may have contributed to the overall chemical variation in the HCQP. REE patterns of unit HCQP1 resemble granodiorite patterns of the SMB, but patterns of units HCQP2 and HCQP4 are different from both HCQP1 and the SMB. Field, petrographic and geochemical characteristics suggest that the economic potential of the HCQP is limited.

### **The Mackenzie Delta - Beaufort Shelf depositional system**

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The Mackenzie Delta presently provides the largest supply of sediment to the eastern Beaufort Shelf. This sediment is transported offshore and eastward in a storm-dominated shelf regime. The modern delta is the latest stage in a complex series of delta progradation and transgression events that has partially infilled the Mackenzie Trough since the last glaciation. Based on coastline retreat measurements and seismic interpretation, the modern delta presently appears to be undergoing transgression. As a consequence, the prodelta region is extremely flat-lying. A distinctive sequence of storm-influenced facies characterizes this region. In water depths of 5 m or less, graded silt and sand

beds predominate and exhibit a range of primary sedimentary structures including wave ripple cross-lamination, lenticular and flaser-bedding, and mud-clast gravel beds. The proportion of silt and sand decreases rapidly with water depth and the sequence is dominated by bioturbated silty clay with thin graded silt beds. The coastline east of the delta is characterised by extensive subtidal and intertidal mud and sand flats. Cores through a now submerged mud bank show wave and current structures similar to the prodelta region, as well as evidence for emergence, including oxidation and possible freeze-thaw related secondary structures.

### **Lithochemical variation in the granodiorite and biotite monzogranite of the South Mountain Batholith, Nova Scotia**

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The South Mountain Batholith is a large composite intrusion consisting of several leucomonzogranite - leucogranite (biotite-muscovite-bearing) plutons intruding an envelope of predominantly biotite monzogranite-granodiorite (biotite only). The similar textural and modal mineralogy of the envelope rocks makes separation of these plutons difficult. Thus, a detailed geochemical study was undertaken to assess the elemental variations within the granitic rocks of the envelope.

Contouring of geochemical data indicates previously unrecognized systematic chemical variations within the envelope rocks. Using the observed geochemical variations and known geological boundaries the data have been grouped geographically. Final groupings are based on both absolute contents and variation trends, the latter of which reflect (i) normally zoned (relatively mafic borders), (ii) reversely zoned and (iii) unzoned areas. The distinction of these groups has facilitated the interpretation and modification of geological boundaries previously

based on bedrock mapping. We consider these groups to represent separate intrusive suites.

Binary plots of the geochemical data and normative mineralogy collectively indicate single uniform trends with variable intragroup ranges for the respective x and y parameters. This systematic behavior of the data suggests that all the chemical variation can be explained in terms of crystal fractionation of the observed mineral phases. However, statistical treatment of the data using discriminant function analysis shows that near perfect separation of the groups exists. This indicates the existence of distinct chemical differences among the groups that are not recognized using conventional Harker-type diagrams.

Preliminary interpretation of the data suggests that the envelope rocks consist of discrete intrusive suites which have geochemically distinct signatures. More speculative is the fact that the geochemical distinctions among the groups may ultimately be reflecting different source regions.

### A gravity profile across the Cumberland Basin

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A north-south gravity profile was constructed approximately perpendicular to the main axis of the Cumberland Sedimentary Basin in northern Nova Scotia. The profile has been extended to the north coast of Prince Edward Island to include the gravity effect of both margins of the basin. The profile was extended to the south coast of Nova Scotia to assess the gravity contribution of the older rocks in the Cobequids and the sedimentary basins

south of the Cobequids.

Rock densities have been measured for some of the Carboniferous rocks using borehole cores. Other density contrasts have been assumed from previous interpretations for evaporites and basement rocks. Simplified models are presented to account for the observed gravity anomalies.

### Fluid inclusion studies of quartz vein polytypes from the Beaver Dam and Caribou Gold Deposits, Meguma Zone, Nova Scotia; Evidence for a single vein-forming event

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There have been numerous theories advanced for the genesis of the auriferous quartz veins hosted by the Lower Paleozoic Meguma Group of southern Nova Scotia. In almost all models the veins have been considered to represent multiple episodes of vein injection that collectively lasted for considerable time because of the highly variable states of strain presently observed (e.g., early folded bedding parallel vein versus late ac vein). We have interpreted the veins as representing a single hydrothermal event, the consequence of fluid penetration into a subvertical shear regime at ca. 370 Ma; the differential states of strain within individual quartz veins merely reflect relative timing of vein formation (i.e., highly strained early versus low strain late). One way to test this "single-vein forming event" model is to examine the nature of the vein-forming fluid as preserved in fluid inclusions - a single population of fluid inclusions would at least corroborate the model suggested.

Petrographic examination and thermometric measurements (approx. 2000 to date) of fluid inclusions from quartz and carbonate material from all vein types (bp, ac, en echelon, bull-crosscutting) in the Beaver Dam and Caribou deposits reveals very uniform features for all samples. The dominant fluid inclusion type consists of a mixed  $H_2O-CO_2-CH_4$  brine with a uniform composition of  $XCO_2 = 0.10 \pm 0.5$ ,  $XCH_4 < 0.05$  and wt.% equivalent NaCl < 10. The minor but persistent presence of

vapor-rich  $CO_2$  inclusions and low salinity (i.e., <10 wt.% equiv. NaCl) aqueous-type inclusions is interpreted to indicate that incipient unmixing occurred during vein formation of both deposits. The only difference noted in thermometric data for the two areas is in final  $T_b$ , which is  $300 \pm 20^\circ C$  for Beaver Dam and  $275 \pm 10^\circ C$  for Caribou.

Analyses of leachates (N - 18) from ultrapure quartz separates from all vein types at the Beaver Dam deposit give exceptionally uniform results (cationic concentrations: Na- $0.511 \pm 0.49$ , Ca- $0.255 \pm 0.108$ , K- $0.021 \pm 0.004$ , Mg- $0.0058 \pm 0.0034$ , Fe- $0.0009 \pm 0.0002$ ). These data are consistent with the fluid inclusion observations noted above which indicate the presence of a single fluid inclusion population and, hence, a common fluid chemistry.

The fluid inclusion data for the two deposits are interpreted to indicate that all vein types formed from a single, homogeneous fluid which was focused into structurally favourable sites during one hydrothermal event. The variability of inclusions reflects incipient unmixing of this  $H_2O-CO_2-CH_4$  fluid as a result of P and T changes. The data do not support models invoking multiple generations of veins related to different fluids. An important extension of this study is that auriferous versus barren veins apparently have the same fluid inclusion population.

### Rare-earth-element variability in gangue mineralogy of Meguma-hosted auriferous quartz veins, Nova Scotia: possible consequence of unmixing of $H_2O-CO_2-NaCl-CH_4$ fluids

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Auriferous quartz veins in the metaturbiditic Lower Paleozoic Meguma Group of southern Nova Scotia contain a diverse assemblage of gangue minerals. For example, in addition to quartz, native gold and sulphides there occurs plag, Kf, tour, carb, chl, bt, ms, gar, apatite, amph, epdt, sch and andalusite, albeit in highly variable quantities. Paragenetically an early stage of Ca-

rich plag ( $An_{30-70}$ )-tour ( $sch_{50}$ - $drv_{50}$ )-bt ( $mg-0.50 \pm 0.05$ )-gar  $\pm$  sulphides is overprinted by a later hypogene assemblage of albms-chl-sph-carb-sch  $\pm$  sulphides ( $\pm Au$ ). Stage 1 is constrained by garnet-biotite geothermometry at ca.  $475^\circ C$ , while the latter stage is considered to have formed at  $300 \pm 50^\circ C$  (O isotopes, fluid inclusions). Fluid inclusion studies indicate the vein-forming

fluid was a mixed  $H_2O-CO_2-CH_4$  ( $XC_{O_2}-0.10\pm 0.05$ ) brine with 4.6 wt.% equivalent NaCl (+Ca, K, Fe, Mg). Evidence of fluid unmixing is present in most specimens examined.

We have analyzed plag, chl, bt, apatite and carb from quartz veins in a variety of gold deposits for trace elements, including the REE's. Although major element chemistry of the minerals is remarkably uniform within a deposit, the trace- and RE-element chemistry is highly variable. For example, chondrite-normalized REE profiles (CNRP) for plag and chl from Beaver Dam show a 100 fold range with fractionation ( $(La/Lu)_N$  minor (5-2) for plag but extreme (50-5) for chl. Normalized values of other trace elements (Rb, Sr, Ba, Li, Pb, Y, Li, Ca) show <10 fold maximum variation that does not correlate with the CNRP's. Similarly, a large variation in CNRP's for carb from 9 deposits is observed with variable fractionation ( $(La/Lu)_N = <1>$ ) and chondritic abundances (>10x) within and between deposits. Again, other trace elements do not show obvious correlations. However, we do note that coexisting vein phases (e.g., bt-plag) give comparable CNRP's indicating that locally equilibrium conditions prevailed between mineral phases and that the fluid was of uniform composition with respect to the REE's.

The CNRP's for the vein minerals contrast markedly with the shale-like CNRP for the Maguma Group host rocks, which

remain constant regardless of intensity of alteration types (e.g., sulphide, phyllic, silicification). This variation of CNRP's between wall rock and vein minerals contrasts with what is generally observed in granite-hosted vein mineralization. For example, vein (alb, triplite, clay) and greisen (ms) minerals at the East Kemptville tin deposit mimic closely the CNRP of the host leucogranite.

Possible explanations for the observed variability of the CNRP's of the gangue minerals in the gold veins include: (1) variable mixing of two (or more) fluids with contrasting absolute REE contents; (2) variable contamination of wall rock by a single, homogeneous (with respect to REE's) fluid; and (3) unmixing of the ore-forming fluid due to  $H_2O-CO_2$  immiscibility. The third possibility is considered the most viable considering the known temperature constraints for the mineral paragenesis, uniform isotopic (O, C, S) compositions of vein minerals, fluid inclusion thermometric measurements and leachate analyses, and constant CNRP's for fresh and altered wall rocks. In addition, the experimental and empirical observations that LREE's and HREE's are preferentially partitioned by Cl and  $CO_2$  complexes, respectively, would be consistent with the observations noted above.

### Silurian-Devonian transcurrent movement deformation in the Canadian Appalachians

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Recent field work and radiometric dating has added considerably to our understanding of the Acadian orogeny. The Acadian orogeny can be divided into three major deformation events, i.e., low angle thrusting followed by regional folding and transcurrent movement. This paper focuses on the last deformation event which can be correlated across the Canadian Appalachians.

In Notre Dame Bay, north-central Newfoundland, regional structures are associated with east-west trending dextral movement zones. The late movement zones overprint late Llandoverly conglomerates and are overprinted by Late Silurian intrusions of

the Loon Bay Suite. Southwest Newfoundland is also deformed by several generations of movement zones ranging in age from the Early Silurian to the Early Devonian. In northern New Brunswick and in the Gaspé Peninsula, upright large scale regional folds in the Silurian Chaleurs Group are transected by a regional cleavage associated with east-northeast post-Late Silurian dextral transcurrent movement.

It can be concluded that dextral transcurrent movement zones as early as Silurian were active during the Acadian orogeny.

### Digital terrain model for Cape Breton Island, Nova Scotia

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The growth of digital data banks and the development of new techniques for processing and analysis of field measurements are revolutionizing the interpretation of geoscience information. A variety of data sets are now available, but the most important data on topography are still elusive and difficult to obtain.

Digital Terrain Models (DTM) can be constructed using high resolution satellite imagery (e.g., collected from French satellite SPOT) or by digitizing existing topographic maps. The first approach can produce excellent grids with a horizontal

accuracy of few tens of metres and a vertical resolution of one metre or better. Unfortunately, the cost of this approach is high and not readily available to academic researchers.

We describe a method of digitizing published topographic maps that is practical and applicable on any scale. The method was applied to Cape Breton Island and a DTM at 250 m grid spacing was produced following these steps: (i) Contours on published maps at 1:250,000 scale were enhanced by tracing and the spacing was equalized by thinning out some contours in areas

of high topographic relief and by adding point values in flat areas; (ii) The contours were digitized using AUTOCAD (TM) and the data was plotted as a contour map at the same scale as the original topographic sheets to check for the accuracy of digitizing; (iii) The resulting digital data file was converted from PC to uVAX computer; (iv) This raw data file was converted from PC to interpolation using a Minimum Curvature algorithm; (v) The grid was plotted as a coloured relief map and data was edited if any discrepancies were discovered. At this scale, the Cape Breton example (4 topo sheets) took about three weeks.

The method produces a generalized DTM that can be used at scales of 1:500,000 or smaller, for a general representation of topography and for correction of gravity and magnetic surveys. The accuracy of the method was evaluated by comparison with a file of gravity stations which contained accurate elevation data over a vertical range of 600 m. There was no systematic discrepancy between the gravity station and the nearest grid location elevations. The overall agreement between the two sets was within  $\pm 50$  m. As would be expected, the larger differences were in the areas of greater relief.

### Gold enrichment in the South Mountain Batholith, Nova Scotia

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Elevated values of gold (89 ppb - 10.94 ppm) are reported from seven locations within the South Mountain Batholith of southwestern Nova Scotia. These include: 525 ppb Au in a pyrite-arsenopyrite bearing quartz-greisen vein system at Sandwich Point; 89 ppb Au in a silicified (quartz and amethyst) and brecciated pyrite-bearing fault zone from Roachs Pond; 2010 ppb Au in an arsenopyrite-pyrite bearing quartz vein/albite zone near Upper New Cornwall; 525 ppb Au in a wolframite-scheelite-chalcopryrite-molybdenite (+ unidentified bismuth mineral)-bearing quartz vein from Big Indian Lake; 690 ppb Au from a quartz-muscovite-tourmaline-molybdenite-bearing greisen zone at Inglisville; 2035 ppb Au in a chalcopryrite-galena-sphalerite-pyrite-arsenopyrite-bearing quartz vein from a fault zone near Little Tobeatic Lake; and 10.94 ppm Au from a K-feldspathized granite porphyry near Westfield. This enrichment

in Au is significant when compared to either the 'Clarke Index-I' value for crustal rocks (4 ppb Au) or the relatively unaltered rocks of the SMB (av. 5.9 ppb Au, N-422).

All occurrences except Roachs Pond are proximal to a granite-metasediment contact and have associated metasomatic alteration (e.g., greisenization, albitization). A model is proposed in which granitic rocks are the source of heat, aqueous fluids and 'granophile' elements (e.g., F, B, W, Sn, Mo, Cu, Pb, Zn,  $\pm$  Au, Ag). Meguma Group metasediments and underlying basement rocks provide aqueous fluids and Au, Ag, As, Cu, Pb, Zn, Bi and Sb. The contact acts as an impermeable cap, thus providing a locus for fluids and deposition of polymetallic minerals. The Au enrichment in the Roachs Pond fault zone is associated with successive periods of silicification and brecciation and may represent another mode of occurrence.

### Shoreline model for the lacustrine Horton Bluff Formation: implications of wave attenuation, oscillatory groove casts and sediment-starved hummocky cross-stratification

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The Lower Carboniferous (Tournaisian) Horton Bluff Formation was deposited in a tectonically subsiding basin with a major bounding fault (Cobequid Fault precursor) to the north and onlapping relationships to the south. Excellent exposure of the middle and upper members along the basin axis reveals repeated coarsening- and shallowing-upward cycles within a hydrologically open lacustrine system. An ideal cycle contains four facies from base to top: (1) grey clayshale (deep lake); (2) alternating clayshale/wavy-bedded siltstone and sandstone (lake shoreline), with three subfacies (2a) lenticular hummocky cross-stratified siltstone (sediment-starved, transitional zone), (2b) wave-rippled sandstone (shoaling wave zone), and (2c) planar-laminated siltstone (attenuated wave zone); (3) green rooted mudstone (swamp); and (4) tabular and nodular dolomite (early diagenetic

subaqueous and pedogenic horizons).

These sediments were deposited on a gently sloping shoreline where wave attenuation over the wave-rippled shoals (2b) deposited planar-laminated siltstone (2c) from suspension in very shallow water, and facilitated the gradational transition to the swamp environment (3). These shoreline deposits lack beaches, and differ from most modern deposits of glaciated regions where till-cliff erosion supplies sediment locally. Groove, prod, and gutter casts within the hummocky cross-stratified zone (2a) were produced by oscillatory, not unidirectional flows. This means care must be taken when using these structures in sediment transport studies, or as indicators of unidirectional currents associated with hummocky cross stratification.

### Are the Bathurst Camp massive sulphide deposits sediment hosted?

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The New Brunswick No. 6 Pb-Zn deposit lies within the Ordovician Tetagouche Group of Northern New Brunswick. This deposit is underlain by "augen schists" and "chlorite schist" that generally have been interpreted as pyroclastic rocks and chemical sediments (or stockwork alteration), respectively. Lithochemistry shows that the "quartz-feldspar augen schist" is compositionally uniform and comparable to average rhyolites in its SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, CaO and K<sub>2</sub>O contents. Total iron (as Fe<sub>2</sub>O<sub>3</sub>) and MgO are high whereas Na<sub>2</sub>O is low by an order of magnitude, compared to average rhyolites. However, the "quartz augen schist" and "chlorite schist" are compositionally variable

but similar to average sandstones (wackes) and average mudrocks, respectively, particularly in their SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O and K<sub>2</sub>O contents. In short, the No. 6 deposit is underlain by a fining upward epiclastic sequence that is capped by mudstone and underlain by a quartz-feldspar porphyritic volcanic unit, either an ash-flow tuff of low-explosivity origin or a lava flow.

Similar schists are associated with other base-metal deposits in the Bathurst camp, and at one deposit "chlorite schist" contains highly deformed pelecypods. In the absence of fossils, lithochemistry provides a way to identify the sedimentary parts of the stratigraphic pile.

### Seismic profiling investigation of a small area North of Sable Island, Scotian Shelf

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It has become increasingly obvious that the Quaternary seabed geology of glaciated shelf seas is complex. An illustration of this is found in an area at the west end of the Gully, north of Sable Island, Scotian Shelf where a profiling grid at 1 km spacing was run over an area 9 km by 17 km, with Nova Scotia Research Foundation deep-tow and surface-tow seismic equipment de-

ployed from CSS Dawson. The results illustrate the importance of the simultaneous use of seismic systems operating at different acoustic frequencies. Broad relationships are defined among the sediment units - Scotian Shelf Drift, Sable Island Sand and Gravel and Emerald Silt (A and B) - but details remain too fine to be resolved by the 1 km line spacing.

### Fossil Coleoptera studies of Late-Glacial sites in Nova Scotia

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Recent palynological studies of late-glacial sites in Nova Scotia and New Brunswick have indicated a "cold" event between 11,000 and 10,000 years B.P. equivalent to the younger Dryas recognized in Europe. Some sites investigated for pollen content are organic-rich peats and sands suitable for paleontological analysis.

Preliminary studies at two Nova Scotia sites, Lismore (11,900 - 10,500 years B.P.) and Collins Pond (12,700 - 11,800 years B.P.) have yielded fossil Coleoptera (beetle) fragments. Bottom samples from Lismore contain a small beetle fauna. Bottom samples from Collins Pond are almost devoid of beetle fragments, likely resulting from poor preservation. Both sites, along with several yet to be sampled, span the period of the younger

Dryas equivalent recognized in pollen profiles. Beetle faunas from Lismore suggest that shortly after 12,000 years ago conditions were similar to that in the present boreal forest. Species like *Acidota* cf. *quadrata*, *Olophrum consimile*, *O. rotundicolle*, *Tachinus* cf. *tachyporoides*, and *Eocnecosum* are transcontinental, boreal insects. Their presence suggests climatic conditions cooler than present, probably more similar to the southern to middle boreal forest.

Little work has been done on fossil beetles from Atlantic Canada and further research may provide interesting comparisons with more extensive work carried out in the mid-continent over the past two decades.

### Postglacial Walrus from the Bay of Fundy

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New records for postglacial walrus, *Odobenus rosmarus*, from the Bay of Fundy and northern New Brunswick raise the number of documented specimens in the province to nine. Eight specimens are represented by partial skulls or tusks while the other is an almost complete skeleton. The most recent finds, two partial skulls, were dredged from the Bay of Fundy on separate occasions. Both specimens were recovered southeast of Saint John.

Walrus form part of a small Quaternary marine mammal

fauna in New Brunswick that also includes narwhal, beluga (?), minke (?) whale and harp (?) seal. Only the minke whale's present range overlaps with its fossil distribution. Recent accidental occurrences of beluga, walrus and harp seal are known from the Bay of Fundy.

Sea-surface paleotemperatures, determined from studies of littoral marine invertebrates agree well with ecological requirements of the fossil mammal fauna.

### Geochemistry of the Siluro-Devonian mafic volcanic rocks and associated gabbroic intrusions, Upsalquitch Forks area, New Brunswick

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The Upsalquitch Forks area is underlain by a sequence of marine siltstones, conglomerates, and limestones with associated mafic volcanic rocks of Silurian and/or Devonian age to the south of the Rocky Brook-Millstream Fault, and a bimodal volcanic suite also of Siluro-Devonian age, with interlayered grey micaceous siltstones to the north of the fault. Intruded throughout this area are numerous plutons and dykes of gabbroic composition.

Mafic volcanic rocks are massive in nature, generally displaying a pilotaxitic groundmass (<1 mm in grain size) consisting of feldspar, quartz, pyroxene, epidote and calcite. Primary phenocrysts of pyroxene, commonly sector zoned, and plagioclase are present. The gabbroic intrusions consist of medium-to coarse-grained (2 mm-4 mm), intergranular to sub-ophitic groundmass of albitic plagioclase with pyroxene of subcalcic augite to

augite composition. Hornblende and potassium feldspar occur in many plutons throughout the area. Mafic xenoliths are present locally and also consist of gabbro, suggesting a multiple-pulse intrusive history.

Mineral assemblages in mafic rocks of the Upsalquitch Forks area (albitized plagioclase, epidote, chlorite, serpentine and pumpellyite) are indicative of prehnite-pumpellyite to lower greenschist regional facies. Localized contact metamorphism next to the gabbroic intrusions is evident.

Major-element and trace-element geochemistry indicate that the mafic volcanic and intrusive rocks are of tholeiitic affinity, formed in a within-plate environment. Pyroxene geochemistry supports the hypothesis of a within-plate tectonic environment for both the volcanic and intrusive rocks.

### Controls on basin-fill patterns within the Stellarton Basin, Nova Scotia

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The Stellarton Basin is a 6 by 18 km rhomb graben located between the Hollow and Cobequid faults in central northern Nova Scotia. From the Westphalian B through D, over 2600 m of red and grey coal-bearing strata (the Stellarton Formation) were deposited as the graben opened. Basin-fill patterns within the Stellarton Basin varied largely in response to several interrelated factors, specifically: changes in the rate of tectonic subsidence, water levels, and regional versus local sediment supply. When subsidence rates and water levels within the basin were low, lakes developed near the basin center. These lakes were

completely infilled by delta deposits that had a predominantly regional source area. When sediment supply became restricted, and subsidence rates remained low, poorly drained swamps and thick peat mires formed at the basin center. During periods when subsidence rates were high, water levels remained high and a lake was maintained over much of the basin floor. Delta deposits partly infilled this lake when sediment supply rate from regional sources was high. When regionally sourced sediment supply became restricted, swamp and mire deposits developed on abandoned delta plains near basin margins.

## A new ichnogenus (*Compaginatichnus*) from the Late Ordovician Matapédia Group of northern New Brunswick

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The Matapédia Group of northern New Brunswick is essentially Late Ordovician in age and consists of a sequence of thinly interbedded (1 to 5 cm) calcareous argillites and argillaceous calcitic and ankeritic limestones interpreted to have been deposited in a deep-water slope environment. Although poorly fossiliferous, the sequence does contain a relatively abundant but low diversity ichnoassemblage dominated by *Chondrites* von Sternberg, 1833, *Planolites* Nicholson, 1873 and *Helminthopsis* Heer, 1877. Opposite the village of Runnymede, 500 m north of the confluence of the Upsalquitch and Restigouche rivers, 7 km south of Matapédia on the northwestern New Brunswick-eastern Quebec border, the Matapédia Group contains abundant examples of a distinctive trace fossil which cannot be accommodated within any existing ichnogenus. *Compaginatichnus forbesi* n. ichnogen. and ichnosp. is the name proposed for this new trace fossil.

The traces consist of horizontal, unlined, unbranched, straight to curved to meandering burrows, which are deeper than wide and possess an upper-segmented fill articulated by meniscus-shaped partings and a lower unsegmented fill with densely

packed fecal pellets. Simple meniscate burrows are now commonly referred to *Taenidium* Heer, 1877 though a number of alternatives are still in common usage. Simple pellet-filled burrows are referred to *Syncoprulus* Richter and Richter, 1937 or *Alcyniodiopsis* Massalongo, 1856. Pellet-lined burrows are included within *Granularia* Pomel, 1849 or *Ophiomorpha* Lundgren, 1891. *Compaginatichnus* clearly differs from all these ichnogenera as it combines both a meniscate - and a fecal-fill but does not possess pellet-linings. The consistent superposition of a meniscate backfill over the fecal pellets is obligate and such a combination is regarded as a significant and integral portion of the burrow systems.

Electron microprobe (JEOL 733) energy dispersive spectra of the meniscate and intermeniscate portions of the burrows suggest that the menisci resulted from physical sorting of carbonate-rich and aluminosilicate-rich sediment as the producing organism (?annelid) progressed through the sediment. This contrasts to recent suggestions that most menisci in morphologically similar burrows result from active packing of material that is entirely fecal.

## Why Laurentide ice indicators are absent in the Baie Des Chaleurs region, northern New Brunswick

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Mapping of surficial deposits and glacial features in northern New Brunswick was initiated by Robert Chalmers in the late 1800's. Since then, several attempts have been made to unravel the glacial history of this area. Chalmers' original ideas were resurrected and adapted to presently accepted theories and models of glacial processes and isostatic rebound. "Erosion stratigraphy" has been used because of the lack of stratigraphic sections and the abundance of glacial erosional features. This information is supplemented by clast provenance studies and fabric trend analysis. Results of detailed mapping reveal four glacial events. Dating of these events is a problem because of the lack of dateable materials. An early southeastward flow is recognized in the

eastern part of the area and the Chaleur coastal plain. A secondary, strongly erosive, iceflow was in an easterly direction, and might have been of importance throughout the Wisconsinan and possibly throughout the Pleistocene. A third flow, supported by striae and abundant fabric trends indicates a northeastward flow into Baie des Chaleurs. A late-stage local flow took place in several directions off the highlands and possibly out of the Baie des Chaleurs. An attempt is made to place these events in a regional context, in which the interaction of Laurentide ice with Appalachian ice and the concept of the Laurential Channel as an ice-stream channel are evaluated, and to explain the absence of Canadian Shield erratics in the Baie des Chaleurs region.

## Deformation in the Denison Potacan Sylvinitic Ore Body, Clover Hill, New Brunswick

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The sylvinitic ore body mined at the Clover Hill mine near Sussex, New Brunswick is part of the Windsor Group (Cassidy Lake Formation) of the Moncton sub-basin. The sylvinitic is situated close to the NE-SW-trending Clover Hill Fault within a

pillow shaped salt body that has undergone strong internal folding. Lithologies above and below the salt pillow are relatively undeformed, being only mildly warped and fractured by minor faults and joints. The Clover Hill Fault was active prior to

the Carboniferous and again subsequent to the deposition of the Hopewell Formation and has undoubtedly played an important role in the structural development of the basin.

From underground studies it is apparent that southeasterly directed movement occurred across the top of the evaporite body in post-Mississippian times. This resulted in drag fold development within the sylvinitic, as exemplified by the predominantly SE vergence of the folding.

In the past, the Clover Hill Fault has been interpreted to be a high-angle reverse fault which, in itself, is not fully adequate to explain the structures observed underground. As well as the vertical displacement component along the main fault, southeast-

erly directed, top-over-bottom movement has also occurred within the lithologies of the Marchbank Syncline. From a regional viewpoint, the structure can be explained in three ways: (1) General thrusting towards the SE due to regional compression with the main Clover Hill Fault ramping up to the surface and splay décollement occurring across the top of the salt at depth. (2) Strike-slip along the Clover Hill Fault in a transpressional regime with associated sub-horizontal thrusts forming a local "flower" structure. (3) Listric décollement along the top of the salt associated with late extensional events (e.g., the opening of the Atlantic during the Triassic).

### **Stratigraphic variation of $\delta^{34}\text{S}$ compositions in the Meguma Group: implications for paleoenvironment and mineralization**

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The Cambro-Ordovician Meguma Group is composed of a basal sandy flysch (Goldenville Formation - 6000 m) and upper carbonaceous, pyrrhotitic, shaley flysch (Halifax Formation - 5000 m) separated by a Mn-rich, calcareous argillite transition zone. Anomalously heavy  $\delta^{34}\text{S}$  values ( $\text{Po}\pm\text{Py}$ ) in the Goldenville Formation vary from a low of +9% near the exposed base to a maximum of +34% at the top of the unit. Most values are between +15% - +25%. At the transition zone,  $\delta^{34}\text{S}(\text{Po})$  drops sharply to -5% in the Mn-rich calc-argillite, rises again to +20% in the basal part of the Halifax Formation and then decreases stratigraphically upwards to values in the range -9% to +2%, typical of the lower 700 m of the Halifax Formation.  $\delta^{34}\text{S}$  values of sulphide in slate in sandy flysch, and siltstone in shaley flysch are similar to values in the dominant lithology.

The data are interpreted to indicate deposition of rocks of the Goldenville Formation, and the basal Halifax Formation, in a reservoir closed with respect to seawater sulphate, and deposition of the Mn-argillite and most of the Halifax Formation in a ventilated sea open to seawater sulphate.

The occurrence of stratiform Zn-Pb and districts containing bedding-parallel Au veins [ $\delta^{34}\text{S}(\text{Apy}, \text{Po})=+9\text{to}+25\%$ ] in host rocks with anomalous  $\delta^{34}\text{S}$  indicate an association between seawater composition and mineral occurrence, and a marine sulphate source for S in associated sulphides. Reinterpretation of C/O isotopic data from the literature suggests that the vein components may have been mobilized by fluids generated during prograde greenschist facies metamorphism.

### **Oil shales of the Stellarton Basin, Nova Scotia, Canada: stratigraphy, composition, depositional environment and potential uses**

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The fault-bounded Stellarton Basin of northern Nova Scotia contains the Province's largest oil shale resources (825 x 10<sup>6</sup> bbls of shale oil *in situ*). The oil shales belong to the 2600 m thick coal-

bearing Stellarton Formation of Westphalian B-D age. A total of 60 oil shale beds, which are separated by sandstone, siltstone, claystone, and/or coal, occur within the formation. Individual



beds thicken and thin laterally, average 5 m thick (one bed is up to 35 m thick), and are laterally continuous over 3-5 km. Near basin margins some of the oil shale beds are vertically and laterally transitional to coal.

Three lithologies, all silicate-rich (principally illite, quartz), comprise the oil shale beds, namely, fissile shale, cannel shale (massive oil shale), and boghead shale (stellarite). Cannel shales accumulated at or near lake margins while fissile shale and boghead shale formed under open lacustrine conditions.

Average hydrocarbon yields of 25 litres per tonne (l/t) or less, 40 l/t and 110 l/t are obtained from fissile shale, cannel shale and boghead shale, respectively. Total organic carbon (TOC) contents of fissile shale average 5 wt.% and comprise algal debris and minor vitrinite and inertinite. Cannel shales are transitional to coal and contain up to 40 wt.% TOC rich in vitrinite and

inertinite. Boghead shales average 19 wt.% TOC mostly as telalginite. Combustion testing of cannel shale from one bed shows them to be comparable to some currently produced Western Canadian coal generating 7800 BTUs/lb. Testing of boghead shale from 4 different beds gave values of only 150-4500 BTUs/lb.

Hydrocarbon yields of the oil shales show them to have yields too low for direct utilization when compared to higher yielding, but undeveloped, oil shale elsewhere (e.g., Green River, Rundle, and Albert deposits). However, the ability to recognize distinct oil shale beds within sections separated by 3-5 km makes them useful for section correlation. The association of some oil shale beds with coal show them to be a useful guide for coal exploration as well.

### **Variation in drumlin orientation, form and stratigraphy relating to successive ice flows in southern and central Nova Scotia**

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A strong correspondence exists between striation and drumlin long axes trends in Nova Scotia. The variation in striation trends is largely due to successive ice-flow events, which inscribed many outcrops with sets of superimposed striations that can be correlated over broad areas of Nova Scotia. A type of drumlin, in the Nova Scotia fields is the "lobate" or "reoriented" drumlin, which is a form with two principal axes parallel to ice movements established by striations and dispersal of distinctive erratics. The internal structure of Nova Scotia drumlins is generally a layer cake of till sheets. The most common situation is a grey "core" till formed by a southeastward ice flow across grey metasedimentary bedrock and a distinctly red "mantle" till formed by phases of southward to southwestward ice flow.

Drumlins in the Yarmouth Field of southern Nova Scotia exhibit the greatest number of stacked units capped by a coarse-textured till that represents deposition by a late stage ice mass centered inland.

Nova Scotia drumlins appear to have a multi-phase origin. The first and major drumlin-forming ice-flow phase was south-eastward. Nucleating agents for initiation of these drumlins may have been preexisting tills or waterlain deposits. Individual and lobate drumlin axes imply a late, southward drumlin-forming ice-flow phase parallel to the inferred ice-flow trend for the mantle till units based on clast provenance. Some of these drumlins nucleated from preexisting southeast-trending forms.

### **A new interpretation of the relationship between the Long Point Group and the Humber Arm Allochthon, western Newfoundland: implications for timing and magnitude of overthrusting**

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The gross tectonic stratigraphy of the Humber Zone of western Newfoundland comprises two units. The upper unit, represented by the Humber Arm and Hare Bay allochthons, includes the Bay of Islands and Hare Bay ophiolites underlain by thrust sheets of sedimentary and volcanic rocks believed to represent rift, slope, and rise environments of the ancient Cambrian-Ordovician passive margin. The lower unit, traditionally considered to be autochthonous, is represented by a predominantly

carbonate shelf sequence unconformably overlying Grenvillian age crystalline basement.

The Middle Ordovician time of arrival and "emplacement" of the Humber Arm allochthon is constrained by the age of "flysch" with obvious ophiolite-derived detritus overlying the foundered shelf sequence. An absolute position for the allochthon at this time has been traditionally constrained by an interpreted unconformable relationship between it and the overlying

Late Ordovician Long Point Group which outcrops on Port au Port Peninsula.

Industry reflection seismic data gathered immediately offshore in 1973 clearly image the Long Point Group and the overlying Silurian-Devonian Clam Bank Formation as a west-facing homoclinal package that flattens to the west. The shelf sequence is also clearly identifiable as a relatively continuous package, possibly interrupted by short-throw steep faults, which dips to the east, unaffected by the homoclinal fold above. The wedge-shaped region above the platform and below the Long Point is occupied by the Humber Arm allochthon and probably also by a transported slice of platform rocks. This geometry is interpreted to be a "triangle zone," a feature very familiar to workers in the Alberta foothills and other foreland thrust-fold

belts, which is bounded above and below by thrusts of opposing vergence.

The significance of the structure is that the Long Point Group and Clam Bank Formation, in the hanging wall of the east-vergent roof thrust of the triangle zone, must pre-date the development of the zone. Therefore, the Humber Arm allochthon was emplaced in its present position during the Acadian orogeny. Furthermore, the probable inclusion of a slice of the platform within the triangle zone implies significant displacement (>30 km) at this time. The floor thrust of the triangle zone is suggested to extend eastward beneath not only the "autochthonous" platform, but also basement inliers to the north and south (Long Range, Indian Head Complex), implying that they, too, are allochthonous.

### Mechanisms for breccia formation in metaturbidites: implications for gold mineralization at Gordon Lake, Slave Province, Northwest Territories

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Brecciation phenomena are important within a variety of ore-forming environments. Recent studies (particularly within Archean greenstone belts) have focussed on shear-related breccias that are the result of attrition, crushing and implosion processes. The latter dilational breccias are the most favourable for ore formation (because of their greater size and potential for increased fluid/wallrock interaction), and are characterized by a jig-saw clast texture, minor clast alteration and rotation, and high matrix/clast ratios. These breccias resulted from offset jogs along a fault surface or modification of echelon vein systems. However, breccias are also present in metaturbidite terranes where it is difficult to relate them to a discrete shear zone or lineament; these are neither well documented or understood.

Structural mapping of lower greenschist metaturbidites of the Archean Burwash Formation at Gordon Lake (70 kms NE of

Yellowknife) has identified six quartz vein types and four quartz breccia types that are related to three deformational events. From an economic view point, the most important breccias (such as the Kidney Pond Zone 1 of approximately 100,000t grading 12-15g/t gold) appear as stratabound bodies hosted in a lithology of rapidly alternating black siltstones and wackes, and confined to a region of crenulation cleavage. Other breccia types include those that: (1) are aligned along fold axial traces, and (2) occur as erratic 'blow outs' hosted in massive wackes. A model is suggested for the formation of the stratabound breccia zones, whereby late metamorphic fluids were focussed into the central part of regional re-fold, and accompanying bedding-parallel shear induced repeated echelon veining and brecciation within black siltstone horizons.

### Geo-Database integration: Antigonish Highlands

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A multilayer geo-database, consisting of Landsat Thematic Mapper imagery, airborne vertical gradient magnetic and radiometric imagery, digitized bedrock and surficial geology maps, digitized lineaments and mineral occurrences, and radar images, was created over the Antigonish Highlands. The process involved transfer of data from both mini- and micro-computer based image analysis and geographic information systems. The final database residing on the SPANS system was used in various overlay modelling techniques to produce interpretive geologic maps. Specifically, the database was useful in extracting the

following geological information: (1) The detection of lineaments, their distribution, and intersection, (2) understanding the relationship between the occurrence of lineaments and mineralization, (3) delineation of anomalous circular features revealed by the enhancement and modelling of geophysical data, and (4) understanding the relationship between some lithological contacts and mineralization.

The above observations are useful in determining the probability of mineral occurrences in this area.

**Petrology of the Brookville Gneiss and Golden Grove Intrusive Suite,  
southern New Brunswick**

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The Aphebian(?) Brookville Gneiss, in the Saint John area, is characterized by a sequence of cordierite-biotite-K-feldspar migmatitic paragneiss, tonalitic orthogneiss and minor marble. These gneisses are in mylonitic faulted contact with low-grade marbles and quartzites of the Helikian(?) Green Head Group. Both units were intruded by a variety of granitoid plutons of the Golden Grove Intrusive Suite. Metamorphic grade in the Brookville Gneiss is relatively uniform, reaching upper amphibolite facies with garnet and muscovite absent, in contrast to the greenschist- facies metamorphism in rocks of the Green Head Group. The Brookville Gneiss is petrologically similar to low-pressure gneisses of the Bras d'Or Terrane in Cape Breton Island, which occur in faulted contact with carbonate-clastic rocks

similar to the Green Head Group.

The plutons of the Golden Grove Intrusive Suite east of the Saint John River consist of three dominant lithologies: (1) varied dioritic rocks ranging from quartz diorite to diorite and gabbro, (2) relatively homogeneous medium-grained granodiorite/quartz monzonite, which forms the largest intrusive body in the area, and (3) coarse-grained monzogranite/granodiorite characterized by megacrysts of K-feldspar. Medium- to coarse-grained clinopyroxene-hornblende gabbro spatially associated with the Golden Grove Intrusive Suite is inferred to be younger and possibly correlative with the platinoid-bearing Mechanic Settlement gabbro in the eastern Caledonian Highlands.

**Phosphorites, ironstones, and secondary phosphates in Mid-Cretaceous flysch of the  
Blow Trough, Northern Yukon**

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The Blow River Formation was deposited in the Blow Trough, a N-trending, middle Cretaceous downwarp near the junction of the Western Canada Seaway and the Amerasian Basin. At Rapid Creek, the Blow River Formation comprises a 380 m cyclic succession of thick, silty, siderite-phosphate pellet packstone and intraformational boulder-pebble conglomerate lenses interbedded with grey, laminated siltstone and sideritic siltstone. These rocks rest conformably on grey shale with thin ferruginous siltstone beds, and are overlain conformably by grey siltstone with chert pebbles and siderite concretions. To the west, the formation thickens dramatically, as the ironstone-bearing member interfingers with and overlies dark grey shales and thin sandstones. To the east, it thins, passing into 160 m or interbed-

ded shale and sideritic shale at Boundary Creek. Facies changes indicate a clastic source to the west. Early Albian ammonites and charcoal fragments are locally common. The widespread, Fe-P-rich, hemipelagic sequence is an important regional marker. These rocks are best known for the variety of secondary phosphate minerals, found in fractures (related to Eocene folding) or as nodules.

The Blow River Formation contains about  $7 \times 10^9$  t of  $P_2O_5$ . This major deposit falls between the peak global episodes of phosphogenesis in the Callovian and Campanian, and, like them, corresponds to the late stage of a global anoxia. Unlike most phosphorites, this is a high latitude deposit.

**Paleomagnetic investigations of Carboniferous strata in Stellarton Graben, Nova Scotia**

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Investigation of the paleomagnetism of redbeds in Stellarton Graben was undertaken in an attempt to constrain the timing of deposition of critical redbed units and to assess the amount of

angular rotation involved in development of the pull-apart graben. In the simplest interpretation of the results at least two sets of paleomagnetic remanence directions can be recognized.  $ST_1$

was found only in the Namurian Canso Group. As it was not recognized in younger rocks, it is probably late Namurian to Westphalian B. The other remanence data are grouped here to produce ST<sub>2,4</sub>. A negative fold test on the ST<sub>2</sub> data suggests that it post-dates deformation of the Stellarton Formation, and is thus post-Westphalian D. The divergence between ST<sub>1</sub> and ST<sub>2,4</sub> can be explained by progressive anti-clockwise rotation (>65°) of the Stellarton Graven. This is consistent with evidence for late Carboniferous dextral strike-slip on the eastern Cobequid and Hollow faults. Most of this displacement must have occurred before or during Cumberland time.

Remanence:	Az.:	Inc.:	N	Strat. Unit:
ST <sub>1</sub>	082	+ 4	6	Ca
ST <sub>2</sub>	168	+27	13	Ca, Cu, St
ST <sub>3</sub>	178	+ 8	11	Cu, St
ST <sub>4</sub>	171	- 8	9	Cu, St
ST <sub>2,4</sub>	173	+12		

Ca = Canso, Cu = Cumberland, St = Stellarton

### Implication of Recent macrofloral collection to the biostratigraphy of the Sydney Coalfield, Nova Scotia, Canada (Carboniferous, Westphalian C to Cantabrian)

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The macrofloral biostratigraphy for the Sydney Coalfield, first established by Bell in 1938, invites revision as a result of significant collections made over the past 14 years particularly from the top section at Point Aconi. The biostratigraphic value of the new collections is twofold: (1) Stephanian components, observed for the first time, are *Sphenophyllum oblongifolium*, *S. costae*, *Odontopteris cantabrica*, *Pecopteris arborescens*, and possibly *P. lamuriana*, and (2) ranges for some of Bell's records, especially *S. cunneifolium* and *Linopteris obliqua*, are extended upwards. In addition, *Praecallipteridium jongmansii* can be split from Bell's alethopterid records, and *Alethopteris grandinii* is recognized. When the floral records, including relevant elements of Bell's, are re-organized in terms of succession of palaeo-

botanic events, it can be seen that the Lloyd Cove and the Tracy Seams display sufficient macrofloral turn-over events to index their stratigraphic levels as stage boundaries. Specifically, the Westphalian C/D boundary is placed at the Tracy and the Westphalian D/Cantabrian at the Lloyd Cove Seam. This would imply that a minimum of 150 m of Cantabrian and 1,000 m of Westphalian D strata are present in the Sydney Basin. The two recognized macrofloral Zones, *Lonchopteris eschweiliana* and *L. obliqua* Zones, are of Westphalian C, and Westphalian D and Cantabrian age, respectively. A possible development that tonstein (altered volcanic ash band) is present in the Tracy Seam suitable for Ar<sup>39</sup>/Ar<sup>40</sup> dating, increases the prospect for obtaining a North American time line with an European age.