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ABSTRACTS

2005 Colloquium & Annual General Meeting

SAINT JOHN, NEW BRUNSWICK

The 31st Colloquium and Annual General Meeting was held at the Saint John Trade and Convention Centre, Hilton Hotel, and the New Brunswick Museum, Saint John, New Brunswick, on February 4 and 5, 2005. On behalf of the society we thank the organizing committee, collectively and in alphabetical order, Jennifer Bates, Karl Butler, Pam Dickinson, Dave Keighley, Dave Lentz, Randall Miller, Ian Spooner, Joe White, Lucy Wilson and Reg Wilson for providing an excellent meeting. We also acknowledge financial support from the New Brunswick Department of Natural Resources, Geological Surveys Branch; the New Brunswick Museum; the Vice-President Research UNB; and the Deans of Science UNB.

In the following pages we are pleased to publish the abstracts of oral presentations and posters from the Colloquium which included special sessions on Magmas to mineralization and Geoarchaeology.

THE EDITORS

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Bedrock geology and tectonic history of the southwestern half of the New River belt, southern New Brunswick

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The southern New River belt is characterized by two Neoproterozoic igneous units, the Blacks Harbour Granodiorite and the Ragged Falls Intrusive-Volcanic Suite, that together make up most of the belt. Fault-bounded slivers of Cambrian and Ordovician rocks are a minor component. Mapping at 1:20 000 scale during the summer of 2004 focused on these units in an effort to clarify their distribution and structural relationships, provide a framework for the tectonic development of the southern New River belt, and hence to establish grounds for comparison with other units of similar age in southern New Brunswick.

The Blacks Harbour Granodiorite occupies much of the area east of the Letang Harbour Fault. It is strongly tectonized due to an extensive movement history along regional northeast-trending faults. The unit has been previously defined as containing both granite and granodiorite; however, this study indicates that the unit is dominated by granodiorite. The Ragged Falls Intrusive-Volcanic Suite, previously dated by U-Pb (zircon) at ca. 555 Ma, has been demonstrated to be much more extensive then previously interpreted, and occurs throughout almost the entire strike-length of the map area. The intrusive part of the suite consists of diorite-granodiorite, grading to syenogranite, granophyric alkali feldspar granite, and quartz-feldspar porphyry, in intrusive contact with associated overlying felsic volcanic rocks. Whole-rock chemical data for the Ragged Falls Suite indicate that most rocks are silica-rich, typically containing over 75% SiO_2, with high concentrations of K_2O and trace elements Rb, Nb, and Zr. These rocks likely formed in a within-plate extensional environment. In contrast, the Blacks Harbour Granodiorite shows only moderate SiO_2 concentrations, and a continental margin subduction zone signature based on low Y and Nb values. Juxtaposition of these two units may have occurred as late as Late Devonian.

In addition to the Neoproterozoic units, Early – Middle Cambrian fault blocks containing mafic flows, debris flows, pyroclastic rocks, and volcanogenic sedimentary rocks occur throughout much of the southern part of the map area. The Buckmans Creek Formation in Beaver Harbour contains marine faunal assemblages in volcanogenic sedimentary rocks interstratified with volcanic rocks. These rocks may have been deposited in a shallow marine environment on top of the Beaver Harbour Porphyry, the uppermost intrusive unit of the Ragged Falls Intrusive-Volcanic Suite. Rocks of similar age based on a previous U-Pb (zircon) dating occur in the Simpsons Island Formation located west of the Letang Harbour fault lack fossils. Basalt in the Simpsons Island Formation is calk-alkalic, and apparently formed in a volcanic-arc setting.

Temporal and spatial distributions of Early Carboniferous-aged chert in the New Brunswick archaeological record

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Translucent variegated chert, dominated by red and grey shades, is frequently present in Early Carboniferous (Mabou Group) sediments in New Brunswick. The Washademoak Lake Chert Source at Belyeas Cove is the only known exposure exhibiting toolstone-quality variants of this chert, referred to in the archaeological literature as *Washademoak Multi-coloured Chert*. Flaked-stone artifacts made from chert macroscopically consistent with that from Belyeas Cove are widely distributed in the New Brunswick archaeological record, especially in the southern half of the province. Use of this chert by Native people appears to be restricted, temporally, to the Maritime Woodland period (3000–500 B.P.). Distributions of distinctive lithic materials, such as *Washademoak Multi-coloured Chert*, serve as proxy data in the reconstruction of prehistoric exchange and cultural interaction systems in the Maine–Maritimes area.

An assessment of groundwater vulnerability of the Annapolis-Cornwallis Valley, Nova Scotia, using GIS modelling

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Current groundwater vulnerability assessment methods are often based on index and overlay techniques, such as those employed in Geographic Information Systems (GIS). In our study of groundwater vulnerability in the Annapolis-Cornwallis Valley, Nova Scotia, the primary assessment method is the DRASTIC model. DRASTIC is an acronym for the seven hydrogeological parameters including Depth to groundwater, net Recharge by rainfall, Aquifer media, Soil media, Topography, Impact of the vadose zone, and hydraulic Conductivity of the aquifer.

Preliminary groundwater depth data has been processed using piezometric survey data obtained by the Geological Survey of Canada, Quebec (GSC) and the Applied Geomatics Research Group (AGRG/COGS/NSCC) during 2003 and 2004. Net recharge data incorporates interpolated climate normal precipitation and temperature data from Environment Canada stations as well as land use and land cover information derived from classification and available coverage datasets. Both bedrock and Quaternary deposits are being considered

for the aquifer media parameter. Soil data have been processed to soil series and composition using the 1960's N.S. Soil Survey reports. Topography data for the model includes slope data, which has been processed to percent slope from a 20-metre Digital Elevation Model (DEM), and classified. Surficial and bedrock geology, soil data, and depth to groundwater, will be important considerations for developing data for the impact of the vadose zone parameter. When the aquifer media data layers are processed, they will also be rated for the model according to relative hydraulic conductivity of the aquifer media, for the final parameter of the DRASTIC model. While not part of the original DRASTIC model, it is suspected that other factors important to modeling groundwater vulnerability may include depth-to-bedrock and land use, particularly in the case of the agricultural activities along the valley floor.

The groundwater vulnerability model produced will assist in prioritizing specific regions for detailed study as well as providing information critical for effective management of groundwater in the Annapolis-Cornwallis Valley region.

A eustatic sea level curve for the Bermuda seamount – a reference curve for East Coast Canada

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The Bermuda seamount is primarily subject to eustatic sea level rise. Glacioisostatic forebulge effects are minimal, and vertical motion GPS data can be used to correct for minimal tectonic motion. A well-constrained eustatic curve for Bermuda could provide a reference curve for the eustatic component of sea level rise for east coast Canada.

Bermuda has a well-documented history of sea level rise data from the often-cited Neumann curve of 1971 to the most recent works by Javaux (1999) and Volbrecht (1996). These historic data are being supplemented by new data to generate a more constrained eustatic sea level curve for the past 7 ka. Three submerged forests at Gurnet Rock, Harrington Sound and Well Bay in water depths of 9, 6 and 1.5 m respectively are under investigation. Several *in situ* tree stumps with associated forest floor organic layers have been located at each site. In addition, a submerged lake basin identified by a laterally extensive thick peat section is being mapped at Ferry Reach in water depths of 6 m. These sites are being surveyed with multibeam sonar for accurate water/sample depths and for 3-D paleogeographic reconstructions. Surveyed sites are being mapped and excavated using scuba diving techniques. *In situ* tree stump, peat, organic and carbonate samples were recovered from these sites and were submitted for carbon dating. Radiocarbon ages range from 79100 to 1430 BP and are consistently younger with decreasing water depths. Three-D time-series paleogeographic reconstructions facilitate site-flooding geometry relative to rising water levels. Initial results indicate Bermuda sea level has risen 9 m over the past 7 ka with decreasing rate over time.

Systematics of microborings from the Cenozoic White Limestone Group, Jamaica

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The Middle Eocene to Middle Miocene White Limestone Group of Jamaica comprises six formations, the Troy, Swanswick, Somerset, Moneague, Montpelier and Pelleu Island formations. These formations contain, albeit in various quantities, soft-sediment, macroboring and microboring ichnofaunas. Fifteen ichnogenera represented by 27 ichnospecies of uncommon, but moderately diverse, poorly to moderately preserved soft-sediment ichnospecies and 9 ichnogenera represented by 30 ichnospecies of an uncommon but relatively diverse macroboring ichnofauna have already been identified from the White Limestone Group. Seventeen ichnogenera represented by 28 ichnospecies of relatively diverse well-preserved microboring ichnotaxa are discussed.

Observations of the microboring ichnotaxa indicate the presence of: *Catellocaula vallata* Palmer and Wilson, *Caulostrepsis* isp., *Centrichnus eccentricus* Bromley and Martinell, *Conchotrema* isp., *Curvichnus semorbis* Nielsen, *Dipatulichnus rotundus* Nielsen and Nielsen, *Entobia ovula* Bromley and D'Alessandro, *E. volzi* Bromley and D'Alessandro, *Entobia* ispp., 'Fossichnus solus' Nielsen et al., *Maeandropolydora elegans* Bromley and D'Alessandro, *Maeandropolydora* isp., *Oichnus asperus* Nielsen and Nielsen, *O. excavatus* Donovan and Jagt, *O. gradatus* Nielsen and Nielsen, *O. ovalis* Bromley, *O. paraboloides* Bromley, *O. simplex* Bromley, *Penetrantia* isp., *Podichnus centrifugalis* Bromley and Surlyk, *Ramosulcichnus biforans* Hillmer and Schulz, *Reticulina elegans* Radtke, *Scolecia maeandria* Radtke, *S. filosa* Radtke, *Stellatichnus radiatus* Nielsen and Nielsen, *Trypanites solitarius* Hagenow, *T. weisi* Mägdefrau, and *T. fimbriatus* Stephenson.

A majority of the microboring ichnotaxa are preserved in foraminifers from the Somerset Formation and to a lesser extent in scleractinian corals from the Moneague and Montpelier formations.

Deposition of glacial tills on the upper continental slope offshore southeastern Canada

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The distribution of glacial till on the upper continental slope off Nova Scotia and Newfoundland has been interpreted from high-resolution seismic reflection profiles, multibeam and sidescan seafloor images, and piston cores and grab samples. The presence of glacial till on the upper continental slope, to water depths of several hundred metres, is recognised from acoustically incoherent units that terminate on the upper slope. Piston cores confirm the presence of a diamict in these units through grain size analysis and shear strength measurements. Variability in the morphology of iceberg scours also suggests till is present in the incoherent units.

Tills that reach beyond the shelf break thin into wedge-shaped bodies (till tongues) on the upper slope. The termination of the till typically passes laterally into stratified proglacial sediment deposited, on the upper slope, by sediment plumes created during retreat of the ice front. Proglacial sediment also interfingers with the till tongues and this morphology is thought to be created by fluctuation in the position of the glacial front. Till tongues are typically stacked with the youngest terminations progressing upslope in a retrogressive manner. Similarities in the morphology of till tongues (e.g. inflection points) observed throughout a consistent stratigraphic record suggest that overall morphology is controlled by formative processes and/or the ability of the material to resist failure. This is also supported by the consistency in the position of the till terminations, ruling out flow till as a formative mechanism of till tongues. However, there is considerable variation in the morphology of till tongues across the Eastern Canadian margin and many till tongues terminate in failure scarps rather than passing into stratified sediment. Retrogressive failure may occur within the weaker proglacial sediment and halt when reaching the more mechanically stable till.

This study has not yet provided new evidence on the timing of shelf-crossing glaciation. Review of recently published reports and theses shows that on the Scotian Slope, the most recent till-tongue dates from between 18.5 and 20.3 ka; off Laurentian Channel there was a maximal ice advance at about 16.5 ka, whereas off the eastern and northern Grand Banks the maximum ice advance was at about 25 ka.

Cosmogenic nuclide dating of glaciomarine deltas in southern Maine

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Widespread marine transgression and deposition of glaciomarine sediment occurred as the ice margin of the Laurentide Ice Sheet retreated from the eastern continental shelf of Maine beginning approximately 17000 years ago. Evidence for transgression is preserved in ice-proximal and esker-fed deltas deposited along the edge of the retreating ice margin. The topset-foreset contacts within these deltas provide excellent paleo-sea-level indicators. Precise age determinations for the topset-foreset contacts provide valuable information regarding the rate and style of deglaciation. Terrestrial cosmogenic nuclide exposure (TCN) dating provides a means to precisely date surface exposure durations. Using TCN dating, deltaic sediments from the topset-foreset contacts can be dated to provide a more precise age of the ice margin at its time of retreat from southern Coastal Maine. The present study aims to test the validity of using TCN exposure dating on glaciomarine deltas against the existing radiocarbon-based chronology. To date the topset-foreset contacts, three of the best studied glaciomarine deltas in southern Maine will be exposure dated using cosmogenic ^{10}Be. Eleven sand samples were collected in vertical profiles (1 to 3 m) under stones, "fences", along gravel pit boundaries where soil profiles below the tree rooting depth show minimum disturbance in the delta sediments. The results will be compared to the existing radiocarbon dates to determine whether TCN dating can be applied to other deltas and contribute to the glacial chronology of the Laurentide Ice Sheet.

Historical earthquakes (1764–1961) in the Saint John region and effects from regional earthquakes

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A study has been made of historical documents (newspapers, diaries and letters) which could contain information on the effects of earthquakes felt in New Brunswick. Selected weekly newspapers were scanned for mention of previously unlisted earthquakes. Documents for dates following already known earthquakes were also read for accounts of these latter events. Modified Mercalli intensity values were assigned from the described effects of each earthquake at places mentioned in these reports. Finally, magnitudes and epicentres were determined from the intensities and felt areas, using empirical relationships obtained from seismographically recorded earthquakes in eastern North America.

There are 8 earthquakes listed in the National Earthquake

DataBase for a 1° × 1 ° area centred on Saint John for the period 1764 to 1961, the latter year being when the first network seismograph was installed in the province. Re-valuation of these 8 events using the information from the historical documents found that they were not all earthquakes, and the epicentre of one earthquake is incorrect. Vibrations from a slowly moving landslide were mistaken for an earthquake in 1870; a cryogenic event at Rothsay in 1884 was erroneously interpreted as an earthquake. The epicentre of the 1937 earthquake was mislocated in the southern part of the province and this event was really an earthquake in the Central Highlands of New Brunswick. Minor revisions of earthquake parameters were also necessary for some of the other earthquakes. Four previously unlisted events in the Saint John region, in 1838, 1869, 1888 and 1898, have been found by scanning issues of weekly newspapers published in the southern part of the province. All of these local historical earthquakes have magnitudes of less than 4.

Effects of larger regional earthquakes (> magnitude 5) were also investigated by seeking reports of these events in historical documents. For Saint John, these reports show that minor damage occurred as a result of earthquakes in the Passamaquoddy Bay and Central Highlands regions of New Brunswick. Also, intensity values of up to 5 have been estimated for larger, more distant, earthquakes in Quebec and on the Grand Banks. Seismic hazard determinations for Saint John should therefore take into consideration the effects of these larger regional earthquakes.

Apparent conductivity mapping of sludge migration through waste rock at Fire Road Mine, Minto, NB

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The relocation of mine water neutralization sludge from settling ponds to the acid-generating waste rock could provide several benefits for reclamation of abandoned coal mines. These include a low cost final disposal area for the sludge and a minimization of land disturbance for sludge disposal purposes, as well as a reduction in the diffusion of oxygen into the waste rock with and a corresponding reduction in the generation of acid mine drainage (AMD). NB Coal had been depositing lime neutralization sludge from its mine water treatment plant back onto the waste rock at the backfilled Fire Road strip mine since 1992. Chemical investigations have identified a decrease in the mine water acidity and iron and aluminum concentrations, which may be in part due to the application of the sludge. To date, however, there has been no way apart from trenching, to determine the fate of sludge after it has been applied to the waste rock and infiltrated below the surface.

Electromagnetic (EM) surveys were first used over parts of the Fire Road mine in 2000 as part of a UNB field school in environmental geoscience. One unanticipated result was the observation of elevated electrical conductivities in an area that had previously been used for sludge disposal. The possibility of using electrical conductivity as a tracer to track sludge migration within the waste rock motivated NB Coal to sponsor the acquisition of an EM apparent conductivity survey over the entire backfilled cut. Results of that survey, conducted in 2004, show that the conductivity structure is highly heterogeneous but exhibits many well-defined trends and anomalies. A long, linear conductivity high, located along the high wall of the mine, is attributed to pooling of mine water and higher porosities in that zone. Other conductivity highs are clearly associated with historical patterns of sludge application and its subsurface migration. The presence of moist, conductive sludge filling void space in the waste rock above the water table may explain this association. If so, apparent conductivity mapping may reveal which parts of the mine site would benefit most from the application of sludge for purposes of reducing the infiltration of oxygen and production of AMD.

Laboratory experiments are currently underway to measure the electrical conductivity of the sludge relative to the mine water, and its dependence on moisture content. Knowledge of these physical properties will help us to refine interpretations of apparent conductivity and resistivity surveys acquired in the field.

The geology of the Minto Salmon Harbour mine site and its high sulphur coals

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The Salmon Harbour mine, near Minto, central New Brunswick, excavates coal from the upper part of the Minto Formation of the Pictou Group (Pennsylvanian), the uppermost unit within the Maritimes Basin in this area. The stratigraphic succession is informally divided into seven units at the mine site. Unit 1 is the coal seam, a high volatile A bituminous grade of coal containing between 5 to 9 % sulphur. Unit 2, in outcrop, comprises organic rich shale that forms the roof rock to the coal. A laterally equivalent sandstone has recently also been identified in nearby boreholes. Units 3 and 5 contain numerous sandstone and mudstone couplets that exhibit ped-like fracturing. Unit 4 is a laterally extensive sandstone, locally conglomeratic with trough cross beds, rip-up clasts and climbing ripples. Bounding surfaces are variably oriented. Unit 6 is a laterally discontinuous lenticular sandstone that can truncate much of Unit 5. In plan view it maps as a sinuous body and

internally has uniformly dipping bounding surfaces suggesting lateral accretion sets. Unit 7 is the present day overburden.

The outcropping Minto Formation is modelled as a poorly drained coal swamp that was gradually displaced by a fluvial system and associated floodplain. The sand-mudstone couplets likely represent sheetflood and overbank deposits that were subaerially exposed to subsequently form a palaeosol. The widely outcropping Unit 4 sandbody represents either extensive lateral migration of a small channel or a very large fluvial trunk channel, potentially with the variably dipping bounding surfaces defining growth-increments of a mid-channel barform. The Unit 6 sandbody represents a short lived meandering fluvial channel.

At the base of Unit 2, sulphur/carbon analyses indicate 3.1 wt% sulphur and 1.32 wt% carbon. Progressively lower values are recorded up-section. Higher levels of sulphur (6.47 wt%) and carbon (2.23 wt%) were detected immediately below the coal seam. Petrographic analyses have identified quartz as a blocky cement and kaolinite as a pore-filling vermiform clay phase in units 2 and 3. Unit 4 additionally has quartz forming 'dog tooth' quartz crystals enclosed by a later stage calcium carbonate cement (5–10%). Thin sections from sandstone immediately beneath the coal exhibit pyrite likely enclosing kaolinite but postdated by carbonate (late alkaline conditions).

The source of the sulphur in the coal and adjacent strata is debatable. Although sulphate from seawater would provide an abundant source of sulphur, no sedimentological evidence for marine influence is noted. Sulphate-enriched fluvial waters draining upstream outcrops of uplifted Mississippian Windsor Group salt would not likely have produced the acidic pore waters necessary to produce the early diagenetic suite that is identified. Instead it is proposed that, during burial, the strata acted as an aquifer-aquatard system. Sulphate-rich waters were derived from an aquifer system below the coal seam. Sulphate reduction, producing the various forms of pyrite, occurred during basin-wide dewatering along aquifers confined below the impermeable shale and mudstone aquatard above the coal.

Comparative dendrochronological analysis of red spruce from Central PEI and Southwestern NS

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Two stands of red spruce were sampled and analyzed using standard dendrochronological research techniques. One stand from Fort Augustus, Prince Edward Island and one stand from Harmony Lake, Nova Scotia were assessed using similar methods to test for similarities and differences between the two locations.

The growth characteristics were found to be very similar at the two locations except during the years 1974 to1989. The two chronologies revealed that the stand at Fort Augustus experienced a sudden growth decline over this period. A climatological analysis indicates that long-term records show strong similarities over the period in question for both precipitation and temperature patterns. Therefore, the difference in radial-growth trends is likely due to an internal forcing factor such as the effects of a budworm outbreak in the Fort Augustus region.

Aside from the fifteen-year period when the Prince Edward Island stand was experiencing a growth decline, the radial-growth patterns of the two sites are strongly correlated and suggest the presence of similar environmental conditions. This is important for further dendrochronological investigations as it indicates that strong spatial similarities can be found at locations at least 280 km apart within the Maritimes.

Preliminary results of potential field and petrophysical analysis in the area between eastern Prince Edward Island and western Cape Breton Island, Nova Scotia

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Magnetic anomaly maps from the onshore and offshore area between Prince Edward Island and western Cape Breton Island reveal an approximately 50 km wide and 150 km long, east-west striking magnetic anomaly on the order of 500 nT. The presence of this large magnetic anomaly complicates tectonostratigraphic interpretations and makes it difficult to correlate terrane boundaries between Cape Breton Island and mainland Nova Scotia and New Brunswick. The source of the magnetic anomaly is being evaluated by forward-modeling, with constraints from seismic and petrophysical data. The second vertical derivative magnetic anomaly map shows three magnetic aureoles in the region of the large magnetic anomaly, suggesting several separate sources may cause the anomaly. The magnetic aureoles that occur onshore in northeastern Prince Edward Island and in the Northumberland Strait appear to have different signatures than the anomaly that extends into the Mabou Highlands of western Cape Breton Island. The Bouguer gravity map of the region indicates a relative gravity high, on the order of 12 mGal, coincident with the magnetic high in the Mabou Highlands. Low gravity signatures, varying from 0 to -19 mGal, are coincident with the magnetic highs revealed in the Northumberland Strait and northeastern Prince Edward Island. In onshore areas of western Cape Breton Island, lineations in the horizontal gradient of the Bouguer gravity map are consistent with the transition from high to low signatures in the magnetic anomaly map. To the west, in the offshore area, the correlation of horizontal gradient of gravity lineations with changes in magnetic field strength is less recognizable. To aid in the interpretation of the potential field anomalies, magnetic susceptibility and density data have been measured from

hand samples and outcrops in the onshore parts of the study area. Initial results indicate that high magnetic susceptibility and high density values are typically from Late Precambrian to Paleozoic igneous and metamorphic units in the Mabou Highlands, and such rocks may be the source of the positive magnetic anomaly in the adjacent offshore region. Low magnetic and low density lithologies are typical of Late Paleozoic sedimentary units in Prince Edward Island and western Cape Breton Island. Additional petrophysical constraints are being compiled from industry well data available in the study area, and seismic data are currently being interpreted in order to provide geometrical controls in the forward-modeling procedure. It is anticipated that the forward-modeling procedure will establish the origin of the magnetic anomaly source(s) and help to clarify terrane boundary relationships in this critical area of the Appalachian orogen.

Aboriginal exploitation of tidal ponds: an example from southwestern New Brunswick

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Tidal (tide) ponds are formed at the mouth of estuaries and coastal embayments when water is trapped behind an obstruction during ebb tide. This phenomenon is common to many coasts and in particular to the intertidal zone along the Bay of Fundy where tidal range can exceed 16 metres at some locations.

Geoarchaeological studies in southwestern New Brunswick suggest that tidal ponds may have represented an important food source for aboriginal people in coastal areas where fish become trapped in brackish tidal ponds. Here we discuss findings from a shell midden and hearth from Sam Orr's Pond 10 km north of St. Andrews, southwestern New Brunswick. Remains indicate that food, including mammals, birds, clams and small fish, was processed at this site.

Sam Orr's Pond is the uppermost of three main tidewater ponds that occur at the mouth of Taggarts Brook, during an ebb tide into Passamaquoddy Bay that lowers sea level by 9 m at that location. Schools of small fish are sometimes trapped in the ponds during low tide. Local oral history records that these tidal ponds were exploited in the recent past. A collection of boulders forming the shape of an 8 metre wide ring is located at the mouth of Sam Orr's Pond that may represent anthropogenic modification (a stone weir) used to trap fish.

Research is continuing to determine the extent of anthropogenic modification, the date of the earliest possible use of the site and the location of similar tidal pond catchments along the Fundy coast. These results could indicate that weir-technology was used by people along the coast prior to European colonization.

Deep submarine explosive volcanism

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The role water depth plays in inhibiting volatile phase expansion and thereby the depth of explosive eruptions has been the topic of rigorous debate. Due to a misinterpretation of the applicability of the water-vapour curve in previous research, it is assumed that the pressure exerted by the overlying water column is significant enough to inhibit explosive volcanism at depth. This hypothesis assumes that pyroclastic eruptions cannot occur below the critical point of seawater (315 bars or 3150 m water depth). Therefore, most eruptions are interpreted to occur at depths much shallower than the critical point (500 to 1000 m). However, this hypothesis does not fully recognize the role volatile phase expansion (specific volume changes in P-T space) plays in explosive eruptions even at pressures beyond this critical point.

This controversy has lead to debates on the environment of formation of volcanic massive sulphide deposits (VMS), since pyroclastic rocks can be found in both the footwall and (or) hangingwall sequences, and as an alternative they have been reinterpreted as mass flow deposits. The exsolution of water from a crystallizing felsic melt is directly proportional to the solubility of water in a silicate melt and plays a significant role in the explosivity of an eruption. Water solubility is a function of the pressure, temperature and compositional constraints, with water oversaturation resulting in volatile exsolution. The relationship between dissolved volatiles in a melt and the energy released upon exsolution shows that the expansion of the volatile phase is capable of providing enough energy to initiate submarine pyroclastic eruptions in a variety of settings, magma types, and to significant water depths.

To evaluate the possibility of having a submarine eruption at depths of greater than 1 km, we used the 1-d numerical model CONFLOW. This program uses specified melt composition, conduit diameter and length, and the initial temperature and pressure at the base of the conduit to calculate the pressure gradient in a conduit of constant cross sectional area, the enthalpy of the magma, the viscosity of the volatile-magma mixture at specified P-T conditions, the fragmentation depth where $v_g = 0.75$, and the exit velocity of the volatile-magma mixture. Results of the CONFLOW modeling support our hypothesis that volatile phase expansion is capable of providing enough energy to initiate submarine pyroclastic eruptions in silicic magmas to significant water depths.

Investigating the extent and structure of the Cretaceous Basin at Vinegar Hill, NB, using seismic reflection and seismoelectric surveys

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The Vinegar Hill silica sand deposit, located near Cassidy Lake south of Sussex, NB, is of interest both as an economic resource and for its not recently confirmed status as a part of New Brunswick's only known basin of Cretaceous age. The unconsolidated sand and clay sediments within the basin overlie Carboniferous-aged red beds of the Mabou Group and are covered by glacial till. In July, 2004, geophysical data were acquired to investigate aspects of the basin's shape, depth extent and internal structure which could not be inferred from the sparse borehole control.

Surface geophysical surveys were conducted using shallow P-wave seismic reflection and experimental seismoelectric methods. Seismic data were acquired using a 48 channel asymmetric split spread with 50 Hz geophones at 3 m intervals. A 12-gauge in-hole shotgun source was used in shallow holes every 6 m along the line.

The first seismoelectric survey was acquired concurrently with the seismic data, using the same source but a separate 36 channel recording system connected to electric field antennas rather than geophones. A second set of seismoelectric records were acquired in November, 2004 using a stronger, explosive seismic source (trade name Geogel). This follow up investigation was conducted in select areas where strong reflectors had been identified in the seismic data.

A total of 1.7 km was surveyed along two seismic lines – a 1 km line running N-S across the basin, and a 0.7 km line oriented sub-parallel to the basin axis. The quality of the seismic data varied with location, apparently in response to the variations in the depth of the water table or in the properties of the surficial sediments. In some areas we obtained excellent high frequency records exhibiting reflectors to two-way travel times of 150 ms. These two-way times translate in roughly 135–150 m depth assuming an average P-wave velocity of 1800–2000 m/s for the unconsolidated basin fill. These results agree with the estimated depth to Carboniferous bedrock obtained from the drill cuttings log for a nearby borehole (IMC-15) drilled during the 1970's for potash exploration. The seismic data also indicate that the basin has an asymmetrical bowl shape truncated to the north by the Clover Hill fault. Layers on the south side of the basin dipped significantly towards the north and there is evidence of syn to post-depositional folding and faulting within the basin itself.

Structure and stratigraphy of offshore western Cape Breton Island from seismic reflection mapping

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A large sedimentary basin containing over 12 km of Carboniferous and Permian strata underlies the southern Gulf of St. Lawrence. The rocks in the basin consist mainly of red and grey, non-marine, clastic rocks with abundant coal. A thick marine evaporite interval was deposited near the bottom of the sedimentary basin fill, but has since been remobilized to form numerous salt structures.

An extensive grid of seismic reflection data was acquired in the southern Gulf of St. Lawrence from the late 1960s through to the early 1980s. These data were commonly low fold (6–12), not migrated, and by today's standards, had very basic processing. Such data were satisfactory for flat-lying strata, but are grossly inadequate for areas of complex structure such as the area offshore from western Cape Breton Island. A modern seismic program was conducted in the aforementioned area in December, 2003. The survey was acquired with a low-powered source and a 6000 m streamer, resulting in high quality 120 fold data. The data were processed to pre-stack time migration and provide much improved images of the area. Whereas the older seismic data in the area portrayed salt structures as near vertical columns of salt, the new data shows detached salts and vertical salt welds, analogous to some Gulf of Mexico structures.

A number of petroleum exploration wells have been drilled in the Maritimes Basin that show strong indications of natural gas, including the East Point E-49 well that tested natural gas at a flow rate of 5.5 million cubic feet per day. Gas bearing sands from the East Point discovery were mapped on the new seismic data within a closed area called the Cheticamp Prospect. The prospect is located about 20 km southeast of the East Point discovery. The prospect consists of an anticline between two salt structures and encloses an area of roughly 20 km^2. If successful, such a structure could contain a significant amount of natural gas.

The hydrogeology of northern Nova Scotia: preliminary research

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The Carboniferous sedimentary rocks of northern Nova Scotia form regional aquifers in some areas and will become an increasingly important water supply as sustainable and reliable water supplies are sought. However, aside from a few studies conducted during the 1970s and early 1980s, very little research has been conducted on the hydrogeology of these rocks. Currently, an assessment of the potential to expand the

amount of water withdrawn from the Windsor, Mabou, Pictou, and Cumberland groups is underway. Initial research is focused on determining the distribution of transmissivity within the geological units from the pump test database maintained by the Nova Scotia Department of Environment and Labour. This database contains over 100 pump tests for these for units and the statistics of the transmissivities found in each of these units were analysed in this study. Of these geological units, the Pictou and Cumberland groups were found to have the highest transmissivities. However, these were not drastically different from the underlying Mabou and Windsor groups and all groups examined exhibit a wide amount of variability. The transmissivity results for the Mabou, Pictou and Cumberland groups are approximately what would be expected for clastic rocks but it is somewhat conspicuous that the transmissivities measured in the Windsor Group are so similar to the other four units. The Windsor Group is karstic in some areas and transmissivities several orders of magnitude greater than those observed should be present. However, in many areas of the use of the Windsor Group as an aquifer is avoided due to water quality issues and this likely introduces a great deal of bias into the database. In the future, lithological data from water wells and water quality data will be examined to provide a more complete hydrogeological assessment of this region.

Benthic foraminiferal associations in Cenozoic and Late Cretaceous deposits from Shubenacadie H-100 well (Scotian Slope)

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A Late Cretaceous-Cenozoic section from Shubenacadie H-100 well located on the Scotian Slope has been investigated. The benthic foraminiferal content of 52 cutting samples (corresponding to 10 m interval) previously collected for stratigraphic analysis within the interval 2140–4200 m, has been studied in order to provide information about distribution and taxonomy, as well as to evaluate the paleoenvironments.

Shubenacadie H-100 was drilled in 1476.5 m water depth to a depth of 4200 m. The Miocene-Eocene unconformity is recorded at 3050 m. About 170 benthic foraminiferal taxa or taxa groups have been identified. The study of their distribution from Miocene to Upper Cretaceous and the different foraminiferal associations led to the following results:

1) The upper part of the succession (Miocene) contains mainly planktonic and calcareous benthic foraminifers. The occurring benthic species within this interval, belonging to genera *Bulimina, Glandulina, Melonis, Plectrofrondicularia, Pyrgo, Quinqueloculina, Sigmilopsis, Uvigerina* and *Cyclammina*, are indicative of a middle-lower bathyal environment.
2) The Eocene - Late Cretaceous deposits are characterized by foraminiferal associations typical of lower bathyal environments. Agglutinated benthic foraminifers (indicating clastic sedimentation in a lower bathyal environment) are recorded within this interval.
3) The majority of agglutinated benthic foraminifers recorded in the Early Eocene-Upper Cretaceous deposits are big-size, robust and coarse-grained opportunistic taxa (*Ammodiscus, Bathysiphon, Trochamminoides, Paratrochamminoides, Glomospirella, Reophax* and *Subreophax*), characteristic of hemipelagic layers of turbiditic sequences.

Geoarchaeological investigations of the lakebed of Georgian Bay, Laurentide Great Lakes

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A collaborative regional lakebed archaeological-geological investigation is being conducted at Fathom Five National Marine Park Georgian Bay. Archaeologists have recognized the potential for the existence of Paleoindian habitation sites in the marine park area during lake level lowstands 9600–7200 BP following deglaciation. Habitation of the Sheguiandah site on Manitoulin Island, immediately to the north of the marine park during this time interval, coupled with the then exposed escarpment being the only possible regional migratory route for caribou is motivating the archaeological investigation.

New high-resolution multibeam technology has been employed to map the crest of the submerged Niagara Escarpment that would have been subaerially exposed during the early Holocene. Four drainage channels with associated shorelines, spillways and beaches have been discovered and mapped. Drowned beaches indicate lake levels were at least 50 m below present day elevations. Radiocarbon dated *in situ* tree stumps confirm water levels were low during this time interval. Scuba diving and remotely operated vehicle operations are now focusing archaeological activities along these submerged relict waterways. Quartzite fragments located on a beach at –53 m and a series of caves adjacent to a drainage channel are currently under investigation by archaeologists. Chippewa First Nation oral history supports the recently discovered geological features. Stories describing the spillways and travel across the escarpment crest are common knowledge among elders.

Pedogenic mud aggregates in the Boss Point Formation, Joggins, Nova Scotia

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Pedogenic mud aggregates are sand- and silt-sized particles composed largely of clay flakes, and are commonly formed in modern vertisol-type soils during seasonal wetting and drying. Where the soils are rich in smectite, clays expand and shrink seasonally, causing aggregation of the flakes under pressure, and the aggregates may be transported as fluvial bedload with quartz-rich sands. A major problem associated with studying mud aggregates is the low potential for preserving them in the rock record, as the muddy sediments are destroyed by compaction during burial. The presence of calcretes in the Pennsylvanian Boss Point Formation, suggesting semi-arid and seasonal conditions, led to a successful search for aggregates using thin sections and the scanning electron microscope (SEM).

Samples from fluvial channel sandstones, crevasse-splay sandstones and floodplain mudstones in the upper part of the formation all contain preserved aggregates, Although sand-sized aggregates are present, most aggregates are typically 10–15 μ in diameter in all three sediment types, suggesting a common origin. The abundance of aggregates in these sediments is highly variable, ranging from 10–50 %. Some of the best occurrences are concentrated in thin laminae in otherwise structureless floodplain mudstones, where they occur with a few silt-sized grains of quartz and feldspar. Small aggregates are also prominent in large mud fragments within channel sandstones, probably eroded from river banks. Chemical analysis of clays using the SEM-EDS and XRD techniques shows a predominance of illite with lesser proportions of chlorite and kaolinite. No smectite was observed but may have altered to illite during deep-burial diagenesis.

The Boss Point is now one of very few formations in the rock record that have yielded pedogenic aggregates. However, many aggregates are an order of magnitude, smaller than those identified in most previous studies. They are also unusually well preserved within floodplain muds, where small aggregates were probably concentrated by gentle overbank floods and transported across floodplains and into channels. Aggregate preservation probably reflects early carbonate cementation in some samples, as well as shielding by silicate grain frameworks in coarser sediments.

Tectonic influences on Quaternary volcanism of Methana, South Aegean arc, Greece

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The peninsula of Methana is a complex andesite-dacite volcanic centre near the western end of the active South Aegean arc. The most recent eruption was in 230 BC and all radiometric ages are younger than 1 Ma. This study investigates the role that neotectonics has played in localizing volcanic eruptions and its possible influence on magma genesis. To the south of Methana, most active Quaternary normal faults trend N-S, whereas to the north, the regional trend of active normal faults is ESE-WNW. Previously published maps were used as a basis for volcanological observations, sampling and measurement of structures that cut volcanic rocks of different ages. All structural and map data were assembled in a GIS project. Petrographic thin sections and geochemical analyses were made of representative rock samples.

The volcanic succession is divided into eight periods, based on superposition, geomorphology, and a few radiometric dates. At a map scale, many domes are elongate in an E-W direction and previous studies have suggested that stratovolcanoes formed at the intersection of E-W and NE-SW fault systems. Even the youngest volcanic units (period 8) show some tectonic deformation, with subvertical E-W trending shear fractures. Older rocks of periods 6-3 show predominant N-S faulting, although most map-scale fissures trend E-W. In period 2, small flow-banded eruptions are common, with sub-vertical flow banding trending either NE-SW or NW-SE. In period 1, sparse sub-vertical flow banding trends N-S and the faulting patterns are complex, probably reflecting changes in stress fields. The changing patterns of fault deformation can be related to regional changes in fault patterns through the Quaternary in the Aegean arc, with extension across older east-west faults resulting from strike-slip on NE- or NNE-trending faults.

The volcanic rocks are principally andesite and dacite, with some basaltic andesite. Many petrographic textures indicate the importance of magma mixing, including complexly zoned plagioclase with spongy cellular zones, ovoidal crystals, and mafic enclaves with chilled and lobate margins. The relationship of evidence of mixing to the fault patterns has been investigated.

Cooperative Geological Mapping Strategies across Canada (CGMS): public geoscience, exploration and development

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During the past decade cooperative public geoscience involving both federal and provincial-territorial geological surveys (e.g. NATMAP, Targeted Geoscience Initiative (TGI)) has catalyzed private sector investment in exploration. For example, a federal-provincial NATMAP project in northeastern British Columbia (1998–2003) has already led to industry investments of over $100M in petroleum-related exploration and land acquisitions. Similarly, a TGI-supported multidisciplinary federal-territorial mapping project in Nunavut (2000–2003) has already led industry to invest over $8M in gold-related exploration in 2004. However, the NATMAP program has ended and TGI will terminate in 2005. In their place *Cooperative Geological Mapping Strategies Across Canada* (CGMS) is a proposal by the National Geological Surveys Committee (NGSC) for long-term (10-year) renewed federal and provincial-territorial government investment in public geoscience in support of the environmentally responsible exploration and development of energy and mineral resources. CGMS will target four nationally applicable strategic outcomes: *A secure energy supply for Canada, Prosperous resource-based communities,* and *New economic development opportunities in frontier area*, all underpinned by *Environmentally responsible stewardship of geological resources*. Consultations with industry this Fall will help to formulate a project-level operational blueprint to be initiated in 2005, if new funding is forthcoming.

Petrogenesis of the Mechanic Settlement Pluton, southern New Brunswick and controls on associated PGE mineralization

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The Mechanic Settlement Pluton, located on the northern margin of the Caledonian Highlands of southern New Brunswick, is a relatively undeformed Late Neoproterozoic gabbroic intrusion that varies in composition from ultramafic to dioritic. This project is based on a study of 5420 m of drill core from 20 archived drill holes obtained during historical exploration by Noranda, BHP, and Wildhorse Resources, as well as surface outcrops. Eighteen lithologies, with nearly continuous variation among them, have been identified, and grouped into six assemblages. (1) Ultramafic rocks are olivine and chromite cumulate rocks, with interstitial clinopyroxene, orthopyroxene, and phlogopite. (2) Olivine-bearing gabbroic rocks and (3) troctolitic rocks are olivine and plagioclase cumulates with interstitial pyroxene, a minor component in troctolitic rocks. (4) Gabbroic rocks contain plagioclase and pyroxene, as well as hornblende and trace olivine in some samples. (5) Anorthositic rocks are plagioclase cumulates, with trace olivine, pyroxene, and hornblende. (6) Dioritic rocks are composed dominantly of plagioclase, with lesser hornblende, pyroxene, quartz, and alkali feldspar. The petrological variations can be explained largely by fractional crystallization of olivine and plagioclase, with subordinate influence from clinopyroxene. Lithologies cannot be reliably correlated among drill holes, suggesting that well-developed, laterally extensive, layering is not present.

The Mechanic Settlement Pluton contains PGE mineralization (up to 2.4 ppm in drill core and 5.7 ppm in grab sample) with little apparent stratigraphic continuity. In addition to previously identified PGM, the new minerals plumbopalladinite (Pd_3Pb_2), isoferroplatinum (Pt_3Fe), sopcheite ($Pd_3Ag_4Te_4$), froodite ($PdBi_2$), and paolovite (Pd_2Sn) have been identified using SEM and electron microprobe. The PGE minerals occur near the base(?) of ultramafic units (plagioclase-bearing lherzolite or lherzolite). Similarities between the Mechanic Settlement Pluton and the Lac des Iles Complex (Ontario), such as intrusion into an active margin and contemporaneous felsic magmatism, suggest that mineralization style may be like that in the Lac des Iles deposits. These deposits are interpreted to have formed by the interaction of fluids (probably deuteric) with the crystallizing magma, which causes remobilization of PGEs into magmatic breccia zones, mafic rocks containing hydrous silicates, and pegmatitic mafic rocks.

Structure and veins of the Mooseland Gold District, Nova Scotia

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The Mooseland Gold District is one of over 60 similar lode gold deposits hosted by the Meguma Group. The deposit was discovered in 1858 and intermittently worked until 1934, with further exploration in the 1980s. Recent (2003) underground development by Azure Resources provides exposure which has allowed for observations of a section of the auriferous vein system.

The Mooseland vein array occurs in the hinge area and adjacent limbs of the Mooseland Anticline. This fold is a tight (interlimb angle of ~ 35E), steeply inclined, slightly plunging chevron structure within an interbedded sequence of metasandstone, metasiltstone and slate. Fold-related cleavage (S_1) includes a fine, continuous cleavage in slate and spaced cleavage in metasandstone. Oikocryts (mineral aggregates) and, locally, quartz pressure shadows on arsenopyrite, define a down-dip lineation within slate which records fold-related strain. A crenulation cleavage (S_2) locally deforms S_1 and a mineral foliation

defined by biotite within the matrix and orikocrysts is locally developed.

The majority of veins are stratabound, including saddle-reef, massive and laminated bedding-concordant and en echelon bedding-concordant arrays. Stratabound veins are generally confined to the slate-metasiltstone interval of sedimentary cycles. The main "belts", consisting of relatively thick intervals of slate-metasiltstone with multiple veins, may represent the top of sedimentary megacycles. A flexural shear origin for bedding-concordant veins is consistent with: (1) saddle-reef development, (2) down-dip striations within laminated bedding-concordant veins, (3) the geometry and shear sense of en echelon bedding-concordant vein arrays (4) confinement of stratabound veins to incompetent horizons (where flexural shear is focussed) and (5) the spatial relationship of all veins and their common occurrence with flexural-slip movement horizons.

Two sets of discordant veins are recognized within the deposit. Cross veins are roughly parallel to the ac plane of the anticline, and, locally the acute angle between a conjugate set of cross veins is bisected by the oikocryst lineation. Cross veins record various amounts of deformation and some are tightly folded with steep hinges. These observations are consistent with a syn-folding origin for cross veins. Cross veins generally cut stratabound veins. A distinct set of "angular" veins occur in the adjacent Little North Belt. These veins cut stratigraphy at a small angle and are strongly folded, but locally follow bedding-parallel veins, which are thickened by the angular vein. The enveloping surface of folded segments dip moderately to the south (less than bedding) and the fold hinges plunge moderately to steeply east. The fold geometry is interpreted to reflect oblique, sinistral, reverse shear parallel to bedding. The shear recorded by angular veins is inconsistent with the fold-related flexural shear recorded by bedding-concordant veins and its cause is unknown. Importantly, high gold concentrations occur where angular veins overlap bedding-concordant veins, allowing for the definition of ore shoot geometry.

Further unearthing of the hidden Cretaceous basins of central Nova Scotia using seismic reflection profiles and clay mineralogy

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Early Cretaceous rocks of the Chaswood Formation are preserved in isolated sedimentary basins and consist principally of fluvial sandstones and overbank mudstones. This study focuses on the Elmsvale Basin, located within the Musquodoboit Valley of central Nova Scotia. It makes use of seismic reflection profiles and drill cores collected through the 1990s, by government and private sector surveys. Clay mineralogy was investigated by X-ray diffraction analysis of the < 2 μm fraction of mudstone samples. Clay mineral assemblages were related to lithofacies using factor analysis.

Four acoustic stratigraphic packets are recognized in the area north of Middle Musquodoboit, each separated by unconformities, which can be correlated to reference borehole RR-97-23 and to the type section boreholes and seismic profile at Chaswood. Boreholes allow groundtruthing of seismic-reflection profiles; sandy and muddy acoustic facies are distinguished. Unconformities are characterized both by erosional truncations of strata and more commonly onlap. In boreholes, they are commonly marked by a sandstone bed overlying an oxisol, although in some cases, the base of a lignitic mudstone marks the unconformity. Mudstones 5–15 m below the unconformities are principally of light grey colour, whereas regionally dark grey mudstones and red-mottled paleosol mudstones are also abundant.

The clay mineral analysis shows that kaolinite (and kaolinite/expandable layered clay) tend to be more abundant in light grey mudstones. Reddish oxisols are enriched in hematite, whereas brownish ultisols have common vermiculite. Mica/vermiculite mixed layer clays tend to be most abundant in the middle and upper members of the Chaswood Formation. Illite is most abundant in silty mudstones and is relatively more abundant in medium-grey mudstone and red-mottled paleosol mudstone.

Paleogeographic reconstruction and the presence of braided river deposits shows that intraformational unconformities of the Chaswood Formation formed at least 50 m above sea level. The paleosols and paleobotany indicate a humid subtropical environment. The unconformities would thus have been important groundwater recharge zones, particularly where interbedded sands were present. We thus infer a process similar to that in the kaolin deposits of Georgia, where whitening of clays and neoformation of kaolinite took place below the water table in groundwater recharge zones and was synchronous with paleosol development under oxic conditions above the water table.

Dam! What happened to the site? A 3000 year old archaeological site on the Beechwood Reservoir, New Brunswick

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Precariously located on the head pond of the Beechwood dam on the upper Saint John River, the Ultramar site is currently eroding away at an alarming rate. Fluctuating water

levels and ice scouring have significantly contributed to the erosion of more than 15 metres of this archaeological site since dam construction in 1958. Excavation and surface collecting have produced an assemblage of several hundred artifacts dated to approximately 3000 years ago, with lithic material originating from various Maine and Maritimes' sources and, significantly, one as distant as the northeast coast of Labrador. Current evidence suggests this site was first occupied by Susquehanna tradition peoples which may represent the most northerly site of this type in the northeast. Geoarchaeological examination, focussing on site formation processes, local and regional geology, fluvial geomorphology, lithic raw material and artifact analysis is helping archaeologists to chronicle the natural and cultural activities at this alluvial site.

Climatic signature of some Ordovician, Silurian and Devonian paleosols in the Avalon Terrane of northern Nova Scotia; implications for paleogeographic reconstructions

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The relative position of the Avalon Terrane in Neoproterozoic to Paleozoic reconstructions has been a constant source of controversy. Some of the reconstructions are mainly based on paleomagnetics, isotopic signatures and zircon ages, without due consideration being given to the climatic signatures provided by sedimentary rocks. Paleosols are especially reliable paleoclimatic indicators, but those in the Avalon Terrane have received little attention in this regard.

Red paleosols developed between basalt flows of the Middle Ordovician Dunn Point Formation show evidence for a hot and humid equatorial climate, but one with strongly alkaline characteristics. The absence of significant land plants in Middle Ordovician times is thought to explain this apparent dichotomy between high humidity and high alkalinity. The Dunn Point paleosols may have formed at the eve of a major change in near-surface groundwater conditions that took place near the end of the Ordovician as the radiation of land plants terminated the trend of increasing alkalinity (related to a gradual reduction in atmospheric CO_2 levels) that characterized Precambrian and lower Paleozoic times.

The development of calcrete hardpan in the Red Member of the Silurian Moydart Formation indicates that the climate in that part of the Avalon Terrane, though still warm, had become substantially more arid, possibly due to the migration of Avalon to subtropical areas. Calcrete development and inefficient chemical weathering of basalt flows in the Upper Devonian McAras Brook Formation also indicate tropical arid conditions, but equatorial conditions cannot be ruled out due to the context of supercontinentality in which these paleosols evolved. Hence, according to paleoclimatic signatures from paleosols, the Avalon Terrane of northern Nova Scotia apparently remained between the tropics throughout most of the Paleozoic.

Post-Windsor structure in the Sussex area of the Moncton Basin, New Brunswick

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Compressional/transpressional structures post-dating Windsor Group deposition are increasingly being observed in the Maritimes Basin complex of New Brunswick. For example, in the Sackville (sub-) Basin, Mabou Group strata are folded and overturned to produce repeat sections in core.

In the vicinity of Sussex, near the western end of the Moncton Basin, recent field mapping, core logging, and analysis of new and reprocessed geophysical data, is directing interpretations toward similar conclusions. Associated with the Penobsquis salt structure are thrust faults. Further north at Jordan Mountain, Sussex Group rocks (considered to conformably underlie the Windsor Group) have been cored underneath, and in fault contact with Silurian basement. This fault likely links with a major east-west trending reverse fault that marks the northern boundary of the Case Syncline. North of this fault, Windsor and underlying strata form a series of SW-plunging, fault-bounded synclines. To the south of the Case Syncline, Silurian basement is cut by numerous NE-SW faults that bound NE-plunging, Windsor Group cored synclines. A detachment surface may also be present within the Windsor in this area.

Further south, near Upham, an Irving borehole penetrated over 400 m of basement before encountering Carboniferous strata, and the nearby salt mine, now closed, is also structurally complex. An additional observation of note, from mine samples, is the presence of talc crystals intergrown with the halite adjacent to the roof rock of the mine. These talc crystals may be authigenic, or possibly point toward an alkaline hydrothermal event.

The importance of isostatic and climatic events in the geoarchaeology of the Penobscot Valley, Maine

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The landscape encountered by archaeologists today is not necessarily the same as that used by people in the past. Geological and environmental changes since the last glaciation

produced extreme variations in climate, geomorphology, and vegetation, all with implications for the archaeological record in terms of site location and preservation. Geoarchaeological investigations in the central Penobscot Valley, Maine, included the examination of geological and environmental events in the development of the region. One was the post-glacial formation of the Penobscot River. The second, the correlation of regional archaeological information and stratigraphic sections in excavation units with the paleohydrologic record developed for the region.

Geological studies suggest that Early Holocene, isostatically driven changes in drainage divides shifted the outlet of Moosehead Lake, the largest lake in Maine, from the Penobscot River drainage into that of Kennebec. The associated abandonment of the northern outlet, and changes in river discharge, may have had significant impacts on occupation sites and travel routes. Paleohydrologic records of the region indicate times of Late Pleistocene/Early Holocene lake expansion, as well as periods of fluctuating lake levels. These early periods of extensive surface water may have influenced Paleoindian and Early Archaic travel routes and resource use. Later periods of varying lake levels provide climatic information that is correlated with paleosols encountered in archaeological excavations, and provide information about site formation, as well as environmental conditions during occupation. Although local in scale, this study suggests the potential importance of these processes in other similar glaciated regions.

Geology and geochemistry of the Rattling Brook gold deposit, western Newfoundland: an assessment in the context of Carlin-type deposit models

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The Rattling Brook gold deposit is a large, dispersed, low-grade system in which auriferous sulphides are disseminated or present in myriad tiny veinlets. Larger and more continuous quartz vein systems typical of most gold deposits are conspicuously absent. The dominant host rocks are altered Precambrian granites, but some of the best mineralization occurs in altered Precambrian metadiabase dykes and in Cambrian quartzite, limestone and phyllite. The mineralization must be post-Cambrian, but its timing is otherwise unconstrained, although a Silurian or younger age is implied by its undeformed character. The commonality of textures in mineralized rocks, and broadly similar alteration sequences, suggest that a single process deposited gold in all of these host rocks. Petrological and metallurgical studies indicate that free gold is very rare and imply that much of the gold is refractory, likely held within sulphides. The most likely candidates are gold-rich arsenopyrite or gold-rich arsenical pyrite, but the latter has yet to be firmly identified.

Geochemical data indicate that there is very little associated Ag, and essentially no enrichment in Cu, Zn, Pb, Co or Ni. There are strong Au-As-S correlations, and a diffuse Au-Ag correlation, but essentially no correlation between gold and the base metals. Auriferous samples are also commonly enriched in Te and W, and there is more diffuse enrichment in Sb. A few auriferous samples display marginal enrichment in Tl, but no obvious enrichment in Hg or Se is present. There remains a pressing need for more extensive and precise trace element geochemistry, and for more information on sulphide mineral assemblages and the habitat of gold. However, the geochemical characteristics and associations at Rattling Brook in part resemble those described from Carlin-type gold deposits in the southwestern USA, and lend support to the application of new deposit models.

Mineralogical and petrographic characteristics of the Cenozoic and Upper Mesozoic reservoirs in Venture B-13 and Arcadia J-16 Wells, offshore Nova Scotia

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The Mississauga (Lower Cretaceous) and Mic Mac (Middle-Upper Jurassic) formations are reservoir rocks for hydrocarbons in the offshore Nova Scotia. Cores from both formations were studied in Venture B-13 and Arcadia J-16 boreholes respectively for their mineralogy and petrography. Clay mineralogy of cuttings from overlying Cenozoic formations in Venture B-13 borehole was also studied. The upper part of the Mississauga core consists of three units of oolitic-fossiliferous arenaceous limestone (total thickness of 5.81 m) alternating with shaly siltstone and oolitic-fossiliferous calcareous sandstone. The amount of oolites and fossils gradually decreases downward as the limestone turns to calcareous sandstone. The deeper intervals of the core are made up of alternating sandstone, siltstone and shale. Shale intervals become more common in the lower intervals. The alternating sandstone units have calcareous cement, but other cementing materials (e.g. microcrystalline silica - chert and/or clay) are not uncommon. Some units have high porosity / permeability with almost empty pore spaces. Mic Mac core comprises alternating sandstone, siltstone and shale. Mineralogically both Mississauga and Mic Mac sandstones are rich in quartz with minor amounts of feldspar and mica with sporadic occurrences of glauconite, chamosite, pyrite, iron oxides, bituminous material; accessory amounts of zircon, tourmaline, rutile and variable amounts of calcite, minor chert and clay as cementing material. Fluorescence microscopy confirms the existence of relict hydrocarbons in these sands. Sand grain size varies from fine to coarse and is generally poorly sorted and the grains are subrounded to angular in shape. QmFLt, QtFL, QmFK, QpLvmLsm triangular plots for the main constituents of these sandstones, i.e., quartz, feldspar and lithic fragments show that they are quartzarenites and/or

sub-arkoses and have craton interior continental block provenance. Mic Mac sands are more quartzitic, poorer in feldspar and rock fragments relative to those of Mississauga sands. The poor sorting and angular nature of the sand grains suggests the adjacent mainland lithologies dominated by Meguma Group and South Mountain Batholith as the most probable source for these sediments. Preliminary clay mineral studies of shales associated with sandstones over the Mesozoic and Cenozoic succession in Venture B-13 borehole show predominance of chlorite, illite, kaolinite, montmorillonite and mixed-layer clays pointing to the detrital origin for most of these clays with some contributions due to diagenetic effects. Montmorillonite and kaolinite decrease at deeper parts of the succession possibly due to their transformation to illite and chlorite respectively, perhaps associated to the build up of overpressures at a depth of 4500 m.

The East Kemptville tin-base metal deposit, Nova Scotia: documentation of the magmatic to hydrothermal transition in a highly-fractionated, F-rich environment

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The East Kemptville tin-base metal deposit, in operation from 1985–1992 as the only primary producer of tin in North America, is hosted by a 376 Ma topaz-muscovite leucogranite (EKlcgr). Mineralization (i.e., 56 Mt @ 1.65% Sn) occurred as structurally controlled, zoned- and massive-, tin-topaz-sulphide greisens. Geochronological (Rb-Sr, $^{40}Ar/^{39}Ar$, Pb-Pb, U-Pb, Re-Os) and petrological studies indicate that the EKlcgr represented the end product of crystal (Plg-Bt-Kfs)-fluid fractionation of a zoned, peraluminous magma. This zoned magmatic complex, referred to as the Davis Lake Pluton, is one of several plutonic centres comprising the large (7800 km^2), 380 Ma South Mountain Batholith. The EKlcgr (ca. 1 km^2) was emplaced at ca. 3.5–4 kbar and represents the apical portion of a zoned, F-rich magma within which occurred periodic cycling of fluid pressure. The preserved textures and petrological features that reflect this once dominant process include: (1) gradation and heterogeneity of granitic textures inwards from the contact (i.e., roof); (2) a variety of miaroles near the roof zone, some of which contain primary cassiterite; (3) distribution of paired aplite-pegmatite sheets; (3) crenulate layering and USTs marginal to the contact; (4) abundant stockscheider; and (5) an unfractionated chemistry (e.g., whole rock and Kfs)for pegmatite versus the host EKlcgr. Related to the cyclicity of fluid pressure was emplacement of the EKlcgr into an active shear-zone environment, evidence of which includes: (1) the elongate outline of the intrusion; (2) orientation of quartz grains in the EKlcgr and endogenic pegmatites; (3) stockscheider alignment; and (4) the structural control of mineralized greisens and veins (e.g., fibre veins on growth faults). Stable isotopic data (O, D, S) and fluid inclusion studies indicate that the magma evolved as a closed system with no evidence of second boiling (i.e., fluid unmixing), the latter feature of which is commensurate with the depth of formation. The above observations are interpreted to suggest that the mineralized environment evolved due to injection of a volatile-rich, chemically-evolved (i.e., Sn-, Cu-, Zn-, F-rich) magma into a fault zone within which periodic pressure release related to seismic events facilitated exsolution of a mineralizing fluid. Migration of this fluid into structural sites (i.e., fractures) and its subsequent interaction with and neutralization by the wallrock EKlcgr resulted in the formation of zoned- and massive greisens.

Devil Pike Brook gold occurrence, Silurian Mascarene belt, south-central New Brunswick

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The Devil Pike Brook occurrence is a gold-bearing quartz-carbonate vein system hosted within a package of greenschist-grade mafic volcanic rocks composed of basalts, pillowed basalt, tuff, and hyaloclastite of the Grant Brook Formation (Mascarene Group), located east of the Saint John River in south-central New Brunswick. Structurally controlled, quartz-carbonate veins are generally north-trending, which is consistent with the localized intense foliation, but oblique to the regional NE structural trend. The occurrence is located approximately 500 m south of the regional northeast-trending, subvertical, transcurrent Taylor Brook Fault that separates the Early Silurian Mascarene Group to the south (including the Long Reach, Grant Brook, and Henderson Brook formations) from the volcano-sedimentary sequences of the Late Cambrian to Early Ordovician Annidale Group to the north. A younger (?) leucogabbroic unit outcrops on the property and potassium feldspar-bearing gabbro can be found throughout the surrounding areas.

Three major drilling campaigns conducted by Fosters Resources between 1994 and 1996 (59 drill holes) have defined three mineralized zones: 'Baxter', '16', and 'Boyd' from north to south, respectively. The Boyd Zone is the most significantly mineralized. Resampling of quartz-carbonate veins in drill core from the Boyd Zone has confirmed gold concentrations in excess of 80 ppm (2 samples of 25 and 30 cm in length). A 15 cm long channel sample across a quartz-carbonate vein exposed at the discovery trench (Baxter Zone) contained 47 ppm gold. Quartz textures observed in polished hand samples include anhedral buck quartz and brecciation (both infill and aggregate), in association with numerous recrystallized quartz veinlets, which are analogous to other greenstone-hosted gold-bearing quartz vein deposits. The gold content appears to be lo-

cally elevated near the brecciated zones, which is also consistent with other mesothermal gold-bearing quartz veins. Associated sulphide minerals identified include abundant pyrite, lesser chalcopyrite and reported minor sphalerite and trace arsenopyrite. Multielement lithogeochemical logarithmic results on 37 samples (19 samples from 15 drill holes in 3 zones and 18 samples from one outcropping quartz vein) indicate a positive Pearson's product correlation coefficient (r) between gold and silver (r = 0.88), copper (r = 0.83), tellurium (r = 0.74), arsenic (r = 0.72), and sulphur (r = 0.72). Average sulphur and arsenic content in the 15 mineralized samples is approximately 4 wt% and 304 ppm, respectively. The proportions of gold, silver, nickel, copper, zinc, lead, and tin in the Devil Pike Brook occurrence are comparable to other greenstone-hosted, gold-quartz deposits.

Dendroclimatology in Atlantic Canada: ringing the past out of trees

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Tree-ring analysis is a useful technique able to illuminate many areas of paleoenvironmental research. Most regions of Canada have been investigated to some degree using dendrochronological methods, but by far the least studied region is Atlantic Canada.

This presentation will highlight positive and negative aspects of conducting dendrochronological research within the Atlantic Coast region with an emphasis on understanding past climates. Results from initial work establishing long-term chronologies will be discussed, as well as unique methodological approaches incorporating tree-ring samples from several sources. Extensive historical and paleobotanical sources are probably the only means of extending tree-ring records back far enough to produce the kind of long-term annual-resolution models common elsewhere in Canada. By using these methods, useful proxy models of climate can finally be developed for the region to more fully understand past environments, and to better predict future climates through regional and global circulation models.

A novel contemporary fluvial ichnofauna

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A period of low water level (1 m below average) in the Saint John River provided an opportunity to study sediment traces associated with an environmentally stressed fluvial freshwater ecosystem. The fluvial omission event resulted in the creation and preservation of a variety of unbranched, cross-cutting, irregular, sinuous and spiraling interface traces (repichnia and pascichnia), which commonly demonstrate terminal burrowing (cubichnia). Traces were examined on an exposed sand bank between Ross and Jewett islands, and a molluscan fauna, the apparent progenitors of the structures, was sampled. A similar taphofauna, without associated traces, was also observed downstream on the river bank.

The recent trace suite is attributable to the Scoyenia ichnofacies and includes examples of traces with morphologies comparable to the ichnogenera *Lockeia*, *Curvolithus*, *Spirophycus* and *Gordia*. The traces can be directly attributed to the associated molluscan assemblage comprising sphaeriid and unionid bivalves and unidentified gastropods, examples of which are 'frozen' at the end of the traces or in shallow terminal burrows. Evidence of vertebrate activity is also apparent, with avifauna indicated by walking (gull and raven), probing (gull) and excavation (raven) traces as well as faecal material. Mammal tracks include mink and cow.

The mixed-load, braided, alluvial channel depositional system is characterized by frequently shifting sand banks, which would tend to preclude preservation except in the instance of channel abandonment. The epirelief nature of the majority of traces further limits the preservation potential of the assemblage and the relatively high energy of the river system creates a harsh taphonomic regime for molluscan preservation which is characterized by dissolution of aragonite in the case of the Unionacea.

Quaternary geology and seabed geohazards of the continental margin offshore Haddock Channel off southern Newfoundland

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The deep continental margin off Nova Scotia and Newfoundland has numerous submarine landslides. Submarine landslides are a potential hazard for hydrocarbon development and a possible source of tsunamis. The deep-water area off Haddock Channel is unusual for the very active shallow salt tectonics. This area was studied to establish whether the salt tectonics increased the risk of submarine landslides in the area. The region was studied from 300 line-km of Huntec high-resolution seismic reflection profiles, used to map the stratigraphic occurrence and geographic distribution of landslide deposits.

Eight long piston cores were used to determine the age of the stratigraphic section and hence the age of the younger landslide deposits. Chronology was based on the recognition of detrital carbonate beds (Heinrich layers) and their correlation with

dated sections elsewhere. The principal sediment recovered in cores is mud, deposited from proglacial plumes when continental ice crossed the continental shelf.

Seismic correlation was carried out by defining key reflections at a type section. Correlation was difficult due to erosion along the main valleys, fault scarps, mass-transport deposits, and evacuation of failed sediment and resulting changes in the sub-bottom depths of key seismic horizons. In particular, correlation across the major Haddock valley proved impossible. Six reflectors were identified in the upper 100 ms of sediment. The shallowest was correlated throughout most of the study area and correlates with a Heinrich layer observed in several cores. The shallowest regional mass-transport deposit immediately underlies this reflector. Two other major mass-transport deposits are recognized deeper in the section. Failure scarps are recognized at the margins of all three deposits.

Numerous shallow faults were located in the study area and fault-line scarps tens of metres high are common. The orientation of faults is difficult to determine from the available seismic profiles.

The restriction of large mass-transport deposits to only a few stratigraphic horizons and their presence in multiple valleys suggests an origin by regional earthquake shaking, rather than any local trigger. Such regional failures have a recurrence interval of 10–20 thousand years.

The McKeel Lake Zr-Ta-Nb-REE- and Zr-rich pegmatite-aplite dykes, Welsford Granite, New Brunswick: an example of extreme fractional crystallization of a miaskitic peralkaline granite

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The high-field-strength-element (HFSE) enriched McKeel Lake miaskitic peralkaline granitic pegmatite-aplite dyke system is hosted within the Late Silurian mantle A-type, multiphase peralkaline Welsford alkali-feldspar granite (422 ± 1 Ma) in southwestern New Brunswick; both share similar major minerals and textures. The pegmatite-aplite dykes (419 ± 20 Ma) are up to 40 cm wide, closely spaced (10–20 cm), with sharp contacts (170°/90°) within the host granite. Fine-grained saccharoidal quartz, perthitic K-feldspar, and albite with zircon and other numerous rare minerals form a rhythmic layering with the long riebeckitic amphiboles (up to 3 cm) in the aplite extending towards core of the dykes. Micrographic to granophyric texture is also common. These textures are consistent with a predominantly magmatic growth history probably related to pressure quenching (depressurization) of the melts, with a volatile phase involved. These mineralized pegmatite-aplite dykes represent a late magmatic, extremely fractionated part of the Welsford alkali granite intrusion, with Ta (74 to 220 ppm), Nb (750 to 3040 ppm), Zr (1450 to 36000 ppm), Y (540 to 3070 ppm), Th (170 to 870 ppm), U (60 to 250 ppm), Ce (430 to 1950 ppm), Yb (110 to 290 ppm), and Be (20 to 103 ppm). Zoned zircon crystals are characterized by enrichment in Hf, Th, and U, corresponding to peralkaline melt evolution. In addition, Ta-Nb-oxide, euxenite, fergusonite, aeschynite, (Y)-aeschynite, REE-fluorocarbonate, and fluorite mainly occur in the aplitic parts of the dykes, although they also are sparsely distributed in the pegmatitic sections.

Bulk distribution coefficients (D) of these elements, assuming Ta as the most incompatible element and using the Rayleigh fractionation equation, were calculated for the extreme fractionation of these peralkaline granitic melts (Welsford alkali granite to McKeel Lake dykes), in terms of the Allégre method: Sr & Rb (0.96), TiO_2 (0.895), La (0.69), Be (0.54), W (0.53), Pb (0.35), Y (0.26), Yb (0.25), Th (0.17), Zr (0.129), Nb (0.111), U (0.092), and Hf (0.069). The covariation of the observed trends between the two populations reaffirms the genetic parental relationship of the host Welsford intrusion to these pegmatite-aplite dykes. The coherent behaviour of these HFSE suggests a common enrichment process. This suggests that these elements occur as very incompatible elements in the magmatic evolution until the injection of the dyke swarm, with negligible ferromagnesian or HFSE mineral fractionation consistent with their peralkaline composition, i.e., no fluids are required to produce this extreme Ta-Nb-Zr-REE-Y-Th-U enrichment.

Fluid inclusion studies in quartz veinlets of the Darreh-Zereshk and Ali-Abad porphyry copper deposits, central Iran

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The porphyry copper deposits at Darreh-Zereshk and Ali-Abad are located southwest of the Yazd city, central Iran. The porphyries occur as granitoid intrusions, ranging in composition from quartz monzodiorite through granodiorite to granite, hosting copper ore that exhibits intense, hydrofracturing that lead to the formation of veinlets of quartz and sulphides. Four types of alteration are recognized within the ore zones, potassic, phyllic, propylitic, and argillic. The potassic alteration was developed in granitoid rock near the core of the mineralized zone and surrounded by other types of alteration.

Fluid inclusions in the deposits can be classified as a monophase Type I (vapour), liquid-rich Type IIA (liquid + vapour), vapour-rich Type IIB (vapour + liquid), and multi-phase (liquid + vapour + halite + sylvite + hematite + chalcopyrite and pyrite) Type III. Homogenization temperatures and salinity data are presented for fluid inclusions from hydrothermal quartz veinlets associated with hypogene mineralization. Ore

precipitation occurred between 150° to 600°C from low to high salinity (1.1–73.9 wt% NaCl equiv.) aqueous fluids. Two stages of hydrothermal activity characterized by high salinity (> 40 wt% NaCl equiv.) are recognized; one which occurred at relatively high temperature and lower salinity fluid (Type IIIa; $Th_{(L-V)} > Tm_{(NaCl)}$); and one which took place at lower temperature and higher salinity (Type IIIb; $Th_{(L-V)} < Tm_{(NaCl)}$). The high $Th_{(L-V)}$ and salinities of Type IIIa inclusions are interpreted to represent the initial existence of dense fluid of magmatic origin. The coexistence of Type IIIb and Type I and Type IIB inclusions suggest that these fluid inclusions resulted either from trapping of boiling fluids and/or represent two immiscible fluids. These processes probably occurred as result of pressure fluctuations from dominantly lithostatic to hydrostatic conditions, under a pressure of 200 to 300 bar, corresponding to a depth of 2 to 3 km assuming hydrostatic pressure and 1 to 1.5 km assuming lithostatic pressure. Dilution of these early fluids by convecting meteoritic water resulted in low temperature and low to moderate salinity (< 20 wt% NaCl equiv.) fluids (Type IIA). Fluid inclusion analysis reveals that the hydrothermal fluid, which formed quartz mineralized veinlets in the rocks with potassic alteration, had temperatures of ~ 500° and salinity ~ 50 wt% NaCl equiv. Cryogenic SEM analyses of ore-bearing fluids trapped in the inclusions indicate the fluids were dominated with NaCl, KCl and minor $CaCl_2$.

Phreatomagmatism of the Silurian Passamaquoddy Bay subbelt, Maine and New Brunswick

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The Coastal Volcanic belt (CVB) extends from Massachusetts to New Brunswick and comprises bimodal volcanic rocks associated with continental extension. The Silurian Passamaquoddy Bay subbelt is located in the northern part of the CVB in Maine and New Brunswick. The Passamaquoddy Bay subbelt is divided by the Oak Bay fault. Exposures on either side of the fault have been correlated based on similar lithologies and faunal assemblages. This study compares volcanic style across the subbelt, focusing on phreatomagmatic volcanism, as a distinguishing characteristic.

The Passamaquoddy Bay subbelt in Eastport, Maine, includes sedimentary, mafic tuff, mafic flow, and felsic tuff facies. The sedimentary facies is dominated by siltstone and fine-grained sandstone with minor conglomerate. Sedimentary features are characteristic of a littoral depositional environment. Mafic tuffs are variable in composition but are generally characterized by a high percentage of lithic clasts (up to 90%). The low abundance and scoriaceous nature of the magmatic fragments is consistent with phreatomagmatic eruptions. Bedding structures indicate variable depositional processes including surge, airfall and lahars that may represent part of a maar or tuff cone. The mafic flows are fine-grained with structures interpreted to be vesicular flow tops, massive interiors, flow bottom breccias, and *in situ* brecciation. These rocks are interpreted to be Hawaiian-type flows that interacted with water. Felsic tuffs contain a high percentage (up to 90%) of juvenile fragments and < 10% accidental lithic clasts. The high abundance of bubble-wall and platy glass shards and pumice fragments indicates a volatile-rich magmatic eruption. The alignment of elongate pumice clasts and lack of other bedding structures is characteristic of pyroclastic flows. The area is locally intruded by fine-grained mafic dykes and sills. These intrusions show variable contact relationships with the sedimentary rocks and represent multiple intrusive events with evidence for non-explosive interaction with wet and unconsolidated sediment. This style of volcanism is compared to the Passamaquoddy Bay subbelt in New Brunswick.

The Passamaquoddy Bay subbelt is characterized by variable styles of volcanism, but typically indicating the interaction with water in an intertidal environment. These results suggest a significant shallow marine extensional basin within the Northern Appalachians during the Silurian, with variable eruptive styles of bimodal volcanism.

A new geographic information system for the Strand Fiord area, western Axel Heiberg Island, Nunavut

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A Geographic Information System (GIS) assembled for the purpose of geoscience applications in the territory of Nunavut represents the first attempt to integrate multiple databases in areas north of the 75th parallel. We chose the western part of Axel Heiberg Island for this study because of the significant number of geological and geophysical studies that were carried out by the Geological Survey of Canada in this region, over the past 50 years. There is also a renewed interest in the resource potential of this area, linked to the interaction of Cretaceous igneous rocks with evaporite diapirs that intrude the Mesozoic and Tertiary succession of the Sverdrup Basin. Spectacular exposures of volcanic rocks and salt domes are found along the shores of Strand Fiord and Expedition Fiord.

To produce the GIS, aeromagnetic and gravity data were integrated with geological and topographic maps (1:250 000 scale). A digital elevation model was included to allow more

precise identification of igneous intrusions sampled during field work. Lithological data are being compiled for three volcanic successions in the Strand Fiord Formation (Bastion Ridge, Twisted Ridge, and Index Ridge, on the Kanguk Peninsula) and a large sill exposed at the head of Expedition Fiord (Wolf Intrusion). The list of attributes for samples from each location includes: geographic location, lithology, petrography, textural characteristics, whole-rock geochemistry, and geochronological data where available. The GIS is a useful tool to characterize and classify the igneous rocks and salt diapirs, for example, by providing information on the shape and morphology of the structures, nature of geological contacts, attitude and extent of faults, and relative percentage of igneous material "rafted" in the salt domes. A preliminary analysis of the aeromagnetic data revealed the existence of a north-to northwest-trending high, and allowed us to delineate the salt diapirs and some important regional faults. Gravity anomalies change from low negative to low positive values from east to west in the study area.

Inferences on glacial flow from till clast dispersal, Coldstream area, New Brunswick

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Dispersal patterns for till clasts from the Coldstream map area (NTS 21 J/06), New Brunswick, are compared to source outcrops and used to confirm main ice-flow directions across the 1070 km² area. Seven major lithologies are identified for clasts collected at 2 km intervals from 274 sample sites. These results demonstrate that glacial transport was mainly southward and southeastward during the last major glaciation of the area, comparable to the few striae known from the map area.

In general, till clasts were derived from local bedrock sources. The lengths of dispersal trains vary from 1 to 10 km. Sedimentary clasts form dispersal trains that are limited to 1 to 4 km in length extending southeastward of their source outcrop. Dispersal trains for granitic clasts extend over distances of 10 km in length southward and southeastward. Small bulls eye dispersal patterns occur for some resistant lithologies in areas devoid of that rock type. These anomalous occurrences may be due to previously unknown outcrops of that rock type, or derivation from underlying conglomerate units.

Generally the size of the dispersal train is larger for resistant lithologies and shorter for less resistant rock types. This suggests that glaciation was likely a highly erosive and dynamic event throughout much of the study area. However, the local preservation of older unconsolidated deposits indicates that glacial erosion was not ubiquitous, but rather variable and selective.

The McCully Gas Field: production, reserves and challenges

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The McCully Field was discovered near Sussex, New Brunswick, in 2000. Eight wells have been completed within the McCully structure and all wells show a thick sequence of gas-filled interbedded lacustrine sandstones and organic shales deposited within lacustrine deltas, shorelines and fluvial systems of the Hiram Brook Member.

The wells have been on production to the PCS mill since April 2003 and have averaged nearly two mmcfpd (more than one bcf total) with little depletion, indicating an extensive reservoir.

Pressure buildups and production histories provide a good indication of well reserves. McCully # 1 (A-67) has 3.2 bcf of proven reserves despite producing from only the lower zone and having been severely damaged during completion. McCully #2 (P-66) has 9.6 bcf of proven reserves. The Proven and Probable (i.e. mean estimate) of the portion of the field under the 3D survey is 119 bcf. This is estimated to be ~ 20% of the McCully gas-bearing structure.

Challenges remain in the drilling and completion (fracing) of these wells. We will discuss some possible reasons for the failure of previous frac attempts. With a likelihood of over one tcf of gas in place, efficiencies of drilling and completions will determine the ultimate recovery percentage.

Environmental Evolution of the Pleasant River Wetland, Nova Scotia

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Wetlands constitute an important terrestrial sink for carbon. A decrease in productivity or change in groundwater regime will affect this sink and a net release of greenhouse gases could result. As well, wetlands in Nova Scotia provide habitat for several rare, disjunct species, most notably the Blanding's Turtle. The survival of these species may be dependent on the stability of these environments. In our study we are attempting to determine if the Pleasant River Fen has responded to known climate change events, in particular Late Holocene (Neoglacial) cooling.

The Pleasant River Fen is located in southwestern Nova Scotia near Kejimkujik National Park. Sediment depth was measured by probe and sonar, and was highly variable (> 6 m) and dominantly organic. A 4 m long vibracore sample was analyzed for lithostratigraphic proxies including loss on ignition

(LOI) and magnetic susceptibility (MS). Wood at the base of the core provided an AMS date of 9060 ± 70 ^{14}C yr BP. MS values were consistently low indicating low clastic influx. LOI values varied with depth however values in excess of 60% occurred near the base of the core.

A transition in lithostratigraphic properties at 126 cm depth (~ 3000 ^{14}C yr BP) is coincident with the onset of modern moist cool climate as recorded in other records. The lithostratigraphic transition appears to represent a shift to a wetter environment possibly associated with a rising water table. The upper 40 cm of the core (300 BP – Present) exhibits much lithostratigraphic variability which appears related to human activity (fire, water level management) in the region. The results of this study indicate the Pleasant River Fen has evolved significantly in response to past environmental change. Future climate change has the potential to further modify this environment.

Bifurcation ratios and drainage densities of Arctic drainage networks

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River networks commonly are characterized by drainage density, bifurcation ratio, length ratio, stream frequency; many of these properties have been proposed to be scale invariant and common between river networks. Arctic drainage networks are a poorly examined facet of fluvial geomorphology and require attention to complete the global river network picture. Processes differ: for example, the presence of water tracks – linear region 1–10s of metres wide where groundwater flow is channelized through peat – may replace the role played by low-order open-channel streams found in drainage basins of lower latitudes. Using 60 and 90 metre resolution digital elevation models, we compare drainage networks in the Yukon coastal plain with lower latitude networks such as the Peace River hills of Northern Alberta, the Okanogan Valley of south central British Columbia, and the coastal plains of eastern Nova Scotia. Drainage network characteristics, including Hortonian classification and Laws, are extracted. The extremely low drainage density, high bifurcation ratios of low order streams, small length ratios, and high stream frequency of high latitude (Arctic) networks is a hydrological response to the frozen, impermeable nature of the underlying permafrost resisting channelization. Lower latitude, unfrozen channels originate as similar, water-track-like rills in underlying soils, but due to significant precipitation, the ability for overland flow, the erodible nature of the substrate, and lower entrainment energies, are permitted to evolve into numerous deeply incised channels. Continuous peat in the Yukon Coastal Plain further resists channelization due to the high permeability of un-decomposed peat facilitating water track stability by being permeable enough to prevent overland flow. Due this absence of overland flow and underlying impermeable permafrost, Arctic drainage networks remain in the Hortonian low order state until connecting to high order drainages likely emplaced by thaw lake drainage events. Bifurcation ratios are atypically not uniform across different channel orders. Instead, ratios are low between all orders, except the lowest order, consistent with the effects of water track processes. Under current and anticipated degradation of permafrost by anthropogenic warming, water tracks may eventually incise and form open water channels thereby increasing Hortonian drainage density. With warmer temperatures, larger amounts of precipitation, and significant permafrost reduction, incision of water tracks into low order streams will force Arctic drainage networks to mirror their lower latitude counterparts in fractal classifications.

The gold-rich Louvicourt Volcanogenic Massive Sulphide Deposit, New Brunswick: a Kuroko analogue in the Bathurst Mining Camp

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The Louvicourt Au-Ag-Cu-Zn-Pb sulphide deposit is hosted by felsic volcaniclastic rocks of the Flat Landing Brook (FLB) Formation, Bathurst Mining Camp (BMC), New Brunswick. Massive sulphides (136 000 tonnes and grade 1.2% Pb, 1.0% Zn, 0.4% Cu, 90.9 g/t Ag, and 0.96 g/t Au) and iron formation are traceable along a laterally continuous contact demarcated by the presence of sedimentary rocks atop a calc-alkaline sequence of aphyric rhyolite flows and associated fragmental rocks; however, a large percentage of the sulphides occur as a late replacements of altered felsic fragmental rocks in the footwall. Lower metamorphic grades (middle greenschist) and heterogeneous deformation has locally preserved many primary features such as colloform pyrite and perlitic and spherulitic volcanic textures. This syngenetic exhalative deposit is unique for the Bathurst Mining Camp with high Pb/Zn and high Au, as well as its intimate relationship with an emergent felsic dome (FLB), chlorite-silicate-oxide-sulphide exhalite (locally hematitic), and the abundance of barite, which are classical features of many of the Kuroko deposits.

Zr/TiO_2 (avg. 0.110) and Y/TiO_2 (avg. 0.021) of aphyric FLB felsic volcanic rocks are consistent with known values for the Reids Brook Member. Felsic volcanic rocks are conformably overlain by trachy-andesitic volcaniclastic material (possibly pyroclastic) of the Little River (LR) Formation and is enriched in Nb (avg. 39.2 ppm) and P_2O_5 (avg. 0.17 wt.%), and possessing much lower Zr/TiO_2 (avg. 0.056) and Y/TiO_2 (avg. 0.0062). LR Fm. within-plate transitional basalts and hyaloclastite (Nb/Y = 0.60) have higher TiO_2 contents (avg. 2.8 wt.%) consistent with those of the voluminous Brunswick Member, although the Louvicourt mafic volcanic suite (upper LR Fm) is considerably enriched in P_2O_5 (avg. 0.82 wt.%).

The base- and precious-metal content of the Louvicourt deposit is atypical of BMC massive sulphide deposits. Assessment

file assay data from the sulphide intersections (n = 27) yield a Pb/Zn ratio of 2.6, the highest recorded for any massive sulphide deposit in the Bathurst Camp (Pb/Zn avg. 0.39). Lead exhibits a strong Spearman Rank correlation (r' = 0.92) with base metals throughout the sequence indicating a preponderance of galena in the stockwork and massive sulphides (n = 80). The deposit also has elevated Ag and Au contents, among the highest in the BMC. Barite-rich exhalative pyrite (n = 10) exhibits a moderate Au correlation with Ag (r' = 0.77) and Cu (r' = 0.76). This Au-Ag-Cu association displays a strong correlation with Pb/Zn suggesting precipitation of Au in Pb-enriched portions of the exhalative sulphides. The persistence of exhalative hydrothermal activity at the terminal stages of FLB felsic volcanism, with an evolution towards extensional magmatism (alkalic LR Fm), highlights the exploration potential for VMS systems along the contact between the FLB and LR formations within the Middle Ordovician Tetagouche Group.

Correlation and geochemistry of Late Ordovician to Silurian sequences in southwestern New Brunswick: evidence for a northwesterly facing arc complex

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The belt of Late Ordovician to Silurian volcano-sedimentary sequences in southwestern New Brunswick and southeastern Maine occurs within several fault-bounded blocks, each of which represent segments of a faunally connected basin or associated basins. These include the Oak Bay (OBSB), Passamaquoddy Bay (PBSB), Mascarene (MSB) and Kingston (KSB) subbelts from northwest to southeast in the western part of the region and the Nerepis subbelt (NSB) along strike to the northeast. Attempts at correlations across the belt and to establish unifying tectonic models have been hampered by differences in lithological/structural features between subbelts, paucity of age dates and an incomplete geochemical database.

Based on the results of recent mapping programs, available dates, and tectonic discrimination and multi-element plots for new and existing geochemistry, stratigraphic correlations in the region have been re-evaluated and the following generalizations are made. The oldest part of the belt crops out in the MSB and KSB, is Late Caradocian or Ashgillian to mid Llandoverian in age, and exhibits a higher degree of deformation and/or metamorphism than younger sequences in the belt. Volcanism during this early stage of basin evolution reflects episodic, continental arc-type magmatism that changes in composition from mafic and intermediate, to intermediate and felsic up section. Mafic to intermediate volcanism predominates basin-wide during Late Llandovery time and is characterized by mixed arc, MORB and marginal basin geochemistry in the southeastern and northeastern subbelts (MSB, KSB and NSB). However, arc signatures prevail in subbelts to the northwest (PBSB and OBSB) during this time. During Wenlockian to Ludlovian time, episodic arc-related volcanism in the northwestern-most sequence (OBSB) appears to continue, while volcanism to the southeast in the PBSB contrasts markedly by being distinctly bimodal and by exhibiting within-plate geochemical features.

Considering the overall geometry and risking oversimplification by assuming the present subbelt distributions more-or-less reflect their relative positions in Paleozoic time, the following factors are most consistent with a southeasterly dipping subduction zone in a continental arc environment for generation of the complex. Sequences exhibiting geochemical features indicative of arc-type volcanism migrate in space and time to the northwest, remnants of the older parts of the arc complex in the southeastern subbelts are affected by an early deformation and/or metamorphic event and are overlain by sequences with magmatism showing mixed (back-arc) signatures, and within-plate magmatism occurs late in the complex's evolution within the youngest active part of the arc to the north of the marginal basin.

Petrology and tectonic setting of the Seal Island Pluton, offshore southwestern Nova Scotia

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The Seal Island Pluton outcrops on several offshore islands 30 km west of Clarkes Harbour in southwestern Nova Scotia. Previous reconnaissance studies had reported that the pluton consists of coarse-grained biotite granodiorite and monzogranite, similar in texture, mineralogy, and presumably age to the South Mountain Batholith. However, mapping and sampling on Seal Island and smaller surrounding islands in July 2004, have provided new insights into the characteristics of the pluton.

Based on preliminary results, the Seal Island Pluton is divided into two petrologically distinct units. Unit 1 outcrops on Mud, Noddy, and Round islands, whereas unit 2 outcrops only on Seal Island. Both units are composed mostly of biotite monzogranite, but unit 1 contains more microcline that unit 2. It also has more biotite (5–7%) and more abundant accessory minerals (titanite, zircon, apatite, epidote, and ilmenite). Unit 2 has only 2–3% biotite, contains primary muscovite, and exhibits tourmaline layers and patches, in places composing up to 2% of the rock. Relative to unit 1, unit 2 is higher in silica and lower

in TiO_2, FeO_3^T, MnO, MgO, CaO, Zr, V, and Th. Both units are peraluminous but with a volcanic-arc chemical signature. The Seal Island Pluton differs in appearance and chemistry from the Wedgeport, Shelburne, and Barrington Passage plutons, and is unlikely to directly link to any of these nearby "peripheral plutons" of the South Mountain Batholith.

The Seal Island Pluton is characterized by a widespread but weak foliation resulting from preferred orientation of biotite ± muscovite trending approximately north-south. Steep shear zones (< 50 cm wide) occur throughout the pluton but are more abundant along the western side of Seal Island. These zones trend north to north-northeast and have subhorizontal mineral lineations, locally well-developed c-s fabrics, and asymmetric porphyoclasts which exhibit dextral sense of shear. The shearing may be related to the offshore extension of the major Chebogue Point Shear Zone southeast of Yarmouth. The presence of hornfels and metasandstone xenoliths suggests that the pluton intruded the Cambrian-Ordovician Meguma Group.

Pegmatite dykes and pods occur throughout the pluton, and rare mafic dykes (< 1.5 m wide) occur on Seal Island. These dykes are highly deformed as they occur in north-trending shear zones. The dykes are likely syn-to late intrusive within the granite based on observed co-mingling textures. Magnetic susceptibility was measured in the field at all outcrops, and susceptibility values are low in granite and pegmatite, ranging from 0.00 to 0.35, but mainly between 007 to 0.15 $x10^{-3}$ SI units. Mafic dykes have somewhat higher values (0.53–0.75).

Magma evolution in the Pliocene - Pleistocene succession of Kos, South Aegean arc: petrographic evidence for magma mixing

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The island of Kos is the most easterly volcanic centre of the Pliocene-Quaternary South Aegean arc, related to subduction of the African plate beneath the Aegean microplate. Pliocene and early Pleistocene volcanism is represented by dacite flows and rhyolite domes. The mid-Pleistocene Kefalos tuff has abundant lithic clasts of magmatic rocks. The 0.16 Ma Kos Plateau Tuff, derived from an andesite stratocone, now subsided beneath the sea south of Kos, also has abundant lithic clasts.

Lavas, mafic enclaves from more felsic rocks, and lithic clasts from pyroclastic rocks have been examined by petrographic microscope and electron microprobe. The rocks examined range from andesite to rhyolite in composition. Plagioclase is commonly complexly zoned, with corroded and embayed cores, spongy cellular zones, and calcic spikes. Ovoidal quartz is mantled by clinopyroxene crystals and has trapped glass inclusions with a range of compositions. Complexly zoned clinopyroxene is in places overgrown by boxy cellular orthopyroxene. Andesite contains quenched accessory acicular apatite and glass inclusions are found in some plagioclase.

Sr and Nd-Sm isotope determination show mantle values in all rock types, from andesite to rhyolite. Andesitic magma may have been generated by remelting crust underplated with mantle-derived magma during regional mafic plutonism in the Miocene. Episodic replenishment of a fractionating magma chamber would account for the observed mixing textures and the triggering of explosive eruptions.

Decadal-scale sea ice changes in the Canadian Arctic and their impacts on humans during the past 4000 years

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Climate warming of > 1.5°C over three decades has diminished Arctic sea ice and forced drastic changes on Inuit people of the Canadian Arctic. Discontinuities in archaeological records also suggest that climatic changes may have enforced site abandonment and life style shifts in Paleo- and Neoeskimo societies. We therefore carried out a geoarchaeological study to compare the decadal-scale palaeoclimatic changes recorded by quantitative palynological data in marine sediment records from Jones Sound with archaeological records of Palaeo- and Neoeskimo settlement on the North Devon Lowlands. We also compared paleoclimate and sea ice records from the North Water Polynya between Canada and northwest Greenland with archaeological records from southeastern Ellesmere Island. Palaeotransfer functions from dinoflagellate cyst assemblages provide quantitative estimates of changes in sea surface temperature (SST) and sea ice cover (SIC) with the accuracy of historical measurements.

Both marine sediment records show temperature variations of 2–4°C corresponding to changes in hunting modes and occupation-abandonment cycles on Devon and Ellesmere islands. Our data show that from ~ 6500 to 2600 BP, there were large oscillations in summer SST from 2–4°C cooler than present to 6°C warmer and SIC ranged from 2 months more sea ice to 4 months more open water. The warmer interval corresponds to the period of pre-Dorset cultures that hunted muskox and caribou. Subsequent marine-based Dorset and Neoeskimo cultures correspond to progressively cooler intervals with expanded sea ice cover. The warming took ~ 50–100 years and lasted ~ 300 years before replacement by colder intervals lasting ~ 200–500 years. These climate oscillations are more rapid than the archaeological cultural changes, but are of similar length to successive Palaeoeskimo occupations in the Nares Strait region.

Downhole trace and major element chemostratigraphic patterns relating to igneous fractionation processes in the Golden Mile Dolerite, Western Australia

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The largest gold mine in Australia is the Fimiston Superpit, located in the Golden Mile Camp, Kalgoorlie, Western Australia. This mesothermal gold mine is jointly owned by Barrick Gold Corp. and Newmont Mining Corp. through Kalgoorlie Consolidated Gold Mines. The main host to mineralization is the differentiated Golden Mile dolerite: a sill up to 940 m thick. Previous research has subdivided the Golden Mile dolerite into ten units based on mineralogy, primary igneous texture and iron/titanium oxide mode and morphology. The area is structurally complex and boasts several deformational events. Zones of intense hydrothermal alteration with concurrent obliteration of primary igneous textures are common. These factors have made chemostratigraphic studies of the intrusion important for determining stratigraphic position within the sill during deep exploration drilling.

Distinct downhole geochemical patterns in both major and trace elements using molar element ratios have constrained a set of igneous differentiation processes responsible for the mineral mode and textural diversity of the sill. (Al/2+Na/2)/Zr and (Ca/2+Fe/2+Mg/2-Al/4+Na/4)/Zr molar ratios that specifically track the addition or loss of plagioclase and pyroxene, exhibit patterns that allow recognition of pyroxene cumulates in the lower units of the sill, despite the textural ambiguity created by subsequent hydrothermal alteration.

A major lithological discontinuity associated with the introduction of magnetite to the liquidus assemblage occurred at the base of Unit 6. Differences in shapes of the Ti/Zr and V/Zr downhole patterns give insight into the chemical controls that influenced the distribution of these elements in the magma chamber. V has a higher magnetite-melt partition coefficient than Ti. The steeply-decaying V/Zr downhole pattern reflects the rapid depletion of V from the magma chamber as it strongly partitioned into the fractionating magnetite. The 'box'-shaped downhole depletion pattern observed for Ti/Zr is a result of the coupled substitution of Ti with ferrous iron in the magnetite-ulvospinel phase. Additionally, the downhole plots of base metals (Cu/Zr, Zn/Zr and Ni/Zr) exhibit enrichments that coincide with magnetite saturation. However, detectable concentrations of these elements are not observed in magnetite. They reside in anomalous concentrations of disseminated sulphide minerals (chalcopyrite and pyrite) in the magnetite-bearing portion of the sill. The presence of these co-occurring sulphide minerals with magnetite likely resulted from liquid immiscibility of a sulphide melt triggered by the saturation of magnetite in the magma chamber.

In summary, chemostratigraphic patterns observed in ratios tracking the material transfers of major elements and igneous minerals, and ratios responding to trace element partitioning of V, Ti, Cu, Ni and Zn into magnetite and an immiscible sulphide liquid, reveal new information about the igneous evolution of the Golden Mile dolerite. These patterns facilitate confident recognition of stratigraphic level in deep exploration drill cores, despite subsequent hydrothermal alteration effect.

Chaswood Formation lignite records mid-Cretaceous volcanic eruptions

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Lignite and coal, because of their low sedimentation rates of terrigenous detritus, commonly preserve a record of the input of volcanic ash. A reconnaissance study has been made of lignite from the Lower Cretaceous Chaswood Formation of the Elmsvale basin, central Nova Scotia. The bulk mineralogy and geochemistry of lignite and lignitic mudstones has been determined by X-ray diffraction (XRD) and whole-rock geochemical analysis of ashed samples; in addition, selected samples have been examined by electron microprobe (EMP) and scanning electron microscope (SEM).

Lignite from the middle member of the Chaswood Formation has several features indicating the presence of volcanic ash: distinctive REE patterns with low La/Nd ratio; unusual abundance of high-field strength elements such as Nb and Y; the presence of augite in EMP and XRD analyses; and rare presence of possible glass shards and euhedral quartz. Wood or charcoal fragments appear mineralized and diagenetic talc is present. Much of the terrigenous component of the lignite consists of background detrital sediment (characterized by detrital illite) and most of any ash component has been altered to kaolinite. Bulk compositions of ash are inferred to be principally basaltic or dacitic, with rare felsic ash.

Well-defined ash beds are present in the middle member of the Chaswood Formation, but our sampling density was insufficient to correlate single beds from one borehole to another. Several discrete ash beds may be present in a single lignite unit. Evidence for ash in the lower member is sparse and equivocal. The closest source of ash is the early Albian volcanics within the lower Cree Member of the Orpheus graben, in a stratigraphic interval that has been previously correlated with the middle member of the Chaswood Formation. However, paleogeographic reconstructions suggest a monsoonal climate with dominant winds from the SW. More distant sources in the Quebec - New England igneous province are thus possible.

Evidence for early deformation and its timing in the Tournaisian rocks of southeastern New Brunswick

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In the Hillsborough area of southeastern New Brunswick three formations in the Carboniferous Horton and Sussex groups (Tournaisian - Albert, Weldon and Round Hill formations) contain features consistent with deformation characterized by bedding-parallel movement. These features include minor folds, often with box-like profiles, minor folds with strongly curvilinear hinge lines, small thrust faults, bedding-parallel shear zones and vein arrays representing detachments. Deformation is usually characterized by two sets of folds with an overprinting relationship. F1 folds are intimately related to the bedding-parallel motion, taking the form of hanging-wall and footwall structures on thrusts, recumbent folds with sheared limbs, and chevron fold trains with overtightened closures and minor fault-related hinge collapse. F2 folds overprint on these features folding bedding-parallel shear zones. Kinematic analysis of the F1 folds and related shear sense indicators in bedding-parallel shear zones reveals a consistent top to the south movement. F2 refolding, on structures that trend southwest implies a transpressional regime with north-south shortening and a right-lateral strike-slip component.

The occurrence of folds in Tournaisian rocks predating the unconformity below the Visean Windsor Group has been known for some time. We present evidence here that an angular unconformity beneath the latest Tournaisian-early Visean Hillsborough truncates both F1 and F2 structures. A more constrained timing for this deformation hinges on an interpretation of the Peck Creek felsite, a shallow felsic intrusion with features characteristic of magma-wet sediment interaction, emplaced along a thrust fault. Recrystallized quartz textures in this body are characteristic of plastic deformation at elevated temperatures, implying deformation whilst the body was still hot. If the correlation of this felsite with the Boyd Creek Tuff is correct, then this deformation occurred while the Weldon Formation was still being deposited.

The influence of neotectonics and strike-slip faulting on arc magmatism : the example of the South Aegean arc

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The Pliocene-Quaternary South Aegean arc is related to subduction of the African plate beneath the Aegean microplate. Hydrothermal circulation within the volcanic rocks is responsible for significant gold, barite, and manganese mineralisation. The western part of the arc has typical arc-related andesite - dacite volcanism, predominantly of Pliocene age, associated with E-W listric faulting with slow slip rates. Nd and Sr isotopes and trace elements show that their petrogenesis included substantial partial melting or AFC in the lithospheric mantle and viscous felsic magmas were trapped in the lower crust. In contrast, the mid to late Quaternary of the central and eastern part of the arc consists of tholeiitic and calc-alkaline minor basalt, andesite, dacite and minor rhyolite, including voluminous pyroclastic rocks. Major pyroclastic eruptions include the 0.16 Ma Kos Plateau Tuff eruption and the Minoan eruption of Santorini. These younger magmas result from melting both hydrated mantle (calc-alkaline magmas) and asthenosphere (tholeiitic magmas), influenced by regional extension. This young volcanism began at the same time as ENE-trending strike-slip faulting resulting from indentor collision with thinned African plate continental crust. The strike-slip faults provided efficient pathways for all magmas to rise, but also resulted in rapid mid-to-late Quaternary subsidence, at rates > 2 mm/yr.

The role of strike-slip faulting is particularly clear at Santorini and Kos. Near Kos, older dacitic rocks and young volcanic centres lie on a NE-SW-trending lineament, initiated in the early Pleistocene. ENE-WSW sinistral strike-slip faulting initiated in the middle Pleistocene in the area from Santorini to Kos would have produced extension on this older lineament, permitting the ingress of water to the magma conduit, thus triggering the very large Kos Plateau Tuff eruption. A similar mechanism was responsible for the voluminous pyroclastic eruptions of Santorini since 0.2 Ma. Santorini is located at a pronounced change in fault patterns in the South Aegean Arc. To the west, active faults trend E-W, whereas to the east, active faults trend ENE and a slightly older set trend NE. The initiation of the ENE strike-slip faulting led to extension on the older NE faults, which define the major volcanic lineaments around Santorini.

This study shows that rapid changes in fault patterns as a result of progressive plate convergence, on time scales almost un-resolvable in Paleozoic and Precambrian orogens, can result in major changes in volcanic style and eruptive products. Such changes also influence the pathways and style of mineralisation.

The Chaswood Formation at the Atlantic Silica pit, Vinegar Hill, Poodiac, NB and its relevance to the regional depositional pattern of the Chaswood Formation

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The only known Chaswood Formation in New Brunswick is at Poodiac, south of Sussex. The Lower Cretaceous age of the deposit was recently confirmed by Falcon-Lang et al. (Atlantic Geology, v. 39, p. 39–46). Mapping shows a gently dipping succession of braided-river gravels that overlie mudstones with lesser poorly sorted sandstones. Locally, the contact with this lower mudstone unit appears unconformable, where the mudstone dips at 60°. Flat-lying gravels, poorly preserved, unconformably overlie the dipping succession of gravels. The maximum known thickness of sand and gravel is 60 m at borehole 81-1. Only three paleocurrent indicators have been found: trough cross-bedding to 260° and bar- margin planar cross bedding to 190° and 230°. Collectively, these indicate mean paleocurrents to the southwest, parallel to the fault margin of Vinegar Hill.

Three new boreholes were drilled in the Chaswood Formation. VH03-3 proved a thickness of 12 m for the lower mudstone unit, which overlies Carboniferous basement. VH03-2 (27 m TD) and VH03-4 (22 m TD), to the south and west of the pit, respectively, penetrated unconsolidated sands and gravels with minor interbedded mudstone.

Gravel clasts at Vinegar Hill consist overwhelmingly of vein quartz, principally grey in colour. Other rare lithologies include grey rhyolite, similar to Precambrian rhyolite of the Coldbrook Group; quartz arenite that resembles Ordovician rocks of the Miramichi terrane; staurolite-bearing metasedimentary rocks, perhaps from Mount Pleasant or the southern Miramichi terrane; purplish rhyolite; and dark hornfels similar to Silurian metasedimentary rocks intruded by Devonian granite in central New Brunswick. The heavy mineral fraction of the sands consists predominantly of ilmenite and its alteration products (40–70%) and staurolite (20–40%), with monazite, zircon and andalusite more abundant than at other Chaswood Formation localities. The overall heavy-mineral assemblage is similar to all other Chaswood Formation outliers. Monazite dates (Pe-Piper and MacKay, in prep.) show that the assemblage is principally derived from the Taconic orogen, presumably in northern New Brunswick and southern Quebec. Whether one or more rivers transported this detritus southward is unknown, although the wide geographic distribution along strike means several rivers are more probable. Regional variation in heavy mineral assemblages suggests that at any one locality, some 50% of the heavy mineral fraction is derived from local horsts and 50% from more distant sources.

The effects of thaw lake drainage on Arctic river channel morphology, Yukon coastal plan, western Canadian Arctic

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We hypothesize that the morphology and evolution of low-order stream channels in lowland permafrost regions are principally shaped by short-lived, massive floods that occur when thaw lakes drain. Thaw lakes, which form by thawing and collapse of ice-rich frozen ground, are known to drain into either other lakes or river channels and tributaries. The imprint of thousands of drained basins on these landscapes underscores the possible importance of these events to stream channels. However, the influence of floods on channel and valley morphology has been poorly investigated to date. To investigate these effects we use dual frequency differential GPS measurements (accurate to within ± 5 cm) of valley morphology from lower order channels of the Running River drainage basin, Yukon Coastal Plain, Canada. The Coastal Plain is characterized by continuous permafrost (MAAT = -9.9°C), and extensive thaw lake development. A flood from a recently drained thaw lake with water volume of approximately 27×10^6 m^3, incised an approximately 10 m deep and by up to 18 m wide and 300 m long channel. In comparison, maximum limit of flood volume from spring melt is approximately 3×10^5 m^3, assuming instantaneous melt of average snow pack in the entire drainage basin. Using maximum snow depth from 50 year record available, flood volume is approximately 6×10^5 m^3, still far below thaw lake flood volume. GPS measurements also show large flood terraces on Grayling Creek, a tributary to the Running River. Sedimentary sections in flood terraces reveal numerous series of flood deposits of Holocene age. Massively over-fit river valleys are unlikely to have been incised by the small amount of precipitation and melt water runoff that occur in the dry climate of the western Arctic. Thaw lake drainage has a large affect on river channel morphology and acts as a primary architect in shaping low order Arctic rivers and landscapes.

Regional low-pressure metamorphism of the Meguma Group, Pubnico area, southwestern Nova Scotia

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Southwestern Nova Scotia lies in the Meguma terrane, the most outboard terrane of the northern Appalachians. A large area of the terrane was affected by low-pressure metamorphism (< 4 kbar) during the Devonian Acadian orogeny. It was also intruded by many post-tectonic plutons, including the Barrington Passage Pluton, a foliated biotite-tonalite. The nature of metamorphism (low-pressure regional or contact)

affecting the host rocks of the Barrington Passage Pluton has remained unresolved. The Meguma terrane is situated to the south of the Cobequid-Chedabucto Fault Zone, and underlies much of southern Nova Scotia. The major component of the Meguma terrane is the Meguma Group, a 6–10 km thick sequence of metamorphosed Cambrian-Ordovician turbidites. The Meguma Group is divided into two formations: the Goldenville Formation and the conformably overlying Halifax Formation. The Goldenville Formation is psammitic with minor slate; the Halifax Formation is primarily slate with minor psammitic interbeds. Both units are found within the study area. The entire Meguma terrane was deformed and metamorphosed during the Acadian orogeny. Deformation resulted in the formation of regional-scale, upright, shallowly-plunging folds displaying axial planar foliations. The trend and strike of these features is northeast to north in southwestern Nova Scotia. Most of the terrane experienced low-grade (chlorite-grade, sub-greenschist- to greenschist-facies) regional metamorphism, but some areas attained a higher grade (sillimanite-grade, amphibolite-facies) of metamorphism. These regions include the Canso area and southwestern Nova Scotia. Abundant plutons occur in both of these areas. Previous work has focused on the timing of regional metamorphism in the Meguma terrane. This is somewhat complicated in southwestern Nova Scotia by thermal overprinting resulting from the Devonian South Mountain Batholith and related granitoid plutons (ca. 372 Ma), as well as Late Carboniferous to Early Permian plutonism (320–300 Ma; ca. 290 Ma).

The amphibolite-facies metamorphism encountered in some parts of the Meguma terrane was initially assigned to a contact event arising from the intrusion of the post-tectonic South Mountain Batholith and related plutons. It has since been proposed, however, that the higher-grade metamorphism was, in fact, a regional metamorphic event related to emplacement of the Devonian plutons. The most recent available age data suggests an age of 406–388 Ma for the greenschist-facies metamorphism and 373 Ma for the amphibolite-facies metamorphism. These dates were based on $^{40}Ar/^{39}Ar$ data from muscovite and hornblende separates and Meguma Group whole rock samples (slate and metasiltstone), field relationships and the U-Pb age of ca. 373 Ma for the Barrington Passage Pluton. Based on petrographic analysis of representative thin sections from the study area, as well as microprobe data and geothermobarometric studies, it would appear that the host rocks of the Barrington Passage Pluton were metamorphosed during a regional, low-pressure (2–4 kbar) event. Temperatures reached 500–600°C during this event, suggesting the intrusion of the Barrington Passage Pluton was a major contributor to the heat flow required to reach the sillimanite-grade metamorphism attained by Meguma Group rocks within the study area.

Mineralogical and geochemical examination of the gold mineralization within the silica zone and open pit at Cape Spencer, New Brunswick

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The previously mined open pit at Cape Spencer (NB) is being re-examined as a high-grade, vein-related gold deposit instead of the previously reported low-grade bulk gold deposit. The open pit was mined from 1986–1988, which had proven reserves of 606 790 short tons (550 470 tonnes) grading 2.34 grams per ton (2.12 g/t). The silica zone located 600 m northwest of the open pit was explored in 1977 as a possible silica quarry for the purpose of glass making, but the Fe content was too high. Thus far neither research nor exploration has attempted to establish the possible relationship between the silica zone and quartz veins and associated alteration found within the open pit.

Detailed geological and structural mapping accompanied by recent 3-D Induced Polarization geophysics of the silica zone and the open pit was carried out to define the trends of the quartz veins, associated gold and sulphide mineralization, and gold depositional controls. Twenty channel samples were taken for petrographic and geochemical analysis, and assaying of selected samples. The multi-element geochemical analyses were done using a multi-acid 32 element Inductively Coupled Plasma-Emission Spectroscopy and a 30 element Instrumental Neutron Activation Analysis. A Sulphur bioLeco analysis was also completed to determine the percent sulphur.

The quartz veins at the open pit has gold values of up to 100.5 g/t, with the adjacent wall rock containing up to 51.5 g/t gold. The open pit also showed low arsenic values (< 5 ppm) in comparison to the silica zone where gold values ranged from less then 5 ppb to 120 ppb, with arsenic ranging from 3 to 228 ppm, Cu to 1004 ppm, and Mo to 150 ppm. The gold-bearing quartz veins are seen crosscutting the Millican Lake granites (623 Ma), Cape Spencer Formation sediments (post 623 Ma), and Lancaster Formation (310 Ma) suggesting that they were deposited syn- to post-Carboniferous.

The silica zone is approximately 200 m in length, 50 m in width, and greater than 20 m in depth. Within this silica body there are at least five different locations that are enriched in sulphides. There has been no age dating done in the silica zone, but it is assumed that it is close to the age of the illitic alteration (277 Ma), which is based on previous $^{40}Ar/^{39}Ar$ ages of illite in altered Precambrian rocks. Previous work, believed that the D_2 structures host the gold ores, but recent sampling suggests much later stage deposition of gold.

Alkalic-type epithermal gold deposits: Porgera as an example

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If there is a unifying feature of alkalic-type epithermal gold deposits, apart from their association with hydrous alkalic intrusive rocks, it is that they are not coincident with main volcanic arcs. In some cases, such as the Montana alkalic district and Cripple Creek, Colorado, any kind of relationship to subduction activity is tenuous, although continental lithospheric rifting dynamically related to plate-margin processes is likely. In other cases, such as in the SW Pacific, deposits and their source magmas are related to distal (back-arc) or post-subduction processes (arc collision, subduction polarity reversal, arc isolation).

Many other distinctive features are variously but not universally shared by deposits in this class. They include high Au/Cu ratios in epithermal ores, occurrence of telluride minerals, low-sulphidation alteration styles, and the presence of roscoelite (V-rich mica), fluorite, and barite, with relatively minor quartz, as gangue minerals. Some of these characteristics might be attributed to the association with mafic alkalic magmas (e.g., V, F, Ba, Te), but the anomalously high Au/Cu ratio (when compared with other magmatic-hydrothermal ore deposits such as porphyry Cu deposits) is problematic.

It is suggested that the high Au/Cu character of the ores is directly related to the petrogenesis of the source alkalic magmas. In main volcanic arc environments, the influx of sulphur from the subducting slab is likely sufficient to stabilize sulphide mineral phases or melts in the mantle wedge, which will retain highly chalcophile elements such as Au. High volume partial melts from the wedge will be saturated in sulphide, and will thus carry significant dissolved concentrations of base metals, but low concentrations of precious metals. In the absence of a supply of new sulphur, e.g., after the cessation of subduction, melting in the asthenosphere or base of the lithosphere may result in breakdown of residual sulphide minerals, and the release of highly chalcophile elements to the melt. This process may be optimized under conditions of low degrees of partial melting in previously subduction-modified mantle, where (1) highly chalcophile elements have been enriched during earlier arc processes, (2) residual sulphide concentrations are low due to prior extraction of arc magmas, (3) oxidation state is relatively high due to water fluxing, which marginalizes the stability of sulphides, and (4) solidus temperatures are low due to alkali metasomatism and hydration.

Small degrees of partial melting of this previously subduction-modified mantle, yielding highly chalcophile element-rich, hydrous, alkalic magmas, may be triggered by a variety of tectonic processes, as noted above. Localized rifting or shear-fracturing of the lithosphere is likely to be a common factor in all of these settings, however. Such deep-seated fractures provide high-permeability conduits for the ascent of small-volume, mantle-derived magmas to shallow crustal levels. Compared with highly undersaturated rift-related alkalic magmas, which are often water-poor (e.g., carbonatite), these distal-subduction-related magmas are water-rich, and evolve to a magmatic hydrothermal stage during crystallization. In contrast to calc-alkaline porphyries and related epithermal deposits, however, gas contents (such as CO_2) are nevertheless relatively high, and this may explain the much greater depth range (to > 2 km) of alkalic-type epithermal systems controlled by phase separation in relatively gassy hydrothermal fluids.

Dendrochronological potential of buried wood in Atlantic Canada

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Old trees in Atlantic Canada are scarce, but quality material can be found in the form of logs from old buildings and in buried stumps. The latter are found in many situations throughout the region, especially in bogs and marshes. This paper explores two case studies: stumps recovered from a bog exploited by Premier Horticulture near Rogersville, New Brunswick, and stumps recovered from a reclaimed marsh near Amherst, Nova Scotia.

Two large boles were recovered from a bog in Rogersville and analyzed for their dendrochronological potential. The logs were in a good state of preservation and identified as white pine through a scanning electronic microscope analysis. Radiocarbon dates confirmed that the trees were old with both tree ages found to be approximately 4 ky BP. Since the two samples were close in age, it allowed them to be crossdated to produce a floating chronology.

Excavation of six *in situ* stumps in George Daucy's field, near Amherst, NS, produced a more diverse group of data. The sheared stumps, once dried, were still in a workable state even though in some cases the stumps were badly damaged. Species identification through anatomical wood characteristics revealed that a diverse mixed forest once inhabited the site (four different species out of the six samples).

These results show the possibility of producing valuable long-term chronologies from these types of locations, but also highlight some of the difficulties encountered when conducting this type of research.

Kelp holdfasts in peat as an anthropogenic signature on the Burin Peninsula of southern Newfoundland, Canada

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Geological work was carried out in the freshwater peat bogs along the south coast of the Burin Peninsula in 1993–1995 during a search for tsunami-laid deposits. Peat monoliths were collected in, or close to, the communities of Lamaline, Point au Gaul, Taylor's Bay, Lord's Cove, Lawn, and St. Lawrence. In a number of locations a remarkably sharp tsunami-laid sand layer was found marking the onshore incursion of the November 18, 1929 tsunami (see photograph at the Dalhousie University Department of Earth Sciences website <www.meguma.earthsciences.ca/staff/ruffman/ruffman.htm>. In numerous localities, as the peat monolith was cut and removed, isolated, well-rounded, large pebbles and small cobbles were found, sometimes below the tsunami marker and sometimes above it. We had no logical explanation for these occasional finds.

The common element appeared to be an association with communities and former 'meadows' where cattle were known to have been kept and grazed. A series of test monoliths were examined well off the relatively new road between Lawn and Lord's Cove in an area where there had not ever been any known human settlement or farming activity; there were no isolated rounded rocks to be found. The origin of these rounded rocks was eventually realised to have been a result of a process known locally as 'kelping'.

Each Fall as the weather becomes progressively worse, 'kelp', including both *Laminaria* and smaller, more leafy varieties of seaweed, are broken loose and thrown ashore in windrows along the sandy and gravelly beaches of the area. By November such beaches are marked by tall, steep-sided piles of seaweed gathered up by local residents to be spread on gardens and, at one time, to fertilize the meadows. Thus the finding of 'kelpstones' in peat can be taken as a clear indication to an archaeologist of former human occupation, and of the nurturing of 'meadows' for livestock to feed on.

Sulphide minerals in the South Mountain Batholith and the Meguma Supergroup

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Late in the Acadian orogeny in southwestern Nova Scotia, the late Devonian South Mountain Batholith (SMB) intruded the Cambro-Ordovician meta-sandstones and siltstones of the Meguma Terrane. Whole-rock and mineral chemical data from major elements (A/CNK) and radiogenic isotopes (Sr-Nd) show that the SMB evolved by a combination of assimilation of the Meguma country rock and fractional crystallization of its magmas (AFC processes). The purpose of this investigation is to test the AFC model using textural and compositional variations in sulphide minerals from the SMB and Meguma rocks. The dominant sulphide phases in the SMB and Meguma are pyrite and pyrrhotite, with common occurrences of chalcopyrite, and rare occurrences of sphalerite and galena. Meguma rocks remote from the contact with the SMB contain pyrite as the dominant phase, occurring as boudinaged vein structures, as well as in small subhedral to anhedral grains. Meguma rocks near the SMB contact contain large anhedral grains of pyrrhotite as the dominant phase, with small- to medium-sized, 0.25–1.0 mm, subhedral pyrite and chalcopyrite grains occurring as inclusions in pyrrhotite. The SMB contains small to large 0.25–5 mm, subhedral chalcopyrite grains within pyrite and pyrrhotite. Chemical compositions of the sulphide minerals, as determined by EMP analysis, show trace amounts of As, Pb, Zn, and Ni occurring in all sulphide phases. Distinct changes in the abundance, size, shape, and inter-granular relationships exist between sulphide minerals from the SMB, across the contact, and into the Meguma country rocks. These changes indicate both open- and closed-system chemical and physical interactions occurring between the SMB and Meguma during the emplacement and subsequent cooling of batholith. Many of the sulphides in the SMB occur with xenolithic remnants and appear to be texturally and chemically modified equivalents of the Meguma sulphides.

The role of sediments in the formation of oil mineral aggregates at Black Duck Cove

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In 1970 The Arrow, a steam tanker, ran into some rocks in Chebucto Bay, Nova Scotia. Approximately 3.5 million barrels of Bunker C oil were spilled into the bay and 305 km of coast were covered by the oil slick. There were efforts to clean the contaminated shoreline, but crews cleaned only 48 km. Some of the remaining shoreline was cleaned by a natural process called "surf washing", in which the shore is scrubbed by sand grains, in high-energy areas. There are some beaches that are not located in high-energy environments that experienced natural cleansing. The formation of Oil Mineral Aggregates (OMA) has been hypothesized as a cause of the cleansing. OMA form by mineral grains coagulating with the oil. This process traps the oil and makes it more readily dispersed into the ocean by tide and wave action and more susceptible to micro-biodegradation. Controlled laboratory experiments were

done on sediments from one of the beaches that experienced natural cleansing in a low energy environment. The goal of this work was to understand the effects of sediments size and concentration on OMA formation. Results from the experiments provided quantitative data outlining the effects of these parameters on oil trapping efficiency.

A history mystery: dendroarchaeological investigations at the Campbell Carriage Factory, Sackville, New Brunswick

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Dendroarchaeology is the science of using tree rings to determine the age of wood that is of interest in an archaeological study. For the procedure to work, two separate chronologies are needed that have been subjected to the same environmental growing conditions. One ring-width chronology from the wood of unknown age must be constructed, and one ring-width chronology from wood where the age is known, must be constructed. If the patterns of ring growth of the two separate chronologies can be matched, the wood of unknown age can therefore be easily determined.

The results of the dendroarchaeology study at the Campbell Carriage Factory will be discussed. The carriage factory is of particular interest to a local restoration society, as they have refurbished the building, and have reopened it to the public as a historical museum. The building was known to originally be a tannery, but was later converted to the carriage factory. The earliest dates of transactions at the carriage factory were known to be from the 1850s, but the date of construction of the original tannery building remains a mystery. Our dendroarchaeological study indicates that the original building was probably constructed in the period from 1844 to 1845.

Regional scale heterogeneities in the mineralogy of the magma source region: examples from mantle xenoliths from the West Eifel Volcanic Field, Germany

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Our general view of the source of mantle-derived magmas is of homogeneous moderately depleted peridotite. This viewpoint has been reinforced by experimental studies that model the mantle as a simple mixture of olivine, clinopyroxene and orthopyroxene with one or other of the aluminous phases. The real nature of the mantle belies this simple view and indicates heterogeneity from the hand sample scale upward!

The Quaternary West Eifel volcanic field in Germany provides an opportunity to examine mantle heterogeneity since many of the alkaline, monogenetic volcanoes have carried samples of the lithospheric mantle to surface. Volcanism is thought to be related to melting in the asthenosphere associated with a small-scale mantle plume. Variations in the composition of the lavas within the field indicate two distinct sources one enriched in amphibole, the other in phlogopite.

Xenoliths contained in the lavas are from the lithospheric mantle rather than the asthenospheric source and isotopic and trace element data indicate that the xenoliths are not low pressure analogues of the magma source region. Nevertheless, their distribution reveals considerable heterogeneity in the mantle below the Eifel.

There are a number of distinct events that can be identified from the xenoliths. First, there was a widespread melting event that resulted in depletion of incompatible trace elements. This was followed, during the Hercynian orogeny, by metasomatism that led to widespread formation of secondary, Ti-poor amphibole, clinopyroxene and phlogopite. The third event, related to Quaternary volcanism, resulted in the development of hand sample to regional scale heterogeneities. In the central Eifel this event is characterized by the presence of 1–10 cm thick, amphibole–phlogopite–clinopyroxene veins, in lherzolite and harzburgite xenoliths hosted in olivine nephelinite–bassanite suite lavas. These veins crystallised from sodic magma that flowed along fractures in the mantle. In the west central Eifel, the Quaternary event is characterized in wehrlite xenoliths, many of which have 0.1 –0.5 cm thick veins of phlogopite and clinopyroxene that were transported by potassic foid suite lavas. Wehrlite formed by reaction of lherzolite/harzburgite with potassic magma that infiltrated along grain boundaries, with veins being formed only during periodic overpressure events.

In the Eifel we see evidence of heterogeneity in the asthenospheric source region from lava compositions and extreme heterogeneity that developed over a long period of time in the lithospheric mantle. These observations suggest that we should exercise caution in viewing the mantle as a simple, homogeneous body.

Fault offset of the Atlantic Uplands Peneplane: new look at an old concept

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The prevailing concept of landscape development in eastern Canada is that of a regionally extensive low-relief surface, or peneplane, that was uplifted and tilted to the southeast, then set in relief by erosion of weaker rocks. J. W Goldthwait envisioned this upland surface (Atlantic Uplands Peneplane -AUP) as co-planar, cut across rocks of different ages and erodability. Later, more detailed work found anomalous facets within the AUP; enough, perhaps, to cast doubt on the peneplane concept. Douglas Grant observed that the upland surface was

offset along the Cobequid-Chedabucto Fault System (CCFS), thus explaining some of these anomalous surfaces by later faulting. He then suggested a Cretaceous or older age for the AUP based on offshore correlations. Stea and Pullan (2001), using high resolution seismic data, found that unconsolidated Early Cretaceous (EK) outliers were deformed and truncated by basin margin-faults that extend into the Carboniferous and older basement rocks. They suggested that the valleys containing the outliers are structural features, rather than features formed by differential erosion.

The age of the AUP can be constrained by mapping it in relation to known faults in Nova Scotia and the EK outliers. Using a GIS-generated series of topographic profiles we found that the offsets on the SE -dipping erosional surface were not confined to the CCFS but also occurred on the subsidiary fault systems bounding EK outliers. The AUP also exhibits an inflection point associated with major fault systems, changing to a north-dipping surface. Assuming that these surfaces across the inflection point are coeval, the age of the AUP is younger than Early Jurassic, as it truncates rocks of this age. The AUP is clearly pre-faulting, but can we establish the age of faulting from the stratigraphic relationships in the outliers? The lack of Late Cretaceous and Tertiary strata in these structural basins implies that offset-deformation occurred soon after the EK, thus bracketing the AUP between the Late Cretaceous and Early Jurassic. The EK deposits can then be restored to the peneplane surface along the basin margin faults. When this reconstruction is made, the mature quartz arenite and kaolin sedimentary deposits characteristic of the EK outliers can be linked to the AUP. We can, therefore, envision that the AUP formed by subaerial fluvial processes, weathering and denudation during the tropical Early Cretaceous.

Investigating patterns in flaked lithic resource use in eastern Maine and southwestern New Brunswick

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The majority of studies of lithic resource use by prehistoric populations in Maine and the Maritimes focus on site-specific variation of lithic types and technology over time. In this paper I compare a number of site-specific lithic studies derived from a series of recently excavated Archaic and Maritime Woodland period sites in eastern Maine and southwestern New Brunswick. The results of this integration of previous studies are compared to existing notions of regional and temporal trends in lithic resource use.

Some of the patterns which emerge from this analysis suggest a trend towards an increased use of fine-grained felsic volcanic rocks and chert during the Woodland period, and a corresponding decrease in the proportional abundance of quartz and quartzite. The analysis also suggests some variation within the defined study area, which may be related to lithic resource availability.

The incorporation of sites from eastern New Brunswick reinforces the existing notion of a distinct pattern of lithic resource use during the Woodland period, centered around the use of cobble-derived quartz. The geographic and temporal range of this distinctive cobble quartz resource use is also discussed.

Carboniferous transpression, Minas Basin, Nova Scotia: why are the rocks at Rainy Cove upside down?

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On the south shore of the Minas Basin, Nova Scotia, Late Paleozoic deformation affects the Mississippian Horton and Windsor groups, units dominated by lacustrine clastics and evaporites respectively. Structures exposed in cliffs and on wave-cut platforms include tight folds with variably developed axial-planar cleavage, and faults with a variety of offsets. Faults and folds are associated in outcrop-scale flower structures exposed in both cliff and wave-cut-platform view. In the areas around Rainy Cove and Walton, overprinting has led to the development of spectacular, large-scale, downward-facing folds.

The degree of deformation decreases rapidly towards the south. The orientations of folds, faults, boudins, and strain markers are all consistent with an environment of dextral transpression, in which structures were progressively rotated before being overprinted by a new generation. Deformation was probably associated with significant movement along the former Meguma-Avalon terrane boundary. Recumbent folds, low angle thrust faults, and oblique strike-slip faults all played a role in emplacing Horton Bluff Formation strata over younger units of the Windsor Group, as interpreted in outcrop, and as documented in the record of drilling and seismic reflection profiling. However, thrusting and strike-slip motion were followed by diapirism and solution of Windsor evaporates, which have significantly complicated the structure. Stratigraphic and intrusive relationships suggest that most of the deformation occurred in the mid-Carboniferous.

The structures in this zone represent an excellent opportunity to study the effects of transpression on an evaporite-bearing sedimentary succession.

New fossil evidence for an Early Cambrian age for the lower Goldenville Formation (Meguma Group), southwestern Nova Scotia

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The oldest unit in southwestern Nova Scotia, the Cambrian Goldenville Formation, was considered to be a monotonous sequence of undividable thick metasandstone beds. However, based on recent field work related to the Southwest Nova Mapping Project combined with high-resolution aeromagnetic data, a thick interval of metasiltstone (High Head Member) containing abundant trace fossils was recognized as a distinct, regionally mappable unit. A complete section of the member is exposed along the coast in the High Head area north of Yarmouth. It consists of 780 m of well laminated, fine-grained metasiltstone. A series of 7–8 thin (30 cm to 1 m wide) metasandstone beds separated by thin (< 25 cm wide) metasiltstone beds are present in the middle of the section. The base of the metasandstone beds are typically coarse-grained to conglomeratic and fine upwards into laminated to cross-bedded fine-grained metasandstone.

Also in the area of the metasandstone beds are two thin (1 m wide) mafic sills. The lower sill displays peperite-like structures along its lower contact with the metasiltstone suggesting that it originally intruded into unconsolidated wet sediments. Two thin (< 1 m wide), cleaved mafic dykes occur farther down section. Other than the fine laminations and rare ripple marks and cross-bedding, the High Head member lacks sedimentary structures.

The base of this member is gradational over several meters with an underlying unit of massive metasandstone (1–3 m wide) interbedded with minor metasiltstone and rare slate. The upper contact is also gradational and marked by the presence of several thin (< 10 cm) metasandstone beds that increase in thickness (> 1 m) and abundance up section into the overlying unit. Overall, the unit strikes northeast and dips steeply (~ 60°) to the southeast. A steep (~ 80°) northeast-trending and southeast-dipping, weak to moderately developed cleavage is present that results in a shallow southwest-plunging intersection lineation. Kink bands are common throughout the section.

The High Head member appears to be barren of shelly fossils but trace fossils are abundant. Approximately 20 different trace fossil morphologies have been recognized, the most significant being the index trace fossil *Oldhamia*. *Oldhamia* is a characteristic ichnofossil of fine-grained, deep-water siliciclastic sequences of Early to early Middle Cambrian age. This occurrence is important because it is the first in Nova Scotia and the first from the Meguma Group and its presence suggests that the Goldenville Formation, below this occurrence, may extend into the Precambrian.

Late Cenozoic seismic stratigraphy of the Mohican Channel area, Scotian Slope

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The Mohican Channel area of the continental slope, offshore Nova Scotia, is an ideal site to study the Late Cenozoic seismic stratigraphy of the Scotian Slope. High-resolution, two-dimensional seismic surveys across the Scotian Slope are used to identify seismic reflectors and to construct a general stratigraphic framework. The objectives of the study are to understand deepwater sedimentologic processes by investigating the dynamics of the stratigraphy and interpreting seismic reflection profiles based on seismic facies analysis.

Within the study area, an experimental seismic system known as the digital deep-towed hydrophone (DDH) was tested. The DDH consists of a source towed at the sea surface and a receiver towed at depth. This unconventional geometry provides less attenuation of the signal through the water column, better horizontal resolution and reduces the effect of side-echoing. Additionally, it provides for a far-field recorded seismic source signature for each shot. This wavelet is then used to deconvolve the corresponding seismic trace in the reflection profile. The predicted result is greatly improved vertical and horizontal resolution compared with its conventional seismic equivalent. Trial seismic lines have proven to significantly increase near surface resolution; however, imaging at depth within the section is lost in comparison to standard surface seismics.

The Pleistocene Scotian Slope is a glacially influenced continental margin demonstrating classic downslope thinning wedges of reflectors interpreted as turbidites deposited from glacial outwash. Six major reflectors are regionally correlated within this segment of the slope. These have shown stratigraphy gradually thinning both downslope and westward of the study area, approaching the Mohican Channel. The channel erodes nearly all of the Pleistocene section of the slope suggesting a late Pleistocene age. Within the basal Pleistocene, a regionally extensive debris flow deposit, originating from the mid-upper slope, is present and truncates several underlying reflectors. The age, frequency and magnitude of mass transport deposits on the slope, such as this, suggest a possible linkage with glacial epochs, although other factors are likely responsible as well.

Critical effects of the chronology and mode of emplacement of flood basalts on the thermal history of the Sverdrup Basin, Arctic Islands, Nunavut

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Igneous rocks of the Sverdrup Basin Magmatic Province (SBMP) consist of voluminous hypabyssal intrusive sheets and dykes, flood basalts, and central volcanoes that were emplaced episodically from the Early Cretaceous to the Paleogene. In the east-central Sverdrup Basin, basaltic lava flows of Early Cretaceous age are found in the Isachsen Formation (Barremian-Aptian) and Strand Fiord Formation (Late Albian-Cenomanian). Although there is a clear spatial association between volcanic successions and the voluminous sills and dykes that intrude the Mesozoic section, the chronology of intrusive magmatism remains problematic.

We present new field and geochronological data from central Axel Heiberg Island that support the widespread emplacement of sills and dykes during the deposition of the Isachsen Formation. Our preliminary interpretation of the data suggests that the classic model of flood basalt volcanism proposed to explain magmatism in the Karoo Basin of South Africa, may be applicable to the SBMP. We will test several elements of this model using data collected in the East Fiord region of western Axel Heiberg Island during field expeditions carried out in 1990, 1993, and 2004 (Lat. 79°30'N; Long. 93°10'W). We discuss the predicted effects of the Karoo Basin model on the history of salt diapirism in the area surrounding Strand Fiord and Expedition Fiord.

Tectonic evolution of the Moncton Subbasin, southeastern New Brunswick: new evidence from field and subsurface data

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After 150 years of study, there is little consensus as to the tectonic history and setting of the Moncton Subbasin. The northeast-trending faults that define the predominant structural grain in the subbasin have been interpreted in all possible ways, that is, as normal, reverse, sinistral or dextral faults. An incomplete knowledge of the subbasin stratigraphy has led to difficulties in integrating structural and stratigraphic observations. As a result, the fine details of the sense and timing of fault movements, and their relationship to the overall tectonic history, have remained incompletely understood. The problem has been compounded by the lack of outcrop (major fault zones in the Moncton Subbasin are poorly exposed), the lack of adequate displacement markers and the lack of time constraints. In this study, field observations and interpretations of seismic reflection profiles are used to constrain the timing with respect to subbasin stratigraphy, and sense, of fault movements, leading to a more detailed picture of the tectonic history of the basin. Two areas where subsurface data are available were studied: the Hillsborough area, straddling the Petitcodiac River approximately 25 km south of Moncton; and the McCully area, an area of active natural gas exploration approximately 5 km northwest of Sussex.

The geological history of the Moncton Subbasin is a history of deposition punctuated by unconformities and disconformities related to periods of NW-SE tectonic contraction, uplift and basin inversion. In detail, normal-faulting and formation of half-grabens during deposition of the Horton Group terminated during a period of tectonic contraction resulting in a major unconformity. Renewed normal-faulting occurred during deposition of the Sussex Group, and terminated during a bedding-parallel deformation event prior to deposition of the Hillsborough Formation. Marine transgression led to deposition of the Windsor Group. Marine regression was followed by deposition of the alluvial sediments of the Mabou Group. Evidence from seismic reflection profiles shows that local southeast-directed thrusting occurred during Mabou Group deposition. A basin-wide unconformity separates Mabou Group rocks from the overlying Cumberland and Pictou groups. Cumberland Group rocks are folded into an anticline above the Penobsquis salt structure, and are cut by salt-linked faults. This, coupled with evidence of tectonic contraction associated with salt-structure formation and evidence from other parts of the Maritimes Basin, suggests that salt tectonics occurred during Westphalian B basin inversion.

Multichannel techniques for near surface cavity imaging using Rayleigh waves

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The presence of subsurface cavities, either the natural or the man-made, can cause great public safety hazards. The importance of detecting such cavities results in the application of existing methods and the development of new complementary methods. Seismic Rayleigh surface wave imaging is a relatively new non-destructive technique which generates subsurface images without drilling boreholes into the ground. In the last decade, some researchers have applied the technique to near-surface cavity imaging and showed the possibility and potential for the future practical use of this technique.

This study presents the research and development of

using seismic Rayleigh waves to detect and image subsurface cavities. This study made new investigations in the use of Rayleigh wave behaviours in subsurface cavity media, then evaluated the potential of using Multichannel Analysis of Surface Wave (MASW) seismic techniques to image near surface voids. This work is based on literature review and *in situ* test on Sexton Campus of Dalhousie University, Halifax, Nova Scotia, Canada. The primary test field was the Montague Gold District, Dartmouth, Nova Scotia, Canada. The field is a historical gold mining area with numerous narrow steeply dipping mine workings, actively subsiding or collapsed crown pillars, and laterally inhomogeneous bedrock. Seismic surveys were conducted at three test sites using portable components and an effective geophone spacing of 1 m. A complementary gravity survey was also conducted at one of the sites.

Two main strategies for the field data signal processing were used. Pre-processing focused on techniques which highlighted and then isolated the direct Rayleigh waves for each waveform. Then, for the imaging goal, based on dispersion curves derived from MASW, two new imaging techniques were developed which were applied to the resulting pre-processed seismic sections: time delay mapping and shear velocity imaging. Both techniques showed the presence of time-delay or velocity anomalies where mine workings were mapped or inferred from surface subsidence patterns. Velocity imaging proved greater potential to image both the shape and position of the voids. Gravity surveying agreed with both the time-delay and velocity images and highlighted the use of complementary geophysical techniques to image near-surface voids.

LA-ICPMS measurements of gold abundance in sulphide and rock-forming minerals from granitoids, southwestern New Brunswick, Canada: insights into the genesis of intrusion-related gold systems

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The abundances of gold and selected trace elements in magmatic sulphide and rock-forming minerals from Silurian-Devonian granitoids in southwestern New Brunswick, a part of Canadian Appalachians, were quantitatively analyzed by laser-ablation inductively-coupled-plasma mass-spectrometry (LA-ICPMS). Major elements in these minerals were analyzed by electron microprobe. Gold is mainly hosted in sulphide minerals (i.e., chalcopyrite, pyrrhotite, and pyrite) as sub-micron inclusions (nano-nuggets). Gold in major rock-forming minerals (i.e., plagioclase, K-feldspar, biotite, hornblende, muscovite) and oxides (i.e., magnetite, ilmenite) are undetectable (< 0.02 ppm). Gold distribution coefficients between sulphide minerals and granitoid melt are empirically established as:

$$D_{Au}^{cpy/melt} = 948 \pm 269,\ D_{Au}^{po/melt} = 150 \pm 83,$$

$$\text{and } D_{Au}^{py/melt} = 362 \pm 96.$$

This result suggests that the behaviour of gold in these magmatic rocks was controlled by the conditions of sulphur saturation during magmatic evolution; the threshold of physiochemical conditions for sulphur saturation in the melts is a key factor affecting gold activity in the systems. Gold behaves as an incompatible element prior to the formation of any immiscible sulphide liquid that recrystallized sulphide minerals, but it becomes compatible upon sulphide saturation in the melt. Gold would be enriched in sulphur-undersaturated granitoid magmas with fractionation, favouring the formation of intrusion-related gold deposits from late-stage gold-rich fluids (i.e., through partitioning processes). On the other hand, gold becomes depleted in residual felsic melts if they have become sulphur-saturated through differentiation, resulting in the early phases of a granitoid suite having the higher gold concentration. However, Cl-bearing magmatic hydrothermal fluids with low pH have the potential to selectively scavenge gold incorporated into early sulphide minerals formed within an evolving magma, especially with increasing oxidation state of the exsolved fluids. Late stage fluids, derived from either progressively cooling magmas (volatile saturated) at depth or convective circulation of meteoric water buffered by reduced carbon-bearing sediments, may also scavenge gold from early sulphide minerals. If a significant amount of gold produced in this manner is concentrated in a suitable geological environment, such as shear zones and (or) hydrofracture systems, intrusion-related gold deposits may also be generated (i.e., by leaching processes). Exploration for intrusion-related gold systems should focus on the areas around evolved phases of granitoid suites that did not achieve early sulphur saturation. For a sulphur-saturated granitoid suite, however, less differentiated phase and associated structures may be the other target for gold exploration.

Evaporite diapirs in Axel Heiberg Island, Nunavut: gauging their past and present growth rate and their geothermal energy potential

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Diapirs and other salt-cored intrusive structures in the Sverdrup Basin are displaced sedimentary evaporites of the Carboniferous (Upper Mississippian to Middle Pennsylvanian) Otto Fiord Formation. They are spectacularly exposed in the desert-like environment of Axel Heiberg Island, Canadian Arctic Archipelago, as domes and hills made of anhydrite-gypsum (locally with halite) that commonly include rafted blocks of limestone, dolomite and basalt. Field and laboratory work in 2003 and 2004 suggest that some anhydrite bodies had risen, and were exposed at the surface, at a time of active subaerial basaltic volcanism during the Early Cretaceous extensional phase of development of the Sverdrup Basin, although some of the basaltic lava fragments have not all been dated. It is generally known that evaporitic structures moved forcefully during the compressive Eurekan orogeny in the Paleocene-Eocene, a time of active thrust faulting. Our recent field work points to the fact that many of the anhydrite-gypsum structures have risen tens to hundreds of meters from the glaciated valley bottoms in post-glacial times, which could translate in growth rates of 1 to > 5 cm/yr, thus the fastest growing mountains in Canada. This hypothesized rate of growth should be easily detected by In SAR methods, although our preliminary results are disappointing because of the scarcity of suitable radar images. During the next few summers we will perform sequential GPS surveys, and install ultra-sensitive geodesic control stations to measure absolute and differential movements in the region.

Salt is a better conductor of heat than other sedimentary rocks, therefore geothermal heat is funnelled by deeply rooted diapirs. Close to some diapirs, this geothermal heat has melted the (otherwise ~ 600 m thick) permafrost and generated perennial brine springs of constant annual temperature (~ 5°C) irrespective of air temperature (the active springs and remnant examples have been comprehensively studied by the McGill group). We will evaluate the heat exchange capacity of perennial springs in the Expedition Fiord area as a potential source of heat in year-round research stations.

The traditional carving stone for the Inuit is near exhaustion and has to be imported. As an offshoot of the project we are testing the use of alabaster gypsum and anhydrite from diapirs in Axel Heiberg Island as an alternative carving stone in Nunavut.