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ABSTRACTS

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Abstracts from the Atlantic Universities Geoscience Conference (AUGC) are published annually in Atlantic Geology. Such publication provides a permanent record of the abstracts, and also focuses attention on the excellent quality of the oral presentations and posters at the conference and the interesting and varied geoscience topics that they cover.

THE EDITORS

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Determining the heterogeneity of reference materials

Thomas E. Bagley[1], Clifford R. Stanley[1], and John D. Murimboh[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia, B4P 2R6 ¶ 2. Department of Chemistry, Acadia University, Wolfville, Nova Scotia, B4P 2R6

A new method is proposed to determine the heterogeneity of a reference material to separate the analytical and inter-lab errors from the standard deviation. Reference materials are used by geoscientists to assess the quality of a geochemical analysis. Certified Reference Materials are reference materials for which an accepted concentration and standard deviation have been determined by independent labs. Ideally, geoscientists can use Certified Reference Materials to determine laboratory error, and apply it to geological samples with a similar concentration and matrix. However, the accepted standard deviation is a function of Certified Reference Material heterogeneity, lab error, and inter-lab error. Inter-lab error is caused by variations in procedure among the laboratories that determined the certified values. Furthermore, the accepted standard deviation only applies to the sample mass for which the element was certified. Procedures using a larger sample mass will have less variance and procedures using a smaller mass will have more variance. It is possible to algebraically separate the analytical and inter-lab errors from the standard deviation by analyzing both small and large samples. This approach uses the product of the sample mass and the variance to express sample heterogeneity which can be applied to any sample mass.

A ground penetrating radar study of bogs and lakes in the Howley Basin, Newfoundland

Andrew G. Blagdon* and Alison Leitch

Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, A1B 3X5

Ground penetrating radar surveys have been conducted over bogs and lakes in the Howley Basin in western Newfoundland. As a result, physical properties of the lakes and bogs, such as the nature of the base contact, were properly determined and used to make inferences about the Howley Formation rocks underlying them. There is a widespread interest in the Howley Formation rocks because of the presence of a Carboniferous pull-apart basin that may accommodate undeveloped hydrocarbons. Overall, the purpose of this research is to increase understanding of the basic nature of bogs and lakes in the area since they cover much of the geology, particularly that of the Howley Basin. Ground penetrating radar emits electromagnetic pulses into the subsurface and detects reflections from objects and interfaces with contrasting electrical properties. The depth range of ground penetrating radar is limited to a few tens of metres, making it a suitable survey technique for imaging bogs and shallow lakes. The signal penetration depth is limited by attenuation (energy loss) due to the conductivity of the ground and to signal scattering. Although attenuation is high in lakes and bogs there is little scattering, with a strong contrast in electrical properties at their bottom interfaces, making ground penetrating radar the ideal technique for imaging the base of lakes and bogs.

Winner of the Canadian Society of Exploration Geophysicists award for the best geophysical presentation

Genesis of gold mineralization in epithermal quartz veins along the Magaguadavic fault zone in the Pokiok Batholith, southwestern New Brunswick

Laurin Branscombe

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick, E3B 5A3

The Pokiok Batholith, located approximately 45 km west of Fredericton, intruded metasedimentary rocks of the Silurian Burtts Corner Formation (Kingsclear Group) to the east and the Cambrian-Ordovician Baskahegan Lake Formation (Woodstock Group) to the west. The batholith is comprised predominantly of two intrusive units. The Allandale Granite is composed of fine-grained, grey muscovite-biotite granite (402 ± 1 Ma, U-Pb zircon). The multi-phase Hawkshaw Granite consists of fine- to medium-grained, pink biotite granite and minor muscovite-biotite granite (411 ± 1 to 416 ± 2 Ma, U-Pb zircon). The regional-scale Magaguadavic Fault generally strikes north, crosscutting the batholith and locally juxtaposing the Hawkshaw and Allandale granites near the gold-mineralized zones. Gold mineralization with pyrite-sericite-chlorite alteration has been reported along with base-metal mineralization in quartz veins that occupy the fault zone. These veins and associated alteration were re-examined to determine the timing and controls on gold mineralization. Quartz vein textures vary from coarse-grained cockade growth zones to chalcedonic quartz. The sulfide minerals identified by SEM are pyrite, chalcopyrite, matildite, galena, sphalerite, and argentite. Chlorite, chamosite, and muscovite were also identified. The Pearson Product correlation coefficient between Au and Ag in the 10 samples reanalyzed is near zero (r = 0.00). The highest correlations found are between Au and Se (r= 0.98), Cd (r= 0.63), Sb (r= 0.84), and Zn (r= 0.73). Correelations were also found between Ag and Bi (r= 0.99), Cu (r= 0.86), Fe (r= 0.61), and S (r= 0.67). Various types of geochronology are being done to ascertain the timing of faulting, alteration, and related epithermal mineralization.

Preliminary constraints on hydrothermal and mineralizing processes in the Tanzilla district, Stikine Terrane, British Columbia

Laura Carter[1], Jacob Hanley[1], and Tony Barresi[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3 ¶ 2. Kaizen Discovery Inc, Vancouver, British Columbia, V6C 3E1

Fluid inclusions from a mineralized (sulfide-bearing) hydrothermal quartz vein sample hosted by altered subvolcanic rock from outcrop in the Tanzilla area in northern British Columbia (Stikine Arch) were studied to reconstruct the potential conditions of entrapment in order to constrain the conditions of inclusion entrapment and fluid chemistry. Vein and inclusion petrography, fluid inclusion microthermometry, and fluid inclusion microanalysis by laser ablation ICPMS were combined to determine the P-T-V-X properties of the contained fluids. The vein contains quartz-chalcopyrite with a muscovite-sericite-rich alteration selvage. Fluid inclusions are two (Laq + V) or three-phase (Laq + LCO_2 + V) at room temperature and show no evidence of having trapped a boiling fluid (consistent phase ratios). Microthermometry defined a range of salinity between ~6 and 12 wt% equivalent NaCl, with a minimum trapping temperature (homogenization T) between ~260-320°C. Preliminary LA-ICPMS analysis of fluid inclusions shows that the fluids are rich in K and Fe (in addition to Na) and were transporting the ore and accessory metals Cu, Sb, Bi, Pb, Zn, and Ag at the time of entrapment. The trace elements Cs and Ba are also present. The absolute conditions of entrapment are unknown without further constraints; however, the results are indicative of two distinct potential scenarios; (i) a metal-rich (pre-ore deposition stage) magmatic-hydrothermal fluid that did not yet boil, or (ii) a metal-rich (pre-ore deposition stage) condensed vapour phase formed by deeper magmatic boiling suitable for epithermal deposit formation. A detailed study of representative hydrothermal vein samples from recent diamond drilling is in progress and will confirm or refute whether the sample originated from below or above the zone of paleoboiling. If boiling did occur, then distinct mineralization styles (different metal tenor and association) are expected to be present in the study area.

Petrographic and portable X-ray fluorescence geochemical analysis of variably altered granitic rocks associated with the North Zone Sn-Zn-Cu and W-Mo-Bi deposits, Mount Pleasant, New Brunswick

Brittany E. Charnley

Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick, E3B 5A3

The Mount Pleasant deposits are associated with a late Devonian caldera complex containing sedimentary and bimodal volcanic rocks intruded by subvolcanic felsic plutonic rocks. Mount Pleasant is divided into two zones, the North Zone and the Fire Tower Zone, hosting numerous Sn-Cu-Zn-In (North Zone) and several W-Mo-Bi (Fire Tower Zone & North Zone) deposits. This study focuses on ascertaining the primary compositional affinity of the variably altered granitic rocks (chloritized, sericitized, sulfidized, and locally biotitized) associated with mineralization exposed in the North Zone; 35 samples were taken for petrographic and geochemical analysis. Field gamma-ray spectrometry at the sample sites indicate that the highest eTh is 45 ppm, eU is19 ppm, and K is 6.60 wt.%. In terms of elements potentially able to discriminate between granitic rock types, immobile elements were selected, i.e., Ti, Zr, Th, Y, Nb, and P, for analysis by pXRF. The Th/Ti ratio shows the best separation between the samples, with three distinct groupings ranging from 0.00225–0.00833, 0.01194–0.0119, and 0.0847–0.198; this ratio was compared to the abundances and ratios of other immobile elements Nb, Zr, and Y to characterize the sampled granites. Results indicate that at least 3 variably altered granitic intrusions occur in the North Zone. The pXRF results also show Sn up to 3830 ppm, Cu up to 839 ppm, Zn up to 19737 ppm, W up to 835 ppm, and Mo up to 5224 ppm, associated with high Fe and low to moderate K contents, i.e., high Fe/K.

A study of microbial carbon utilization in the deep ultramafic biosphere

Alison Cox and Penny Morrill

Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, A1C 5S7

The Cedars is an active site of terrestrial serpentinization in northern California. Serpentinizing environments have high pH values and low Eh values due to alteration of peridotite to serpentine. High pH values could create a difficult environment for life because the dominant source of inorganic carbon (carbonate ion and rock) is thought to be biologically inaccessible in these environments. Low Eh values in serpentinized areas imply that there is no electron acceptor available for cellular respiration. Serpentinizing environments occur at subduction zones, in ophiolites, and at mid-ocean ridges and are believed to play a role in the origin of life. Studying microbial metabolisms occurring in serpentinizing areas can, therefore, provide insight about survival in the deep subsurface and early life on Earth. This study examines if microbes from The Cedars use carbon monoxide as an electron donor and carbon source, and if microbial methane was produced heterotrophically when the microbes were supplied with ^{13}C labeled acetate to act as an organic carbon source. The experiment consisted of two sets of geomicrobiological microcosms using ultrabasic reducing water from The Cedars to test aerobic carbon monoxide use and anaerobic methane use. Data from live

microcosms was compared to killed controls to determine if the observed processes were microbial or abiogenic. Results show that there is no carbon monoxide utilization by biogenic or abiogenic processes. Methane detected in some live and some killed control experiments was not enriched in ^{13}C, meaning the labeled acetate could not have been the organic carbon source.

Exploring the effect of chloride from de-icing salts on heavy metal concentrations in urban soils: a case study in Halifax, Nova Scotia, Canada

Victoria M. Desjardins

Department of Earth Sciences Dalhousie University, Halifax, Nova Scotia, B3H 4R2

Established in 1749, Halifax, Nova Scotia. has long been home to various factories, extensive military activity and the largest ever non-nuclear explosion, and today remains an active port city. Halifax is rich with history, and so are the soils. A pilot study executed by the 2013/2014 Environmental Geoscience class at Dalhousie University sought to determine heavy metal concentrations in residential soils of the Halifax Peninsula. At each of over 30 residences on the Halifax Peninsula, three samples were obtained: dripline, roadside, and ambient. The samples were then dried, sieved to <1mm and analyzed using X-ray fluorescence. The metals of focus were Pb, As, Cr, Cu, Zn, Ba, V, Cd, Co, Se, Mo, and Sn. Dripline values of a number of metals were commonly greater than ambient values, which in turn were higher than roadside values in many cases. For example, 87% of dripline lead values exceeded the 140 ppm Canadian Council of Ministers of the Environment (CCME) guideline, versus 81% and 57% for ambient and roadside, respectively. One possible explanation for the lower roadside values is that they are attributable to mobilization by chloride from de-icing salts. The objective of this study is to explore the process of chloride leaching and its impact on metal mobility using a variety of soils from the Halifax Peninsula. Soils of various types from sandy to clay-rich, and from different depths, will be subjected to chloride leaching in the lab and will be analyzed before and after to determine whether metals have indeed been leached from the soils, and if so, to what extent.

Microanalytical constraints on geochemical provenance of refined copper and brass artifacts from Gaspereau, Nova Scotia: insight into the metallurgical and trace element systematics of European contact-era trade alloys

Glen D. Hodge, Jacob Hanley, Katie Cottreau-Robins, Chris Mcfarlane, Graham Layne, Bruce Stewart, and Mike Sanders

Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3

During the 16th and 17th centuries while trade was being established with North America, copper items were of great spiritual and cultural importance to the indigenous peoples. A set of 9 artifacts of copper composition from the Gaspereau Lake area of Kings County, Nova Scotia, were analyzed using various analytical methods in order to better determine provenance, giving insight into the historical trade between the indigenous peoples of the Atlantic Northeast and Europe. The studied artifacts have a range of compositions including pure refined copper, gilding metal, bronze, and a variety of brass alloys. Refined copper coinage of a known source (Sweden, Spanish Netherlands, England, Hungary) and age (nearly a 300 year period) were analyzed using SEM to create a database of expected compositions of the bulk metal and "speiss" inclusions, which are contaminant inclusions formed during metallurgical processing. Most speiss compositions range from single element (Pb), to more complex alloy compositions (Pb-As-Sb-Fe-Sn-Ni-Ag). Similarities between Swedish coins produced in the early 17th century exist, and this similarity could be used as a time constraint for artifacts if they are of the same copper source. Preliminary Pb isotope data from the Pb-bearing speiss inclusions is being compiled from countries that had been producing copper items at the same time as European trade was taking place. Initial plots of $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ ratios shows that pure copper sources sit close to the Swedish source data (Falun depost, Great Copper Mountain), while artifacts that are brass alloys sit closer to the Central European sources such as Poland and Germany. This suggests that a non-Swedish source was needed for the brass production, as well as a flux for the Pb. Weathering and corrosion of the artifacts caused destruction of the inclusions and leaching of Zn and other metals from the alloy matrix of the brass objects; thus, to get accurate LA-ICPMS readings for trace data a fresh surface must be used. The artifacts that are of copper or nearly pure copper composition show little to no effect from the weathering, and even corroded surfaces or patina are still representative of the true artifact composition. This allows for corrections to be made to the field observations, which can be misleading due to the weathering and corrosion. The application of nearly non-destructive microanalytical tests can then provide important constraints on artifact provenance, and the better they are developed the better precious artifacts can be preserved.

The fate of olivine in the lower crust: the petrology of coronitic metagabbro in the western Grenville Province, Ontario

Jillian Leigh Kendrick*, Rebecca A. Jamieson, and Glenn Chapman

Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3

The petrology, chemistry, and age of alkaline mafic bodies have been used to differentiate between autochthonous and allochthonous domains in the southwest Grenville orogen. In allochthons, the characteristic mafic suite is a group of coronitic metagabbros intruded at approximately 1170 Ma. The olivine gabbro protoliths were metamorphosed in the lower crust during the Ottawan stage of the Grenvillian orogeny at approximately 1060 Ma. Metamorphism produced spectacular coronitic textures between igneous olivine and plagioclase and other primary minerals. This study examines a 150 m-wide outcrop of one such body in the Algonquin domain, recently exposed by highway construction. Petrographic and microprobe analyses of samples collected along the roadcut are underway to determine the metamorphic reactions and P-T conditions that the body experienced during Grenvillian metamorphism. This study focuses on metamorphic assemblages overprinting primary olivine. Olivine replacement is ubiquitous in these samples, but was previously undocumented in Grenvillian coronitic metagabbros and remains poorly understood in localities where it exists. Orthopyroxene + ilmenite + magnetite form symplectic pseudomorphs of olivine, separated from relict plagioclase by corona assemblages of orthopyroxene ± clinopyroxene, amphibole ± biotite, garnet + amphibole ± clinopyroxene ± orthopyroxene ± plagioclase symplectite. Preliminary P-T estimates of ≥ 800°C and ~12 kb for coronas correlate with P-T estimates from nearby granulite- and upper-amphibolite-facies gneisses. Determining the reactions responsible for the olivine pseudomorphs and corona assemblages will help constrain P-T conditions and relative timing of their formation, and shed light on the deep crustal processes active during and after gabbro emplacement.

Winner of the Science Atlantic Award for best overall presentation

Carlin-style gold mineralization in the Yukon Territory, Canada; Venus Zone, Einarson property

Nikolett Kovacs[1*] and Graham D. Layne[2]

1. Department of Earth Sciences, Memorial University of Newfoundland, Newfoundland and Labrador, A1B 3X9 ¶ 2. Anthill Resources Ltd., Vancouver, British Columbia, V6C 2W2

Carlin-style deposits are broadly categorized as a sediment- (predominantly carbonate-) hosted class, with gold contained as solid solution or submicron particles within disseminated pyrite and arsenian pyrite. To date, Carlin-type gold deposits have been largely defined and described in the Great Basin region of Nevada. However, recent discoveries in the Yukon Territory show many of the defining characteristics of Carlin-type gold deposits. The Einarson Property is located in the central eastern part of the Yukon Territory at 64° 0' N, 131°57' W - 15 km east from the 50 km long Nadaleen Trend, which hosts six recently recognized zones of Carlin-type mineralization in Middle Proterozoic to Middle Paleozoic carbonates of the Selwyn Basin. The 1.65 km^2 Venus Zone is located on the northwestern side of the Einarson property, where initial drilling has intersected values as high as 9.67 g/t Au over 38.7 m within silicified, sandy dolostone. This honours project is designed to compare the Venus Zone to the Carlin-type deposits and environments in Nevada. Thin section analysis, SEM-EDX-MLA and a compilation of field and exploration geochemical data will be used to further elucidate the ore paragenesis, deportment and localization of gold mineralization of the Venus Zone. This will form the basis for the comparison of this example, within an emerging gold district in the northern Cordillera, with the classic examples and characteristics described from the Nevada districts of Carlin-style mineralization.

Winner of the Frank S. Shea Memorial Award for best economic geology presentation

Polymetallic Co-Ni-As-Bi-Sb-Ag veins in the southern Slave Province, Northwest Territories

Haley Leblanc[1*], Jacob Hanley[1], and Hendrik Falck[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3 ¶ 2. Northwest Territories Geoscience Office, Yellowknife, Northwest Territories, X1A 2L9

Polymetallic ("five metals association") veins containing Co-Ni-As-Bi-Sb-Ag mineralization in the area of Caribou Lake in the Southern Slave Province, Northwest Territories, Canada, exhibit various stages of mineralization consisting of an early barren (quartz ± ankerite) stage, an intermediate (A) nickel-cobaltarsenide (nickeline ± bismuthinite ± sulfarsenide solid solution [SSS] ± ankerite± quartz) stage, an intermediate (B) sulphide (pyrite ± galena ± chalcopyrite±sphalerite ± ankerite ± quartz) stage and a late (ankerite) stage. The mineralized veins show open-space filling textures containing nickeline rimmed with SSS. This suggests nickeline formed early followed by SSS as S fugacity in the mineralizing solutions increased. Compared to other mineralization sites of this type in the Slave Province (Great Bear magmatic zone) and in other areas (e.g., Cobalt, Ontario) the veins are devoid of native silver and uranium minerals indicating the inability of the hydrothermal fluid to transport these elements, or a lack of these elements in the original source rocks that the fluids

obtained their metal endowment from. Stable carbon and oxygen isotope analyses of calcite and quartz in the veins show ^{13}CVPDB ranging from -0.3–3.3‰ and ^{18}OVMSOW from 12.4–18.1‰, broadly consistent with data from the deposit at Echo Bay, Great Bear Lake but with 13C values in the upper (most ^{13}C-enriched) range reported for all deposits of the Great Bear magmatic zone. Fluid inclusion data from quartz and calcite suggest a NaCl + $CaCl_2$ hydrothermal fluid responsible for metal transport and deposition with salinities ranging between 25.4–36.6 wt%eq. NaCl (absolute: 10.0–19.5 wt% NaCl and 5.8–18.7 wt % $CaCl_2$). LA-ICPMS analyses of single fluid inclusions confirms this and indicates Na:Ca ratios varying widely from one inclusion assemblage to another, ranging from 1.5 to 5.4. The homogenization temperatures for late quartz-hosted inclusions range from 143–196°C and in early calcite-hosted inclusions range from190–256°C. The similar phase ratios in inclusions suggests there was no boiling during ore deposition although the varying salinities, homogenization temperatures, and Na:Ca ratios from one assemblage to another could indicate mixing of two fluid end-members (e.g., magmatic and meteoric water). Where the polymetallic veins cross-cut the Caribou Lake gabbro, constraints on fluid composition, temperature-pressure of entrapment, and timing are provided. First, a comparison of the chemical composition of fresh and altered gabbros shows that fluid influx caused enrichments in Li-Rb-Cs-Tl-Pb-U-Cu-Ni-Bi-Co-Mo-Ag-Sb, but removed Ba, Sr, Zn and V through the breakdown of feldspars and oxides. LA-ICPMS analyses confirm that the latest stage fluids in the polymetallic veins were highly enriched in K and Ba. Second, primary magnetite-ilmenite intergrowths have been altered to rutile+ankerite in the alteration selvages of the veins. The relative stability of rutile vs. titanite depends on XCO_2. Once this is constrained, an accurate P-T window for an alteration stage involving rutile formation can be determined. A preliminary U-Pb age was obtained from hydrothermal rutile of 1320 ± 80 Ma (discordant). This age has a large error because of Pb contamination from the surrounding country rock but overlaps with the age of the Mackenzie and Berthoud orogenies, suggesting that resetting of U-Pb isotopes occurred during these orogenic periods, or that the mineralized veins themselves formed during these events and are much younger than comparable mineralization styles in the Great Bear magmatic zone.

Winner of the Imperial Oil Award for the best poster presentation

Sediment disturbance due to storm wave action on a steep, mixed sand and gravel beach on the Bay of Fundy

Winson Li and Alex Hay

Oceanography and Earth Sciences, Dalhousie University, Halifax, Nova Scotia, B3H 4R2

Little work has been conducted on mixed sand and gravel beaches compared to their single sediment-type counterparts, although they are a common occurrence on Canada's shoreline. Understanding the interaction between these beaches and incoming waves in the Bay of Fundy is important due to its potential for tidal power generation. The purpose of this study is to contribute new understanding of mixed sand and gravel beach dynamics and more specifically examine how waves affect the beach profile and the depth of sediment reworking, since this affects burial depths for cables crossing the beach. Energy from storm waves arriving at our study site (Black Rock Beach on the Minas Passage) is dissipated through reworking of the beach sediments, creating an active layer, whose depth is referred to as the depth of disturbance. Post-tropical storm Arthur has been the only wave event to have significant effects on the study site to date; it generated waves with significant heights as high as about 1 m. An array of equally spaced aluminum rods with free-sliding washers are deployed normal to the shoreline up the beach face. The array records the maximum depth of sediment activation and relative changes in bed elevation. The maximum depth of disturbance was observed to be about 42.5 cm ± 0.2 cm near the high-tide line, with decreasing depths seaward to about 9.8 cm ± 0.2 cm near the low- tide line. We intend to continue this study through the fall and winter.

Variations in the composition of elbaite and elbaite-hosted fluid inclusions from the Greenbushes Pegmatite, southwestern Australia: insights into Ta-transport

Johnny X. Macfarlane

Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia, B2G 2W5

The Greenbushes pegmatite in southwestern Australia is one of the largest Lithium-Cesium-Tantalum (LCT) type pegmatites in the world. The pegmatite consists of many linear dikes ranging from 2–3 km in length and 10–300 m in thickness. It is located in the Western Gneiss terrain of the Yilgarn Block in Western Australia and was emplaced in the Donnybrook-Bridgetown shear zone where it underwent syntectonic crystallization. The pegmatite is an important resource of Sn, Ta, and Li and has been economically mined since 1888. Petrographic observations of thin sections show that tourmaline grains are host to complex crystal-rich and aqueous carbonic fluid inclusions and also show evidence of zoning. The inclusions vary greatly in their solid-vapour-liquid ratios. Various microanalyti-

cal techniques used to determine the major and trace element variation within tourmaline growth zones and of the inclusions show the tourmalines have gone through a diverse growth history and the inclusions are heterogeneous in their chemical make-up. Varying proportions of Sn, Pb, Sr, Ta, and different transition metals (Ti, V, Ni) are associated with the changing colour zones throughout the elbaite. The inclusion chemistry is highly variable, with elements like Cs, As, Sb, and Rb commonly detected as well as trace amounts of Ta, Bi, and W. Ta was also present in late-stage fractures within the tourmaline crystals. Trapping temperatures of inclusions, determined in a separate study, suggest entrapment at a temperature of about 700°C and pressures of about 500 MPa. Major and trace element chemistry variations within tourmaline grains and inclusions indicate that the Ta-bearing fluids were enriched in Cs, As, and Sb. The presence of Ta within inclusions and the anomalous concentrations of Ta in microfractures indicate that Ta is being transported by an aqueous fluid, a process that is not well understood or seriously considered in mineralized pegmatite.

Structural geology of a faulted shoreline section of the Fourchu Group along the Bras D'Or Lakes of Cape Breton Island; implications for local hydrogeology

Adriana Maclean and Deanne van Rooyen

Department of Mathematics, Physics, and Geology, Cape Breton University, Sydney, Nova Scotia, B1P 6L2

The owners of a lakeside property located in Johnstown, Cape Breton Island, were looking for information to help them decide where to drill a well. Measurements of fractures, foliations, bedding, faults, dykes and contacts were used to make a map and a SW-NE shoreline cross-section of the property. The two types of rocks present are the Fourchu Group (Precambrian) and the Windsor Group (Carboniferous). On this property the Fourchu Group consists of greenschist-facies ash tuff, and the Windsor Group is conglomerate and siltstone. Bedding in the Fourchu Group dips 30°SE and the Windsor Group rocks are sub-horizontal with shallow dip to the east. The contact between the two groups is an angular unconformity which dips at 28°SE, and strikes 052°, parallel to the bedding in the Windsor Group rocks. On the southern edge of the property, another contact between the groups is interpreted as a sub-vertical fault striking roughly east; the Fourchu Group continues south of this interpreted fault and the Windsor Group is not seen again in outcrop. Faults on the property are generally sub-vertical, striking at 110°, with fault gouge and breccia present in zones 2–4 m wide. Drilling for a well should be oriented to intersect only the damage zones around the faults and avoid the gouge. Drill holes intersecting the unconformity between the Windsor and Fourchu groups are likely to be productive wells because many surface seeps of water were observed along the contact.

Facies changes in the upper third of the Albion Member of the Stellarton Basin

Daniel John Macleod

Department of Earth Sciences, St. Francis Xavier University, Antigonish, Nova Scotia, B2G 2W55

Core from two drill holes containing sandstone, mudrock, coal and oil shale from the Stellarton Basin was examined in detail. The Stellarton Basin is located within the larger Maritime Basin and formed as a result of dextral movement along the Cobequid and Hollow fault system. Previous studies of the basin indicate rapid clastic facies changes, particularly within the lower members of the basin. Less frequent lateral variations within the coal and oil shale-rich layers has been attributed to movement along the most distal basin-bounding fault. Soft sediment deformation observed in the core from this study indicates that the basin was tectonically active at the time of sediment deposition. The objectives of this study are to further the understanding of the distribution of sediments within the basin, their provenance, and to interpret the depositional environment. An interval within the upper third of the Albion Member was chosen to for a detailed study because any lateral continuity of these clastic units may possess hydrocarbon potential. Preliminary petrographic analysis of sixteen samples indicates that there is some lateral continuity to these units. Heavy minerals and clasts found in the thin sections require further investigation before provenance interpretations can be concluded.

Analysis of the Eurydice Formation type section (Eurydice P-36 core), offshore Nova Scotia

K. T. Martyns-Yellowe, D. E. O'connor, R. L. Silva, and G. D. Wach

Basin and Reservoir Lab, Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia, B3H 4J1

The Eurydice Formation is recognized along the Canadian Atlantic Margin, and corresponds to one of the earliest rift phases that eventually led to the opening of the Atlantic Ocean. In the Orpheus Graben, the Eurydice Formation conformably underlies or is laterally equivalent with the Argo Formation and may be coeval with the upper Triassic Wolfville and Blomidon formations of the Fundy Group of Nova Scotia. The latter are dated as Rhaetian-Hettangian, based on palynology. With thickness greater than 570 m, as observed from a type well in the Orpheus Graben, seismic profiles suggests that similar sediments are widespread on the Scotian shelf. In this study, we investigated the sedimentary features, gamma-ray response and permeability of the single core that was recovered from the Eurydice P-36 well (located offshore Cape Breton Island, Nova Scotia, Canada) to characterize the reservoir properties of the Eurydice Formation in its type section. In the studied core,

the Eurydice Formation comprises reddish shale, siltstone, and rare feldspathic sandstone, with iron oxide stains in the clay matrix. There tends to be an accumulation of elongate anhydride nodules towards the top of the silty beds that grade into the overlying shale beds. Preliminary results from gamma-ray and permeability suggest that this unit is semi-pervious to impervious, and hence is not attractive as a good hydrocarbon reservoir.

Unconventional hydrocarbon geochemistry in abiogenic igneous and metamorphic settings: an exploration into ancient petrochemistry in the Canadian Shield

Daniel Meagher, Jacob Hanley, and Mitchell Kerr

Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3

The objectives of this senior thesis are to (i) characterize the volatile chemistry and origin of hydrocarbon-nitrogen-rich fluid inclusions occurring in the Lupin deposit, an Archean gold system hosted within banded iron formation in Nunavut, Canada, (ii) compare the fluid chemistry and origin of these Archean volatiles to those in modern petroleum/natural gas systems as well as other magmatic-hydrothermal ore deposits, in order to discern whether specific trace gas hydrocarbon compositions are diagnostic of their formation via abiogenic vs. biogenic processes, and (iii) develop exploration criteria that can be used to locate Archean gold systems under buried cover using trace hydrocarbon analysis of gases in ancient metamorphic terrains. An extensive analytical study of the chemistry of the fluid inclusion gases in the Lupin deposit will be undertaken by using in-line crushing gas-chromatography, laser Raman microscopy, microthermometry, and N-S-C-H isotope systematics of inclusion fluids and associated altered host rocks. These analytical tests will constrain the temperature-pressure window of entrapment of these phases. Comparison to gas chemistry in conventional hydrocarbon systems will be done to establish petrochemical criteria as to the diagnostic aliphatic hydrocarbon species that allow differentiation between biogenic (bacterial reduction, thermal maturation) vs. abiogenic (polymerization, Fischer-Trophsch) synthesis, and differentiation between barren and mineralized metamorphic rock suites in Archean greenstone belts.

Petrographic and chemical characteristics of mafic dykes and sills in the Antigonish Highlands, Nova Scotia

Celine Elise Porter[1], Sandra M Barr[2], and Chris E. White[2]

1. Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia, B4P 2R6 ¶ 2. Nova Scotia Department of Natural Resources, Halifax, Nova Scotia, B3J 2T9

The Antigonish Highlands of northern mainland Nova Scotia have a long and complex tectonic history with major episodes of magmatism during the Neoproterozoic, Late Neoproterozoic, Ordovician, and Devonian-Carboniferous. Mafic dykes and sills are abundant throughout the Antigonish Highlands, presumably related to one or more of these magmatic episodes. Dykes and sills have been observed at more than 220 locations. They are rare in the Silurian Arisaig Group, but abundant in Ordovician and older units. In older units, many of the sills were originally thought to have been flows. Wide variation in petrographic, magnetic, and chemical characteristics suggests multiple episodes of dyke/sill emplacement. For this study, 70 samples were examined in thin section. Based on petrography, six types of dykes/sills were identified: plagioclase-porphyritic, fine-grained equigranular, medium-grained clinopyroxene-bearing, ophitic, hornblende-bearing, and secondary amphibole-bearing. Whole-rock chemical analysis of 37 of these dykes/sills shows that the majority are mafic but some are intermediate with up to 55% SiO_2. Most are subalkalic, and show characteristics of within-plate or ocean-floor tholeiite, although some dykes display within-plate alkalic characteristics. The plagioclase-porphyritic dykes display calc-alkalic characteristics, and appear to have formed in a volcanic-arc setting. Some of the chemical and mineralogical characteristics of the mafic dykes are similar to those of gabbroic components in Ordovician plutonic units.

The role of X-ray fluorescence in source rock analysis

Philip R.G. Sedore and Ricardo L. Silva

Basin and Reservoir Lab, Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia, B3H 4R2

X-ray fluorescence (XRF) is a non-destructive method that can be used to determine elemental concentrations of well-bore samples. This study examines how an XRF machine works, what geochemical characteristics can be calculated, and why this analysis is useful in the determination of source rock intervals. An XRF machine completes an analysis by bombarding a core or cutting sample with a spectrum of X-rays. These high energy electromagnetic waves eject electrons from the inner shell (K and L) of the atoms that make up the sample. The ejected electrons produce vacancies in the K and L shells that outer shell (M and N) electrons fill. The transition of electrons from an outer shell to an inner shell emits fluorescent, characteristic X-rays. The concentrations of key elements: Si, Fe, K, Al, Ca, Mo, and U are used to determine relevant geochemical ratios. These ratios define characteristics of sample lithology, lateral continuity, and depositional environment. By defining these attributes, a better understanding of the hydrocarbon generation potential and a more accurate description of source rock intervals is developed. The use of XRF analysis to supplement additional well-log data leads to a thorough and complete analysis of well-bore samples.

Variation in style of overpressure in Scotian Shelf wells, Scotian Basin

Dillon White[1*], Georgia Pe-Piper[1], and David J.W. Piper[2]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3 ¶ 2. Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2

Overpressure is a phenomenon where pressures greatly exceed normal hydrostatic pressure and occurs in many wells within the Scotian Basin. Due to this area being actively explored for oil and gas over the last five decades, it is very important to understand where and what is causing overpressure. The main causes of overpressure are disequilibrium compaction, clay diagenesis, and hydrocarbon generation, although, the relative importance of these processes in the Scotian Basin is uncertain. To assess and interpret the causes of variability in the style of overpressure in different wells in the Scotian Basin, velocity and density data from wireline data logs were used to produce velocity vs. density cross plots. These plots allow the possible secondary mechanisms of overpressure generation to be visualized. XRD of < 2 μm clays from shale in overpressured wells were analyzed based on clay mineralogy to possibly find a link between overpressure and diagenesis occurring in the studied samples. The method of cross plot analysis does indeed work for finding patterns of velocity vs. density changes below overpressure. Down-well variation in velocity vs. density of shale based on wireline logs shows wide range in velocity vs. density patterns in overpressured sections. There was an apparent regular distribution of different types observed based on velocity-density patterns. Fractures and cementation may have an influence on velocity and density downwell. The fractures may be due to the buildup of overpressure and its eventual release. The opening of fractures would cause a decrease in velocity and that would be observable in velocity-density plots.

Winner of the Canadian Society of Petroleum Geologists Award for the best petroleum geology-related presentation

Carboniferous lamprophyres in the central Cobequid Highlands, Nova Scotia: precipitation of REE minerals

J. Wisen[1], A. Papoutsa[2], G. Pe-Piper[1], and D.J.W. Piper[3]

1. Department of Geology, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3 ¶ 2. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia, B3H 4R2 ¶ 3. Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2

Late Paleozoic A-type granite plutons were intruded along an active shear zone in the Cobequid Highlands of Nova Scotia. The majority of these granites host primary REE minerals, and contain evidence of several events of hydrothermal REE remobilization. Granites of the West Moose River Pluton, however, contain exclusively secondary REE minerals. The West Moose River Pluton is located in a stepover zone between two major late Devonian faults, and just north of the Carboniferous Cobequid fault. It intruded Horton Group rocks and has been dated at 361 +5/-3.5 Ma (U-Pb on zircon). Small mafic dykes and sills in the area post-date the granite (ca. 334 Ma Ar/Ar on whole-rock, biotite), and some mineralogically resemble minette (biotite-rich lamprophyre). The minette dykes and sills contain mineralized veins of different relative age and mineralogy. Based on cross-cutting relationships, the types of veins from oldest to youngest include albite, chlorite and calcite-fluorite-filled fractures. Rare late pyrite-barite veins are also present. Re-opening of old fractures led to the formation of composite veins. The only REE mineral found in the minette dykes/sills is synchysite-(Ce) which occupies late cross-cutting veins. Remobilization of REE was enhanced by fluorine-carbon-rich fluids, which caused the simultaneous precipitation of fluorite, calcite, and synchysite-(Ce). The precipitation of synchysite-(Ce) in minette was governed by the interaction of REE-bearing fluids with the Cl-bearing biotite of the host-rock. This study underlines the importance of halogens during fluid-rock interactions for the precipitation of REE, and identifies minette dykes/sills as possibly important hosts of hydrothermal REE-minerals.

