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Atlantic Universities Geoscience Conference 2013

ABSTRACTS

October 24–26, 2013

63rd Annual Conference

Faribault Geological Society, St. Francis Xavier University
Antigonish, Nova Scotia

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 and the interesting and varied geoscience topics that they cover.

The Editors

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The possible role of the petroleum system in ore genesis in Nova Scotia: spatial coincidence or active involvement?

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Most economic metallic deposits (e.g., Pb, Zn, Cu, U, Au, W, Ba (barite), and Sn) in Nova Scotia have some association with organic carbon in the form of coaly matter, liquid petroleum or solid bitumen, black shale, or carbonate of organic origin. It has been proposed that organic matter can be used as a guide to ore; some authors suggest that the association is more than just a spatial coincidence, that organic matter may have played a primary or secondary role in metallogenesis as a scavenger of metals, a participant in metal transport, an agent in precipitation as a chemical reductant, a substrate for the development of diagenetic sulphides, or a physical role in the preservation of porosity and as an agent during rock deformation. It is locally important environmentally in the preservation of sulphides from oxidation/destruction.

This review highlights and summarizes the current knowledge regarding this spatial association and provides a brief introduction to an honours project. The thesis will explore the relationship between organic carbon and gold in the Meguma terrane of Nova Scotia, to determine if the carbon and the deposits are linked in more than just a cursory way. For instance, it is known that anticlines and domes host the richest Au deposits in Nova Scotian gold districts, and these structures may have represented ideal hydrocarbon reservoirs during the onset of the Devonian Acadian orogeny. Was organic matter, or intimately associated diagenetic sulphides in black shale, playing a role as a source, or an agent in transporting or concentrating Au?

Seismic stratigraphy and attribute analysis of Mesozoic and Cenozoic geology of the Penobscot area, offshore Nova Scotia*

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The Penobscot area is located on the Scotian Shelf, northwest of Sable Island within the Scotian Basin, offshore Nova Scotia. The Penobscot dataset comprises a 3D seismic survey, covering 87 km², two well logs (Penobscot L-30 and Penobscot B-41), and cored intervals from both wells. These wells are two of approximately 180 exploratory wells that have been drilled in the Scotian Basin since 1980. Penobscot L-30 and Penobscot B-41 had hydrocarbon shows but did not test enough hydrocarbons to be economic.

In this study, geologic software (e.g., Petrel) was used to interpret the seismic facies, structure, and seismic sequence stratigraphy, and for seismic attribute analysis to interpret the petroleum system. The focus of the study is on seismic inversion that solves for acoustic and elastic properties from the 3D seismic data. Inverting the seismic data to a layer property provides a clearer understanding of the subsurface geology and the potential hydrocarbon reservoirs within the survey area. Seismic inversion was also used to correlate the well logs across the survey area to define the reservoirs of interest. The cored intervals from both wells were studied, examining the characteristics of different lithofacies and their corresponding depositional environments. The lithofacies from the core were tied to the well logs to develop petrophysical facies, and then were tied to the seismic data to define the seismic facies. These new detailed analyses of the stratigraphy, seismic facies, and attributes suggest missed opportunities.

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

Geochemical and mineralogical constraints on the provenance of L'sitkuk pottery from the Annapolis Basin, Nova Scotia

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Seven potsherds of Mi'kmaq pottery (Ceramic/Eastern Woodland period) from L'sitkuk (Bear River, Annapolis Basin, southwestern Nova Scotia) and potential raw materials used in its manufacture were chemically analysed with the goal of determining whether the ceramic vessels were locally made or imported to this important trade and meeting site. The results identified two compositional groupings of pottery. Group A samples are enriched in diverse trace elements (notably the Rare Earth and some high field-strength elements) that exploratory statistics (multidimensional scaling) indicate are geochemically linked to clay and sand from the Annapolis Basin/Bear River and disaggregated biotite granodiorite that can be sourced to Devonian plutons cropping out inland. Sherds with lower concentrations of these trace elements (Group B samples) are linked to clays along the Annapolis Valley and vicinity, and are depleted in granodiorite constituents. The trace element signature of L'sitkuk pottery is largely controlled by accessory minerals, notably phosphate minerals such as monazite (and probably xenotime) that originate at least in part in the granodiorite. That the analysed L'sitkuk pottery samples were locally made is confirmed by diagnostic temper grains rather than clay compositions.

Correlating PGE enrichment with alteration assemblages at the Afton-Ajax Cu-Au-Pd porphyry system, Kamloops, British Columbia

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The Afton-Ajax alkalinic copper-gold porphyry deposit is located just outside Kamloops in the southern Cordillera of British Columbia, and has been noted to contain up to 3 ppm of palladium in multiple ore zones. The platinum group elements (PGE) occur in (i) platinum group minerals (PGM), specifically Hg-Te-As-Sb-Pd phases, commonly associated with chalcopyrite, pyrite, bornite, electrum, and hematite, and in (ii) pyrite (as dissolved constituent with Co and Ni). Cu and Au grades rarely correlate with PGE abundances and, therefore, the timing and conditions of Cu and Au precipitation are different from those of PGE. The exact modes of occurrence and alteration assemblage associated with the PGE-enriched zones are unknown. Variations in alteration assemblages may be useful to differentiate between PGE-rich and PGE-poor zones. Petrographic analysis and infrared spectroscopy will be used to determine the alteration assemblages within the suite of 44 samples. An attempt to correlate these specific alteration assemblages with enrichment in PGE will be made.

Alteration styles determined through the use of transmitted light microscopy include silicification and argillic, potassic, phyllic, and propylitic alteration. Silicification occurs as a pervasive front in high sulfidation and vein-rich samples, typically associated with phyllic or argillic alteration. Argillic alteration is characterized by a matrix of indistinguishable clay minerals. Two forms of potassic alteration were found: (1) large biotite in places replaced by chlorite in hornfels; (2) fine-grained biotite localized around veins and blebs of sulfide minerals. Phyllic alteration is pervasive and characterized by sericite and clays. Propylitic alteration is locally pervasive around quartz/carbonate veins, blebs or infilling fractures, and is identified by the presence of chlorite, actinolite, and/or epidote.

The Terraspec4 Hi-res mineral spectrometer (ASD Inc) will be used to conduct infrared spectroscopy with the aim of identifying the alteration minerals, specifically clays and other phyllosilicates. The data collected from infrared spectroscopy will also be used to determine compositional variations in clay minerals that may correlate with an increased abundance in PGE/PGM. This process, if applied in a field or lab setting, has the potential to assist in determining in which stages of alteration PGE were deposited. Alteration-PGE criteria may assist in creating exploration guidelines for the occurrence of PGE in other similar porphyry deposits in the Canadian Cordillera.

Carbon capture and storage: overview, reservoir options, and future possibilities

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Climate change is of significant concern in the world today. Anthropogenic sources are adding to the amounts of Green House Gases (GHGs) in our atmosphere, which in turn, are leading to an increased warming of the planet. A notable option for mitigating the effects that humans are having on the planet is Carbon Capture and Storage. In order to select reservoirs for potential storage, multiple criteria must be considered. These reservoirs provide different kinds of storage and each poses various obstacles. Potential areas for Carbon Capture and Storage in Nova Scotia include the Joggins Fossil Cliffs, Sydney Basin Carboniferous strata, and the North Mountain Basalt. The reservoir with the highest long-term storage potential is basalt formations, due to the fact that their minerals have the ability to react with the injected CO_2 and convert it into a solid carbonate material. Importance also lies in the pore sizes, which affect porosity and permeability of a material, which in turn can determine the storage capabilities of reservoirs (Sydney Carboniferous strata and its reservoir potential due to its lithology type). Overall, Nova Scotia has multiple opportunities for Carbon Capture and Storage that should be further investigated in future studies.

A hydrogeological investigation at the Crane Mountain Landfill, Saint John, New Brunswick

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The Crane Mountain Landfill is located in southern New Brunswick and is operated by the Fundy Region Solid Waste Commission (FRSWC). Although 61 monitoring wells are located on and around the site, they have mostly been used for water-quality sampling, and the groundwater flow system is not well understood. This study, sponsored by the Fundy Regional Solid Waste Commission, was designed to develop a better understanding of the hydrogeology of the site. The landfill is an engineered system designed with clay and geomembrane barriers, and a leachate collection system. It is underlain by glacial till that may be up to 20 m thick, and the till overlies fractured tonalite with minor argillite. Outcrop is sparse, but from observations at ten

locations the bedrock is moderately to highly fractured.

Continuous monitoring of hydraulic head at 24 well locations over a period of ten months indicates a variety of hydraulic responses to precipitation and snowmelt. They include: (1) rapid response indicating a shallow, unconfined aquifer condition; (2) no response indicating the monitoring well is isolated in unfractured bedrock; and (3) a time lag indicative of a confined aquifer condition. Pump tests were conducted at three water supply wells, while continuously recording head in surrounding monitoring wells, to investigate the connectivity of the fracture network and its influence on groundwater flow. The data collected from these tests will be used to construct a site conceptual model to visualize the influence of geologic features such as lithology, fracture network, and distribution of glacial till on groundwater flow beneath and adjacent to the landfill.

Petrology and geochemistry of ca. 2680 Ma pillowed lavas at Sharrie Lake, southern Slave province, Northwest Territories*

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Circa 2680 Ma volcanic rocks in the Tumpline Lake subarea of the Cameron River - Beaulieu River volcanic belt in the southern Slave craton are being assessed by the NWT Geoscience Office to determine their potential as a prospective Volcanogenic-hosted Massive Sulphide (VMS) environment. Bedrock mapping, geochronology, petrology, geochemistry, and isotopic studies are being employed in this evaluation. Bedrock mapping at Sharrie Lake in the Tumpline Lake subarea, located approximately 70 km ENE of Yellowknife, was completed at 1:7500 scale in 2012 and 2013. Two types of pillowed flows were selected for further study from this strongly bimodal subarea in which the "mafic" constituents are the Tumpline basalt flows including basalt, andesite and dacite members. In addition to some true pillowed basalt, many flows have basalt-like textures yet appear to be dacitic to rhyolitic. The VMS-potential of these pillowed lava flows will be assessed by characterizing the alteration and constraining the timing of alteration and deformation relative to metamorphism. A petrographic study will be complemented by whole-rock major, trace, and rare-earth element data from 23 samples and electron microprobe analyses of selected minerals. Metamorphic assemblages and P-T conditions will be documented in order to assess the effects of post-alteration processes. The flows sampled for this study were mapped as mafic or intermediate based on consistent field criteria, although some were previously mapped as felsic volcanic rocks. A detailed petrographic and geochemical study of these volcanic rocks is valuable for determining their primary composition (i.e. pillowed basalt or pillowed dacite) and understanding the alteration history of this belt. Primary volcanic features, including pillows, have been variably preserved at Sharrie Lake despite heterogeneous strain and greenschist- to lower amphibolite-facies metamorphism. Distinct and heterogeneous outcrop-scale alteration textures indicate the possibility of variable silicification and sericitization which could be associated with a VMS-potential environment. In thin section, ovoid aggregates of quartz and carbonate, interpreted in the field as deformed amygdules, display textures indicating recrystallisation during regional metamorphism.

Winner of the Imperial Oil Award for the best poster presentation

Substrate (CO and CO_2) utilization in chemolithotrophic microorganisms at a site of serpentinization: Tablelands Ophiolite, Newfoundland

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Studying ultra-basic reducing springs discharging from serpentinite can inform us about how life can survive in these extreme (i.e. high pH, anoxic) environments. We need to better understand metabolic pathways in these locations where ultra-basic springs discharge at the surface because they give us a window into what is going on in the subsurface. By studying these springs, we can extrapolate the data to biogeochemical reactions occurring underground. Biotic processes may take up carbon through CO or CO_2 from the system and use it for their metabolic processes. The Tablelands, located in Gros Morne National Park in western Newfoundland, Canada, is a prime example of an active site of ultra-basic serpentinization springs in North America.

To determine the potential for autotrophic metabolisms at the Tablelands site of serpentinization, water and sediments that were sampled from an ultra-basic spring at the site were incubated in sealed 100 ml wheaton bottles, known as microcosms. Bicarbonate (HCO^{-3}) was adding to microcosm experiments that tested for a carbonate reduction metabolism, and $CO_{(g)}$ was added to microcosm experiments that tested for CO supported metabolisms.

The results of the CO-enriched microcosms showed that CO was constantly utilized in the Live experiments but not the Killed. In the Live microcosms with $CO_{(g)}$ additions the CO became more enriched in ^{13}C, and had a decrease in the fraction of CO remaining in the headspace. Conversely, in the Killed microcosms with $CO_{(g)}$ additions, minimal ^{13}C enrichment was observed in the residual CO. Rayleigh

isotopic distillation fractionation factors calculated using data from the Live CO experiments showed consistent fractionation in duplicate microcosms. This result suggests that there was consistent microbial CO utilization in these experiments. ^{13}C labelled CO microcosm experiments corroborated the data from the non-labelled CO experiments.

The bicarbonate experiments showed very little to no methane production. Therefore, under the environmental conditions of this experiment, bicarbonate was not used as a substrate for microbial methanogenesis in these experiments. Therefore the results of this experiment suggest that the autotrophic metabolism in the ultra-basic spring may be fueled by CO and not dissolved CO_2.

Examination of surface features on kimberlitic iron-titanium oxide minerals

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Oxide minerals, including chromite and ilmenite, are found in abundance in kimberlite deposits, brought to the surface during the eruption of a kimberlitic magma from the upper mantle. Previous studies have shown that the dissolution of these oxide minerals reflects magma chemistry and fluids present, which also cause the dissolution of diamonds. The goal of this study is to establish a connection between surface features and reaction products occurring on kimberlite oxide minerals and the dissolution found on diamonds from the same kimberlite pipe. This study will also address the specific chemical and fluid interactions that result in the features seen on the examined grains.

Chromite and ilmenite grains from two kimberlite bodies were examined for distinct dissolution features and imaged using a Scanning Electron Microscope. The chromite grains from both kimberlites display consistent regular polygonal, stepping, and triangular pitted features on the grain surface. The ilmenite grain surfaces are predominantly covered by reaction products, primarily perovskite and titanite, and in some cases by kimberlitic groundmass. Several grains were cleaned in hydrochloric acid in an attempt to reveal the ilmenite grain surface beneath the carbonaceous groundmass. This procedure yielded some unique surface features unlike those seen on the chromite grains, mainly circular pitting. Following imaging, the chemistry and zonation of selected grains were analysed through wavelength dispersive spectroscopy and elemental X-ray mapping methods. Several ilmenite grains were found to show complex zonation, as well as an abundance of reaction products on the surface. The chromite grains, however, display only a very thin ring of zonation, as well as some minor pitting around the very edge of the grains. The eventual aim is for the possible prediction of preserved quality diamonds in a kimberlite through examination of the more abundant oxide minerals.

Petrological comparison of sills and dykes in metasedimentary rocks of the Meguma terrane, Nova Scotia, and the Harlech Dome, Wales*

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The Meguma terrane of southern Nova Scotia and the Harlech Dome of North Wales have similar Cambrian metasedimentary successions consisting of thick basal units of quartzose turbidite deposits, grading upward into early to middle Cambrian mud-rich and sand-rich units, containing manganese-rich layers, and overlain by turbidites deposited in anoxic environments and Tremadocian mudstone. Coarse clastic units in the lower parts of both successions contain similar detrital zircon age populations, and both areas are considered to have originated as peri-Gondwanan terranes. Their similarities have led to the suggestion that both areas were part of one palaeogeographical domain, for which the name Megumia has been proposed.

In addition to their stratigraphic similarities, both areas are characterized by abundant intrusive igneous rocks. The Harlech Dome hosts a large number of sills, dykes, and plutons of mafic to intermediate composition, generally assumed to be related to the Ordovician Rhobell and Aran volcanic groups. The northwestern part of the Meguma terrane, northwest of the Chebogue Point Shear Zone, is also characterized by abundant intrusions, mainly mafic sills, some of which show syn-sedimentary relationships with their Cambrian host rocks and some of which are Silurian-Devonian. A comparison of petrographic and chemical characteristics of the intrusions has been undertaken to shed additional light on the possibility of a paleogeographic relationship between the Harlech Dome and the Meguma terrane, using a compilation of petrological data from previous studies as well as analyses of new samples collected in both areas for the present study. Samples from the Harlech Dome range from mafic to felsic whereas those from the Meguma terrane are mafic. Preliminary results show that the Harlech Dome samples are calc-alkalic and likely formed in a magmatic arc setting at a convergent plate margin. In contrast, the mafic sills in the Meguma terrane are tholeiitic transitional to alkalic and formed in a within-plate tectonic setting.

Winner of the Science Atlantic Award for best overall presentation

Permeability and porosity of collapsed cone structures associated with Ophiomorpha trace fossils in offshore Newfoundland cores*

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Collapsed cones commonly associated with *Ophiomorpha* trace fossils are poorly documented structures and their effects on reservoir quality are seemingly underappreciated. As such, the focus of this honours dissertation is to investigate the characteristics of collapsed cone structures and the role they play in localized reservoir systems. To do so, four samples of varying morphology were selected from two cores originating in the Hibernia Formation of the Jeanne D'Arc Basin. Permeability data were collected with a gas probe permeameter and porosity was calculated from blue-dye epoxied thin-sections. Half-core faces were turned into semi-translucent thin-slabs to enhance sedimentological and structural features. Because the scale of the collapse structure is relatively modest in comparison to grain size, packing efficiency overrides grain sorting as the dominant characterisation factor. Preliminary results seem to indicate a thin zone of heightened communication between the surrounding sediment and the significantly decreased permeability and porosity zone of the collapsed cone structure. This research indicates that collapsed cone structures associated with trace fossils such as *Ophiomorpha* have the potential to dramatically alter reservoir estimations and should be incorporated into reservoir characterisation studies.

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

Gravity and magnetic surveys of a mafic Proterozoic sill at Cape St. Francis, Newfoundland

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The geology of the Cape St. Francis region near Pouch Cove consists of Late Neoproterozoic rocks. They include flow-banded rhyolite overlain by hematite-rich basalt, and then siliceous sandstone and siltstone. One distinctive feature in the region is a 600 m-long, ENE-trending topographic feature southeast of Jacobs Cove. The southeastern part of this feature is a steep cliff face with underlying scree. The cliff is noticeable from the nearby dirt road, and shows a mafic sill in the cliff. The sill has been determined from previous surveys to be highly magnetic, and dipping toward the northwest.

The objective of this BSc honours thesis is to model the thickness and the extent of the sill in the subsurface by performing geophysical surveys in the area. These surveys are (1) an elevation survey using a TopCon Hiperlite + DGPS, (2) a gravity survey using a Scintrex CG-5 Autograv Gravity Meter, and (3) a magnetic survey using Scintrex Envi Proton Precession Magnetometer. The DGPS survey determined the UTM coordinates for the stations and their elevations. These elevations were then used for Free-Air and Bouguer Correction for the gravity data. The Bouguer-corrected gravity data show that the sill has higher gravity readings than the surrounding sedimentary rocks, dipping and extending to the NW. Most of the magnetic data obtained were from an earlier survey in 2003. Another survey was conducted in 2013 to correlate these two groups of data due to magnetic drift. The magnetic survey shows total magnetic intensity (TMI) along the sill that are higher than in the surrounding sedimentary rocks, which is the same intensity as the Earth's magnetic field. But the concentrated high magnetic intensity at different spots along the sill may suggest that rather than the sill being highly magnetic, it may be younger dykes intruded throughout the sill that may be highly magnetic, most likely belonging to the Beaver Hat Intrusive Suite.

The gravity data still need to be terrain corrected using the Hammer terrain correction. The corrected data will then be modelled using Potent to determine the depth and the extent of the sill into the subsurface.

Gold in the Cantung W-skarn deposit, Northwest Territories: distribution, mineralogy, and petrogenesis

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Cantung is a world-class W-Cu-(Au-Bi) skarn deposit located in the Northwest Territories close to the Yukon border. It is within the polymetallic W-Au Tintina Belt of the northern Canadian Cordillera and is currently operated by North American Tungsten Corporation Ltd. Despite multiple mine closures since opening in 1962, Cantung had an estimated 6.21 Mt with an average recovered grade of 1.56 % WO_3 extracted as of the end of 2009. The most recent estimate of the indicated mineral resources is 2.06 Mt grading 1.04 % WO_3 with probable mineral reserves of 1.34 Mt grading 1.05 % WO_3 as of October 2011. The deposit is located in both an underground mine, termed the "E Zone", and an Open Pit resource near the surface. Extensive magmatic systems formed the W skarns that were later altered by magmatic-hydrothermal events.

Previous research indicates that the hydrothermal fluids were predominately supercritical, hot magmatic brines with homogenization temperatures that ranged from 270 to 500 °C. Mineralization at the Cantung mine comprises calc-silicate skarn replacements within the Ore Limestone, a clean limestone receptive to skarn development, and lower grade replacements in the Swiss Cheese Limestone, a calc-silicate/chert unit. Pyrrhotite is abundant in all skarn facies and is positively correlated with the W mineralization. Scheelite and chalcopyrite are dominant, although locally abundant sphalerite and anomalous Bi and Au concentrations were also significant. The purpose of this study is to characterize the distribution, mineralogy, and petrogenesis of Au in this deposit. From the E Zone, five samples with bulk rock Au assay values greater than 0.5 ppm were examined petrographically. Using the bulk assay data (n = 48), Au correlates positively (Spearman's Rank, r') with Bi (0.76), Ag (0.70), Fe (64), Cu (0.64), and Mo (0.60). No free Au (electrum) has been identified optically or by SEM and FEG-SEM in analyses thus far. The hypothesis is that the Au is present as nano-inclusions within chalcopyrite or is lattice bound within Bi-minerals or related tellurides and selenides that occur in the interstices of calc-silicate minerals that have been identified. The liquid bismuth collector model is tested using LA-ICP-MS analysis to determine the extent of lattice bound Au. This model involves Au scavenging from magmatic hydrothermal fluid by complex liquid Bi-sulphide phases saturating during W-Cu mineralization.

Multiple Sclerosis and geology in Nova Scotia: is there a correlation?

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Multiple Sclerosis (MS) is a chronic inflammatory disease of the central nervous system that predominantly affects patients of European descent. Evidence shows that Nova Scotia has one of the highest prevalence rates of MS in Canada and the world. In Nova Scotia there may be a correlation of MS to certain rocks. A review of the literature did not confirm this, in part due to the lack of published data for the rates of MS by geographic location within the province. Various authors have identified potential bedrock types and geologic intervals that may have a correlation or be a trigger mechanism to the development of MS, such as the presence of radon, but there is no clear evidence to support this. To further our understanding, it would be beneficial to undertake a formal study to obtain data from the Nova Scotia MS database, which would be used to identify present and childhood postal codes and then analyze that data in reference to the geologic bedrock. If a correlation is identified, we may be able to extend the assessment to other provinces, including Alberta which also has a very high prevalence of MS.

Petrology of drill core from the Taylors Brook property in the Stirling belt, southeastern Cape Breton Island, Nova Scotia: implications for tectonic setting and economic potential

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The Stirling belt in southeastern Cape Breton Island, Nova Scotia, is one of several belts of Precambrian rocks in the Avalonian Mira terrane of the northern Appalachian orogen. It consists of ca. 670 Ma volcaniclastic rocks, flows, porphyries, breccias, and clastic sedimentary rocks (Stirling Group), intruded by ca. 620 Ma dioritic to granitic plutons and overlain by Cambrian sedimentary rocks. The Stirling belt has high potential for economic sulphide mineralization but outcrop is limited and hence the geology and tectonic setting are not well understood. This project is the first petrological study of rocks in core from three new holes that were drilled in 2012, along with data from two holes that were drilled in 1991, to depths of 500 m at the Taylors Brook property, site of a copper-gold mineral occurrence in the southern part of the Stirling belt. Logging of the core showed that the rock types include basalt flows, mafic dykes, mafic and felsic tuffs, quartz-feldspar porphyry, rhyolite, and volcanogenic and pyritic siltstone and wacke. Over 500 analyses were obtained from all rock units in the drill core using a portable X-ray fluorescence instrument. The data show consistent some chemical differences between basalt flows and mafic dykes, corroborating the distinction between these two major components of drill core which in some cases were not easily distinguished from one another during logging. In addition to the portable XRF data, whole-rock chemical data were obtained from 27 samples representative of the main rock types in the core for comparison with published data from elsewhere in the Stirling belt. Preliminary assessment of the chemical data suggests that the mafic and felsic rocks are calc-alkalic and formed in a volcanic-arc setting.

The southern margin of the Rhodes Basin and its geological relationship with the Anaximander Seamounts, eastern Mediterranean

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The boundary between the deep Rhodes Basin and the Anaximander Mountains represents a critical region at the junction between the Hellenic and Cyprus arcs, here investigated by multi-channel seismic reflection profiling. The seismic data were processed using the Landmark Graphics ProMAX software running on a Linux operating system. The raw data were passed through quality-control flows to eliminate noisy and dead traces, and to filter out low-frequency noise. The data then underwent velocity analysis, CDP stacking, and migration. Geological interpretation of ~1500 km of profiles (including those processed and adjacent lines) allows us to assess plate motion-related deformation in the area. Westward tectonic escape of the Aegean-Anatolian microplate from the Arabian-Eurasian collision in the east and collision in the west with the Apulia-Adriatic platform forces a counterclockwise rotation of the microplate towards the subduction of the African plate at the Hellenic Arc. This rotation is responsible for the protracted Miocene convergence (episode P1), which resulted in the development of a mainly SSE-verging fold-thrust belt, affecting the Anaximander Mountains. The belt is composed of several south-verging fore thrusts, and a number of prominent back thrusts, which collectively create significant morphological expression and continuing development as positive flower structures in the Pliocene-Quaternary sediments. The morphology of the strong late Messinian M-reflector and the architecture of the lowermost Pliocene growth strata in the central portion of the Rhodes Basin demonstrate the existence of rugged paleo-relief over the pre-existing Miocene fold-thrust belt. Later Pliocene–Quaternary deformation is characterized by NE-SW sinistral transpression (P2), and rapid regional subsidence. The P2 deformation is likely related to the rollback of the subducting plate at the Hellenic Arc and the consequent tear in the down-going African plate resulting in the transform fault of the Pliny-Strabo Trenches. During this time, the P1 structures became reactivated as transpressional faults. Immediately above the M-reflector lies a poorly reflective unit at the base of the Pliocene–Quaternary of Unit 1. This is interpreted as a thin succession continuing from the Messinian evaporites below. The succession is interpreted as very thin evaporites (and/or interbedded siliciclastics) formed prior to the post-Messinian flooding of the Mediterranean.

Sedimentology and paleoenvironment of a Jurassic dinosaur bone bed, Parrsboro, Nova Scotia

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The Early Jurassic McCoy Brook formation at Wasson Bluff has been a site of dinosaur bone discoveries for over thirty years. The formation crops out on the north side of the Minas subbasin, deposited during the break up of Pangea and prior to the opening of the Atlantic Ocean. The first discovery of dinosaur bone was in 1976 with numerous excavations in 1998-2006 which yielded several articulated prosauropods within a confined bone bed. The prosauropod bone bed is of particular interest to the scientific community because it represents the richest prosauropod site in North America and the oldest dinosaur bones discovered in Canada. Recent field work took place in August 2013, led by Dr. Tim Fedak, where 15 disarticulated bones and bone fragments were collected in an eastern extension of the bone bed. The dinosaur material has been well documented by multiple researchers and the detailed sedimentology of this particular bone-bearing bed is now of interest. Assessing the stratigraphy at Wasson Bluff is complicated by syn-depositional faulting that occurred as the Fundy rift basin matured. Faults are present on a meter scale as well as a centimeter scale, as displayed by offsets of some bone.

During this study a comprehensive account was prepared of the bone bed strata and the strata immediately above, which have been described at a centimeter scale. Important features of the strata include interbedding of thin mudstone containing abundant micas with coarse- to medium-grained sandstone; isolated boulders presumably eroded from a paleocliff, and trough cross beds. Poorly sorted sands are also present, with some outsized, well rounded grains. These sediment characteristics lead to the conclusion that the dinosaurs were preserved in a river channel with episodic flow and eolian additions to the river sediment. This detailed account, as well as grain size analysis, thin sections, and paleoflow will be used to interpret the paleoenvironment in which the dinosaurs were buried.

Provenance of pre- and post-contact copper artifacts used by aboriginal people in Atlantic Canada: implications for understanding historical metal trades and usage

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Native copper had in many cultural applications by both pre-and post-contact Mi'Kmaq peoples throughout the Maritimes, including the fabrication of tools, jewellery, gifts, and ceremonial wares. The central role of native copper in the Mi'Kmaq culture is better understood than the provenance of this metal, which this research seeks to address. Archaeological excavations within Nova Scotia have uncovered a large collection of native copper artifacts ranging from the Early Woodland Period (2500–2400 BP) to the Protohistoric Period (450–350 BP) to Post-European Contact (1500+BP). Specifically, this innovative study will build upon past archaeology research by applying laser ablation inductively-coupled plasma mass spectrometry (LA-ICPMS) to characterize trace element compositional signatures that can identify different native copper compositions derived from natural occurrences of the metal and synthetic (refined) sources. The methodology used in this study and the interpretation of results improve on previous bulk analytical methods that suffer inherently from the presence of contaminating grains of other accessory minerals within the native copper, and most importantly, is a comparatively non-destructive technique.

Evaluation of LA-ICPMS data (i.e., trace element compositions) collected from 15 artifacts reveals four distinct native copper compositions. Each group is characterized by specific elemental enrichment/depletions, and for single artifacts, little compositional variation was observed (i.e., samples are homogeneous). Group 1 is distinguished by significant enrichment in Zn, Sn, Pb, and Au and is consistent with the composition of refined Cu originating from Europe. Group 2 (enrichment in Hg and depletion in Au), Group 3 (Mo-enrichment), and Group 4 (enrichment in Ag and Cd, and depletion in Hg) are suspected to be objects derived from native copper sources. Native copper from many known sources of the metal along the Bay of Fundy, Nova Scotia and New Brunswick, as well as other documented localities outside of the Maritimes will be analyzed in order to assign provenance to the three groups of suspect non-European-source artifacts. A variable trace element composition within the collection of artifacts provides evidence that supports a multiple-provenance theory for the origin of native copper within the collection. The application of these results may have a great significance in our understanding of Maritime cultural history.

The Early Devonian, Evandale Porphyry Cu-Mo-(Au) deposit, southern New Brunswick: petrologic, geochemical, geothermobarometric, and geochronologic characterization of the host rocks and its origin*

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Relatively little research has been dedicated to porphyry Cu-Mo-(Au) systems associated with the granitoid rocks in Eastern North American orogenic belts. The circular Middle Devonian, hornblende-biotite Evandale Granodiorite (U-Pb zircon, 391.2 ± 3.2 Ma for the granite, and 390.2 ± 1.6 Ma for the aplite) intrusion is a locally Cu-Mo-Au mineralized polyphase pluton intruding through deformed Silurian sedimentary and mafic volcanic rocks of the Mascarene Basin in southern New Brunswick. The two intrusive phases have been identified as magnesian, calc-alkalic to alkali-calcic, peraluminous I-type granite generated by decompressional melting of the lower crust caused by post-collisional uplift. The Evandale Granodiorite consists of two textural, petrochemically related but distinct phases ranging from medium-to coarse-grained seriate to porphyritic and aplitic texture. INAA analyses of the aplitic and coarser granite phases found the highest concentration of Cu and Au (108 ppm Cu, and 33 ppb Au) and associated with pyrite, chalcopyrite, and arsenopyrite in the sampled aplitic dykes. Concentrations of up to 6 ppm Mo were detected in the coarse-grained granite, whereas only trace amounts of Mo were recognized in the aplite. Current models suggest that the transport of metals (particularly Cu and Au) are sourced from secondary two-phase fluids at shallow depths (approximately 1–2 kb), and is greatly affected by Cl fugacity of the magma. Analyses of biotite phenocrysts from both the aplite and granite contain an average of 0.21 wt% Cl, which is similar to other high grade Cu-Mo-(Au) porphyry deposits. The hornblende-plagioclase thermometry revealed the crystallization temperature of the granite to be 642°C and 600°C for the aplite (cooler than most deposits of the same type). Al-in-hornblende geobarometery indicates crystallization depths of approximately 2.1 kb for hornblende in the aplite and ~0.7 kb for the coarse-grained granite. The higher crystallization pressure of hornblende in the aplite phase indicates that it intruded to higher levels rapidly and pressure quenched (aplite to porphyritic texture) within the host granodiorite, which is consistent with volatile exsolution controlling emplacement and formation of porphyry Cu-Mo-(Au) mineralization at a shallower depth.

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

Reservoir characterization and forest density of the Joggins Formation, Joggins, Nova Scotia

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The Carboniferous Joggins Formation crops out along the shoreline of Chignecto Bay, Nova Scotia, within the Cumberland Basin. The Joggins Fossil Cliffs present a 2D and 3D exposure of the meanderbelt channel deposits and fossils of the Joggins Formation. These outcrops demonstrate the stratigraphy of the formation and the preserved flora in the Carboniferous. This study uses LiDAR as a survey technique with a spatially calibrated Differential GPS (DGPS) to image the meanderbelt channel architecture and the fossils of the Lycoipsids, Calamites, Lepidodendron, Alethopteris, and Sigillaria in the Joggins Formation. This high resolution imaging provides a 3D image of the cliff with details of the channels and the fossil tree trunks. The data collected can be used to identify the fossil tree density and architecture of the channels within the formation. Post-processing methods involve in a reconstruction of series of LiDAR images of the area that have been taken in past years. This reconstruction provides a time series of the cliff profile. These high resolution images will provide a record of the fauna and the architecture of the meander channels in the Carboniferous.