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# Atlantic Universities Geoscience Conference 2012

## ABSTRACTS

October 18-20, 2012

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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 and the interesting and varied geoscience topics that they cover.

THE EDITORS

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### Field observations on $D_1$ and $D_2$ deformation fabrics and metamorphic mineral growth in the Newton Fjord region on Hall Peninsula, Nunavut, Canada

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Hall Peninsula, located on southeastern Baffin Island, Nunavut, represents an underexplored region of Canada's North owing to outdated geoscience knowledge. The Canada-Nunavut Geoscience Office in Iqaluit undertook the first of two field seasons of regional bedrock and surficial mapping during the summer of 2012. Hall Peninsula comprises three main tectonostratigraphic domains, an eastern domain of Archean tonalitic gneiss, a central domain of Palaeoproterozoic metasedimentary rocks, and a western domain of ca. 2860 Ma orthopyroxene-bearing monzogranite. The earliest recognizable Paleoproterozoic deformation ( $D_1$ ) is characterized by a foliation that in most outcrops is near bedding-parallel and accentuated with a partial melt phase. The second deformation ( $D_2$ ) transposes bedding and earlier fabrics and controls the N-NW trending regional map pattern. This study focuses on a small region (ca. 4 km<sup>2</sup>) straddling Newton Fjord in the central metasedimentary domain where two areas with contrasting deformation styles were mapped in detail. The areas are termed "Sillimanite Ridge" in the east and "Barrow Peninsula" in the west. Rocks in the Sillimanite Ridge area consist of interbedded pelite and psammite with minor crosscutting orthopyroxene-bearing monzogranite. All rocks are cut by leucocratic garnet-bearing monzogranite.  $D_1$  is characterized by a bedding-parallel foliation defined by sillimanite-biotite-garnet-K-feldspar and melt.  $D_2$  is characterized by the reorientation, or transposition, of  $D_1$  fabric elements on the limbs of tight to isoclinal  $F_2$  folds. In the hinges of  $F_2$  folds  $D_1$  fabric elements are preserved and crenulated. Sillimanite defines the  $L_2$  lineation but it is unclear in outcrop if the sillimanite is new growth or reoriented. The Barrow Peninsula area consists of interbedded pelite, semi-pelite, and psammite with minor calc-silicate lenses and subordinate cross-cutting orthopyroxene-bearing monzogranite and leucocratic garnet-bearing monzogranite. This area is composed mainly of inhomogeneous diatexite hosting rafts of psammite, which is more competent and has a higher melting temperature. The bedding-parallel  $D_1$  foliation is moderately transposed by  $D_2$  shortening and folded into steeply south-dipping open to close  $F_2$  folds. Areas with extensive melt are deformed by  $D_2$ , but not by  $D_1$ , which constrains the timing of the melt to

late  $D_1$ . Initial observations suggest that the inhomogeneous diatexite and the leucocratic garnet-bearing monzogranite at Barrow Peninsula are related and likely late  $D_1$  in origin. The contrasting  $D_2$  structural styles between and within the two areas indicate a  $D_2$  varies in strain intensity from east to west. However,  $D_1$  and  $D_2$  metamorphic mineral assemblages appear to be similar and therefore may reflect comparable thermal conditions. Future work will involve detailed lithological descriptions from both areas, careful analysis of mineral-fabric relationships, and mineral chemistry studies.

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### The petrogenesis of REE-enriched dykes in the Eastern Cobequid Highlands, Nova Scotia

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High Field Strength Element (HFSE)-Rare Earth Element (REE)-enriched granite was discovered at the contact zone of the Hart Lake-Byers Lake granite and rhyolite of the Byers Brook Formation in the Debert Lake area, northeastern Cobequid Highlands, Nova Scotia. The HFSE-REE-enriched granite has been found in two types of occurrences. Most prominent are dykes ~1–50 cm wide. The second type occurs in patches 1–25 cm wide in locally-pegmatitic arfvedsonite-bearing granite. Dykes are of two types based on grain size, texture, and geochemistry. Type 1 dykes are medium to coarse grained with 'granitic texture', whereas type 2 dykes are fine grained, typically display mineralogical banding, and have noticeably lower silica content and higher HFSE-REE-enrichment. The HFSE-REE-enriched granite is being studied to investigate whether or not a genetic relationship exists between the dykes and the nearby Hart-Lake Byers-Lake A-type granite pluton. Polished thin sections of HFSE-REE-enriched granitic dyke samples were analyzed for modal % of minerals. Quantitative chemical analyses of HFSE-REE-rich mineral phases were then conducted. Type 1 dykes contain ~70–80 vol. % quartz, K-feldspar, albite, and magnetite/hematite, <10% epidote and <5 % zircon, and trace amounts of pyrochlore, sphene, monazite, fergusonite, chevkinite, bastanaesite, allanite, ilmenite, yttrialite, and fluorite. Type 2 dykes show a similar modal mineral assemblage with additional minerals including thorite, talenite, apatite, and calcite. Detailed mapping of the Hart-Lake Byers-Lake pluton from Debert Lake to the mylonite zone of the Rockland Brook Fault was completed in 2012. More than 500 samples were collected, slabbed, and analyzed using a Innovex X-5000 Mobile XRF whole-rock geochemical analyzer. Amphibole compositions in the Hart-Lake Byers-Lake granite and

HFSE-REE-enriched granite will be determined using a JEOL 8200 electron microprobe at Dalhousie University. It is postulated that the HFSE-REE-enriched dykes may have originated from F-rich fluids that segregated from the Hart-Lake Byers-Lake pluton, possibly as a result of fractionation of the granitic melt. The patches may represent localized F-rich areas in an arfvedsonite-rich and HFSE-REE-rich part of the Hart-Lake Bykers-Lake granite.

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**Evaluation of the controls on the distribution of scheelite and wolframite in mineralized zones at the Sisson Brook W-Mo-Cu deposit, west-central New Brunswick: a petrogenetic analysis**

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Sisson Brook is a porphyry-related W-Mo-Cu deposit located near the village of Stanley in west-central New Brunswick and is one of several notable W-Mo deposits in the northern Appalachians. The geological and mineral-chemical controls on the distribution of scheelite versus wolframite mineralization within the deposit are the focus of this study. The project is currently held by Northcliff Resources Ltd. and hosts a measured and indicated resource of 383 Mt grading 0.072% WO<sub>3</sub> and 0.024% Mo. The Sisson Brook deposit is a system of mineralized vein and replacement zones located near the eastern boundary of the Middle Devonian Nashwaak Granite. The deposit is hosted within the Silurian-Devonian Howard Peak Diorite and Gabbro and a sequence of late Cambrian-Ordovician metamorphosed tuff and psammite. Mineralization was discovered in 1979 by Kidd Creek Mines. Early work determined that mineralization occurred over two zones: Zone A and Zone B. Mineralization in Zone A is characterized by wolframite and chalcopyrite, whereas Zone B is primarily scheelite and molybdenite. In 1985, Heidi Nast determined that economic mineralization within the deposit is distributed across four vein sets showing different mineral proportions. Work by Nast and Williams-Jones in 1991 determined that wall rock composition was a major control on tungsten mineralization, evidenced by scheelite occurring in the calcium-rich metagabbro and metavolcanics, and wolframite occurring elsewhere. Current research is focussed on determining further controls on the distribution of scheelite versus wolframite mineralization with a focus on biotitization associated with many of the replacement zones mantling the vein systems. The formation of metasomatic biotite liberates calcium from primary mineral assemblages during mineralization, contributing to the formation of scheelite instead of wolframite. Scanning electron microscope examination has revealed small scheelite inclusions within coarser grained ilmenite, which

is rimmed with titanite. Scheelite is also hosted in the vein selvages. Thus far, molybenite and wolframite seem to occur only in the axial quartz veins. This indicates that scheelite was the earliest phase to form hydrothermally, and fluid composition variations led to the formation of ilmenite via reaction with precursor Ti-bearing silicates. As iron in the system was depleted by sulphidation producing pyrite, titanite began to form on the rims of ilmenite grains. Metasomatic titanite grains and zircons within and outside reaction zones will be dated to assess the timing of mineralization relative to intrusive rocks in the area. This petrogenetic and geometallurgical research will assist in the development of the Sisson Brook deposit.

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**An Investigation of factors influencing drumlin erosion in Mahone Bay, Nova Scotia**

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The processes that influence the erosion of drowned drumlins in Atlantic Canada are not particularly well understood. Consequently management strategies and engineering practices focussed on mitigating erosion have had limited success and in some cases have resulted in shoreline modifications that have significant ecological and social impacts. This study focuses on determining the relative importance of the sedimentological, geomorphological, and physical parameters that contribute to headward erosion of seven drowned drumlin islands in Mahone Bay, southwestern Nova Scotia. The islands being studied are palimpsest drumlins formed during Wisconsinan ice advance from 30 ky to 17 ky BP. Sea level rise following deglaciation and recent and gradual subsidence associated with foreland bulge migration has exposed these islands to marine influence (drowned drumlins). A 60 year long historical airphoto survey established long term erosion rates of up to 0.46 m/yr and determined the orientation of eroding surfaces, transportation corridors, and subsequent deposits. A suite of marine physical parameters (bathymetry, fetch, swell) were studied to constrain energy transfer processes. Site investigation involved documenting the sedimentology and stratigraphy of eroding surfaces as well as hydrological conditions (water table elevation, permeability) that might contribute to headland instability. The results of this study indicate that the erosion rates are the result of a combination of complex interacting factors. Sandy and clay rich lodgement tills are more prone to mass wasting than coarse grained ablation tills that contain a greater number of cobble to boulder clasts. Multiple tills and layering within tills also produce hydrological anisotropy and contribute

to the activation of glide planes along which mass wasting occurs. Hydrogeologically triggered rotational and translational failure occurs in response to oversteepening. The consequent exposure of underconsolidated sediment to wave activity expedites erosion. Most rapidly eroding headlands are exposed to both maximum storm fetch and ocean swells. Wave energy input can be considered as the limiting factor when determining the locations of highest rates of erosion.

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### Structural geology of the Meguma Supergroup and White Rock Formation contact in the Cape St. Marys area, southwest Nova Scotia

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The contact between the Halifax Group (Meguma Supergroup) and White Rock Formation is strongly deformed, and the exact nature of the contact is disputed. The Halifax Group is slate with lesser amounts of metasandstone, metasilstone, and calcareous rocks; it is underlain by the Goldenville Group composed of metasandstone and slate. The White Rock Formation consists of bimodal tholeiitic-alkalic volcanic and volcanoclastic rocks. The rocks have been metamorphosed to greenschist facies. Cape St. Marys was in a strategic position during the Neocadian orogeny and formed the current synclinal structure with heterogeneous shear as a result of overprinting Alleghanian deformation. The Neocadian orogeny was a result of oblique accretion of the Meguma terrane (Africa) with the Avalonia microcontinent, which generated northeast-trending upright folds. The Alleghanian Orogeny overprinted these  $F_1$  folds, overturning them and forming southwest-plunging reworked folds in a broad zone of transpressive deformation. The Cape St. Marys heterogeneous shear zone extends from Bear Cove to Point David where the Halifax Group is in contact with the underlying Goldenville Group. The centre of the heterogeneous strain zone is an exposed contact between the Halifax Group and White Rock Formation. The contact dips steeply southeast, and kinematic indicators (e.g., curved quartz fibers in pyrite pressure shadows and sigma-tail volcanic clasts) show reverse-sense shearing. The details of the structural conditions, the kinematic evolution, and the origin of the deformed contact need to be better refined.

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### Bedrock incision and surface uplift rates of the western Hangay Dome, Mongolia

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The origin of relief of the Hangay Mountains is problematic because they are situated in western Mongolia, far from any plate boundary or major tectonic structure. By correlating and dating straths of differing heights preserved along valleys incising the western Hangay Dome, it is possible to deduce the record of stream incision over time and relate this to the tectonic or isostatic processes that contribute to the relief. Two approaches are undertaken. The first is to study the pattern of the paleo-longitudinal profiles in selected valleys throughout the study region. Data were collected in the field, and complimented with satellite imagery of identified strath surfaces. We will analyze the surfaces and recreate paleo-profiles of the modern incised rivers to identify the history of the stream. The second approach is to determine the age of the exposed straths, to help confirm our correlation of the straths in Approach 1, but also to estimate the rates of incision between periods of strath abandonment by using cosmogenic  $^{10}\text{Be}$  and  $^{36}\text{Cl}$  exposure dating of the strath surfaces. The age of strath abandonment can be calculated, which will be interpreted to represent the time when the river continued to incise its bed, exposing the remaining bedrock bed surface to cosmogenic nuclides. Given the age of river abandonment, and paleoriver and modern river elevation, we can approximate river incision rate. If uplift has occurred in the dome, the strath surfaces will show faster incision rates at the head of the river, so the paleo-longitudinal profiles will converge downstream. Alternatively, if incision was due to a drop in base level (i.e., extra-dome basins to the west have subsided), then incision rates will be relatively slower in headwaters, and the paleo-long profiles will diverge downstream. After establishing if the dome rocks are uplifting (or if the basin is dropping) we can interpret the rates of rock uplift (or subsidence) and determine if the rates have varied over time. These results are important because it will help understand the incision history over the past few million years. Patterns of variability may be able to fingerprint unique cause of the relief, such as a late Cenozoic mantle avalanche (which, for instance, would be potentially identified as having a period of very rapid incision preceded and followed by a slower rate). By analyzing the uplift (or subsidence) of the Hangay Dome, we will have a greater understanding of the intracontinental movement, and lateral motions in the greater plate tectonics theory.

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### Mineralogical study of a uranium-niobium-rich alteration zone at the Lofdal Carbonatite-Silicate Complex, Namibia

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The Lofdal Farm area, located in NW Namibia, is host to a mid Neoproterozoic (ca. 750 Ma) rift-related silicate-carbonatite intrusive suite. The intrusive core of the complex is characterized by nepheline syenite and carbonatite plugs, and diatreme breccia, surrounded by a wide area (200 km<sup>2</sup>) of carbonatite and phonolite dyking accompanied by hydrothermal alteration. The carbonatite dykes are strongly mineralized with rare earth elements, showing particularly strong enrichment in heavy REE, believed to be associated with late stage hydrothermal alteration. The core of the complex, referred to as the “Main Intrusion”, outcrops as a large carapace of nepheline syenite (1.5 km<sup>2</sup> exposure area) intruded by a calciocarbonatite (sovite) plug. Airborne radiometric surveys identified a large uranium anomaly along the western and NE extremities of the Main Intrusion. Reverse Circulation drilling and analysis of 5 m-composite chip samples proximal to the main geophysical anomaly has identified a zone of uranium and niobium enrichment averaging 110 ppm U and 3200 ppm Nb. A grab sampling program over the main U anomaly identified enrichment averaging 500 ppm U and 5000 ppm (0.5%) Nb. Detailed field mapping of the Main Intrusion identified two alteration styles, mafic and felsic fenitization, affecting syenite and breccia marginal to their contacts with the intruding carbonatite body. They are interpreted to be a result of alkali metasomatism of host rocks during the carbonatite intrusion. Mafic fenitization is strongly radioactive and consists of coarse-grained aegerine intergrown with calcite and microcline. It is not very extensive and appears to be constrained to the contact margins with thicknesses of approximately 2 m. Felsic fenitization is much more widespread and is characterized by nearly complete replacement of the rock by potassium feldspar. Felsic fenites also show anomalous radioactivity, although not as intense as mafic fenites. Uranium and niobium mineralization in the Main Intrusion is currently of significant interest, although much uncertainty remains about the nature of the mineralization. RC chip analysis has proven that significant mineralization is present at depth, although it is not clear how this mineralization relates to what is seen at surface. This study will focus on describing the mineralization and alteration styles of the syenite, fenite and carbonatite within the main uranium anomaly of the Main Intrusion. This information should provide some insight into the nature of mineralization at depth, helping to constrain targets for a future diamond drilling program.

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### Influence of native Newfoundland sea cucumber *Cucumaria frondosa* on sediment mineralogy and texture

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The orange-footed sea cucumber, *Cucumaria frondosa*, is the most commonly occurring sea cucumber along the northeastern coast of the North Atlantic Ocean. *C. frondosa* is abundant in benthic environments, and may be either a suspension feeder or deposit feeder. In both cases the sea cucumbers ingest mineral grains (either suspended or sedimented). *C. frondosa* was chosen for study because of its propensity to process large volumes of sediment in the course of its feeding activities. Sea cucumbers as indiscriminate filter-feeders will ingest any small particles in the water column. Whether they are grain-selective deposit feeders has not been determined. The process of digestion has the potential to affect organic and inorganic materials. The conditions in the guts of organisms that are considered conducive to breakdown of both mineral grains and organic matter are: low pH in the foregut; high pH in the hindgut; low oxygen content, abundant microbes and enzymes. To-date no studies have been carried out on the effects of digestion on carbonate-rich materials. Carbonate minerals are strongly affected by (1) low pH, which causes dissolution; and (2) high pH, which encourages precipitation of carbonate phases. This study has two areas of focus: (1) the examination of mineral grains before and after ingestion to study the effects of pH fluctuations on dissolution of carbonate grains- in the form of surface etching of grains present in fecal material; (2) mineralogical study of digested carbonate minerals with high magnesium content (high Mg calcite from a coralline alga *Lithothamnium glaciale*, ingested by the animal from an artificially induced suspension of clay-grade ground alga) which has the potential to produce dolomite in the guts of organisms. Examination of fecal material for dolomite and changes in crystallinity and surface texture was undertaken using X-Ray diffraction, Scanning Electron Microscopy, and Fourier Transform Infrared Spectroscopy. Preliminary results reveal the dissolution of carbonate as weathering observed on *L. glaciale's* outer surfaces post digestion by the animals and the formation of small (1 micron) rhombohedral carbonate crystals evident on channel openings.

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### Racing to the surface – the dynamics of the feeder system to a cinder cone

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The West Eifel Volcanic Field in western Germany comprises more than 250 individual volcanic edifices spread over an area of ~ 500 km<sup>2</sup>. The first eruptions occurred around 940 ka BP and the last recorded eruption was ~ 11 ka BP. Seismic data indicate that a thermal plume contains 1–2% melt in the asthenosphere below the field. This indicates that the field is still potentially active. As several large towns are located in the region and the Eifel is on the flight path for many major airports, any assessment of volcanic hazard must be based on the dynamics of magma emplacement. The Rockeskyllerkopf volcanic complex (RVC) first erupted ca 474 ka BP with the final eruption more than 100,000 years later at ca 360 ka BP. For each volcanic event the first stage was phreatomagmatic but as groundwater was reduced eruptions became increasingly strombolian. The deposits of the first event commonly contain mantle and high pressure cumulate xenoliths that were entrained in the rising magma over a range of depths of 3–45 km. Numerous studies have shown that olivine in mantle xenoliths is generally not in equilibrium with the magma that brought them to surface. This disequilibrium is reflected in the development of Fe-Mg diffusion profiles in the olivine. We know the rate of Fe-Mg diffusion and we can estimate temperature, so we can use such profiles to determine how long the xenoliths were in transit. We have analysed olivine in 10 peridotite and 5 high pressure cumulate xenoliths. The peridotite has the deepest source (~45 km) and our models show that the xenoliths took less than 5 days to reach surface. Olivine from fragmented xenoliths included in high pressure cumulates records a much longer contact time – from a week to nearly one year. These results indicate that magma was present below the RVC for up to as much as one year prior to the first eruption. The short transit times for the mantle xenoliths indicate that new batches of magma cross the lithosphere quickly at a minimum speed of 400 m/hr. If magma input is accompanied by significant seismic activity we can expect precursor events for approximately one year before an eruption. However, the rapid rise of the magma that is erupted indicates that there will be very little warning of the actual eruption itself.

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### Form, distribution, and genesis of gold within the contact metasomatic aureole of the Early Devonian Lake George granodiorite, southwestern New Brunswick

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The Early Devonian Lake George granodiorite stock is located approximately 40 km southwest of Fredericton. It intruded turbiditic Silurian metasedimentary rocks of the Kingsclear Group. The contact metasomatic aureole is known to contain tungsten, molybdenum, antimony, and gold mineralization. The W, Mo, and Sb mineralization has been characterized in various publications and publicly available gold numbers have been reported. However, no published ore mineral studies have been conducted in an effort to better understand gold mineralization in this deposit. Analyses conducted on sulfide-rich quartz-iron carbonate veins yielded significant gold results as published in an open file report. These veins possess sericitic alteration envelopes 1 to 10 cm wide, with sulfide assemblages containing variable amounts of pyrite, arsenopyrite, and pyrrhotite. Studies to date have not identified any gold-silver-bismuth alloys which are normally associated with intrusion-related deposits. The mineralization, therefore, appears to be “invisible gold” hosted in the crystal lattice of the sulfides. Backscattered electron imaging of the sulfide assemblages reveals that many of the sulfide minerals in the veins are zoned. Some of the pyrite grains possess arsenian pyrite rims. Several studies have demonstrated higher gold solubility in arsenian pyrite and arsenopyrite and preliminary results from laser ablation elemental mapping of the arsenopyrite in quartz-carbonate-sericite veins yielded an average of 2 ppm gold. Gold is known to occur in multiple generations of veins in the Lake George metasomatic aureole, although the gold distribution in this polymetallic system has not been investigated fully. Quartz-iron carbonate veins appear to have played a significant role in the gold mineralization history in the development of this potentially multi-phased hydrothermal system, although gold is also present within some of the generations of antimony mineralization. Determining the style and location of gold mineralization and quantifying it is a crucial component in determining the challenges for processing the sulfides and estimating the resources in the area.

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**Relationship of mineralization in the Volcano  
Sedimentary Complex (Iberian Pyrite Belt) to the Sierra  
Norte Batholith, Southern Iberia**

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The Iberian Pyrite Belt (IPB) is part of the South Portuguese Zone, the southernmost tectonic unit in the Variscan Orogenic Belt. The IPB is one of the most outstanding massive sulphide provinces in the world, with about 1700 Mt total reserves that make it one of the largest sulphide concentrations in the earth's crust. Traditionally, the deposits of the IPB have been considered to be similar to the Kuroko type of VMS deposits. However, their location within a transpressive basin located at a passive continental margin dominated by detrital sediments suggests that they form an independent group of volcanic-related stratabound deposits, with no known modern analogues. It is generally considered that the volcanic rocks in the IPB are unrelated to the Sierra Norte batholith which also intrudes the South Portuguese Zone. This relationship is based primarily on age data. However if the IPB is related to batholith development then it is possible that mineralization in the pyrite belt is related in part to tectonic processes associated with the collision of Laurussia with Gondwana. This interpretation suggests that the mineralization in the IPB is not a simple VMS system but rather associated with collisional orogenesis. Various age dates from across the belt were used to create a spatial age map of the IPB in order to investigate deposit evolution. Geochemistry of the mineralized host rocks show a chemical signature consistent with rocks formed from intrusion into continental crust from a deep source. Also, mineralization occurred in the underlying Phyllite-Quartzite unit which suggests that the ore-forming material was emplaced from a deeper source that also intruded the older and stratigraphically deeper unit. These data together indicate that the mineralization did not occur through vents onto the seafloor like the traditional volcanogenic massive sulfide deposits. A detailed study of the field relationships and textures of volcanic rocks has revealed that nearly all the volcanic rocks in the Spanish sector of the IPB are intrusive with some minor associated hydroclastic volcanogenic deposits. Millions of tons of tin have been extracted from the VSC. The occurrence of tin in the IPB suggests an alternate model for mineralization. Traditional VMS deposits typically include Pb-Zn-Cu, whereas hydrothermal porphyry systems are the source for tin deposits. The occurrence of tin in the IPB indicates that a hydrothermal system was present and participated in the formation of the deposits.

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**Multi-scale permeability modelling of the Cretaceous  
Missisauga Formation of the Scotian Shelf offshore Nova  
Scotia**

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The Cretaceous Missisauga formation of the Scotian Shelf offshore Nova Scotia was investigated for geological controls that potentially affect fluid flow. The Scotian Shelf, a sediment depositional center established during the Mesozoic-Cenozoic, is a 125 to 225 km-wide continental margin that covers an area of 300 000 km<sup>2</sup>. The Sable Offshore Energy Project (SOEP) led by ExxonMobil produces natural gas and condensate from the reservoir rock which is located beneath the Sable Island area. The six SOEP fields are Thebaud, Venture, North Triumph, South Venture, Glenelg, and Alma. This thesis project tests and critically assesses sequence stratigraphic concepts developed by Exxon Mobil in order to highlight and resolve fundamental limitations in the conventional permeability modeling workflow. Identifying flow units within the Missisauga Formation can improve long term production rates. Furthermore, this pilot study will serve to develop best practices for future projects in the areas of high-resolution reservoir modeling of the greater Scotian Basin.

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**Late Quaternary variations of the Labrador Current in  
Flemish Pass**

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B2Y 4A2*

Sediment drifts of alternating sand and mud, shaped by the Labrador Current in 600–1000 m water depth, formed during the Late Quaternary in Flemish Pass, seaward of the Grand Banks of Newfoundland. These sediment drifts preserve variations in the Labrador Current flow throughout the last glacial cycle. The northern section of Flemish Pass is well known and previous work there shows that significant grain size variations are influenced by the Labrador Current. During a 2011 cruise on the CCGS Hudson, high resolution seismic profiles and numerous sediment cores were obtained throughout Flemish Pass. Seismic profiles and 4 sediment cores from southern Flemish Pass, an area not well studied, are of interest to this research. A prominent sediment drift is located on the eastern side of Flemish Pass, within a transect of the 4 cores. Cores 0021, 0022, 0023 and 0024 are from on top of the sediment drift, adjacent to the sediment drift, in the middle of Flemish Pass and next to the margin



of the Grand Banks of Newfoundland, respectively. Core descriptions, down-core measurements of colour, grain size, X-radiography and velocity and density measurements, seismic profiles and correlations provide evidence for the history of the Labrador Current during the Late Quaternary. In core 0022, a 0.12 m thick unit of transported and reworked volcanic rocks is located approximately 4 m beneath the seafloor. A chondrite-normalized REE abundance plot and a spider diagram for the 0022 volcanic rocks show that they are mildly alkaline basalt, presumably transported by floating ice from Iceland or Jan Mayen. A comparison study with basalt from these locations may determine the source of this basalt, providing additional evidence for ocean circulation in glacial times. The petroleum infrastructure in Flemish Pass is designed to withstand forces from the modern Labrador Current. However, if the Labrador Current was stronger in the past, this study will provide a baseline for the required infrastructure strength in Flemish Pass, reducing risks for deep sea drilling. Variations in the Labrador Current also provides a proxy for the strength of the North Atlantic Subpolar Gyre, which influences deep ocean circulation offshore Greenland. If this gyre is weakened by freshwater additions from a large meltwater event (e.g., the Lake Agassiz outburst), then deep water production decreases. A decrease in deep water production offshore Greenland weakens global ocean circulation, providing huge implications for global climate change. This work thus contributes to making predictions for future ocean circulation and climate change.

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#### Rare earth element and Y substitution in synthetic apatite

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Apatite is the most abundant phosphate mineral in the crust and is formed in igneous, sedimentary, and metamorphic settings. Although apatite forms generally as an accessory mineral, it controls the Rare Earth Element (REE) abundance in some rock types. The chemical sensitivity of apatite towards REE concentrations may give insight to the formation and history of the environment in which it formed. Previous work has been done using synthetic apatite to determine the diffusivity of REE. These rates have also been compared to natural apatite with high REE concentrations. No research has been completed to evaluate the maximum concentrations of REE that can be incorporated into an apatite crystal structure, and if substitution of Silicon (Si) and Sodium (Na) for Calcium (Ca) and Phosphorous (P) will allow for higher REE concentration. Synthetic fluorapatite was produced to determine the concentration of REE that can successfully

be incorporated into the structure. Microcrystalline apatite was created by combining calcium Phosphate ( $\text{Ca}_3(\text{PO}_4)_2$ ) with fluorite ( $\text{CaF}_2$ ). The fluorapatite was then prepared by combining fluorite with the microcrystalline apatite. The process for the fluorapatite ( $\text{Ca}_5(\text{PO}_4)_3\text{F}$ ) was repeated for each batch with the addition of REE and Si or Na. Dysprosium, erbium, lanthanum, neodymium, samarium, and yttrium were used as the REE in concentrations of  $1\times$  (~300 ppm),  $10\times$  (~3,000 ppm) and  $100\times$  (~30,000 ppm) natural abundance for both Si and Na apatite batches. The apatite samples were analyzed for REE, P, Ca, Na, and Si concentrations present in the apatite by electron microprobe analysis (at the University of Maryland), laser ablation – inductively coupled plasma mass spectrometry (at Memorial University) and powder X-ray diffraction. With the collected data, the relationship between REE substitution, charge balancing, and the equilibrium partitioning controlled by Si or Na will be investigated. Early analysis indicates silica is the preferential choice for charge balancing in the apatite crystals, at all dopant levels. The relationship between Si and Na is evident and the final REE concentrations observed in the synthetic apatite will be compared to natural apatite crystals with abundant REE.

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#### Tectonic evolution of mafic dykes in a suture zone, southern Iberia: implications for the formation of Pangea

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The formation and emplacement of syn-collisional mafic dykes that intrude suture zones and their association with orogenic processes are enigmatic. Southern Iberia records the Late Paleozoic amalgamation of Pangea and exposes today a fragment of Laurussia (South Portuguese Zone), which is spatially juxtaposed with autochthonous Gondwana. Fault-bounded oceanic metasedimentary rocks, mélanges and ophiolite complexes characterize the suture zone and are in turn crosscut by intrusive granitoid rocks and mafic dykes. The generation and emplacement of these mafic dykes and their relationship to the suture zone are undetermined. Field evidence shows the dykes were emplaced at high angles to pre-existing orogenic fabrics in the mélange, granitoid and metasedimentary rocks. Geochemical analyses (major, trace, REE) indicate the dykes exhibit a MORB signature. U-Pb zircon geochronology reveals the crystallization age of the dykes is ca. 350 Ma and Sm/Nd isotopic analysis suggests a deep mantle source. Taken together, these data give insight into complex tectonic processes at work during the waning stages of continent-continent collision.

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### Three-dimensional identification and morphological characterization of a *Trichichnus*-like trace fossil

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The ichnogenus *Trichichnus* is recognized as branched to unbranched, straight to sinuous, cylindrical burrows interpreted as the Domichnia (dwelling structures) of meiofaunal deposit-feeding vermiform, or a crustacean-like organism. These burrows are less than 1 mm in width, and are mostly vertical with respect to bedding. *Trichichnus* can be found in sedimentary strata from the lower Tremadoc to Holocene, and is an indicator of marine palaeoenvironments. *Trichichnus* is also identified to be eurybathic, meaning it can be found in both deep- and shallow-water settings. Most reports are however, from shallow-water settings. *Polykladichnus* is an ichnogenus morphologically similar to *Trichichnus*, and is characterized by vertically oriented burrows with Y- to U-shaped branching that point upwards to the surface. Junctions of these branched burrows tend to be slightly larger in diameter. These branches are mostly connected at bedding surfaces, and the burrow fill is generally finer-grained than the surrounding sediments. *Polykladichnus* is not a strictly marine trace fossil, however it is dominantly found in a marine facies. The aim of this study is to identify the trace fossils collected from the Bell Island sample by constructing a high resolution three-dimensional morphological model of the ichnofossil burrows. The sample collected from the Power Steps Formation in Grebes Nest point, Bell Island, contains many closely spaced vertical burrows that are study in this project, that are considered to be either *Trichichnus* or *Polykladichnus*. This identification will be achieved through the use of serial grinding techniques, high-resolution digital photography, and the three dimensional modeling software. The model created by this method will help better the morphological variability within the present material, which seems to show some characteristic elements of both ichnogenera. In addition, the model will also be used to assess whether the burrows were gregarious in life, and caused sediment-trapping functions to produce bioherms in the manner of modern *Sabellaria* “worm reefs”.

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### A Chelsea porcelain (London, mid-18th century) P-Pb repair glaze: results of analogue firing experiments and implications for in situ analytical authentication studies

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The crazed glaze on mid-18<sup>th</sup> century phosphatic (bone ash) porcelain sherd excavated from the Chelsea factory site is coated with a novel P-Pb repair glaze evidently derived from a mixture of nearly equal proportions (wt.%) of red lead and dicalcium phosphate. The composition of the crazed glaze (e.g., 36% PbO, 52% SiO<sub>2</sub>) is typical of those used on artificial porcelains, but the repair glaze, with little silica (1.9% SiO<sub>2</sub>) but abundant phosphate (27% P<sub>2</sub>O<sub>5</sub>) and lime (21% CaO) as well as lead (49% PbO), is highly unusual. Its low model calculated viscosity accounts for the infilling of micron sized craze cracks in the inner glaze. Analogue firing experiments demonstrate the propensity of the repair glaze to take up components (notably alumina) from the ceramic substrate, and to lose components (notably lead) to the kiln atmosphere particularly at elevated temperatures (T > 900 °C). The red lead-dicalcium phosphate mixture resisted melting even at temperatures exceeding those (800–1000 °C) generally thought to have been used in 18<sup>th</sup> C glost kilns, suggesting that either fluxing components originally present in the repair glaze mixture were volatilized during firing, or that the glaze was fired at unusually high temperatures. The uptake of ceramic substrate components and volatilization of lead presents serious challenges for those seeking to authenticate intact high-fired ceramics using glaze compositions.

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### Oil production enhancement strategy by using integrated simulation and well log data, Norne Field, Norway

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The Norne Field, a mature hydrocarbon reservoir is located on a 9 km × 3 km horst block with an overall depth of roughly 380 m on the continental shelf of the Norwegian Sea. This honors project focuses on developing a strategy that will contribute to efficiently allow the remaining hydrocarbons in the Norne Field to be recovered. This will be achieved by running computer simulations based on a variety of new injector and producer well configurations. The data have been released by Statoil as part of the “Norne Field Benchmark Case” and include both the petrophysical/geological well reports and original DATA file that describes the current wells in the field, that will be used as background information for this thesis. The DATA file is carried out

through simulation software such as Petrel, Eclipse and S3GRAF. The geology of the reservoir is classified into four formations from top to base: Garn, Not, Ile, Tofte, and Tilje (which are further subdivided). These Mid to Late Jurassic rocks are dominantly sandstone, generally buried 2500–2700 m deep. The average porosity is 25–30% and permeability ranges from 20 to 2500 mD. Horizontal permeability is mostly favorable, although vertically it is highly affected by the 7.5 m. thick Not Shale, as well as limestone, claystone and siltstone stringers, likely to have originated from depositional environments and/or diagenetic processes. In fact, mechanical compaction is responsible for most porosity reduction. One of the issues to be addressed by this thesis is the correlation of the information contained in the petrophysical/geological well reports with that contained in the simulation grid blocks (controlled by DATA files). This will allow for verification of the continuity of the Not Shale throughout the entire reservoir, and thus, modify the production plan accordingly. Currently, 49 wells (3 exploration, 46 production and injection) have been drilled and as of December 2007, 86% of recoverable reserves were produced. From April of 2008 to March of 2010 water production showed an overall increase. However, both oil and gas production has decreased within the same time frame. The degree of success achieved will be measured by comparing the new injection strategy with the already existing ones, while analyzing parameters such as oil, gas and water production rates during the simulated time periods and fluid/rock interactions.

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### Employing contact metamorphism to assess the conditions of pluton emplacement in southwestern Kellys Mountain, Cape Breton Island, Nova Scotia

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At Kellys Mountain, Cape Breton Island, Nova Scotia, the Precambrian meta-quartz wacke of the Barachois River Metamorphic Suite has been intruded by diorite and granite plutons and hosts a narrow metamorphic contact aureole. In the contact aureole metasedimentary rocks are biotite and cordierite-bearing, and most likely have reached amphibolite-facies metamorphism. Outside the aureole, metamorphic grade is at lower greenschist facies, but farther to the north grade increases into the sillimanite zone in the eastern Cape Breton Highlands. In this study the conditions of metamorphism of the aureole have been determined to have resulted in the development of neoformed cordierite, biotite, andalusite, and sillimanite, a mineral assemblage also found in the Kellys Mountain Gneiss as a result of regional metamorphism. The mineral assemblages are

sufficiently developed to determine the depths of intrusion of the plutons in the Precambrian meta-quartz wacke that were the agents of metamorphism of the metamorphic contact aureole. Understanding the level of intrusion allows consideration of questions involving the relationships among the plutons, and the comparisons of this contact aureole with other metamorphic rocks in the area (e.g., Kellys Mountain Gneiss, and northern extensions of the Barachois River Metamorphic Suite). On a preliminary basis, petrographic and microprobe analysis have been performed in order to determine the possible temperature and pressure conditions. Using an assessment of the metamorphic conditions of the meta-quartz wacke in the Barachois River Metamorphic Suite, a better understanding will be gained depth of intrusion of the plutons and the tectonic setting and geological history of the entire Kellys Mountain area.

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### On the discovery of a new ichnofossil assemblage from the Early Carboniferous Bloomfield Formation in Bloomfield, New Brunswick

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A new invertebrate ichnofossil assemblage has been discovered in Bloomfield, New Brunswick (45° 34'11.94" N, 45° 44'54.91" W). An array of ichnogenera have been identified from three stratigraphic horizons exposed within the Midway Quarry and surrounding road cut outcrops in the Bloomfield area. Ichnogenera include: *Cruziana*, *Dendroidichnites*, *Diplichnites*, *Diplopodichnus*, *Kouphichnium*, *Paleohelcura*, and *Rusophycus*. The sedimentary package is assigned to the upper Horton Group, lower Bloomfield Formation. This assignment is based on rare plant fossils (i.e., *Lepidendropsis*), previous spore analysis, and lithostratigraphy from new structural and stratigraphic mapping. Three sedimentary facies are identified: the lower and middle fine grained mottled and alternating red-grey transitional facies, an intermediate reduced, planar siltstone-mudstone dominated aquatic facies and an upper well-drained red-bed, fine sandstone and channel-sandstone-dominated facies. The lower reduced facies is dominated by grey, planar siltstones with centimetre-scale microripples and interference ripples. The lower and middle transition facies contain dominantly alternating reduced and oxidized mudstones. The upper fluvial red-bed facies contains is dominated by red fine sandstones with current ripples, climbing ripples and trough cross-beds, with localized reduced bedding surfaces. Trackways are preserved on reduced shaley siltstone beds

within the lower reduced and basal red-bed facies. Within the uppermost red-bed strata, reduced beds are rare and trackways are preserved on red laminated siltstone horizons. Ichnofossil assemblages represent both aquatic and terrestrial conditions. Trace fossil assemblage 1 within the lower reduced sedimentary facies contains surface trackways of *Kouphichnium* and *Diplichnites*, tentatively interpreted to be produced by limulids and tealiocarid shrimp respectively. *Cruziana*, *Dendroidichnites*, *Diplopodichnus* and *Rusophycus* are here interpreted to be morphological and behavioral variations produced by the same invertebrates. Trackway assemblage 2 of the upper redbed sequence is dominated by *Paleohelcura* and *Diplichnites* walking traces, and are tentatively interpreted to be produced by scorpions and myriapods. The *Kouphichnium* trackways discovered in the upper Horton Group are evidence of limulid activity in the Maritimes Basin during the late Tournasian/early Visean of New Brunswick. Modern-day limulids are marine animals with a high salinity tolerance for brackish conditions. This ichnofauna could be explained by the Horton Group being periodically connected to the sea as has been suggested for the Horton Group of Nova Scotia by other workers. The depositional setting for these sediments and traces is tentatively interpreted to represent a shallow, near-shore, low energy embayment, likely under local fresh water conditions with a distant marine connection.

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**Paragenesis and composition of native gold from the Valentine Lake Deposit, central Newfoundland: a secondary ion mass spectrometry and S scanning electron microscope – energy dispersive analysis investigation**

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The Valentine Lake Deposit is an orogenic-structurally controlled gold occurrence located in central Newfoundland, 57 km south of the town of Buchans and 90 km southwest of the municipality of Millertown. The occurrence is hosted by altered and locally metamorphosed trondhjemite of the Precambrian Valentine Lake Intrusive Suite located in the western extension of the Exploits Subzone. The native gold mineralization is found predominantly along the sheared contact of the intrusive unit and the younger, yet structurally underlying, Silurian Rogerson Lake Conglomerate. It is hosted mainly within extensional and shear-fracture filling auriferous quartz and quartz-calcite veins but is also seen in limited amounts within both the host rock and underlying conglomerate. The mineralized veins are generally quartz-tourmaline-pyrite veins, with the native gold closely associated with the pyrite. The veining also contains

sulphides such as chalcopyrite, pyrrhotite, galena, sphalerite and a variety of telluride phases. This honours research project is focused on elucidating the paragenesis and origin of the mineralization through the trace element signatures of the native gold found at Valentine Lake, as well as the compositions of other sulphides and alteration assemblages associated with the mineralization. The samples for this project were collected from two of the license areas of the project (Leprechaun Pond Deposit and Valentine East Zone), and have been cut to produce a series of polished thin sections and 1" diameter polished pucks. The thin sections are presently undergoing petrographic and SEM analysis to identify possible titanium bearing minerals and complex mineral intergrowths, and to develop a host rock-alteration-veining-ore mineral paragenesis. Secondary Ion Mass Spectrometer (SIMS) analyses are being conducted on the polished puck samples to determine the detailed element composition of the native gold. With these data, the ultimate goal is to describe the paragenesis of gold mineralization in the Leprechaun Pond and Valentine East zones, and utilize the trace element signatures of the native gold to identify the consanguineous episodes of gold mineralization and/or discriminate multiple gold mineralization events within single or multiple zones. Further, the trace element compositions of the native gold may allow a comparison Valentine Lake to other similar gold mineralization in the Dunnage Zone, and begin to establish a regional relationship for at least some of the gold forming events and occurrences.

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**Sequence stratigraphy and reservoir analysis of the Cretaceous of the Penobscot area, offshore Nova Scotia**

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We use an integrated approach, combining seismic data, well log correlations and core descriptions to apply sequence stratigraphy to the Penobscot area on the Scotian Margin. The stratigraphy will be assessed using the ExxonMobil approach to sequence stratigraphy and correlations of seismic and well data will be completed using Schlumberger Petrel software. The Penobscot area is located N-NW from Sable Island and covers an area 12 km by 6 km. Two wells drilled on the area penetrated the Cretaceous Missisauga, Logan Canyon, Dawson Canyon and Wyandot formations. Sandstone units within the Missisauga and Logan Canyon formations have been identified as reservoirs in other locations on the Scotian Shelf; however, they are not actively producing from the Penobscot area. In applying these sequence stratigraphy methods the aim is to identify zones of possible producing quality reservoir and reasons for failed wells previously drilled in the area.

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**Fluid-inclusion thermometric and stable isotope data constraints on the occurrence of quartz-carbonate-copper sulphide vein/fracture infill in the Caledonian Highlands, New Brunswick**

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Outcrops of quartz-carbonate-copper sulphide-bearing veins cutting Neoproterozoic Broad River Group (BRG) metavolcanic and metasedimentary rocks occur along the Bay of Fundy coast in southern New Brunswick, approximately 75 km northeast of Saint John. The source of the vein/fracture fluid(s) is unknown. However, a single quartz grain (~0.5 cm × ~0.5 cm) in a vein sample collected within 100 m vicinity of the abandoned Vernon Mine site (NTS 21H/11E), contains hundreds of primary, two-phase (liquid + vapour) fluid inclusions (FI), the isotope and element compositions of which are theoretically equilibrated with the parent fluid. Only FIs with a clearly visible, uncompromised vapour bubble were analysed (n = 81). Qualitative microthermometric data, including homogenization temperature, melting temperature, freezing temperature ( $T^{ICE}$ ), and salt content (wt. % NaCl), provides temperature constraint of minimum trapping conditions. This constraint may be extrapolated into PT-space along isochores superimposed on the melting curve for the two-component H<sub>2</sub>O – NaCl system. Collectively,  $\delta O^{18}_{SMOW}$  and  $\delta C^{13}_{PDB}$  data, including  $\delta O^{18}$  of vein quartz and carbonate (13.7–15.1 ‰), and  $\delta C^{13}$  of two distinct phases of calcite (4.4–4.6 ‰), provide a qualitative pressure correction for the isochore PT field (250–275°C and 700–2000 bar). Applying the Clayton and Matsuhisa equilibrium equations to  $\delta O^{18}_{mineral}$  data constrains  $\delta O^{18}_{fluid}$  composition to 6.1–7.3 ‰.  $T^{ICE}$  values as low as -38 °C, well below the eutectic temperature for H<sub>2</sub>O – NaCl system (-21.1 °C), suggest a more complex fluid composition than that inferred from microthermometry, and for which future LA-ICPMS analysis will provide better constraint. At present, preliminary inferences regarding the origin of the Qtz-Cal-Cc vein/fracture infill from the Caledonian Highlands include: (1) spatial distribution of FIs in a small (< 1 cm<sup>2</sup> plane area) quartz grain permits the organization of 81 analysed FIs into four fluid inclusions assemblages (FIA), which invokes a multiple-reservoir fluid origin; (2) salinity variability within each FIA suggests temporal evolution of a magmatic brine, or the introduction of an exotic fluid; (3) qualitative microthermometric analysis suggests vein crystallization occurred at relatively low PT conditions, invoking the potential for magmatic-meteoritic fluid interaction; (4) petrographic investigation may determine if sulphide deposition was coeval with, or post, quartz-carbonate mineralization.

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**“Teardrop” structures of the Nepewassi domain in the Central Gneiss Belt of the Grenville Province, Ontario**

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The Nepewassi domain, dominantly composed of Archean to Paleoproterozoic gneisses, lies within the Central Gneiss Belt of Ontario. The Nepewassi also contains plutonic groups from two magmatic events at ~1400 Ma and ~1200 Ma, respectively. A link between the metamorphism and deformation of the gneiss, the two magmatic groups, and the ~1100 Ma Grenville orogeny is probable. The target area of this study is a “teardrop” structure near the West Bay of Lake Nipissing, Ontario, within the Nepewassi domain. The structure is visible from air and satellite imagery and is of interest because it may help explain the deformation patterns in deep crustal rock during the Grenville orogeny. The teardrop is ~3 km across the long axis, ~2 km across the widest short section, and trends ENE, pinching in this direction. It is composed of several concentric ridges and valleys formed by foliation of the local ~1200 Ma granite and older gneiss. Rock samples from the area include foliated and megacrystic pink granite, gray gneiss, and lensoid amphibolite. The structure lies within a domain of gently dipping, highly strained gneiss with open, ESE trending folds. High strain fabrics occur throughout as well as widespread migmatitic textures. The structure is separated from irregular Archean gneiss to the N by a steep shear zone striking WNW. Foliation dip in the teardrop has a bimodal distribution, with one set shallowly dipping SSW and another dominant set dipping NNE. It is reasonable to propose that Grenvillian deformation began with formation of the high strain gneissosity accompanying thrusting and recumbent folding followed by upright folding. Interference between the first and second fold types would explain the bimodal distribution of fabric orientations seen within the teardrop structure as well as the surrounding domains.

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**A paleolimnological record of anthropogenic impact on water quality in First Lake, Lower Sackville, Nova Scotia**

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Lakes situated in urban environments are commonly subjected to a variety of anthropogenically induced pressures including nutrient loading, erosion, metal and salt inputs, and hypolimnetic anoxia. Since the 1920s, First Lake in Lower Sackville has been the focus of watershed

development and lake water quality degradation is an ongoing concern. A paleolimnological approach was undertaken in order to better understand the relationship between watershed development and water quality. A time stratigraphic, multi-parameter, multi-proxy, geochemical investigation was conducted on a sediment core from First Lake in order to determine pre- and post-development water quality conditions. A year-long study of limnological conditions in the lake (pH, D.O., conductivity, secchi depth) and a historical survey of existing data were conducted to characterize seasonal lake physical and chemical conditions. First Lake is 82 ha in size with a maximum depth of 23m. The lake stratifies strongly during the summer and algal blooms and hypolimnic anoxia commonly occur. Elevated *Escherichia coli* (*E. coli*) concentrations have led to beach closures. Survey results indicate that shallow secchi depths (<2 m), strong stratification (~6 m), neutral pH values, and oxygen-deprived bottom waters (<5%) commonly develop as summer progresses. A 33 cm-long sediment core from the lake basin captured approximately 600 years of sediment accumulation. Atmospheric Pb concentrations were used to approximate sedimentation rates. Predevelopment (pre-1920) data indicates a productive, likely mesotrophic lake. Higher  $\delta^{15}\text{N}$  values and lower C/N ratios near the top of the core indicate increased primary productivity within the lake as a result of increased nutrient input from early agricultural development during the 1920s. Changes in concentrations of Ti, Cu, K, loss-on-ignition and magnetic susceptibility values indicate landscape instability, and an increase in sediment and toxin transfer into the lake associated with urbanization in the 1960s. These data indicate that changes in water quality in First Lake are strongly linked to specific anthropogenic activities in the watershed, an understanding of which is a fundamental factor in developing effective lake management strategies.

Analysis represent two such gold exploration strategies that utilize large sample sizes. In contrast, some geochemists (mostly in China) have advocated collecting and analyzing small samples in gold exploration (<5 g). Their rationale is that small samples are likely to contain no large nuggets, but will still contain a large number of small nuggets if anomalous. As a result, the samples are likely to be equally reproducible, and thus can be reliably used to explore for gold mineralization. Because the large nuggets are likely to be absent in these small samples, the anomalies derived from them typically have lower geochemical contrast and concentrations. Provided that a small sample strategy is used only in gold exploration, and not in grade estimation, the bias to lower concentrations is immaterial because the anomalous patterns, and not the absolute magnitudes of geochemical anomalies, are what are used to vector to gold mineralization. This research investigates the size distribution of gold in anomalous soils developed over the Fifteen Mile Stream saddle reef gold deposit on the eastern shore of Nova Scotia. These distributions will provide an understanding of the number and sizes of gold nuggets in the soils, and will illustrate to what extent each sample suffers from the 'nugget effect'. Comparisons of gold concentrations derived by both large and small sample methods will test these alternative gold exploration strategies. Preliminary results suggest that both techniques can be effective in gold exploration. Although the small sample strategy is clearly less expensive, it depends on the use of high sensitivity analytical equipment to quantitatively measure low gold concentrations.

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### Strategies to avoid the nugget effect in soil samples from the Fifteen Mile Stream Gold Deposit, Nova Scotia

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Samples containing gold are known to be influenced by the 'nugget effect', a source of variation in geochemical data that prevents the recognition of dispersion patterns used by explorationists in the search for gold mineralization. Strategies used to avoid the nugget effect typically involve analyzing large samples (>30 g). Large anomalous samples can be expected to contain a large number of gold nuggets, and thus provide reproducible gold grade estimates. Bulk Leachable Extractable Gold (BLEG) and Metallic Screen