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TABLE OF CONTENTS
TABLEAU DES MATIÈRES

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BIOSTRATIGRAPHY, BIOFACIES AND PALEOENVIRONMENT OF THE UPPER CRETACEOUS DEPOSITS IN THE NORTHERN FLANKS OF CENTRAL ALBORZ MOUNTAINS, JORBAND SECTION, NORTH OF IRAN

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In order to study the biostratigraphy and paleoenvironment of the Upper Cretaceous deposits in the Northern flanks of Central Alborz Mountains, Jorband section located in the South Noor, selected. 91 samples collected and studied by washing method and thin sections. The study of above deposits led to recognition at least 35 species of planktonic foraminifera and 5 biozones that correspond with universally standard biozones in Mediterranean regions and Tethian domain : biozones 1) *Globotruncanita elevata* interval zone, 2) *Globotruncana ventricosa* interval zone and 3) *Globotruncanita calcarata* total range zone, represent the early, middle and late Campanian, respectively and biozones 4) *Globotruncana aegyptiaca* interval zone and 5) *Gansserina gansseri* interval zone suggest the early and late Maastrichtian, respectively. In this section 2 biofacies of open marine facies belt recognized, consist of biomicrite wackestone and biomicrite packstone, that represent deep water with low energy environment. Also, ratio of the morphotype groups of planktonic foraminifera, including shallow, intermediate and deeper water fauna, shows that deposition during Campanian-Maastrichtian in Jorband section, was generally in open marine.

FIELD INVESTIGATIONS FROM THE NORTHERN WESTERN CANADIAN SEDIMENTARY BASIN: HYDROCARBON POTENTIAL OF THE UPPER DEVONIAN TO LOWER CARBONIFEROUS TUTTLE FORMATION, YUKON TERRITORY

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The Upper Devonian to Lower Carboniferous Tuttle Formation was an exploration target for oil and gas in the Eagle Plain and Peel Plateau regions of the Yukon and Northwest Territories in the 1960s and 1970s. To date, seven minor gas shows have been identified in the Tuttle Formation in the Peel region, which lies at the northwestern extent of the Western Canadian Sedimentary Basin. This study is part of a four-year project to investigate the sedimentology, stratigraphy and hydrocarbon potential of Upper Paleozoic strata in the Peel region.

The Tuttle Formation forms the upper part of a siliciclastic wedge that was deposited in the foreland basin of the Yukon and Ellesmerian fold belts. Field investigations, limited to the eastern Richardson Mountains, identified the Tuttle Formation as alternating resistant and recessive intervals. Resistant intervals, 23 to 54 m thick, comprise five lithofacies units including fining-upward sandstone, massive sandstone, siltstone, conglomerate, and diamictite. The sandstone and conglomerate lithofacies of the Tuttle Formation are characterized by tripolitic chert and quartz grains, ranging from fine-grained sandstone to pebble conglomerate. Recessive intervals, 55 and 144 m thick, consist of siltstone and shale and are mostly covered. Field investigations suggest that the Tuttle Formation represents deposition within a turbidite sequence.

Rock Eval/TOC results from samples collected in the field indicate that organic matter within the Tuttle Formation is composed of Type III and admixtures of Type II/III kerogen, which are typically gas-prone. Total organic carbon content values suggest that the Tuttle Formation has a good to very good potential to produce hydrocarbons, typically ranging between 1 and 4% TOC. Thermal maturation (Tmax) indicate that the organic matter is in the immature to mature stage of thermal diagenesis.

Porosity determination for outcrop samples ranged from 1.6 to 18.6%. Thin section analysis shows both intergranular and intragranular porosity, the latter observed most frequently in tripolitic chert. In many samples, porosity is occluded by clay minerals and quartz overgrowths. Permeability for outcrop samples ranged from 0 to 13.7 mD. Based on surface samples, the best prospects for reservoir rock are medium-grained sandstones.

MINERAL CHEMISTRY OF CHLORITE IN ALTERED VOLCANIC ROCKS OF TOTMAJ AREA, SE OF KASHAN, IRAN

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The Oligocene Totmaj volcano-sedimentary sequence which is located southeast of city is composed of lava flows (basalt, basaltic-andesite and andesite), pyroclastics (various types of tuffs and agglomerate) and sedimentary rocks (limestones and sandstones). Field and petrographical evidence indicate that some secondary minerals such as epidote, chlorite, calcite hematite and sericite are formed in the volcanic rocks due to hydrothermal alteration. Geothermometrical studies on chlorite minerals show that they have been formed at a temperature about 270 ± 30°C. Furthermore, the ranges of temperature stability of coexisting secondary minerals in the volcanic rocks coincide with the calculated alteration temperature.

GEOCHEMISTRY AND TECTONIC SETTING OF BASALTIC LAVA IN TOTMAJ AREA, SE OF KASHAN, IRAN

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The volcanosedimentary rocks of the Totmaj area, located at the SE of Kashan, belong to west part of central Iran zone. These rocks consist of interbedded lava flows (mainly basalt, basaltic-andesite and andesite), pyroclastics (various types of tuffs and agglomerate) and Oligocene sedimentary (limestones and sandstones) rocks. The Totmaj basalts show a selective enrichment of low ionic potential elements (eg., Rb, Sr, Ba) and are depleted in high ionic potential elements (eg., Nb, P, Y, Cr) compared to chondrite. Trace and rare earth elements geochemical data demonstrate that the Totmaj basalts are Calc-alkaline and are similar to subduction zone basalts. According to the tectonic discrimination diagrams, these volcanic rocks have formed in a continental volcanic arc environment.

ALTERATION STUDIES OF VOLCANIC ROCKS IN TOTMAJ AREA, SE OF KASHAN

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The Totmaj volcanic-Sedimentary rocks district contains the Oligocene outcrops of lava flows (basalt, basaltic-andesite and andesite), pyroclastics (various types of tuffs and agglomerate) and sedimentary rocks (limestones and sandstones) which have been hydrothermal altered.

Secondary minerals have been formed of this olteration such as epidote, chlorite, calcite, quartz, hematite and sericite. The microprobe analyses result of plagioclase and pyroxene defined they respectively have composition Ab_{98} and $W_{40}En_{65}Fs_{35}$. Chlorite minerals present with composition Picnochloritte and Clinochlor in the body rock. Geothermometic studies of chlorite minerals show that they have formed in temperature about 270 ± 30°C. On the basis of these result and limit of stability temperature in coexisting minerals with chlorite (such as

epidote, actinolite, calcite and quartz) seemingly Totmaj volcanic rocks altered in temperature about 270 ± 30°C.

AN INSIGHT INTO THE MINERALOGY AND GEOCHEMISTRY OF A DISTURBED MINING ZONE AT THE WORLD-CLASS PCS ALLAN MINE, SASKATCHEWAN: POSSIBLE VECTORS TO THE PREDICTION OF LOWER ORE GRADES

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Saskatchewan is the world's largest producer of Potash and accounts for about 25 per cent of the world's potash production. Structural disturbance zones are sporadically present in many mines sites, which result in a decrease in ore grade and create potential catastrophic water inflow problems. The understanding, and ultimately the prediction, of these zones is of great interest to the mining geologists.

This study investigates the geochemistry and mineralogy of a disturbed zone at the PCS Allan mine, Saskatchewan, and evaluates if they can be predicted using these methods. Previous studies have focussed on either only a select number of elements, the isotopic systematics of fluid inclusions, the mineralogy of clay seams or the isotopic profiles of formation waters.

Quantitative XRD data show that the mineralogical system comprises mainly halite and sylvite, with lesser amounts of dolomite, anhydrite, quartz and clay minerals (kaolinite, illite). Many of the elements analysed are either below detection limits or do not show any spatial distribution patterns that indicate their applicability as a pathfinder / vector elements for the prediction of these anomalous zones. Many of these trace elements distribution patterns are controlled by the amount non-soluble material within the sample.

In contrast, however, some elements (Br, As, Li) do show distribution patterns that may indicate their applicability as pathfinder / vector elements for the prediction of anomalous zones. Of additional interest, is that the bromine contents are very low (2 to 3 orders of magnitude) compared to those from other potash deposits, which suggests that either the original evaporitic sea-water basin had an anomalous chemistry that was out of chemical equilibrium, or that during diagenesis, bromine was removed from the rocks on a large scale. Of geo-environmental interest, is the release of arsenic into the geologic system during the sylvite-halite transformation (up to 4 ppm). Mass balance calculations using a block of ore material (500m × 500m × 5m) with an initial mineralogy of 75% sylvite (4ppm As) and 25% halite (0.5 ppm As), show that alteration to halite (100%; 1 ppm) would result in a loss of 2.6m^3 of As.

U-Pb ZIRCON AND MONAZITE GEOCHRONOLOGY OF ARCHEAN BASEMENT GRANITOID ROCKS FROM RUSSELL LAKE, WESTERN WOLLASTON DOMAIN, NORTHERN SASKATCHEWAN

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New, high-quality U-Pb results from basement rocks in the Russell Lake area are presented here for regional thermotectonic interpretation of the eastern sub-Athabasca basement. Two drill core samples, a foliated meta-tonalite and a granitic gneiss were dated at the Jack Satterly Geochronology Laboratory, University of Toronto, using U-Pb IDTIMS methods on zircon and monazite.

In the foliated meta-tonalite, four single zircon crystals and three monazite crystal fragments were analyzed. Zircons are translucent subhedral with 2/1 aspect ratios. They have $^{207}Pb/^{206}Pb$ ages of 2357±6 (6.5% discordant), 2355±8 (7.0% discordant), and 2334±4 Ma (6.2% discordant). These have Th/U values of 0.33-0.37, typical for magmatic zircon. The fourth datum is distinctly younger and is interpreted to be of metamorphic origin. It is 4.2% discordant from a $^{207}Pb/^{206}Pb$ age of 1818±2 Ma with very low Th/U of 0.04, typical of metamorphic zircon. Two of the monazite data overlap the metamorphic zircon age with $^{207}Pb/^{206}Pb$ ages of 1821±2 (0.5% discordant) and 1816±2 (0.7% discordant). The third datum is younger at 1803±1 (0.07% discordant). The spread in these data may indicate metamorphic conditions first at about 1821 Ma, and again later at ca. 1803 Ma (the concordant monazite age). A regression line calculation through zircon data and anchored at 1803 Ma gives an upper intercept age of 2612±22 Ma, which represents the primary age of the rock. Primary zircons were affected by up to 40% loss of their Pb, or they developed small metamorphic rims; both explaining the extensive amount of discordance. The rock experienced either a protracted period of metamorphism from 1821±2 Ma to 1803±2 Ma, or a second discrete event at about 1803 Ma, which resulted in Pb loss, recrystallization, or new rims on older monazite.

In the granitic gneiss, five zircons and three monazites were analyzed. Zircons are 2/1 prismatic, euhedral to rounded grains. Four of the 5 zircons plot on or close to a reference line from 2583 Ma to 1822 Ma, the $^{207}Pb/^{206}Pb$ age of concordant monazite. The fifth zircon data point plots well below the reference line, indicating extensive recent Pb loss. Clear yellow monazite fragments give overlapping $^{207}Pb/^{206}Pb$ ages of 1821.9±2 (0.4% discordant), 1820.4±2.2 (0.5% discordant), and 1820.8±2.5 Ma (-3.1% discordant). The granitic gneiss has a primary age of 2583±14. This age overlaps with the meta-tonalite age, however, in both samples a precise primary age was not obtained as the zircons were strongly affected by an intense Hudsonian metamorphic overprint at circa 1822-1803 Ma.

AN OVERVIEW OF CURRENT HYDROCARBON EXPLORATION ACTIVITIES IN GREENLAND

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There is broad political agreement in Greenland to work towards developing the hydrocarbon sector into an important industry. Development of the hydrocarbon sector should take place in a manner, which provides the greatest possible benefits for society in Greenland. Exploration in Greenland has high costs. Therefore, an important strategic goal is to encourage interest from the industry in investing in oil exploration in Greenland.

Encana Corporation holds the two existing licenses for exploration and exploitation licenses offshore Southwest Greenland. Considerable amounts of seismic data have been collected in the license areas and basin modelling and other studies have been conducted. Drill-or-drop decisions are to be made for both Encana licenses later in 2007.

The oil industry has shown great interest in the ongoing Disko West Licensing Round offshore West Greenland. Twelve companies have been approved as pre-qualified operators in the area. At the deadline for applications of exploration and exploitation licenses December 15th 2006 BMP received 6 license applications from 4 companies. These license applications are currently being evaluated and licenses will be granted later this year. Subsequently non-awarded license blocks will be allowed to be applied for in an open door phase 2 during August 1st 2007 to February 1st 2008.

The growing interest in hydrocarbon exploration in Greenland has furthermore led to the collection of growing quantities of speculative data. Great quantities of aeromagnetic data have been collected offshore West Greenland and also considerable amounts of seismic data have been collected offshore West and East Greenland during 2006. A seabed sampling survey was conducted offshore West Greenland

COOLING OF PIPELINE AND ROAD ROWS USING COLD AIR CONVECTION

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The thermal and mechanical disturbance of the insulating surfaces during and after the construction of linear infrastructures, such as pipelines or roads, in cold regions may result in accelerated degradation of the underlying permafrost. In addition, global warming may warm the ground and frozen foundation soils may warm reducing the bearing capacity, which can lead to excess differential settlements and reduced service life of a structure. To reduce the impact of changing air temperatures and/or change in the ground surface conditions, natural air convection can be utilized as a passive cooling agent. In this process, the higher density cold air is used to cool the ground during winter and the low thermal conductivity of the air is used in summer to prevent warming. By placing a highly air permeable layer on top of the pipeline, building an air permeable embankment for a road or protecting the embankment shoulders and toes with a coarse layer, such an air buffer can be created. A series of numerical simulations were carried out to investigate the effect of different protection geometries, temperature boundary conditions as well as pipeline temperatures on the cooling effect of the ground. These analyses show that under certain condition it is possible to cool the ground beneath the right of way by several degrees, which would imply that thaw can be delayed or prevented.

METALLOGENY OF THE MARCO ZONE, CORVET EST AURIFEROUS DEPOSIT, JAMES BAY, QUEBEC

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The Corvet Est gold deposit is located in Archean rocks of the Superior province in the James Bay region. It hosts two mineralized zones: 1) the Contact zone is close to the faulted contact between the Lac Guyer volcano-sedimentary greenstone belt (2749 Ma) and the Laguiche Group metasedimentary rocks (<2698 Ma). 2) the Marco zone is hosted by a lenticular andesite/dacite unit near the southern boundary of the Lac Guyer volcano-sedimentary greenstone belt. The rocks are metamorphosed to the amphibolite grade and show polyphased deformation.

The Marco zone comprises disseminated gold mineralization with an apparent thickness of 1.8 to 39.5 m, with gold grades up to 23 g/t over 1 m, and laterally continuous along strike for approximately 1.3 km. The lithotectonic sequence shows from south to north basaltic amphibolite in the footwall overlain by a lenticular unit of extrusive and volcanoclastic andesite/dacite and then basaltic amphibolite in the hangingwall. Footwall basaltic amphibolite and andesite/dacite are intruded by quartz-feldspar porphyry sills. The andesite/dacite-basalt contacts are abrupt to gradual. Andesite/dacite, basalt and quartz-feldspar porphyry show calc-alcaline to transitionnal affinity. They plot in the plate margin arc basalts field. Andesite/dacite displays weak alteration whereas basalt is unaltered. Spidergrams show typical volcanic arc trace element patterns, with Nb-Ta and Ti depletions. High La/Lu (77) for andesite/dacite shows strong magmatic differentiation.

Mineralization consists of up to 4% pyrite, 7% arsenopyrite, traces of chalcopyrite and visible gold disseminated in deformed andesite/dacite, or in quartz-feldspar porphyric intrusions. The deformation index ranges from 2 to 5, with up to 50% quartz-feldspar-biotite leucosome, <10% garnet, and <10% biotite in andesite. The alteration sequence of andesite/dacite starts with albite vein and host rock alteration, followed by damouritization of metamorphic plagioclase and late chloritization. Gold forms inclusions in metamorphic quartz, feldspar and pyrite, or free grains interstitial to quartz, feldspar, pyrite, chalcopyrite and arsenopyrite. Some free gold is in late quartz veins cutting the damouritized metamorphic fabric.

In conclusion, inclusion and interstitial gold within metamorphic quartz and feldspar shows that gold mineralization preceded regional metamorphism, with some gold remobilized in later veins.

THE AGE AND PROVENANCE OF ARCHEAN DIAMOND-BEARING ROCKS IN THE WAWA AREA, NORTHEASTERN ONTARIO

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Archean diamond-bearing rocks (DBR) occur in two environments within the Michipicoten Greenstone belt (MGB). DBR1 consist of diatreme breccias up to 70 m across, and associated lamprophyre dikes up to 4 m thick, intruding mafic and felsic volcanic units in a northwest-trending cluster of 50 occurrences from Musquash to Lalibert townships. DBR1 units contain heterolithic fragments of volcanic, intrusive and probable mantle derivation. Clear white to yellow diamonds are typically associated with fragments, with 0.95 carat the largest stone reported. Xenocrystic zircons from the dikes and heterolithic breccias yield a maximum U-Pb emplacement age of 2680±2 Ma, whereas adjacent felsic volcanic units, with ages of 2700±2 Ma, correlate with the Catfish Lake volcanic assemblage (cycle 3), indicating that DBR1 were intruded at least 20 My after volcanism. Compositionally the dikes are minettes and spessartites of the calc-alkaline shoshonitic lamprophyre clan. Units with more than 16 wt.% MgO, represent lamprophyres that entrained cumulate olivine, probably at the base of the crust. Abundant altered ultramafic xenoliths in the dikes display uniform major element compositions but highly variable trace element abundances and Nd isotopic ratios that are characteristic of cryptic metasomatism associated with the flux of an oxidised fluid above a subduction zone.

DBR2 is a northeast-striking, 7 km long conglomerate unit up to 200 m thick, extending from Chabanel to Corbiere townships. It occurs at the base of the more extensive Dore assemblage, a Timiskaming-type sedimentary unit unconformably overlying older volcanic assemblages. DBR2 is unbedded, poorly sorted, and heterolithic with subangular volcanic clasts, compositionally similar to underlying units, and lesser sedimentary and gabbroic clasts, but no obvious ultramafic and lamprophyric clasts (unlike DBR1). The diamonds are mostly clear and white (about 10% coloured) and are more abundant in the matrix (unlike DBR1), with 0.68 carat the largest stone reported. The conglomerate grades into overlying turbiditic sandstones, a more typical facies of this part of the Dore assemblage. Detrital zircons from the Dore assemblage in other parts of the MGB, yielded a maximum depositional age of 2680±3 Ma.

Although our geochronological and geochemical results on DBR2 are pending, facies association, geometry and correlation with the Dore assemblage, in conjunction with spatial proximity to DBR1, suggest that the diamonds were derived by erosion and were emplaced in proximal submarine debris flows from a hinterland source containing abundant DBR1 deposits.

REDUCING RISK OF NATURAL HAZARDS THROUGH PUBLIC OUTREACH AND EDUCATION

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Education is the first step in the successful mitigation of Natural Hazards. An informed population is more aware of the potential hazards that may occur in their area; better able to recognise early warning signs of potential events; and more likely to respond appropriately with evasive or mitigative actions before or during the event. An informed population is also more likely to accept the necessity of mitigative actions – whether restrictive zoning, property expropriation, or expensive engineered works – undertaken by various authorities to reduce risk. The outreach and education activities of two projects within the Reducing Risk of Natural Hazards Program of Natural Resources Canada are intended to raise awareness within the general public of our vulnerabilities to natural hazards.

At the national level, the Geohazard Awareness Project will result in authoritative information on natural hazards being readily accessible to Canadians in general and educators in particular. This involves a significant updating and enhancement of the Atlas of Canada website (http://atlas.nrcan.gc.ca/site/english/maps/environment/naturalhazards), a source widely used by students and teachers. Some webpages have been updated; the rest will follow in year two of the project. As an aide to educators who must prepare lessons on geohazards, the website will also incorporate lesson and activity plans for a range of geohazards (landslides, floods, earthquakes, tsunamis and volcanoes). These lesson plans will be designed to meet specific provincial curriculum goals at several grade levels across Canada. Where possible, a variety of datasets and examples will be available, so that teachers can choose to highlight local events to engage student interest.

At a community level, the Geological Survey of Canada is collaborating with the District of North Vancouver to promote awareness and understanding of local landslide hazard. This community experienced a devastating landslide in January 2005, one of many on their steep slopes. The District has initiated measures to assess the hazard and reduce risk to its population and infrastructure and has openly released all information on their website. The GSC has promoted this work as an example of good practice in landslide threat reduction. To help deliver the message to the general public, the GSC is developing, in collaboration with North Vancouver, some user-friendly educational products that highlight the hazard and the District's efforts, successes and lessons-learned. Although intended for the constituents of North Vancouver, these products also present a valuable case study for other municipalities in Canada.

TOURMALINE FROM THE DIFFERENT DEPTH GOLD DEPOSITS

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Tourmaline occurs in early quartz veins and wall rocks of the different depth granitoid-related gold deposits. These deposits can be divided into deep-seated and shallow. Large deposit Berezovskoe and small deposits Shabrovskoe, Shul'ginskoe, and Zolotaya Gora in the Urals, giant Muruntau in Uzbekistan and others belong to the first group. Large deposit Darasun, occurrences Talatuy and Teremkinskoe in Transbaikalia, Elenovskoe in the Urals, Choiskoe in Altai belong to the second group. Second group deposits in Russian literature are known as volcanic-plutonogenic, Au-porphyry or Au-Cu-porphyry. Based on fluid inclusions the early assemblages from deep-seated deposits were formed at 1.7 to 2.5 kbar, whereas those from shallow ones at 0.5 to 1.5 kbar.

Tourmaline from deep-seated deposits develops usually dark brown isolated needles or as needle aggregates. Microscopically single tourmaline crystal is pleochroic and can be optically and chemically complicated zoned. Compositionally tourmalines are generally intermediate members of the schorl-dravite series, but in some deposits they can be ascribed to the dravite-"oxy-dravite" or magnesiofoitite – "oxy-magnesiofoitite" series. The $Fe_{tot}/(Fe_{tot}+Mg)$ ratio (Fe#) ranges from 0.08 to 0.46. Fluorine content in these tourmalines does not exceed 0.20 *apfu*. On the basis of Mossbauer data Fe^{3+}/Fe_{tot} ranges from 0.12 to 0.60, indicating a relatively high f_{O2}. The $\delta^{18}O_{smow}$ value of studied tourmalines from Berezovskoe, Shabrovskoe and Zolotaya Gora ranges from +5.0‰ to +13.1‰. Calculated $\delta^{18}O_{H2O}$ value ranges from +2.9‰ to +11.1‰. There is a good positive correlation between Fe# and $\delta^{18}O_{SMOW}$ (R=0.89) and Fe# and $\delta^{18}O_{H2O}$ (R=0.94).

Tourmaline from shallow deposits develops usually black or dark green isolated needles or as needle aggregates. Microscopically single tourmaline crystal is pleochroic, split and optically and chemically complicated zoned. Compositionally tourmalines are generally intermediate members of the schorl ("oxy-schorl") – dravite ("oxy-dravite") series, with Fe# ranges from 0.09 to 0.74. Fluorine content in these tourmalines is up to 0.37 *apfu*. On the basis of Mossbauer data Fe^{3+}/Fe_{tot} ranges from 0.50 to 0.85, indicating a high f_{O2} and possible presence of the buergerite and/or povondraite components. The $\delta^{18}O$ (SMOW) value of studied tourmalines from Darasun, Talatuy, and Teremkinskoe range from +1.9‰ to +8.3‰. Calculated $\delta^{18}O_{H2O}$ value ranges from +0.1‰ to +7.7‰, indicating a significant influx of meteoric water. Unlike deep-seated deposits there is no linear correlation between Fe# and $\delta^{18}O_{SMOW}$ and Fe# and $\delta^{18}O_{H2O}$.

Thus, a combination of crystal form, chemistry and oxygen isotopic composition of tourmaline enables to distinguish deep-seated and shallow granitoid-related gold deposits.

PROSPECTING AND GEOLOGY COURSES IN THE NORTHWEST TERRITORIES

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The Northwest Territories Geoscience Office (NTGO) offers a basic Prospecting and Geology Course. The course aims to increase the knowledge of geology and mineral resources by NWT residents in order to promote jobs in the fields of prospecting, geology, mineral exploration and mining. The course can be run in any NWT community which requests it.

The NTGO provides one geologist and one seasoned prospector along with a wide variety of hands-on samples and materials to teach the course. Three to five one-week courses are taught every year in local learning centres and community facilities throughout the thirty-three NWT communities. The course curriculum includes mineral and rock identification, basic geology, claim-staking, and prospecting and mineral exploration techniques.

Successful completion of the course allows NWT residents eligibility to apply to the Government of the Northwest Territories' Prospector's Grubstake Program, a mineral incentive program for northern residents.

PROSPECTING FOR EVIDENCE OF LIFE IN ANCIENT OCEANIC BASALTS FROM CANADIAN GREENSTONE BELTS AS ANALOGUE SITES FOR STUDIES OF ANCIENT LIFE ON MARS

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Over the past decade, studies of volcanic glass from modern oceanic crust have demonstrated the importance of endolithic microbes in the alteration process. Microbial alteration features are ubiquitous within the oceanic crust, having been discovered in basalts of all ages, wherever fresh glass is preserved. More recent work in ophiolites and greenstone belts has extended the evidence for microbial alteration of oceanic basalts beyond the record preserved in the modern oceans as far back as the Archean. For example, biosignatures have been well documented in the formerly glassy rims of ~3.2 to ~3.5 billion-year-old pillow lavas from the Barberton Greenstone Belt, South Africa (BGB) and the Pilbara Craton, W. Australia (PWA). We have recently discovered micron-sized tubular structures mineralized by titanite identical to those from the BGB and PWA in hyaloclastites sampled from the ~2.7 Ga Abitibi Greenstone Belt, Canada (AGB). Based on the similarity to textures observed in recent glassy pillow basalts, we interpret these structures to represent ancient mineralized traces of microbial activity in the AGB samples. We plan to extend our studies of Canadian greenstone belts by sampling tholeiitic pillow lavas of the ~2.7 Ga Kam Group, superbly exposed near Yellowknife. These rocks display exquisite preservation of primary volcanic features.

Subaqueous volcanic rocks preserved in greenstone belts worldwide are a new geological setting in the search for early life on Earth. This has important implications for the exploration for life on Mars and in our solar system. It shows that robust biosignatures of a presently observable, global microbial process can be preserved for billions of years. Also, it suggests that microbial life had already colonized volcanic rocks on Earth at a time when liquid water may have been present at or near the surface of Mars. A great deal of interest has been focused on the possibility that liquid water once existed on the surface of Mars and evidence for palagonite formed by aqueous alteration as a major component in the Martian regolith. Basalts are commonplace on the surface of Mars and the cratered surface likely hosts countless glassy impact breccias and loose fragments that may have interacted with water in the past. Since basalts are likely to be returned by any extra-terrestrial sample return mission, detailed studies of microbial alteration signatures preserved in aqueously altered basalts provide a useful Earth analogue for studies of possible extraterrestrial microbial habitats.

QUANTITATIVE GEOLOGY: ALLOWING STUDENTS TO LINK MATHEMATICAL CONCEPTS WITH GEOLOGICAL PROBLEMS

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The practise of geology requires a unique skills set, including three and four-dimensional visualization, numeracy, data modeling and analysis, computer skills (including programming), and an understanding of geological problems. The geology undergraduate curriculum commonly follows a list of prescribed courses; their successful completion allows students to apply for professional registration. Such courses often concentrate on one skill at a time. As a consequence, students find it difficult to link the different skills. This disconnection is often most pronounced in the application of mathematical reasoning to geological problems. We will present examples from a course "Quantitative Geology" that uses a problem-based approach to help students develop their skills set and recognize mathematical concepts when confronted with geological problems.

UNIQUE Sn-BEARING OSCILLATORY-ZONED HEMATITE AND ASSOCIATED W- AND Bi-RICH MINERALS FROM CANADIAN CREEK, YUKON

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We report on the first natural example of Sn-bearing hematite. It occurs as a placer grain, *ca.* 0.5 × 0.7 mm, with oscillatory zoning. It is associated with grains (1–2 mm) of Fe–Mn tungstate minerals and various Bi-rich phases in a placer deposit located in Canadian Creek, Yukon. A Raman spectrum indicates that the Sn-bearing oxide is hematite (α-Fe_2O_3), not maghemite (γ-Fe_2O_3). The Sn-bearing oscillatory zones are up to 10 μm thick, diffuse, and "bright" in back-scattered electron images. The observed zoning is a reflection of covariations in Fe, Sn, and, to a lesser degree, Al, which displays a positive correlation with Sn. The "bright" zones contain up to 2.26% SnO_2 and 0.42% Al_2O_3. On the basis of experimental data, we suggest that this unusual solid-solution extends from α-Fe_2O_3 toward SnO_2 (cassiterite), in which Sn^{4+} enters octahedral sites, and a substitution Sn^{4+}-for-Fe^{3+} is combined with a reduction of Fe^{3+} to Fe^{2+} in order to maintain charge balance. Oscillatory zoning is commonly associated with diffusion-controlled growth in an open system, especially in hydrothermal systems, which may be driven sufficiently far from thermodynamic equilibrium to produce such autonomous patterns *via* geochemical self-organization. The associated placer grains of Fe–Mn tungstates are members of the ferberite – hübnerite series, nearly continuous from $FeWO_4$ to $MnWO_4$, and containing up to 10–12 mol.% of the $MgWO_4$ component (unnamed). The identified Bi-rich minerals are bismuthinite (Bi_2S_3), tetradymite (Bi_2Te_2S), and daubreeite? [BiO(OH)]; the latter species was probably formed by the oxidation and desulfurization of primary grains of bismuthinite, as implied by relics of bismuthinite present in grains of daubreeite. The Sn-bearing hematite and associated W- and Bi-rich species could be derived, as a placer material, from a mineralized zone (or zones) associated with a fluid-rich environment, for example a pegmatite or hydrothermal deposit related to granite emplacement in the placer area. A skarn-type deposit seems to be a more remote possibility, because no scheelite was observed among the placer minerals. The derivation from a hydrothermal Sn–W–Bi deposit, possibly Au-bearing, is preferred in view of the regional geology. Hydrothermal Sn-rich mineralization is known in the region in the central part of Yukon; it is related to a granitic pluton located close to Canadian Creek across the Tintina fault system. It appears likely that the latter pluton is related to the Prospector Mountain suite of late Cretaceous age, cut by Canadian Creek.

AN UNCONVENTIONAL TYPE OF MINERALIZATION IN THE TRINITY OPHIOLITE COMPLEX, CALIFORNIA

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Systematic analyses of placer grains collected in the drainage of the Trinity ophiolite complex, California, have led to discovery of a new pattern of mineralization involving metasomatic modifications of "normal" platinum-group minerals. Our work focuses on the discovery of Os–Ir and Ir–Os alloys enriched in W and Mo, clearly not a normal geochemical association. These alloys are found in a polycrystalline annular grain about 1 mm across. In the Os–Ir alloy, the level of W varies from 11.4 to 18.6 wt.%, whereas Mo attains 1.5 wt.% (close to 20 at.% W + Mo). The amount of Os is about 50 at.%, and is strongly negatively correlated with Ir, W and Mo. A possible formula is $(Os,Ir)_5(W,Mo)$, and it coexists with $(Ir,Os)_5(W,Mo)$. Both seem to be secondary phases, formed under conditions of low fugacities of O_2 and S_2 as a result of interaction of primary Os–Ir–Ru alloys with a reducing fluid phase, and could be new mineral species. These unusual alloys coexist with grains of hexaferrum, a rare Fe-rich alloy of Os, Ru and Ir containing up to 19.1 wt.% Fe. They are microporous, with relics of a non-porous Fe-poor alloy in the core. Here, Fe is negatively correlated with Os and Ru (and Ir?). The W, Mo and Fe are possibly derived from a ferberite-, scheelite-, and powellite-bearing skarn assemblage destabilized by the reducing fluids equilibrated with and infiltrated from the alloy-bearing ophiolitic source-rock. Similar unusual assemblages can be expected in placers derived from the tectonically juxtaposed terranes in the Yukon and northwestern British Columbia.

GLACIAL DISPERSION OF A LAMPROPHYRIC HETEROLITHIC BRECCIA FROM THE ENGAGEMENT ZONE, WAWA, ONTARIO, CANADA

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A study was undertaken to determine if till sampling and analysis could be used for the exploration of diamonds hosted by Archean rocks in the Wawa area; some of the oldest diamond deposits in the world. The harder, relatively more erosion-resistant Archean diamond-bearing rocks do not produce the same indicator mineral signatures as the kimberlitic rocks that are the common target of diamond exploration in Canada. The area of the West Timmins Mining Inc. Engagement zone was selected for study as the lamprophyric heterolithic breccia exposed there is diamond-bearing, its mineralogy has been studied, it is easily accessible and there is a thick cover of till in and around the occurrence to sample. The direction of ice flow associated with the deposition of the till in the area was toward the south (175°-185°). Till samples for heavy mineral concentrate (HMC) analysis (methylene iodide, S.G. 3.2), till matrix geochemistry and pebble lithology studies were collected at 11 sites up-ice flow, over and down-ice of the Engagement zone.

HMC samples collected from till contained few kimberlite indicator minerals (<18 grains/10 kg of sample). However, samples closest to the diamond-bearing heterolithic breccia contained the greater amounts. Heavy minerals that appear to indicate the presence of the breccia include: pyrope garnet, chromite, low-chrome diopside, forsterite, chalcopyrite, pyrite, gold (total and pristine grains) and goethite. For all heavy minerals studied the glacial dispersal trains are short. The best defined train is of gold grains that extends for more than 400 m in length. Actinolite, an S.G. 3.2 light mineral, is abundant in the breccia and the dispersion of this mineral is being investigated. Geochemical analysis of the fine fraction (<0.74 mm) of till matrix samples returned elevated levels of in Cr, Ni, Mg and Zn (ICP-MS) in the immediate vicinity of the Engagement zone. The grain-size distribution of the till matrix samples changes down-ice flow of the breccia and may have promise as an exploration method in locating diamond-bearing Archean rocks.

RECORD OF LATE-GLACIAL LAKE LEVEL FLUCTUATIONS IN THE LAKE NIPIGON BASIN, NORTHWESTERN ONTARIO, CANADA

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River banks along the Little Jackfish River, north of Lake Nipigon, expose sediment sequences that record large fluctuations of lake level in the Lake Nipigon basin during ice-marginal recession of the Laurentide Ice Sheet. Two fining-upward cycles of rhythmically-bedded sediments are separated by a thin bed of marl. The lower part of the upper sequence, marl and upper part of the lower fining-upward sequence are fossil-bearing. Molluscs, ostracodes and oogonium and carbonate casts of the algae *Chara* occur in these sediments.

Fourteen species of ostracodes were identified from a 105 cm interval that bracketed the marl bed. The silts of the uppermost part of the lower fining upward sequence contain ostracode assemblages that indicate the presence of a large cold-water lake environment. Subsequently, there was a decrease in water level, warming and an increase in the content of fluvial ostracode species that corresponds to the presence of *Chara*, a shallow water algae. The base of the upper fining-upward sequence contains ostracodes that indicate a renewed high-water stage of the lake.

The sequence of sediments and the fossils indicate that a large ice-contact glacier-fed lake fronted the northward receding ice margin. The level of the proglacial lake lowered until very shallow water existed at the site until after marl formation. Water levels then rose rapidly flooding this locality. The sequence of lower sediments is believed to represent ice marginal retreat, to the Nakina I moraine (deep water event) and beyond, to uncover an eastern outlet (the Pic River via the Mullet outlet) that allowed for the bypass of Lake Agassiz waters via the Whiteclay Lake-Ogoki channel, a proposed outflow route. This resulted in the low water stage in the Nipigon basin. A readvance of the ice margin to the Nakina moraine II closed the eastward outlets and channel, once again raising the water level in the Nipigon basin; producing the upper fining-upward sediment sequence.

LINKING THE MISTASSINI AND OTISH BASINS WITH THE PALEOPROTEROZOIC EVOLUTION OF THE SUPERIOR CRATON

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The Mistassini and Otish Basins are the only remnants of early Paleoproterozoic sedimentation along the margin of the Superior craton between the Huronian Basin and Labrador Trough. Geochronological and stratigraphic constraints are poor thus limiting their correlation with other successions and hence our understanding of the early Paleoproterozoic evolution of the southeastern margin of the Superior craton. Platformal carbonates of the thin basal stromatolite member of the lower Albanel Formation in the Mistassini Basin have 13C values as high as +6.7‰ and are sharply overlain by organic-rich sulfidic shales related to platform drowning. Overlying thick carbonates of the lower and upper Albanel formations have ¸13C values

consistently close to 0‰. This change from high to normal ¸13C values punctuated by a flooding event is also observed in other Paleoproterozoic successions, known to have been deposited between ~2.1 and 2.0 Ga. At the northern end of the Mistassini Basin, the Papaskwasati and Cheno formations are presumed to underlie the lower Albanel Formation, although their contact is not exposed. The upper Cheno Formation contains carbonates with ¸13C values as high as +7.2‰, similar to those in the basal stromatolite member of the lower Albanel Formation. In the Otish Basin, the predominantly siliciclastic Indicator and Peribonca formations mainly were deposited in fluvial environments with eolian and marine sabkha influence during Peribonca time. The lower Peribonca Formation contains dolostones with ¸13C values as high as +11.4‰. These values match those from possibly correlative carbonates of the 2.17-2.14 Ga Seward and Pistolet subgroups of the Labrador Trough and are typical for the middle part of a globally recognized 2.22-2.10 Ga carbon isotope excursion. Our isotopic data support correlation of the Otish Basin with continental rifting and initial breakup of the Superior craton documented in the Labrador Trough. Subsequent rifting and continental separation at ~2.1-2.0 Ga, along the southern margin of the Superior craton, may be recorded by deposition of platformal carbonates and shales of the Mistassini Basin. A significant break in sedimentation is inferred to have occurred before deposition of the Temiscamie Iron Formation at the top of the Mistassini basin succession, which may correlate with ~1.88 Ga iron formations of the Animikie Basin and Labrador Trough. Sedimentary successions of the Mistassini and Otish basins provide a link between the Labrador Trough and the Animikie Basin but are likely younger and unrelated to development of the >2.22 Ga Huronian Basin.

AGE AND PROVENANCE OF THE PALEOPROTEROZOIC THLUICHO LAKE GROUP BASED ON DETRITAL ZIRCON SHRIMP GEOCHRONOLOGY: NEW INSIGHTS INTO THE TECTONIC DEVELOPMENT OF THE SOUTHWESTERN RAE PROVINCE

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The Thluicho Lake Group is a succession of coarse clastic rocks that was deposited in continental alluvial basins in the central Zemlak domain of the southwestern Rae Province. Over 100 analyses were performed on detrital zircons from two stratigraphically well controlled samples from the Waterloo-Wellington lakes area, 10 km west of Uranium City – the 'Camel Lake Member' pebbly arkose of the 'Powder Lake Formation' and the 'Falls Member' arkose-argillite of the 'Camsell Portage Formation'. Four analyses of one of the youngest detrital zircons recovered from the Falls Member yielded a mean $^{207}Pb/^{206}Pb$ age of 1922 ± 6 Ma, establishing a new maximum depositional age for the group. This result, coupled with regional relationships, suggests that the group is intermediate in age between development of two tectonic fronts; an older, ca. 1.93 Ga east-southeast-trending front that formed at the tail end of Thelon-Taltson orogeny, and a younger, ca. 1.91-1.90 Ga northeast-striking front expressed by the Black Bay Fault and associated northeast-striking structures affiliated with the Snowbird Tectonic Zone. The younger age limit for the group may therefore be older than the previously reported minimum age of ca. 1.82 Ga.

The distribution of detrital zircon ages from the two samples is remarkably similar, with most lying within two age-ranges: 2750-2500 Ma and 2450-2250 Ma. The older age-range is dominated by ca. 2600 Ma zircons whereas the younger contains two distinct subgroups of ca. 2420 and ca. 2320 Ma. The principal sources of the Thluicho Lake Group were therefore local basement rocks of the Nolan, Taltson, Zemlak (Ena), Beaverlodge and Train Lake domains. Abundant 2450-2250 Ma zircons indicate that the ca. 2.4-2.3 Ga Arrowsmith Orogen was also a major source of the detritus. A few older (>3100 Ma) and younger (<2250-1920 Ma) zircons were likely sourced, locally or regionally, within the Rae Province. All told, the Thluicho Lake Group detritus appears to have come from rocks that formed the exhumed hinterland of the Taltson mountain belt.

A notable feature of the Thluicho Lake Group dataset is the near-complete absence of 1990-1960 Ma zircons, an age-range typical of arc plutonic rocks of the Taltson Magmatic Zone. The Taltson arc did not supply detritus to the Thluicho depositional basins, suggesting that such basins were located in the hinterland of the orogen, which was separated from the foreland by a continental divide.

The results of this study support correlation between the Thuicho Lake and Nonacho groups.

THE "DESSERT LAKE" RED-BED BASIN: A NEWLY RECOGNIZED PROTEROZOIC BASIN (OUTLIER) OVERLYING THE SOUTHERN EXTENSION OF THE SLAVE AND BEAR PROVINCES

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SNORCLE seismic reflection data reveal a distinct basinal reflector at 0-1 s, west of the exposed Slave craton, between Edzo and Fort Providence. With only sparse drill hole control, this reflector has been interpreted to represents a thin cover of Paleoproterozoic Great Bear Magmatic Zone (GBMZ) rocks on more complex Hottah terrane basement (Cook et al., 1999).

Based on outcrops of the GBMZ to the north, we challenge this interpretation and propose an alternative: the sub-Phanerozoic bowl-shaped reflector represents exactly what it appears to be on the seismic profile — a shallow sedimentary basin remnant, up to 2.5-3.0 km deep, with a prominent basal reflector representing an unconformity overlying more complex crystalline basement of GBMZ, Hottah terrane, and (or) Slave craton. We base this interpretation on the following:

The basinal reflector occurs below thin, south-westward thickening Phanerozoic platform strata. It shows only very shallow dips, while clearly overlying and truncating more highly structured basement. Although there are weak reflections within the "basin", the main reflector occurs at the base and resembles the signature of an unconformity overlying crystalline basement. Its seismic character compares well with, for instance, the base of the Athabasca Basin. Two other shallow red-bed basins overlie the western shield (Athabasca, Hornby Bay) and there are few fundamental reasons against other basin remnants in this part of Laurentia, albeit largely underneath Phanerozoic cover. Aeromagnetic maps of the southwestern Slave craton and adjacent GBMZ show high-amplitude, short-wavelength anomalies, interpreted as Archean basement intruded by ca. 1.9-2.2 Ga diabase dykes, are being masked by southwest-thickening cover distinct from the thin Phanerozoic platform further to the southwest. This masking cover is cut by at least two Proterozoic dykes, a NNW-trending Mackenzie dyke (1.27 Ga) and an E-W trending dyke that extends across the inferred Bear-Slave boundary (i.e., <1.8 Ga). There are sparse outcrops of undifferentiated pre-Cambrian sandstones on the shores of Great Slave Lake (Henderson, 1985, GSC Memoir). And finally, at least some exploration drill core from the area of interest intersects shallow dipping, well-sorted (eolian?), arkosic red sandstones that extend for >150 m below flat-lying (white!) basal Cambrian sandstones.

Much remains to be done, but we are confidant that we have identified at least parts of a major red-bed basin outlier or

erosional remnant similar to the Athabasca Basin. It overlies first-order basement structures of the western shield and is at a depth where it could be explored for unconformity-type uranium deposits.

THE HEARNE CRATON COVER SEQUENCE IN MANITOBA: WHERE THE HURWITZ MEETS THE WOLLASTON

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Exposures of the Paleoproterozoic cover sequence to the Archean Hearne craton in Manitoba bridge the areas where similar sequences have been defined separately: the Hurwitz Group of the central Hearne craton in Nunavut and the Wollaston Supergroup of the south Hearne craton in northeast Saskatchewan. These sequences record rifting, basin opening and basin closure during the breakup of 'Kenorland' and the assembly of Laurentia.

In Manitoba, the cover sequence consists of a thick succession of quartzite, arkose, calc-silicate, psammite, semipelite and pelite (from base to top), which is intruded by younger, Paleoproterozoic, granitoid plutons, and was deposited as a passive-margin sequence along the rifted southeast margin of the Hearne craton, and/or within restricted extensional sub-basins inboard from the craton margin. U-Pb detrital zircon age data are comparable to similar rocks from both the Hurwitz Group in Nunavut and the Wollaston Supergroup in Saskatchewan. For example, quartzite samples from exposures in the Nejanilini and Kasmere lakes areas of Manitoba are characterized by predominantly ca. 2.7 Ga zircons, with fewer zircons as young as ca. 2.5 Ga, which is comparable to quartzite in the Lower Hurwitz Group and/or the lower-most Wollaston Supergroup. Variable amounts of Mesoarchean zircon detritus in the quartzites reflects the presence and degree of recycling of Hearne proto-crust that is largely preserved in the Nejanilini granulite domain. Psammite samples from Manitoba's far north, in comparison, have abundant ca. 1.9–2.1 Ga, minor 2.3–2.4 and variable 2.6 and 2.7 Ga detrital zircons like those from the upper Hurwitz Group in the central Hearne craton of Nunavut. This data is also similar to the Wollaston Supergroup sediments in northeast Saskatchewan, which, in addition, have abundant 1.90–1.88 Ga detrital and younger (metamorphic) zircons.

Based on similarities in lithologies, provenance and depositional age constraints, the new data from Manitoba suggest that at least portions of the Hurwitz and Wollaston sequences are likely equivalent, and that these ca. 2.45–1.90 Ga cover sequences have formed contemporaneously and in a similar or related tectonic setting over hundreds of kilometres including northern Manitoba.

MINING AND SOCIOECONOMIC DEVELOPMENT IN NUNAVUT: LEARNING FROM POLARIS AND NANISIVIK

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Nunavut has gained importance in the last few years as an area of high mineral potential, with exploration leading to discoveries of several mineral deposits that have, or will in the coming years, become mines. As a territory with an economy based in large part on government employment, new mining operations can provide Nunavut with an alternative way to develop its economy through job creation, local business opportunities, royalties, and taxes. Mining can also provide the people of Nunavut with training opportunities for various jobs that can later be used for employment with community-based businesses. Understanding the socioeconomic impacts of past Arctic mining operations, such as the Polaris and Nanisivik Pb-Zn mines, becomes important if the above opportunities are to become reality, and if Nunavut is to maximize its benefits from future mining operations.

The Polaris and Nanisivik mines closed in 2002 after over 20 years of operation. Each mine was located near an Inuit community: Polaris, located 100km northwest of Resolute, was a fly-in fly-out operation that used Resolute as a staging point; and Nanisivik, a community-based operation, is connected to Arctic Bay by a 21 km-long all-weather road. The differences in the physical connections of the mines to Inuit communities provide a good opportunity to compare and contrast the mines' socio-economic impacts on each community.

Research methods used for this study included the review of company and government reports, and interviews with residents of Resolute and Arctic Bay. Fifty-one interviews were conducted over a 4-week period in January-February 2005 to learn how the mines affected these two communities both during mining operation and after closure.

The results reveal that community members felt the mines had the following impacts during operation: (1) positive economic impacts because new businesses were created and many residents benefited from increased incomes; (2) negative social impacts such as increased alcohol consumption; and (3) mixed employment impacts because employment was available to local Inuit but training and certification were limited, which restricted opportunities after closure. Overall there were few benefits and these did not persist after mine closure, showing that these mines did not significantly assist with longer term sustainable development in the region. To increase socioeconomic benefits and assist Northern communities to develop sustainably, mining companies in Nunavut should emphasize education and training for local people, and encourage local business development and partnerships through strong relationships with involved stakeholders and government.

INDUSTRY AND THE ENVIRONMENT ON THE KOLA PENINSULA, NW RUSSIA, AND ADJACENT PARTS OF NORWAY AND FINLAND

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The mineral industry on the west half of the Kola Peninsula is the most varied in any comparable area north of the Arctic Circle (Ni-Cu-, Fe- and apatite mines, five smelters and a roasting plant): these include two of the largest point-source emitters of heavy metals in the Arctic. The greatest concentration of nuclear reactors in the world, many of them decommissioned, is found in the same area.

These factors led geological survey organizations in Russia, Norway and Finland to implement a regional geochemical study covering an area of 188,000 km^2 on the Kola Peninsula and adjacent parts of Norway and Finland. The study involved a range of media, including C- and B-horizons, humus and moss, sampled at over 600 sites throughout the area, and analysed for up to 60 elements, including 6 radionuclides. The study showed, i,a, that:

- Most metal deposition is within 50 km of the source and background levels are reached within ca. 200 km.
- Modelling of the emissions based on deposition in 1994 confirmed official figures from the Russian authorities.
- Previously published estimates based on the use of emission factors grossly overestimated emissions of certain trace metals.
- Emissions of Ni, Cu and Co had a value of ca. USD 19 million in 1994 (using 1994 metal prices).

- Each type of heavy industry (e.g. also apatite processing and oil-fired power stations) has a characteristic spectrum of emissions.
- No indication of radioactive contamination was found at the sites sampled.
- Overgrazing by reindeer had led to serious damage at 70% of the sites sampled in Norway.
- Even at the low density of 1 station/ca. 300 km^2 the data generated from B- and C-horizon samples, including follow-up analyses for noble metals, are relevant to regional-scale prospecting and to a better understanding of the bedrock geology.
- Great care should be taken when interpreting data based on plants: their ability to take up metals varies greatly – also from species to species.
- A full understanding of the scale and causes of environmental damage is a pre-condition for effective remediation. The main cause of environmental damage around the Ni-Cu smelters on the Kola Peninsula is emissions of SO_2: plans exist for their reduction.

As_{Out} >> As_{In} ??? MISUSE OF EMISSION FACTORS IN CALCULATING THE RELEASE OF TRACE METALS TO THE ATMOSPHERE FROM THE Ni-Cu INDUSTRY IN ARCTIC RUSSIA

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Published estimates for heavy metal emissions from the Cu-Ni industry on the Kola Peninsula in NW Russia are examined in the light of: a) Official Russian emission figures for 1993 and 1994, b) Modelled emissions based on calculated dry and wet deposition estimates based on snow and rain sampling carried out in 1994, c) Chemical data on the composition of the ores being processed. The modelled emissions, official emission figures and chemical data are mutually compatible for Ni, Cu and Co and indicate that figures published up until the late 1990s underestimated the emissions of the major elements, Ni and Cu (by a factor of 4-6). Consideration of the published estimates in relation to the modelled emissions and to chemical data for trace elements in the ores indicates that previously published figures overestimated the emissions of certain trace metals by up to several orders of magnitude, in some cases (As, Pb, Sb) exceeding the calculated total input of these metals to the plants. These conclusions have implications for estimates of emissions from the Cu-Ni industries in Siberia (Noril'sk-Talnakh) and from the metallurgical industry in the Urals; published estimates of these emissions have neglected the implications of information on the nature of the ores being processed (plants in the Urals) and on the chemistry of the ores (plants in the Urals and at Noril'sk). The basic weaknesses in published estimates based on the use of emission factors have not prevented their use as part of the basis for international conventions on emissions of heavy metals.

Emission estimates for all mineral-based industries should be re-assessed, considering:

- Basic geological knowledge about the raw materials used in the industries.
- Modern data on the chemistry of the raw materials.
- Application of relevant observational data where available.

Ore geologists and geochemists bear a responsibility for ensuring that society recognizes the importance of their data in all fields, in which they are important.

MISCONCEPTIONS OF LEARNERS IN THE ELEMENTARY CLASSROOM AND THE POWER OF INQUIRY

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When a learner is participating in the Study of Science, they come into the classroom with many ideas already embedded in their thought processes about their world and how it works. These misconceptions are very powerful. They become a part of the learner's brain network of knowledge and become a very important part of how the learner interacts with the world. You cannot simply ask the learner to dismiss these misconceptions. They become too important to the learner and at the same time, new, more accurate information cannot be learned if these misconceptions are not questioned by the learner. In fact, learner misconceptions are so powerful that the learner will "memorize" the correct answer for a test to get a good mark, but will revert back to their misconceptions the moment the test is over.

Recently, the American Museum of Natural History conducted a survey. It found that over 35 percent of the adult population believed that humans lived at the same time as dinosaurs. In my own classroom, 98 percent of my grade six students believed that all rocks sink in water.

So, how can these misconceptions be replaced if they are deeply held to be true by the learner?

First, the learner must become aware of the conflict between what they thought was correct and what they observed. These leaner misconceptions must fail to explain a new observation. This process is difficult for the learner. Learners are emotionally attached to their misconceptions and will work very hard to protect them.

How can we do this if traditional lecture, read and answer, memorize and test teaching techniques will produce the correct answers on paper, but not in the web network systems of the learner's own brain?

TWO-PHASE, TECTONICALLY INDUCED, REDBED-ASSOCIATED COPPER MINERALIZATION IN THE KEWEENAW DISTRICT, NORTHERN MICHIGAN

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Oxygen-rich meteoric water descending from marginal highlands adjacent to the Mid-continent Rift System (MRS) may be called upon to have reddened the upper immature, coarse-grained, sedimentary fill of rift subbasins in the Lake Superior area and to have become saline by evaporite assimilation. As this water lost oxygen during low-temperature diagenetic reddening of the Copper Harbor Conglomerate, it passed through moderately oxidizing conditions at which copper is particularly soluble as chloride complexes and thus the evolved meteoric water was able to leach trace amounts of copper from the voluminous sandstone-conglomerate aquifer and form the sulfide-facies sediment-hosted stratiform copper deposit in initially pyritic basal carbonaceous beds of the overlying Nonesuch Formation at White Pine, Michigan. This copper mineralization may be said to have been tectonically induced by the opening of the MRS and the elevation of marginal highlands which led to the gravity-driven descent and circulation of meteoric water. The ore-forming system may have been active for some millions of years during early diagenesis of the Oronto Group sediments at about 1080 Ma.

The above ore-forming system may have effectively terminated with erosion of the marginal highlands, but subsequent closure of the MRS during Grenvillian compression at about 1045-1060 Ma may have been responsible for increasing the tilt of rift-fill

strata toward the rift axis, for much of the reverse thrusting along the Keweenaw Fault, and for the elevation of new marginal rift highlands. A renewed circulation of descending meteoric water to deep levels of the rift fill could then have reddened the amygdaloidal and fragmented portions of the basalts and interbedded sandstones-conglomerates of the stratigraphically deeper Portage Lake Volcanics and, if transformed into a hot brine by the dissolution of evaporites and the addition of deep mantle heat, could also have leached trace copper from its aquifers. Upon ascending along the Keweenaw Peninsula, the cupriferous brine could have deposited native copper lodes in the absence of a sulfide precipitant as the ore fluid became highly depleted in oxygen. This second phase of copper mineralization, resulting again from gravity-driven meteoric water, may be said to have been induced during terminal tectonic stages of the MRS.

MINE TRAINING CURRICULUM

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The Mine Training Program offered at the Kimberlite Career and Technical Centre (KCTC) in Yellowknife, NT, is a partnership between the KCTC and Aurora College. The program curriculum was developed by educators and industry representatives and was initially presented at Chief Jimmy Bruno School in Rae-Edzo, NT through the Tlicho Trades and Technology Program.

The curriculum is delivered as five Career and Technical Studies (CTS) modules for both secondary school students attending St. Patrick's High School, Yellowknife and Aurora College students through the Yellowknife campus. Modules presented in the fall semester 2006 and again in the spring of 2007 were: Introduction to Geology of NWT, Mapping - GPS/GIS, Environmental Studies I, Introduction to the Mine Life Cycle, and Introduction to Mining - Surface and Underground.

A twelve-week, pre-employment program of Mine Training was presented by Aurora College. College students received instruction in the five mining modules, as well as Ready-to-Work North, WHMIS, academic upgrading, and Safety and the Young Worker trainings. Instruction of the mining modules was shared with St. Patrick's students for one period each day.

What is the value of continuing to offer mine training programs in the NT through secondary and post-secondary schools? Why are numbers so low for program enrolment? Why are completion numbers low?

What strategies can be implemented to promote enrolment in mine training programs in NT? If industry needs qualified workers, what is current status of industry participation in mine training programs?

TOWARDS A PALEOPROTEROZOIC APPARENT POLAR WANDER PATH (APWP) FOR THE SLAVE PROVINCE: PALEOMAGNETISM OF PRECISELY-DATED MAFIC DYKE SWARMS

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Comparing the drift of Precambrian cratons and reconstructing paleocontinents is most easily accomplished when a reliable apparent polar wander path (APWP), based on a sequence of well-defined and precisely-dated paleopoles (or “key” paleopoles), is available for each craton. Early attempts to construct Paleoproterozoic APWPs were frustrated by a paucity of high quality paleomagnetic data, uncertainty about the age of remanence, and very imprecise dating of paleopoles. However, progress is now being made as more key paleopoles become available. Of particular note is a series of nine key Paleoproterozoic poles with ages between 2450 and 1880 Ma, eight of which now form the basis of a rudimentary Superior Province APWP between 2220 and 1880 Ma. By comparison, no key Paleoproterozoic poles have previously been reported from the Slave Province. However, a number of Paleoproterozoic diabase dyke swarms in the Slave Province now have precise U-Pb baddeleyite ages, eliminating an important obstacle to obtaining key paleopoles.

Here, a key pole, located at 12°N, 268°E, is reported for the 2030-2023 Ma (U-Pb baddeleyite) Lac de Gras dyke swarm of the central and northeastern Slave. A positive baked contact test demonstrates that the pole is primary. New paleomagnetic data of a more preliminary nature are also described from 2230 Ma Malley dykes of the same area, as well as from dykes that likely belong to the 2108 Ma Indin and 1880 Ma Ghost swarms, both in the southern Slave Province near and west of Yellowknife. In addition, published paleomagnetic data from the 2188 Ma Dogrib dykes and 2181 Ma Duck Lake sill near Yellowknife are reassessed. With the exception of the Lac de Gras result, paleopoles from these units are not considered to be key poles, either because they have not been demonstrated primary or because dating has not yet been carried out at the paleomagnetic sites.

Comparison of the 2030-2023 Ma Lac de Gras paleopole with the Superior Province APWP suggests that the Slave and Superior provinces were at a similar paleolatitude of ~30°, but not in their present relative orientation. More speculatively, if the other Slave Province poles are correctly dated, they suggest a Slave Province APWP in the 2230-1880 Ma interval that is distinctly different in shape from that of the Superior Province. This in turn would indicate that the two cratons did not drift as part of a single supercontinent through that time interval.

PROTEROZOIC MAGMATIC EVENTS OF THE SLAVE PROVINCE AND WOPMAY OROGEN

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Large magmatic events are critical for establishing the location and timing of continental breakup and collision. In addition, comparison of the age distribution (or “bar code”) and paleomagnetic signature of magmatic events on different cratons can help identify which cratons were contiguous in ancient supercontinents. The distribution and ages of Proterozoic magmatic events in the Slave craton and Wopmay Orogen are compiled in a new map. Relatively widespread events are now known to have occurred at: ca. 2230 Ma (Malley dykes); ca. 2210 Ma (MacKay dykes); ca. 2188-2175 Ma (Dogrib dykes-Big Spruce complex-Duck Lake sill-Blachford complex-Squalus Lake intrusion); ca. 2108 Ma (Indin dykes); ca. 2025 Ma (Lac de Gras dykes-Booth River complex); ca. 1884 Ma (Ghost dykes); units of similar age within Wopmay including granites of the Hepburn intrusive suite; ca. 1880-1850 Ma (Great Bear magmatic arc); ca. 1870 Ma (Mara River sheets); ca. 1740 Ma (Cleaver dykes); ca. 1267 Ma (Mackenzie dykes-Muskox intrusion-Coppermine volcanics-Christie Bay sills); ca. 780 Ma (Hottah sheets-Tree River dykes); and ca. 723 (Franklin dykes-Coronation sills). It is expected that other significant Proterozoic events may be recognized as further studies are conducted.

Some pre-Laurentia Slave-Wopmay magmatic events are correlated closely in time with events on other cratonic blocks whose paleogeographic relationship to the Slave craton is unknown. For example, ca. 2188 Ma Dogrib dykes have a similar age to Tulemalu-MacQuoid dykes in the Churchill Province. Ca. 2108 Ma Indin dykes are close in age to the

Griffin gabbro sills of the Churchill Province and Marathon dykes of the Superior Province. Ca. 1884 Ma Ghost dykes are time-correlative with widespread magmatic rocks around the margin of the Superior craton. Paleomagnetic work on these units can test potential paleogeographic reconstructions. Three of the Mesoprotrozoic and Neoproterozoic Slave Province dyke swarms that were emplaced after the formation of Laurentia form parts of continental scale giant radiating dyke swarms. The ca. 1267 Ma Mackenzie swarm radiates from a focus near Victoria Island across much of northern Laurentia, and extends as far south as the Superior Province. The ca. 780 Ma Tree River dykes form part of the widespread Gunbarrel event in western Laurentia which focuses near the Queen Charlotte Islands. The ca. 723 Ma Franklin swarm has a less certain geometry, but appears to focus in the vicinity of Banks Island and to extend eastward as far as northwestern Greenland.

DATING OF ARCHEAN BASEMENT IN SOUTHERN ALBERTA BY LASER ABLATION-MC-ICP-MS

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As part of a long-term study to understand the Precambrian basement of the Western Canada Sedimentary Basin, we have undertaken a geochronological investigation of crustal xenoliths enclosed in Tertiary minette dykes from the Milk River area of southern Alberta and of nearby basement core samples. Zircon grains within standard petrographic thin sections were analyzed for their U-Pb isotopic composition by laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS) using a novel in-situ technique developed at the University of Alberta. The MC-ICP-MS instrument has a unique collector configuration that allows for simultaneous acquisition and high precision measurement of very low Pb ion signals on three separate ion counting channels. Consequently, small sample volumes are consumed; the zircons investigated here were ablated using a 20 micron spot size. This technique is ideal for this study as it conserves scarce sample material.

Six crustal xenoliths from Coulee Two Nine and drill core samples from two wells were chosen for analysis. The xenoliths are thought to represent present-day upper crust because their large size (up to 1 m^3) and angular nature suggest only a short transport distance in the minette magma. The freshest xenolith (Oc 8-15), a metagraywacke, contains zircons with 2911 ± 11 Ma cores and 2835 ± 23 Ma rims. We interpret the older date to be the igneous crystallization age of detrital zircon grains in the sample, and the younger date to reflect the time of formation of a metamorphic overgrowth. Analyses of zircons in the other xenoliths yielded ages similar to either the older or younger ages obtained for Oc 8-15. Two xenoliths also record zircon growth at ~ 2670 Ma, which we interpret as a later episode of metamorphism. Zircons in a thin section of Home Pacific Knappen 16-29 yielded an age of 3304 ± 20 Ma, which is within uncertainty of an ID-TIMS age for the same core reported by the GSC. Notably, the 2.8 to 2.9 Ga ages obtained for the xenolith samples are distinct from the widespread 2.71 to 2.59 Ga ages reported for scattered drill core from southern and central Alberta.

These age data, in conjunction with previously reported data, should prove useful in reconstructing western Laurentia in Late Archean time. The ages from southern Alberta broadly resemble those from the Wyoming Craton, Superior Craton (Winnipeg River Belt) and parts of the Slave Craton.

NEW INSIGHTS INTO THE FORMATION OF THE WESTERN SLAVE PROVINCE BASED ON U-Pb GEOCHRONOLOGY AND Sm-Nd ISOTOPIC GEOCHEMISTRY FROM THE WECHO RIVER AREA

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The Wecho river area, located in the western Slave Province is an area dominated by Neoarchean granitoid plutonic rocks with lesser amounts of metasedimentary rocks. It represents an area between the known Central Slave basement Complex that is greater than 2.8 Ga to the east and the Snare River area interpreted as a juvenile terrain to the west. Nd isotopic data collected throughout the Wecho river area defines a Nd isotopic boundary at ca. 2608 Ma. This is the age of a diorite pluton that is the oldest rock that defines the boundary. This boundary is interpreted as the extent of the western edge of the Central Slave Basement Complex. 2608 Ma thus represents a minimum age for the suture between the Snare and Wecho terrains. The presence of the ca. 2630 Ma Defeat suite on either side of the proposed suture area suggests that collision occurred prior to the Defeat age plutonism and is likely the result of westward subduction as there is no evidence of magmatism beneath the Wecho River area prior to ca. 2635 Ma.

The lithologies within the Wecho River area are not unique to the Slave craton and instead can be correlated to other suites across the south central and central parts of the craton. The westernmost exposure of the Central Slave Basement Complex is found at the Nardin Complex and was dated at 3391±9 Ma. The Sm-Nd isotopic data for this rock range from -0.42 to -1.64 which is representative of crustal reworking of tonalite-trondhjemite-granodiorite plutons within the early history of the craton. Mafic volcanism in the Wecho River area, relatively dated between ca. 2660 and 2640 Ma, shows similarities in its geochemistry to the Banting formation indicating a mantle origin. Between 2635 and 2600 Ma metaluminous plutonism dominated throughout the Wecho river area with correlative plutons in the central and eastern parts of the craton such as the Defeat and Concession Suites. Between 2600 and 2591 Ma peraluminous plutonism occurred in the western Slave Province that can be correlated to the Contwoyto and Yamba suites in the east central part of the craton. The regional nature of these plutonic events indicates that there may have been a large scale event such as the delamination of a dense ultramafic or eclogitic layer at the base of the crust that would have been accumulating since the formation of the Defeat Suite.

REGIONAL STRUCTURE OF THE BERENS RIVER AREA WITHIN THE ARCHEAN SUPERIOR CRATON: A MESOARCHEAN TECTONIC RELICT AND NEOARCHEAN TRANSPRESSIVE DEFORMATION WITHIN THE NORTH CARIBOU TERRANE

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Considerable geochronology and isotopic data across the Archean Superior craton reveal a substantial history of Neoarchean magmatism and deformation. However, the earlier tectonic record is poorly documented. The North Caribou terrane (NCT) within the Superior craton contains narrow, north and northeast-trending greenstone belts. This contrasts with the Uchi domain on the southern flank of the NCT where greenstone belts and flattening fabrics are E-trending, the result of late Neoarchean (circa 2.7 Ga) deformation. We suggest that this northward structural trend of greenstone belts in central NCT

preserves a relict, Mesoarchean (ca. 3.0-2.86 Ga) tectonic fabric that has not been rotated by younger Neoarchean orogenesis.

The region north of the Red Lake belt and across the NCT is characterized by 1) an apparent NNW-trending Mesoarchean anticlinorium across the Berens River plutonic complex and 2) a broad Neoarchean transpressive zone of SE-trending dextral transcurrent shear zones and sygmoidal plutonic lozenges. This broad zone of deformation terminates and deflects southwards into the north-trending chain of greenstone belts through Berens River and McInnes Lake. These belts effectively acted as a buttress to the younger deformation, evident from aeromagnetic patterns. The region east of the belts is dominated by semi-circular batholiths. Sheet-like, Neoarchean felsic intrusions separate the Berens River, McInnes and Hornby belts and appear to have been emplaced during and late to the regional SE-trending D_2 deformation. These insights arose from recent bedrock mapping under the Far North Geological Mapping Initiative in the McInnes Lake and Berens River areas. The foliation and bedding within the Berens River area trend in a NNE direction and dip steeply west. The structural history of the area shows a D_1 shortening producing elongation of the belts. There was subsequent extensive plutonism, which likely occurred within the mid to upper crust creating upper greenschist to upper amphibolite assemblages in the volcanic and sedimentary rocks as well as the formation of migmatites. The D_2 structural event is a regional transpressive shortening highlighted by SE-trending, dextral shears and centimetre to metre-scale folds in supracrustal rocks. D_2 stretching lineations and Z fold axes plunge moderately to steeply southward. The axial planes of these folds range from counter clockwise to parallel to the penetrative foliation reflecting intense progressive shear strain as the fold axes rotated towards the foliation. The deformation was completed prior to ca. 2.696 Ga, the crystallization age of the Frame Lake pluton that exhibits none of the regional deformation.

GIANT QUARTZ VEINS WITHIN THE GREAT BEAR MAGMATIC ZONE, AN EXAMPLE FROM THE NICO DEPOSIT

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The Great Bear magmatic zone (GBMZ) is the central tectonic subdivision of the Bear Province and consists of Paleoproterozoic calc-alkaline intrusive and extrusive rocks west of the Wopmay fault zone, a major crustal suture. Within the GBMZ there are approximately 80 giant quartz vein and stockwork zones of unknown age and origin. These quartz vein zones can be up to 100 m wide and traceable for over 30 km, crosscutting magmatic and supracrustal rocks of the area. Throughout the GBMZ known mineralization occurs proximal to vein zones; however, whether or not the veins are genetically related to the mineralization remains unclear. For instance, veins are located near two advanced exploration projects, NICO, a Co-Au-Bi deposit with mineral reserves of 22 Mt, and Sue-Dianne, a Cu-Ag deposit with mineral resources of 24 Mt. Some of the quartz veins, however, are barren. Eight giant quartz vein zones were sampled; these samples have been taken from veins associated with base metal mineralization (NICO, Sue-Dianne, “Fab” Lake), Uranium mineralized systems (Wopmay fault, Beaverlodge Lake) and barren veins (Hardisty Lake, Margaret Lake, and “Arm” Lake). The focus of this study is to constrain the paleoconditions of the fluids that deposited the quartz veins and to ascertain whether there are significant differences between veins that are proximal to mineralization versus veins that appear to be barren. Preliminary results of the giant quartz vein at NICO will be presented here.

NICO is considered Canada’s preeminent IOCG deposit. Less than 400 m north of the deposit occurs a giant quartz vein. This vein zone is 25 m wide and trends 050° over 4 km. The vein zone at NICO shows a variety of textures and crosscutting relationships with at least two distinct episodes of veining. Early veining is represented by multidirectional stockworks of cloudy to clear quartz with strongly silicified and hydrothermally altered host rock. The following stages exhibit thicker (10-15 cm) blue-gray quartz veins and milky-white euhedral coxcomb quartz crystals. Late stage veining contains crustiform-like banding in which each band is 1-2 cm in width with a compound width of 35 cm. Preliminary microthermometric data will be presented and will constrain the temperature, pressure, and salinity of the fluids that formed the veins at NICO. These findings will also be compared to the other giant vein zone localities in order to develop a tentative model for the relationship to these giant quartz veins and mineralization in the GBMZ.

CORUNDUM IN ECLOGITIC MANTLE

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The objective of this study is to determine the origin of corundum recovered from the Yogo dike in central Montana. The Yogo dike is situated ~95 km southeast of Great Falls on the eastern edge of the Little Belt Mountains. The dike is the only known corundum-bearing member of the Central Montana alkalic province and is classified as an ultramafic lamprophyre. A collection of 210 corundum crystals from Yogo have been examined and sorted using an optical microscope. Mineral inclusions observed include rutile, garnet and Ni-rich pyrite.

Rutile is the most common mineral found as inclusions in the Yogo corundum. The inclusions are large (0.25 - 1 mm), euhedral to subhedral, and dark orange to brown in colour. Needles of exsolved rutile are very rare. Eighteen rutile grains from six corundum crystals were analyzed. The inclusions are Fe-rich (1.11 wt.%) with minor amounts of Nb_2O_5 (0.22 wt.%), Al_2O_3 (0.16 wt.%), and Cr_2O_3 (0.06 wt.%). A rutile U-Pb age of 46.6 ± 2.3 Ma was obtained. This age overlaps within error the 48.66 ± 0.06 Ma emplacement age of the dike. We believe that the rutile U-Pb age reflects the emplacement of the magma and that the corundum was formed at temperatures above 450°C, the closing temperature of rutile.

Garnet inclusions were found in nine of the corundum crystals. The inclusions are subhedral to euhedral and pale reddish orange in colour. The Mg, Fe, Ca, Cr, Ti and Na values of garnets can be used to distinguish between different parageneses. The garnet inclusions in Yogo corundum have low concentrations of Cr_2O_3 (0.02 wt.%), TiO_2 (0.12 wt.%) and NaO (0.02 wt.%) with MgO, FeOT, and CaO contents of 10.7, 13.8 and 11.0 wt.%, respectively. The low Cr contents of the garnet and rutile inclusions indicate a low-Cr environment. In terms of the three end-members pyrope, almandine and grossular the garnet inclusions have the composition: 30.99% pyrope, 38.33% almandine, and 30.68% grossular. This indicates that the garnet inclusions were formed in the mantle in Group II eclogite (B) and that the corundum is xenocrystic in the melt.

MINERAL PLACERS IN A SEQUENCE STRATIGRAPHIC FRAMEWORK

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Mineral placers (“reefs”) may be studied within the framework of sequence stratigraphy, as they tend to be associated with specific sequence stratigraphic surfaces. Understanding the origin of each individual placer is the key for the strategy of exploration of that particular deposit, because both the

distribution and the changes in grades along dip are a function of its genesis. Most placers represent lag deposits associated with one of the following three types of unconformities: the "subaerial unconformity", which forms by processes of fluvial or wind degradation in the nonmarine environment during base-level fall; the "regressive surface of marine erosion", which forms by wave scouring in the shallow-water environment during base-level fall; and the "transgressive ravinement surface" which forms by processes of tidal or wave scouring in the coastal to shallow-water environment during base-level rise and shoreline transgression.

Facies relationships across these unconformity surfaces are critical to establish their nature and sequence stratigraphic significance, to evaluate the distribution of the associated placers within the basin, and to predict changes in grades and placer quality along the depositional dip. As a general principle, the thickness and textural maturity of the lag deposit are proportional to the amount of erosion during the formation of each particular unconformity, and also to the time available for sediment reworking. In the case of subaerial unconformities, the levels of downcutting and reworking change along dip depending on factors such as landscape gradients and associated fluvial energy, sediment supply, and the mechanism controlling base-level fall. If the fall in base level is controlled by differential uplift (e.g., isostatic rebound in foreland basins), then placers may develop best in the proximal parts of the basin, where the rates of uplift are highest. Such reefs loose quality basinward, where the amounts of uplift and reworking decrease. If the fall in base level is controlled by sea-level change, then the amounts of downcutting and reworking increase in a basinward direction. Such reefs not only loose quality upstream, but they thin and ultimately disappear altogether beyond the area of influence of sea-level changes. Depending on the distance between the paleo-shoreline and the proximal rim of the basin, such placers may not have a physical expression along the basin margins, and may be missed if exploration is solely based on mapping basin-margin unconformities. Examples from the Witwatersrand Basin illustrate these concepts.

ASSESSING THE ENVIRONMENTAL IMPACTS OF NATURAL GAS FROM COAL (NGC) EXPLORATION IN ALBERTA: RELATIONSHIP BETWEEN THE GEOCHEMISTRY OF COAL-BEARING STRATA, PRODUCED WATER AND GROUND WATER

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Conventional gas reserves in Alberta are expected to decline in the next decade. This prediction has led to the exploitation of other sources of energy, such as natural gas from coal (NGC), otherwise known as coalbed methane (CBM). The exploration of NGC will also lead to the decrease of uncontrolled methane released into the atmosphere. The use of NGC can decrease the amount of other Greenhouse Gases in the atmosphere, such as CO_2. Alberta's diverse geology and its vast coal fields have allowed for the exploration of NGC since the late 1980's and since then, approximately 81% of the gas produced in the Western Canada Sedimentary Basin was from Alberta, 15 % from British Columbia, and 3% from Saskatchewan.

The underlying hypothesis of this project is that the composition of produced waters may be impacted by the depositional environment of coal-bearing strata, and may be contaminating regional groundwater. The data collected in this study will be used to create a database of guidelines for coalbed methane exploration.

In order to characterize the depositional environment of the coalbeds, the boron, petrology, and carbon/sulfur isotopes of the coal is assessed. The produced and ground water are being analyzed for their isotopic composition (sulfur, dissolved inorganic carbon, hydrogen and oxygen, and nitrogen). This will give us insight on the biogeochemical processes that the water by have undergone.

In order to assess the relationship between the chemistry of the coal, produced waters and groundwater, the chemical composition of the samples are compared. The enrichment of elements in the produced water relative to the associated ground water and coals is determined by comparing the rare earth elements. Subsequently, the dissolved constituents and the trace metal content of the waters are compared to the freshwater guidelines. The water samples are also analyzed for their speciation and complexation of arsenic and chromium, as this can give insight on the bioavailability and ecotoxicity of these elements.

DEVELOPING A DATA INTEGRATION TOOL FOR MINERAL EXPLORATION TARGET MAPPING WITH EMPHASIS ON RELIABILITY AND UNCERTAINTY

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Defining the target areas for mineral exploration involves predicting the location, size and grade of undiscovered deposits in a study area. Methodologies range from simple heuristic evaluation of expert opinion with little to no formal data compilation, to sophisticated multi-disciplinary procedures combining geological and mathematical models with complex databases using advanced software and hardware. Regardless of the methodology, prediction automatically introduces uncertainty. The degree of this uncertainty is controlled by the level of geoscience knowledge and by the modeling process. As in any prediction of a hidden asset, understanding the uncertainty of the prediction is key to assessing the reliability of the identified exploration targets. Although traditionally, much emphasis has been placed on "how to produce mineral target maps", the main concern of this study is "how to evaluate/validate the uncertainty of the prediction maps". Ironically, the cost of generating a mineral target map depends greatly on the level of uncertainty that is acceptable to a particular exploration company. Among several ways to assess the uncertainty, we have evaluated the target map in terms of its success in predicting the next discovery. Using the uncertainty estimated, the probability of the next discovery in the target area was also estimated. To illustrate the methodology developed, we have selected two case studies, one concerning diamond exploration in the Lac de Gras area of Slave Province, and the other concerning exploration for iron-formation-hosted gold in central Western Churchill Province.

MINING MATTERS: EDUCATION, TRAINING AND CAREERS

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Prospectors and Developers Association of Canada Mining Matters (Mining Matters) is a charitable organization that has reached more than 400,000 teachers and students through educational resources that promote the importance of rocks, metals, minerals, mining and Canada's geology.

Partnerships between educators, mining and aggregate industry associations, corporations, and government have lead to the development of a series of educational resources to fulfill the challenging curriculum requirements and engage and support teachers with professional development opportunities. Through partnerships, Mining Matters also strives to promote awareness about the modern mining industry, the range of exciting career opportunities it offers, and the kind of education it requires.

Giving students the opportunity to experience Earth Science and mining-related activities is at the heart of the educational outreach programs provided by Mining Matters. Examples from Mining Matters most recent outreach endeavours and future projects will be highlighted including:

Discovering Diamonds

A unique Canadian Earth Science high school curriculum resource designed to teach teachers and students about Canadian diamonds. The goal of this resource is to use diamonds as an integrating theme through with to study the concepts expected in a senior Earth Science course. Using authentic data and donated materials from government and industry, learning activities have been designed to illustrate real world experience with diamonds – not just theories and concepts.

Northern Outreach to First Nation Youth Network Project

Partnering with Shibogama Kanawayneemidowin First Nation Youth Network Project – a non-profit charitable organization, whose mandate is to proactively address and manage health, education, and social issues affecting youth in First Nation communities within several northern Ontario communities – Mining Matters will deliver interactive workshops during a two week camp and align youth with mentors involved in the minerals industry and the related service/supply sector.

Mining New Opportunities

The Ontario Mining Association (OMA) recently produced Mining New Opportunities a film offered in five languages - Cree, Oji-Cree, Ojibway, English and French. Created by Big Soul, an Aboriginal television production company, Mining New Opportunities helps First Nations residents gain a better understanding of the mineral industry, employment and the entrepreneurial opportunities available. Mining Matters partnered with the OMA to develop the Teacher's Resource and Speaker's Guide for Mining New Opportunities.

NEW PETROLOGICAL AND GEOCHEMICAL DATA FROM THE ENNADAI GREENSTONE BELT (SASK.) AND ITS RELATIONSHIP TO THE CENTRAL HEARNE SUPRACRUSTAL BELT (NWT AND NUNAVUT)

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Historically referred to as the Ennadai-Rankin or Rankin-Ennadai greenstone belt, this supracrustal sequence is now redefined as six belts of minor to extensive expression: Ennadai (northern Saskatchewan and southern NWT), Central Hearne (NWT and Nunavut), MacQuoid, Angikuni, Yathkyed and Josephine River Beds.

The aims of this study are to present new petrological and geochemical data from the Saskatchewan segment of the Ennadai greenstone belt and to identify the original tectonic setting of the supracrustal sequence. Existing data from the literature for the Central Hearne supracrustal belt (CHSB) are used mainly for comparative purposes.

Petrologically, the Ennadai greenstone belt exposed in northern Saskatchewan is composed of a range of rock-types: (picro-) basalt to rhyolite, mafic-felsic volcaniclastic rocks, pillowed and more massive lava flows, and their hypabyssal equivalents. The mineralogy suggests that these rocks have attained at least greenschist to lower amphibolite facies metamorphism.

Ennadai samples range from subalkaline (predominantly) to alkaline; many represent metamorphosed equivalents of Fe-rich tholeiite. Trace element ratios favour their generation in a back-arc basin environment; they appear to have more affinity with enriched MORB and oceanic island tholeiites generated from a slightly depleted mantle source. Chondrite-normalised REE patterns are essentially flat, at 6-30 × chondritic values, with a slight tendency towards light-REE enrichment, and positive or negative Eu anomalies. The trace element chemistries of these sample are complex and the petrogenesis of these rocks may involve a variety of mantle sources, including: MORB, OIB, and a subduction-zone component. Sm-Nd whole-rock isotope analyses indicate that the rocks are mostly juvenile. Nd-Sr isotope analyses, of a wide variety of rock types from the Ennadai supracrustal belt exhibit a large spread of isotopic compositions (0.5113 – 0.5127 for $^{143}Nd/^{144}Nd$ ratio), and on a plot of $^{143}Nd/^{144}Nd$ vs $^{87}Sr/^{86}Sr$ they occupy a considerable area within the field for oceanic island basalt.

In conclusion, the results of this study are strikingly similar to those published data relating to the CHSB, and as such, these two sequences are thought to have been generated in similar, possible related, tectonic environments towards the end of the Archaean.

EVALUATION OF THE HORN PLATEAU FORMATION, MACKENZIE DISTRICT, NWT: A CASE STUDY OF DEVONIAN REEF GROWTH NORTH OF THE WESTERN CANADIAN SEDIMENTARY BASIN

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Devonian reefs, including those in western Canada, host some of the largest hydrocarbon resources in the world. Despite this, many questions remain with respect to the environments that favoured Devonian reef development and the subsequent emplacement of hydrocarbons. The Horn Plateau Formation (HPF), which includes a series of isolated reef buildups (60 to 130 m thick), surrounded by black shale, contains varying amounts of hydrocarbon. The formation outcrops ~180 km west of Yellowknife in the Northwest Territories, and from there, continues along a SW trend for ~320 km. The reefs in the HPF are unusual because (1) corals constructed the reefs in the NE part of the trend whereas those in the SW were built by stromatoporoids, (2) the fossils in the reefs have not been dissolved, and (3) the reefs have not been dolomitized. The transition from corals to stromatoporoids coupled with unparalleled preservation will allow insights into reef development that are impossible to gather from the highly altered reefs normally found in Devonian strata of western Canada. Several cores have been drilled through the HPF and have been analyzed to (1) delineate the paleogeographic conditions of reef growth, (2) determine the environmental factors that controlled growth of the coral-dominated as opposed to stromatoporoid-dominated reefs, and (3) resolve the post-depositional processes (i.e. diagenetic alteration) that affected the reefs.

Examination of the cores has revealed that the Horn Plateau Formation reefs are dissimilar in structure and biological composition, than other age-equivalent reefs (e.g. Keg River Formation) in the Western Canadian Sedimentary Basin. These differences can be attributed to the paleogeographic location of the HPF reefs and the surrounding environmental conditions. The HPF reefs were located in the open ocean, north of the Presqu'ile Barrier, which blocked the open ocean from the interior shallow basin. The sedimentary facies present in the HPF reefs reflect the higher energy conditions associated with their location in the open ocean. Preliminary isotopic analysis ($\delta^{18}O_{PDB}$, $\delta^{13}C_{PDB}$, and $\delta^{18}O_{SMOW}$) of unaltered calcite from the HPF has indicated that ocean temperatures were lower than in the shallow basin south of the Presqu'ile Barrier. The HPF has not been dolomitized and shows relatively little diagenetic alteration. Post-depositional processes affecting the Horn Plateau Formation reefs were minimal and influenced their potential as hydrocarbon reservoirs.

ARCHEAN GOLD SETTINGS OF THE KAMINAK GREENSTONE BELT

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The Kaminak greenstone belt is situated in the Hearne Structural Sub-Province within the Western Churchill Province. Located 100 km south of Rankin Inlet, it borders Hudson Bay and stretches southwest to Henik Lake. The eastern most segment stretching from Kaminak Lake to Pork Peninsula represents a near stable Neoarchean craton nucleus with a similar geological history to the Abitibi greenstone belt in the Superior Province.

Preservation of a primitive volcanic arc assemblage is observed in syn-volcanic tonalite plutons and gabbroic sills within the volcanic succession. Orogenic granodiorite emplacement syn-dates upright folding and terminates with a regional extensive ash flow tuff eruption at various felsic centers. High level porphyry plug emplacement is located at several of the felsic centers including Quartzite Lake, Fat Lake, Big Lake, Gill Lake and Wilson Bay. A majority of these strongly zoned porphyries either host or are spatially associated with known Au prospects and showings situated along regional shear zones. A late 2660 Ma alkaline igneous phase accounts for widespread lamprophyric dyking and the Kaminak Alkaline Complex. Polymictic granite cobble conglomerates are coeval in age with late stage alkaline magmatism of which both are cross cut by dextral shear zones. These shear zones are in turn crosscut by undeformed 2450 Ma Kaminak dykes. Porphyry emplacement, late alkaline magmatism along with coeval conglomerates accompanied by late dextral shearing is analogous to the geology and structural controls located in the Abitibi gold camps.

High level porphyries intruding greenschist facies, located along belt scale retrograde regional shear systems, are tied to megacrystic granite stocks with well developed thermal hornblende aureoles. These systems define the crustal continuum involved in gold concentration. Devolitization of the orogenic structure is key in the fluidization of post peak metamorphic shear systems. Reactivation of Archean breaks during the Proterozoic along with subsequent tectonics has preserved infolds in the Hurwitz, Kaminak and White Rock synclines. These settings account for the majority of gold prospects occurring proximal to the Hurwitz.

GEOLOGY AND GEOCHEMISTRY OF THE VANCE SEAMOUNT CHAIN NEAR THE JUAN DE FUCA RIDGE

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The Vance Seamounts comprise a ~57 km-long, NW-SE trending chain of near-ridge seamounts located ~19 km west of the Juan de Fuca Ridge on 0.8-2.6 Ma Pacific Plate crust. The six volcanoes (Vance A, B, C, E/D, F, G) have an average height of 875 km, an average volume of 34 km^3, and are found between 1460-3080 m below sea level. Geologic evidence suggests the seamount chain is progressively younger from Vance A in the NW toward Vance G in the SE. The morphology of the seamounts, excluding Vance B, consists of steep sides, flat tops, and nested calderas offset toward the ridge axis. Vance B is a low-lying area of small volcanic cones and pillow-lava ridges. Sulphide chimney fragments have been recovered from Vance A and E, indicating some hydrothermal venting has occurred.

During the summer of 2006, the R/V Western Flyer and ROV Tiburon completed six dives, each to a different seamount. Caldera floors consist of flat-lying volcaniclastite and variable amounts of overlying pelagic sediment. Locally, post-caldera pillow flows protrude through the sediment. Caldera walls consist of interbedded massive flows and pillow basalts, with talus accumulated at the base. Volcanic sandstone and siltstone are found at the caldera rims. Rock samples were collected from each seamount, and glassy rinds were sub-sampled for geochemical analysis. The geochemical data show there are variations both within each seamount and between the seamounts comprising the Vance chain. Major-element data indicate all lavas are subalkaline MOR-basalts, though data also provide evidence for fractionation (Mg# 0.56-0.70) and for both very depleted and slightly enriched sources (0.02-0.31 wt.% K_2O). Trace-element data show depletion of LREE relative to HREE, and correlations can be made between isotope ratios and trace element concentrations. New Sr-Nd-Pb isotope data from 24 glass samples show variations in source characteristics ($^{87}Sr/^{86}Sr$ = 0.702477-0.703083; $^{206}Pb/^{204}Pb$ = 18.262-18.580; and $^{143}Nd/^{144}Nd$ = 0.513052-0.513180). Variations are just outside of analytical error for many of the seamounts. Vance A and B, the oldest seamounts, show the strongest contrast in chemistry and morphology. All samples with K_20 > 0.2 wt.% were collected from Vance A, consistent with an enriched source. Samples from Vance B, the only seamount with no clear evidence for a large magma chamber, have distinctly low CaO/Al_2O_3 ratios, consistent with high-pressure clinopyroxene fractionation.

LOOKING FOR ATYPICAL MINERAL POTENTIAL – THE ROLE OF IRON OXIDE COPPER-GOLD (URANIUM) DEPOSITS IN SUSTAINABLE RESOURCE DEVELOPMENT IN CANADA

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Atypical in terms of mineralization, commodities and host settings, Iron Oxide Copper-Gold (Uranium-Ag-Co-Bi) deposits can be nation builders and have recently emerged as a deposit-type of choice for exploration in Canada. The 3.81 billions tonnes Olympic Dam deposit, ranks 1st in world Uranium resources, 4th in gold and 4th in copper. Canada has no IOCG mine, yet, but it has stunningly exposed IOCG deposits under feasibility study and advanced exploration in the Great Bear Magmatic Zone, NWT. Moreover, its ancestral active continental margins, now frontier felsic-to-intermediate volcano-plutonic terranes and their metamorphic derivatives, have been identified by the industry as prime targets.

IOCG deposits are “non-traditional” metallic deposits in that they have oxide-rich rather than sulphide-rich ore zones cryptically disseminated over kilometres within barren iron oxide and alkali-altered host rocks. In contrast to other deposit types, they are associated with voluminous granitic plutonic suites rather than with causative sedimentary basins or volcanic belts. This non-traditional character challenges current methods of investigation and forces us to: 1) re-evaluate entire new geological terrains, 2) take new research avenues in economic geology to develop adequate metallogenic models for exploration, 3) adapt exploration expertise and strategies, 4) reassess former mines and remediation practices and decisions, and 5) establish new and progressive land use policies that open frontier lands to the next generation of sustainable resource development partnerships.

Prospective settings remain largely under mapped, under explored and poorly studied even though the IOCG deposit type was recognized in other parts of the world by the early 1990s. Critical knowledge gaps on the key alteration and mineralization types increase risk to exploration, and impair informed mineral

resources assessment and land use decisions. Fortunately, the large alteration footprint allows effective regional scoping of prospective territories for IOCG signatures and, within such systems, points to mineralization. In many former deposits, mining was restricted to relatively small and peripheral high-grade copper, uranium and/or silver rich veins. Current recognition of their host rocks as part of large IOCG systems has implication for both exploration and environmental baseline studies as the extent over which areas can be naturally enriched in metals is large – 10's of square km. Moreover, old mine tailings may now be ore themselves. Though much work is needed before we can assess the mineral resource endowment of these non-traditional exploration terranes, current knowledge provides informed decisions at our doorstep.

ALTERATION VECTORING AND PRACTICAL GUIDES FOR IOCG-U EXPLORATION IN UNDER EXPLORED TERRANES: INSIGHTS FROM THE GREAT BEAR MAGMATIC ZONE, NORTHWEST TERRITORIES

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Exploring for polymetallic iron oxide copper-gold/uranium (IOCG/U) deposits in Canada commonly involves grassroots exploration of felsic to intermediate volcano-plutonic belts formed in continental magmatic arcs. Targeting these regional systems relies heavily on hydrothermal alteration vectoring and systematic protocols during field work. The Great Bear Magmatic Zone (NWT) offers stunning cross-sectional exposures of IOCG/U alteration patterns. Those associated with deposits, such as Port Radium and Contact Lake (past production of 15,000,000 lbs U_3O_8 and ~32,000,000 Oz Ag) and NICO (total mineral reserve: 21.8 Mt@ 1.08 g/t Au, 0.16 % Bi, 0.13 % Co), provide means to refine the zoning models and vectors to ores developed from reference but poorly exposed world-class deposits. Lesser explored systems such as DeVries and Fab lakes provide testing ground for the defined vectors. Collectively, these studies indicate that mapping of alteration zones can point to mineralization.

Sodic alteration zones (including albitites) develop distal to mineralization and most proximal to the associated intrusive heat sources. Such alteration also occurs as relict patches within extensive, non-productive, calcic-iron (magnetite-actinolite-apatite) alteration core-zones. Subordinate potassic alteration is common within these zones.

Where K-feldspar (or biotite) alteration becomes intensive (with magnetite at first), brecciation and polymetallic sulphide enrichments generally follow. Locally, skarn-like, calc-silicate alteration may overprint early potassic alteration and is associated with several variations of igneous-hydrothermal mineralization. K-feldspar-bearing overprint may occur. Hematite alteration is late stage, either pervasive, disseminated or in veins. In some of the larger hydrothermal systems, distal phyllic (quartz-sericite-pyrite) and propyllitic (chlorite-epidote-carbonate ± albite) alteration may be present and very extensive. Alteration types that host uranium are characterized by distal hematite and/or quartz-carbonate-hematite, ± potassic-rich zones, however, the occurrence of uranium oxide minerals is not as predictable in the field as the sulphide zones. Pervasive textural pseudomorphing of host rocks, striking grain coarsening alteration processes and cryptic potassic alteration can make it difficult to fully appreciate alteration patterns. In earthy hematite, skarn, biotite-amphibole-magnetite and phyllic alteration types, field measurements of K-Th-U with a portable spectrometer help identify otherwise cryptic potassic alteration, a style of alteration known to be associated with mineralization in the studied deposits.

HUDSONIAN REGIONAL METAMORPHISM OF PALEOPROTEROZOIC SUPRACRUSTALS IN THE THOMPSON NICKEL BELT, SUPERIOR BOUNDARY ZONE, MANITOBA

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The Thompson Nickel Belt is part of the Superior Boundary Zone, a portion of the collisional zone between the Superior craton and the internal zone of the Trans-Hudson Orogen. Previous regional studies in the belt have concentrated on structural and tectonic interpretations. A regional metamorphic study commenced during the summer of 2006 with field investigations into the Hudsonian metamorphism of Paleoproterozoic supracrustal rocks in the belt. Outcrops were examined throughout the exposed portions of the belt for mineral assemblages useful for temperature-pressure determination. Along the eastern side of the belt, orthopyroxene was identified in Ospwagan Group metasediments from Nichols and Phillips lakes and may also be present in garnet-bearing metadiorite at Thompson Mine suggesting granulite grade metamorphism (> 800°C, uncertain pressure). K-feldspar-bearing metasediments from the Hambone and Setting lake areas, in the south of the belt, contain sillimanite intergrown with biotite along the foliation and an absence of muscovite suggesting grades of upper amphibolite facies. Sillimanite is common as discrete knots at Mid Lake, central Thompson Nickel Belt. In the north, at Moak Lake, sillimanite knots contain possible andalusite cores suggesting conditions near the andalusite-sillimanite phase transition and middle amphibolite facies grade. Along the western edge of the belt at Ospwagan Lake, metasediments are found to be andalusite-bearing. Staurolite- and andalusite-bearing metapelites (middle amphibolite facies) and non-migmatitic K-feldspar- and sillimanite-bearing metapelites (upper amphibolite facies) are present in close proximity (~200 m separation) at Pipe Mine, which is also situated along the west side of the belt. This makes interpretation of metamorphic conditions difficult, although both assemblages indicate pressures of 3.5-4 kbar. The distribution of higher grade and lower grade rocks within the belt suggest that grades may be higher along the eastern side and southern end of the Thompson Nickel Belt and lower along the western side and northern end of the belt.

THE IMPORTANCE OF TUFFACEOUS FELSIC UNITS AS STRATIGRAPHIC MARKERS IN THE KAM GROUP, YELLOWKNIFE VOLCANIC BELT

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The Archean Kam Group of the Yellowknife volcanic belt has traditionally been divided into four formations. These are, from oldest to youngest, the Chan, Crestaurum, Townsite, and Yellowknife Bay. Key marker horizons between the formations include felsic tuffs that consist of both a volcaniclastic and a cherty sedimentary component. These tuffs and associated formation boundaries have been correlated across the numerous Proterozoic brittle faults. In particular, the base of the Crestaurum formation is defined by the Ranney chert and tuff, two laterally persistent but discontinuous bands that extend from Joe Lake in the west to Daigle Lake in the northeast. Cherty tuff

bands in the Crestaurum Mine area (Crestaurum chert) are correlated with the Ranney chert. Felsic tuffaceous beds that occur stratigraphically higher in the volcanic pile are commonly collectively termed the Cemetary Tuff. U-Pb zircon dating of tuffs yield discordant and variable ages for the Ranney chert (2783-2842 Ma) but more concordant and tightly-clustered ages for the Cemetary tuffs (2712-2702 Ma). Geochemically, the Ranney chert is consistently different from the overlying Cemetary Tuffs: the Ranney chert has dramatically low rare earth element abundances, lacks a negative Eu anomaly, and generally has Nd isotope ratios greater than chondritic, whereas the Cemetary tuffs have higher rare earth element abundances, negative Eu anomalies, and Nd isotope ratios that tend to be lower than chondritic. The contrast in zircon populations and geochemistry indicate a different source rock(s) for the Ranney chert and Cemetary tuffs. The U-Pb zircon systematics of the Ranney chert are similar to that of a rhyodacite unit in the Central Slave Cover Group at Dwyer Lake, directly underlying the Kam Group, suggesting that the Ranney chert includes detritus from pre-Yellowknife volcanic belt rocks. In contrast, the Cemetary tuffs are geochemically identical to felsic volcanic rocks in the overlying Townsite formation, which includes volcano-sedimentary material that is primarily syn-volcanic. The Ranney chert – Dwyer rhyodacite similarity suggests that volcanic rocks of the Chan Formation may pre-date most of the overlying Crestaurum Formation volcanic rocks by at least 70 Ma. Tuffs mapped as Ranney chert at Joe Lake and in Fred Henne Park have chemical characteristics similar to the Cemetary tuffs rather than Ranney chert. We interpret this to indicate that the basal formation of the Kam Group (i.e., Chan Formation) is not present west and south of the West Bay Fault.

COASTAL EROSION ALONG THE YUKON COASTAL PLAIN

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The Arctic coastal environment is extremely susceptible to changes in environmental forcings because it is affected on three fronts: by oceanic, atmospheric, and terrestrial processes. The Canadian Beaufort Sea coast has been identified as highly vulnerable to the effects of sea-level rise and climate warming, but how exactly will coastal systems in this ice-rich area be affected? Because erosion along arctic coasts is both a thermal and a mechanical process, erosion rates are a function of the composition and morphology of coastal features, as well as wave energy. In order to predict how climate changes are likely to impact on this system, this study provides a synthesis of the environmental and physical conditions along the Yukon Coastal Plain and, using erosion models, shows how they interact with coastal processes.

Elements of the regional climate in the southern Beaufort Sea that are relevant to coastal dynamics are presented, with the most important being fetch and wind. The resulting wave climate is described, which determines how much wave energy is available for coastal erosion, as well as where and when this energy is expended. The shape and composition of the nearshore zone and the coast itself have a bearing on the response to this input of energy, so the variation in coastal morphology and ground ice contents for the Yukon Coastal Plain and their effect on the coastal dynamics of this region are therefore examined. The current status of these processes in the Canadian Beaufort Sea and the relationships among them is evaluated. Predictions are provided of the environmental forcings that will alter the system including changes in the extent and duration of sea ice and landfast ice, storminess, air and water temperatures, and sea levels. These are used as inputs to the erosion models to predict the location and rate of future erosion.

LANDSLIDE INVENTORY ALONG A PIPELINE CORRIDOR IN THE MACKENZIE VALLEY, NORTHWEST TERRITORIES

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A regional landslide mapping project was initiated by Natural Resources Canada to develop a synthesis of the types, regional distribution, and controlling factors of landslides in the Mackenzie Valley through a compilation of existing and new spatial data.

The Mackenzie Valley study area encompasses a corridor extending to 20 km on either side of the Inuvik - Tulita section of a newly proposed pipeline route, with a length of 540 km and an area of 24,000 km^2. This also includes the Ramparts and the Thunder River regions, both known for widespread landsliding. The study area is covered by unconsolidated sediments (99%), which are dominated by morainal (60%), lacustrine (18%), and alluvial (10%) deposits. Three types of permafrost were mapped: i) continuous, ii) extensive discontinuous, and iii) intermediate discontinuous.

Using classical air photo interpretation techniques, a preliminary inventory of 1,807 landslides and other natural terrain hazard features has been identified using 665 colour air photos (1:30,000 scale) acquired in 2004. The digital air photos that contained at least one landslide were then orthorectified. The landslide limits were digitized from the orthophotos and catalogued in the Mackenzie Valley landslide Spatial Database. For each landslide feature, the following attributes were recorded: unique identifier, landslide type, size (area), location, morphological parameters, relative age, activity, material, flight line, air photo number, and topographic map sheet number. A collection of several hundred photographs of landslides, taken while carrying out field surveys in 2005 and 2006, completes the database.

Using the spatial database attributes, landslide mapping and statistical analyses were performed to characterise the landslide distribution. The results indicate an average density of one landslide per 5 km^2 and show that the dominant landslide types are retrogressive thaw flows (28%) and active layer detachments (25%). Rock falls (10%), debris flows (10%), earth slides (9%), surficial landslides (6%), and retrogressive thaw slides (5%) are lesser represented. About 46% of all landslides took place in morainal deposits, 19% in lacustrine sediments, 14% in bedrock, and 13% in glaciofluvial sediments. The relative age of landslides was estimated based on tone, texture, and vegetation re-growth attributes, where 39% were classified old (>50 years old), 39% intermediate (10-50 years old), and 22% recent (<10 years old).

OXIDATION STATE OF THE LITHOSPHERIC MANTLE BENEATH THE CENTRAL SLAVE CRATON

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We have applied a newly developed technique for measuring ferric iron with the electron microprobe to garnet peridotite xenoliths from the A154 North and South pipes at Diavik Diamond Mines in the central portion of the Slave Craton. The calculated equilibrium oxygen fugacity (f_{O2}) conditions of these samples range from ~FMQ (the f_{O2} defined by the fayalite-magnetite-quartz buffer) to 5.5 log bar units below FMQ (Δlog FMQ=-5.5). These data extend the previously observed range of f_{O2} from garnet peridotites to both more oxidized and more reduced conditions. An overall trend of decreasing f_{O2} with increasing depth from ca. Δlog FMQ=0 at 80 km to Δlog FMQ=-4 at 220 km is observed; below ~180 km depth increasing scatter in the data set blurs possible correlations with depth.

This depth-f_{O2} trend intersects the EMOD/G buffer reaction that defines the maximum stability of native carbon in peridotite (Eggler and Baker, 1982) at depth (~135 km) just above the diamond stability field. This implies that beneath the Central Slave Craton graphite could only be stable in a very restricted depth interval from ~135 to 145 km. At <135 km depth, the peridotitic samples are oxidized to f_{O2} values above the EMOD/G buffer implying that carbonate is the stable carbon species in the shallower portions of the lithosphere. Below the graphite-diamond transition at 145 km, diamond is stable relative to carbonate.

Similar studies on xenoliths from other localities on the Slave (Jericho and Gahcho Kue kimberlites, McCammon and Kopylova, 2004) and the Kaapvaal (kimberlites in Lesotho and the Kimberley area, Woodland and Koch, 2003) cratons suggest that subcratonic lithospheric mantle generally becomes increasingly reducing with depth. Although following the same general trend, the lithospheric mantle beneath Diavik is more oxidized than any of the other sections of lithosphere measured to date. However, in all cases studied so far, below the depth of graphite-diamond transition the lithospheric mantle is reduced enough to favor the presence of diamond relative to carbonate.

RESEARCH AND DEVELOPMENT STUDIES OF THE MALLIK GAS HYDRATE DEPOSIT, MACKENZIE DELTA, NWT

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The Mallik gas hydrate field is located at the northeastern edge of the Mackenzie Delta, NWT. Ground temperature and pressure conditions are similar to many offshore gas hydrate settings, although the geothermal regime at Mallik is controlled by the presence of approximately 600 m of permafrost rather than by cold sea bottom temperatures. Quantitative well log analyses and core studies have identified numerous discrete gas-hydrate-bearing strata at depths between about 890 m to 1106 m. High gas hydrate saturations, in some cases exceeding 80% of sediment pore volume, establish the Mallik field as one of the most concentrated gas hydrate reservoirs worldwide. The availability of high-quality geologic and engineering data, favorable site logistics, and the similarity of the Mallik deposit to offshore gas hydrate occurrences, affords a number of unique research and development opportunities. In 1998, the Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) undertook the first gas hydrate drilling, coring, and geophysical characterization of a permafrost gas hydrate deposit. This was followed by another international research program in 2002, which included 7 partners from five countries. The primary goal of the Mallik 2002 Gas Hydrate Production Research Well Program was to conduct the first modern production testing of gas hydrates. A hallmark of the program was the adoption of an integrated multidisciplinary approach to science and engineering, which culminated in the successful drilling and completion of three research wells in a single winter season. The main production test well (Mallik 5L-38) was utilized for controlled pressure drawdown and thermal heating experiments designed to constrain the production characteristics of the Mallik reservoir. Two monitoring wells (Mallik 3L-38 and 4L-38) were employed for geothermal studies and cross-hole tomography. Continuous coring through the gas hydrate interval provided a representative suite of high-quality core samples, supporting a variety of novel field experiments, and subsequent specialized post-fieled laboratory studies.

Natural Resources Canada and Japan Oil Gas Minerals National Corporation are currently undertaking a new research program at Mallik which will include extended gas hydrate production testing and additional research and development. Year 1 field activities include completion of a production well and a monitoring well, followed by limited-duration production testing. Year 2 will consist primarily of an extended-duration production test and ancillary geophysical studies. Aurora Research Institute, the research and scientific arm of Aurora College is acting as the designated operator for the field program.

EXPERIENTIAL SCIENCE 10-20-30

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The Department of Education, Culture and Employment, for the NWT, is currently developing a new pathway for high school science education called Experiential Science. These courses, offered at grades 10, 11 and 12 respectively, are designed to engage students in hands on learning while applying scientific knowledge, processes and protocols in a context based learning environment. The program of studies is designed to appeal to a wide variety of students by providing learning opportunities that engage their own learning style. The curriculum for Experiential Science integrates Western science and Aboriginal knowledge and principles through field and laboratory experiences and applications. The program of studies investigates ecology and geology through the systems approach. Each course has a specific focus: Grade 10 - Arctic and Subarctic Terrestrial Systems; Grade 11 - Arctic and Subarctic Marine Systems; and Grade 12 - Arctic and Subarctic Freshwater Systems. A balance between classroom and field investigations allows students to learn in a dynamic environment, which fosters a better understanding of ecological and geological principles and processes.

TIMING OF GOLD MINERALIZATION AT THREE BLUFFS, COMMITTEE BAY GREENSTONE BELT, NUNAVUT

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The Three Bluffs gold discovery is among many that occur within the >300 km, northeast-trending Committee Bay greenstone belt and has the highest potential for economic gold mining. Mineralization in the Three Bluffs area is associated with iron formation units situated within parallel belts of supracrustal rocks belonging to the Prince Albert Group. The iron formation units are approximately 20m thick and are of both oxide- and silicate-facies. Gold mineralization is associated with silica flooding of the iron formation and a significant increase in pyrrhotite (with lesser pyrite, arsenopyrite). Visible gold typically occurs within these silica-flooded zones but can also occur intergrown with actinolite and/or arsenopyrite in less silicified zones. Gold is associated with later sulphide mineralization, both within the silica flooded zone and in the silicate iron formation. These observations suggest that gold mineralization is syn- or post-metamorphic.

Re-Os dating of euhedral arsenopyrite intergrown with gold within the iron formation suggest that gold mineralization was late in the metamorphic/tectonic evolution of the deposit from 1.7 to ~1.82Ga. Likewise, in-situ U-Pb laser ablation MC-ICP-MS dating of 11 monazites in 4 thin sections of metasediments interbedded with iron formation yielded concordant or near concordant analyses with a mean $^{207}Pb/^{206}Pb$ age of 1783.2 ± 6.1 Ma (2σ; n=16). These ages correspond well with the timing

of regional scale D_2 deformation associated with the Proterozoic Trans-Hudsonian orogeny.

The structure of Three Bluffs is interpreted as an upright isoclinal fold with a local core of iron formation; however, stratigraphic units are not symmetrically arranged about the axial plane giving the appearance of a homoclinal assemblage. The north limb of the fold generally has a higher degree of silica flooding with correspondingly higher gold grades toward the diorite body. The iron formation in this limb lies stratigraphically above a dacite horizon that sporadically re-occurs on the south limb. ID-TIMS U-Pb dating of zircons within the dacite reveal an igneous crystallization age of 2714.0 ± 1.8Ma.

The fold hinge in the iron formation has been removed by erosion in the western portion of the drill area, and has been truncated by a gently dipping diorite intrusion to the northeast. The diorite is slightly foliated near the edges but generally undeformed throughout. ID-TIMS dating of selected zircons within this body yielded an age of 2623.4 ± 4.1Ma. Therefore, even though the diorite body truncates a portion of the iron formation, later gold mineralization should continue, potentially expanding the size of the resource.

NEW AGES FOR PALEOPROTEROZOIC MAFIC INTRUSIONS IN THE WESTERN SLAVE PROVINCE AND THEIR POTENTIAL RELATIONSHIP TO TECTONIC EVENTS IN THE ADJACENT WOPMAY OROGEN.

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Mafic intrusions within Archean cratons provide an indirect record of the response of cratonic lithosphere to tectono-magmatic events occurring on, or adjacent to their margins. The western margin of the Slave craton underwent rifting and continental margin subsidence followed by subduction and collision in the interval ~2.1 Ga to 1.85 Ga. New U-Pb ages of mafic intrusions in the western and central Slave, including the Indin dykes at 2.108 Ga, the Booth River complex at 2.025 Ga, the NE-trending Ghost dykes at 1.884 Ga, and the Mara River sills within the Kilohigok basin at 1.870 Ga, provide a record of magmatism within the Slave craton spanning the formation and development of the Wopmay orogen to the west.

Rifting and continental margin initiation on the western margin of the Slave craton occurred by ~1.97 Ga (Bowring and Grotzinger, AJS, 1992). Mafic magmatic events at 2.108 Ga and 2.025 Ga within the craton may preserve a part of the magmatic record leading to the development of this margin. The mafic intrusive events at 1.884 Ga and 1.870 Ga occurred during the collisional phase of Wopmay orogen. The 1.884 Ga age of the Ghost dyke swarm in the SW Slave is contemporaneous with ages of the syn-collisional Hepburn Intrusive suite, and estimated age of the Morel sills, which were both intruded and deformed during west-directed subduction and collision of the Hottah terrane with the Slave craton between 1.89 and 1.88 Ga. In this scenario the Ghost swarm represents syn-collisional, lower-plate magmatism perhaps related to plate bending. A similar tectonic setting was inferred for the Morel sills and interpreted as lower-plate extensional magmatism due to slab-breakoff (Hildebrand and Bowring, Geology, 2003). The Mara River sills at 1.870 Ga are younger than the minimum age estimated for the Morel sills, and should not be correlated with them. The Mara River sills may be related to backarc magmatism contemporaneous with development of the Great Bear arc (1.878-1.855 Ga) above an east-directed subduction zone. The similarity of the ages of mafic intrusions to published ages of Paleoprotoreozoic eclogites within the central Slave lithosphere allows that some eclogite xenoliths may be samples of Paleoproterozic intrusions rather than underplated oceanic slabs.

INTACT PRECAMBRIAN CRATON AT SMITH SOUND (NARES STRAIT): LINCHPIN IN PALEOGEOGRAPHIC RECONSTRUCTIONS OF THE NORTH ATLANTIC — ARCTIC

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Canada (Ellesmere Island) and Greenland are in closest proximity in the far north at Nares Strait, the 500 km long, linear series of basins and narrow channels. Modern-day paleogeographic reconstructions continue to portray this seaway as a fundamental crustal break between North America and Greenland and the transform link between the oceanic areas of Baffin Bay and the Arctic Ocean. Restored paleopositions back into the Precambrian imply that neighbouring rocks on Ellesmere Island and northwestern Greenland developed far from each other and that Greenland moved as an independent plate both obliquely and perpendicularly with respect to Ellesmere Island before colliding in the Palaeogene. In kinematic models based on sea-floor spreading scenarios, Nares Strait is depicted as the site of major Cenozoic tectonism: transcurrent motion, subduction and continental collision.

At Smith Sound at the head of Baffin Bay, the geology of Canada and Greenland is in perfect harmony across the 40 km-wide seaway. This applies to the main provinces that record 2000 million years of Earth history, viz. the Paleoproterozoic Ellesmere–Inglefield mobile belt, the Mesoproterozoic Thule Basin, Neoproterozoic Franklin basic intrusions and the Lower Paleozoic cover sequence. A dominant feature is the intracratonic Thule Basin that straddles northern Baffin Bay and Smith Sound. It has a varied sedimentary–volcanic section (Thule Supergroup) that is exposed on the opposing coasts and is correlatable in detail; even down to individual basic sills and dykes. The northern margin of the basin, defined where the sediment prism drastically thins from kilometres to a few hundred metres, is aligned across the seaway. Recent geophysical data confirm the presence of the Thule Supergroup and basic dykes offshore. New fission track ages along a transect perpendicular to Smith Sound show no evidence of a Cenozoic thermotectonic regime as predicted by plate-tectonic models. The ages demonstrate a coherent evolution from Canada to Greenland, thus adding further evidence to an already overwhelming case that Smith Sound represents an intact lithotectonic crustal block unaffected by a major Cenozoic suture zone.

A pertinent question to ask this symposium is: Are we are making overall progress in understanding paleogeography and the earth processes involved when conventional reconstructions that bring Labrador and Greenland with their comparable geology closer together, at the same time completely dismember the well-ordered geology across a 40 km gap farther north? To reiterate, Smith Sound has to be acknowledged as an irrecusable linchpin in any paleogeographic reconstruction of the region.

GROWTH HISTORY OF JERICHO DIAMONDS: EVIDENCE FROM CL IMAGERY AND MINERAL INCLUSIONS

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The aim of this study is to unveil the growth history of diamonds recovered from the kimberlite of Jericho, Nunavut. The study of mantle xenoliths carried by this Mid-Jurassic kimberlite (172±2 Ma) has revealed that peridotitic diamonds in this terrane of the craton should be stable at depths between 140 and 160 km, whereas diamondiferous eclogites are restricted to a narrow

depth interval between 150 and 160 km. Our new studies on Jericho diamonds test these conclusions.

We described 209 diamonds ranging in size from 0.2 to 6.7 mm. Morphological studies showed a predominance of octahedral shapes over cubic and dodecahedral shapes and low resorption. Surface features include trigonal (86 stones), tetragonal (7 stones), and hexagonal (4 stones) etching pits. Nitrogen content and aggregation state for 15 diamonds have been determined from Fourier Transform Infrared (FTIR). Concentrations of nitrogen range from 0 to 750 ppm, with B aggregates comprising between 0 and 59.1%. Mineral inclusion studies showed that Jericho diamonds are predominantly eclogitic. Eclogitic garnet and clinopyroxenes were found in 72% of the studied diamonds, whereas olivine and orthopyroxene were only present in 8% of the diamonds; the remaining 20% contained oxides, sulphides, and/or epigenetic inclusions and could not be assigned to a specific paragenesis. The Jericho diamonds have a very light carbon isotopic composition ($\delta^{13}C$ between -5 and -39‰), lighter than that of Archean eclogites and consistent with extremely light carbon isotopes found in Proterozoic eclogites. Such C isotopic signatures are expected as Jericho eclogites were dated as Late Proterozoic. Equilibrium temperatures were calculated for 4 diamonds with coexisting garnet and clinopyroxene inclusions using the Ellis and Green (1979) geothermometer and assuming an equilibrium pressure of 50 kb. The temperatures range from 1040 to 1160°C and are consistent with equilibrium temperatures of diamondiferous eclogites carried by the Jericho kimberlite. 8 diamonds were cut and polished along the {100} plane to map the internal structure of the stones and to analyze exposed mineral inclusions by growth zones. Cathodoluminescence (CL) imaging of the diamond plates reveals complex zonation patterns of the crystals and stages of growth and resorption. This information is combined with the chemistry of mineral inclusions to reconstruct the history of diamond growth and an evolution of the diamond forming environment.

A GEOCHRONOLOGICAL AND PALEOMAGNETIC STUDY OF THE FRANKLIN INTRUSIONS, HIGH ARCTIC CANADA AND GREENLAND, AND THE PROBLEM OF ALPHA RECOIL IN BADDELEYITE DATING

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The Franklin magmatic event is responsible for one of the world's largest sets of intrusions, with related dykes and sills extending for more than 2500 km across the Canadian Arctic Archipelago from western Victoria Island to the eastern tip of Baffin Island, and to the north as far as central Ellesmere Island and the Thule region of Greenland. This magmatism is related to a mantle plume located to the north of Victoria Island that has been tied to the incipient breakup of the Neoproterozoic supercontinent Rodinia. It was previously dated at 723 +4/-2 Ma (Heaman et al. 1992).

New U-Pb baddeleyite ages and paleomagnetic poles have been obtained for dykes on Devon Island and Ellesmere Island in the Canadian Arctic, and one sill from the Thule region of Greenland, that are associated with the Franklin magmatic event. The paleomagnetic pole obtained for the Canadian dykes is 5.8°N, 188°E, N = 12, A_{95} = 9.9°, which is significantly different at the 95% confidence level from paleomagnetic results previously published for the Franklin events. These are commonly averaged together but are themselves significantly different at the 95% confidence level from each other. The difference in the pole locations may be explained by rapid plate motion of the fragments of a supercontinent, the presence of a significant non-dipole component in the Earth's magnetic field at the time of emplacement, and/or true polar wander, related to the long-term effects of a Paleoproterozoic supercontinent. Dykes radial to the Franklin plume source are dated here to 721 ± 2 Ma. Three dykes on Ellesmere Island orthogonal to the main swarm give a consistent younger age of 714 ± 3 Ma. The Thule sill of Greenland is dated to 712 ± 2 Ma. Most recovered baddeleyite crystals are thin plates and some would be predicted to have suffered Pb loss on the order of 1% due to alpha recoil if recoil distances are similar to zircon. However, ages do not appear to correlate with grain sizes, but do correlate with dyke geometry suggesting that alpha recoil distances in baddeleyite are significantly smaller than in zircon. If so, the Franklin magmatic event lasted about 10 million years and shows differing modes of emplacement over time.

A SOLUTION TO THE NARES STRAIT PROBLEM: PALEOMAGNETIC, GEOCHEMICAL, AND U-Pb GEOCHRONOLOGICAL CORRELATION OF PROTEROZOIC DYKE SWARMS BETWEEN ARCTIC CANADA AND NORTHWEST GREENLAND

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In an effort to constrain the relative motion between Canada and Greenland that began with the opening of the Labrador Sea in the Cretaceous, and to identify the location of the plate boundary in the Nares Strait region, a correlation of two dyke swarms across Nares Strait was attempted. The NW-trending Paleoproterozoic Melville Bugt dyke swarm of northwestern Greenland, dated to 1628 Ma (U-Pb baddeleyite), has been thought to have an along-strike extension into Ellesmere Island. An extensive survey of the intrusions of similar trend on Ellesmere and Devon Islands of Canada indicated that no such continuation is apparent, though a result of this survey was the discovery of a U-Pb (baddeleyite) age of 1337 Ma for a dyke at Dundas Harbour, on the south coast of Devon Island. This represents a previously-unknown age of magmatism in the region, and this dyke may be correlatable with dykes of northwest Greenland that are not well-studied, but have been proposed to also have a Mesoproterozoic age.

The Franklin magmatic event, previously dated to ca. 723 +4/-2 Ma (Heaman et al. 1992), is represented in the area by a high-density swarm of E/W-trending dykes on Devon Island in Canada, and the Inglefield Bay area of Greenland. These dykes intersect Nares Strait at a high angle, and so are excellent candidates for correlation between the continents. The two sets of dykes appear to be offset by ca. 200 km, the amount of relative motion prescribed by plate tectonic reconstructions. This offset cannot be explained as an artifact resulting from absence of outcrop since exposure is excellent along the coast. U-Pb geochronological results indicate that the two sets of dykes are of the same age, and their correlation is further corroborated by identical major- and minor-element geochemical signatures. The paleomagnetic pole for the Canadian dykes (5.8°N, 188.0°E, A95 = 9.9°, N = 12) is shown to be primary by a baked-contact test, and is similar to that for the Greenland dykes (8.8°N, 178.7°E, A95 = 7.2°, N = 10), though not presently significantly different at the 95% confidence level, which would be required to conclusively indicate the direction and degree of relative motion between North America and Greenland. The offset of the poles, however, is of the expected sense and magnitude for large-scale (ca. 200 km) motion of Greenland, with the plate boundary lying under the waters of Nares Strait.

HYDROCARBON SOURCE POTENTIAL DETERMINED BY ROCK EVAL/TOC DATA FROM THE CANADIAN ARCTIC ISLANDS

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Rock-Eval/ Total organic carbon analyses characterize the quantity, quality, and thermal maturity of indigenous sedimentary organic matter, as well detecting migrated hydrocarbons. A total of 6320 Rock Eval and 19,700 TOC analyses from 109 oil and gas wells and 1650 outcrops are used to characterize the hydrocarbon source potential of the eighteen major tectono-stratigraphic successions from the Phanerozoic sedimentary basins of the Arctic Islands.

The stratigraphic successions that contain an appreciable number of samples with total organic carbon (TOC) greater than 1.0 % are: the Silurian basinal succession, (average TOC = 2.1%), Carboniferous Emma Fiord Formation (16.2%), Triassic Schei Point Group (1.9%), Jurassic McConnell Island-Deer Bay succession (2.4%), and the Cretaceous Isachsen (3.7%), Christopher (2.7%), and Kanguk (2.5%) formations. These TOC levels are not corrected for differences in thermal maturity or carbon loss through the out-migration of hydrocarbon.

Pseudo-van Krevelan diagrams indicate that oil-prone, Type I/II kerogen is the dominant organic matter in the Silurian basinal succession, Carboniferous Emma Fiord Formation, Triassic Schei Point Group, and Cretaceous Kanguk Formation. Oil-prone kerogen occurs in thin, discontinuous intervals within: algal-rich beds in the Cambro-Ordovican carbonate succession; flysch shed from the Devonian Boothia uplift; shallow-water carbonates of the Devonian carbonate succession; coal in the Devonian clastic wedge; and as very rare, possibly coaly, intervals in the Triassic Bjorne, Barrow and Grovesnor Island formations. The thickness and extent of these oil-prone source beds are poorly constrained. They would likely be minor contributors to the total petroleum resource in the islands, although they may be important locally.

The S1 parameter from Rock Eval indicates the amount of migrated hydrocarbon (i.e., those pyrolyzed at low temperatures). Histograms of S1 for each of the main hydrocarbon source rock intervals help determine if an active petroleum system was present. Histograms of the total gas derived from cuttings (a technique in which cuttings are homogenized in a gas-tight blender and the headspace gas analyzed for methane, ethane, propane and butane) also indicate which source intervals may have generated gas. Paradoxically, the Schei Point Group has very high S1 values but very low cuttings gas, whereas the younger and less thermally mature McConnell Island-Deer Bay succession has much higher cuttings gas.

Rock Eval results are helpful in defining new plays, especially in areas of complex salt deformation on Axel Heiberg Island, where enormous variations in burial occur over short distances, and where many stratigraphic intervals may have been source units.

ULTRA PLAGIOCLASE-PHYRIC MORB FROM EASTERN PACIFIC SPREADING CENTRES: XENOCRYSTIC OR PHENOCRYSTIC?

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Most mid-ocean ridge basalts (MORB) are sparsely phyric and include phenocrysts of olivine and plagioclase. However, rare occurrences of highly phyric, plagioclase-rich basalts are found on the Juan de Fuca Ridge, Gorda Ridge (common), and East Pacific Rise. The goal of this study is to elucidate the origin of the plagioclase crystals. Plagioclase-rich basalt lavas from six localities on the Juan de Fuca and Gorda Ridges, the Blanco Deep (within-transform volcanic centre), and the East Pacific Rise were collected by dredging and during ROV Tiburon dives of the Monterey Bay Aquarium Research Institute. The basalt samples consist of glassy pillow and sheet flow rinds with only minor olivine but between 25% and 50% modal plagioclase crystals up to 1 cm in size. The plagioclase megacrysts commonly include trains of melt inclusions and, less commonly, chromite inclusions. Disequilibrium textures in the megacrysts are common, including rounded grain shapes, sieve textures, and complex chemical zonation (normal, reverse, and oscillatory). Megacryst cores are, except in one sample, always more calcic than plagioclase microlites in the basalt glass. Glass inclusions in the megacrysts are commonly more primitive (higher Mg#) than host basalt glass rinds. Olivine crystal compositions range from Fo_{89} to Fo_{84}, but in one basalt olivines are distinctly bimodal: Fo_{86} and Fo_{74}. In most samples, $^{87}Sr/^{86}Sr$ and Pb isotope ratios in plagioclase megacrysts differ from host glasses. In the four samples from the southern Juan de Fuca and Gorda ridges, megacrysts are clearly xenocrystic based on disequilibrium textures and chemistry. Feldspars from a plagioclase-phyric basalt flow from the northern Juan de Fuca Ridge (Cousens et al., 1995) show similar features and were also interpreted to be xenocrystic. The East Pacific Rise sample shows little evidence of disequilibrium other than isotopic ratios, and we conclude that they are also xenocrystic. The lava from the Blanco Deep also showed little chemical or petrographic evidence of disequilibrium between megacrysts and host glass, other than in melt inclusion composition. Like most MORB, the plagioclase-phyric lavas evolved in open-system ridge environments. However, the extreme size and abundance of the megacrysts suggests that the megacrysts were added to the ascending magma just prior to eruption, perhaps derived from plagioclase accumulation zones in a melt lens or as true xenocrysts from crustal, gabbroic wall rocks.

RECENT ADVANCES IN UNDERSTANDING POST-IMPACT DEFORMATION OF THE SUDBURY IGNEOUS COMPLEX AND ITS HOST ROCKS, ONTARIO

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The 1.85 Ga Sudbury Igneous Complex (SIC) in central Ontario is now widely considered to be the erosional remnant of a deformed paleo-horizontal impact melt sheet. Deformed impact breccias of the Onaping Formation overlie the layered SIC, which rests on shock-metamorphosed Archean and Paleoproterozoic country rocks. Previous workers considered non-cylindrical folding and NW-directed reverse faulting as the structural processes that formed the syn-formal geometry of the SIC apparent today. Structural studies support this model in the central and southern part of the Sudbury impact structure. However, little evidence for fold-induced strain has been reported from the eastern part of the SIC, characterised by steep basal dips and strong curvature in plan view. The objective of this study is to assess the structural inventory of the NW-SE trending eastern SIC, the East Range, in terms of post-emplacement deformation mechanisms.

A metamorphic foliation is developed within the uppermost granophyric SIC of the NE-lobe that connects the SIC's North and East Ranges in an 80° arc. The foliation is formed by an anastomosing network of chlorite-filled fractures accompanied by intra-crystalline deformation of quartz, indicating deformation under low-grade metamorphic conditions. The orientations of foliation are concordant to greenschist-metamorphic foliations in

the overlying Onaping Formation and to the NE-lobe's bisector plane. This indicates buckling of the SIC-Onaping Formation contact associated with shortening of the NE-lobe. Apart from these foliations, the East Range SIC and its granitic basement are free of pervasive post-impact ductile strain fabrics. Both units feature a coarse-grained feldspar-rich texture that deformed predominantly by cataclastic deformation under low-grade metamorphic conditions. Localised strain fabrics, i.e., centimetre- to metre-scale shear zones and brittle shear-fractures, are developed but do not form pervasive outcrop-scale networks. Kilometre-scale faults striking N-S cut the East Range SIC and caused minor strike separations of SIC contacts. Maximum principal shortening directions inferred from inversion of fault-slip data collected in the NE-lobe SIC and its host rocks are orthogonal to metamorphic foliation surfaces in the Onaping Formation. This points to a similar deformation regime during ductile and brittle deformation and, thus, is compatible with a common deformation of the SIC and its host rocks. Quantitative brittle strain data and information on the subsurface geometry of first-order structures is needed to assess whether brittle deformation may have accommodated rotation of the East Range SIC from an initially horizontal orientation. Additionally, magmatic mineral fabrics may offer independent information on the emplacement geometry of the SIC.

ENHANCING PUBLIC AWARENESS OF THE GEOSCIENCES AT SEA

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The widespread lack of public understanding of our planet's tectonics and geohistory poses a special challenge. To help address this, geoscientists should consider the opportunity offered by cruise-ship tourism. Up to 400 cruise ships regularly ply the world oceans, each of them carrying 100 to 5000 passengers. Along with the usual range of activities provided during a typical cruise, a growing market has arisen for the provision of educational lectures during days spent at sea. An opportunity thus exists for transmitting basic information about the geosciences via a series of well-prepared, well-illustrated talks.

Cruise participants are typically well educated, yet almost all lack formal training in geology. They are eager to learn, and if their interest can be caught during the first lecture, a responsive audience will develop for the balance of the cruise. On an extended trip, the audience will grow as attendees relay to others their evaluations of initial presentations; this in turn will win others away from concurrent activities.

Lecturers generally are placed aboard ships through organizations run by people with little understanding of the sciences. As a result, lecturers tend to be selected from the liberal arts, business and economics. Some organizations, however, list "naturalists" as desirable speakers, but biologists almost invariably are taken on to fill this category. Nevertheless, geoscientists have increasingly managed to convince cruise and placement organizations that geology is an essential component of nature, so the room for earth scientists to join the cruise circuit is gradually expanding.

As cruise lecturers, Canadians have been particularly successful in proselytizing to adventure-loving passengers, especially aboard small ships cruising Arctic waters, where those with field experience can pitch in and run Zodiacs to take participants ashore for guided tours to see a wealth geological features firsthand. Having spent a total of more than four months at sea as a geoscience lecturer, including two sessions in the latter exhilarating category, I can vouch for the potential this offers for outreach. Retired or soon-to-be retired geoscientists are encouraged to consider this enjoyable avocation as a way to remain active, with the added bonus of contributing significantly to the enhancement of public awareness of, and appreciation for, our science. A complementary opportunity is similarly being created for inhabitants of northern communities, who can link with geoscientists to educate southern visitors about the meaning behind their spectacular legacy of Arctic landscapes.

YELLOWKNIFE GEOHERITAGE, EMPHASIZING SUBMARINE VOLCANIC ERUPTIONS, UNIQUE SEDIMENTARY DEPOSITS, AND CONTINENTAL GLACIATION

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A Display Complementary to the Workshop, "Towards an Integrated Future in Geoscience Education and Outreach

Several basic geological processes responsible for the evolution of Canadian Shield landscapes are exquisitely recorded along the shores of Great Slave Lake near Yellowknife. Of particular note is "The Giant Section", a site visited for decades by numerous geologists seeking a better understanding of undersea volcanic processes and products. This locality provides a world-famous display of ancient pillow lavas. Not only can the tops of folded sequences be immediately recognized by morphology of the constituent "pillows" (actually sections through lava tubes), but lava flow directions also can be determined on the basis of asymmetric pillow sections and breached selvages (outer margins) of the pillows. Feeder dykes that provided pathways for release of molten lavas are abundant throughout the area. Some volcanic rocks display structures such as fiamme, which document deposition by gas-driven glowing avalanche flows (nuées ardentes) during violent eruptions.

The volcanic history recorded in the Giant Section can be readily understood by those with little or no geological training. To draw public attention to some of the many marvellous geological features that can be recognized, a 1:10 scale map of the central part of the Giant Section has been prepared. Using this map, after a brief introduction to geological principles, the public can attain an appreciation of relative ages of different rock units based on their own observations of primary structures, unconformities and crosscutting relationships. The enormity of geological time, the dynamic nature of volcanism, recent glacial history, and sequential episodes of tectonism can all be readily assessed on the basis of features in the Giant Section and nearby exposures. Interbedded and overlying sedimentary strata provide additional clues to allow inferences about depositional environments as well as rates of recent and ancient sedimentary erosion, transport and deposition. Evidence of ice sheets that covered most of Canada during the last Ice Age is well displayed by glacial polish, scours, striae, and erratics plus distinctive landscape forms such as eskers, drumlins, crag-and-tail structures and roches moutonées. Given Yellowknife's geology-related history, it is appropriate that such a fine example of Canadian geoheritage is so well preserved nearby.

GROUND THERMAL MODELING IN THE MACKENZIE RIVER VALLEY: FROM DATABASE DEVELOPMENT TO PRACTICAL APPLICATION

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It is generally accepted that the earth is currently experiencing a period of global climatic warming. In permafrost terrain, warming of the ground in response to increasing atmospheric temperatures will lead to a general deepening of the annual thaw (active) layer, and to partial or complete thawing of permafrost where ground temperatures are currently close to

0°C. To increase our understanding of the distribution and rate of change of permafrost conditions, the GSC has developed a physically-based ground thermal modeling capability at 1 km and 30 m spatial resolution within the broader Mackenzie River valley (north of 60°N). The model is constructed on a digital representation of the landscape, derived from conventional map data of surficial geology and vegetation cover, satellite imagery, and digital elevation models, which serve as the basis for the assignment of appropriate parameter values at grid locations within the study area. The TTOP analytical relation has been implemented as a GIS-resident model for predicting the occurrence and thickness of permafrost under conditions of thermal equilibrium. Results indicate that equilibrium temperatures (at the top of permafrost) range from about –0.5 to +2°C in the vicinity of the Alberta/NWT border to colder than –10°C at the northern edge of Richards Island and Tuktoyaktuk Peninsula. While TTOP serves as a useful scoping tool for rapid assessment of the spatial distribution and thickness of permafrost, recently a more sophisticated finite-element model (T-ONE) was implemented. It supports detailed investigations of the linkages between climate and the ground thermal state (e.g. permafrost thickness, active layer development and the formation of taliks) and is utilized for rigorous assessments of the potential impacts of progressive climate warming in permafrost landscapes. GIS-based mapping of T-ONE solutions facilitates prediction of the transient (time-dependent) response of ground temperatures to changing atmospheric temperatures and/or altered surface conditions. The model employs reconstructions of historic climates (from circa 1700 AD to present day) and scenarios for future climate warming based on GCM outputs. Currently, the GSC ground thermal modeling capability is being applied to practical issues related to the viability of northern transportation systems, and the assessment of terrain stability along the propose Mackenzie Gas Pipeline right-of-way.

GEOLOGY AND STRUCTURE OF THE BIRD RIVER GREENSTONE BELT, SOUTHEAST MANITOBA

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The Bird River Greenstone Belt of the Superior Craton is located between the North Carribou Superterrane and the English River subprovince to the north and the Winnipeg River subprovince to the south. The major tectonic event is dated at ca. 2695 Ma and corresponds to the closure of the oceanic domain that existed between the North Carribou Superterrane and the Winnipeg River subprovince. However, the structural and the kinematic framework of the belt are poorly constrained. Elucidation of the geology and structure of the Bird River Greenstone Belt is important for a better understanding of the geodynamic evolution of this part of the Superior Craton.

The Bird River Greenstone Belt was affected at first by apparent vertical movements with a minor strike-slip component. In the north flank of the belt, the E-W-trending Peterson Creek Shear Zone deforms at the solid state the Maskwa granite with a top-to-the-south shearing. The central part of belt consisting of supracrustal formations was affected by a top-to-the-north shearing. This event led to the emplacement of the Bernic Lake Formation to the south upon the Booster Lake Formation to the north, which also overlay the Peterson Creek Formation to the north and the Flanders Lake Formation to the east. In the north part of the belt, this event is coeval with an amphibolite facies metamorphism reaching the peak conditions (550°C - 5 kbars) after a pressure increase. This structural framework can be interpreted as an initial low-angle thrusting before steepening of all the formations. This interpretation is supported by new geochronological data which indicate that the Booster Lake Formation is slightly older than the Flanders Lake Formation (P. Gilbert, *pers. comm.*).

Along the Winnipeg River in the southern part of the belt, the Birse Lake granite to the north overlies the basalts of the Lamprey Fall Formation to the south. The North Winnipeg River Shear Zone marks the contact between the two units and shows a dextral and top-to-the-south shear sense. Southward, the Lamprey Fall Formation is separated from the Winnipeg River subprovince by a later NE-trending shear zone with a sinistral and top-to-the north shear sense.

The last tectonic event in the belt is characterized by NW-trending upright folds in the east and NE-trending top-to-the-north shear zone in the west. In the west, the deformation took place under the greenschist facies conditions, retrogressing the previous amphibolite-grade assemblages, whereas in the east the formations experienced high temperature-low pressure amphibolite facies metamorphism due to late magmatism. The Marijane granite which has been dated at 2645.6 ± 1.3 Ma (U-Pb on monazite) is coeval with this event.

FLOW OF LOWER CONTINENTAL CRUST BENEATH LAURENTIA: NEOARCHEAN SUB-HORIZONTAL DUCTILE FLOW IN THE ATHABASCA GRANULITE TERRANE, WESTERN CANADIAN SHIELD

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The Athabasca Granulite Terrane (AGT) is the largest known exposure of Laurentian lower continental crust. It is preserved in the hanging wall of the Legs Lake shear zone, a ca. 1.85 Ga thrust-sense structure that aided exhumation of >20,000 km^2 of HP-HT granulite-grade gneisses in the eastern Rae Province of the western Canadian Shield. The dominant tectonic fabric in a 40 km-long transect across two shear zone-bounded, litho-tectonic domains in the AGT is a penetrative, early shallow fabric (S_1).

The Lower Deck domain of the East Athabasca mylonite triangle (EAmt) exhibits km- to m-scale domains of shallow, granulite-grade gneissic foliation (S_1) in granitoid orthogneisses. The gneisses contain a pentrative stretching lineation (L_1) defined by discontinuous ribbons and porphyroclasts of recrystallized Kfs + Pl + Qtz + Hb ± Opx, Grt aggregates, and elongate mafic enclaves. Long rods of compositional banding on the S_1 fabric represent intersection lineation that correspond to hinges of isoclinally-folded (F_1) sheets of granite-granodiorite-charnockite (S_0). Thermobarometric, microstructural, and kinematic data are compatible with high-grade (700-800°C) ductile, top-to-the-ESE flow during sub-horizontal L>>>S strain at 1.0-1.1 GPa. High-resolution, in-situ electron microprobe U-Th-Pb geochronology on syn-kinematic and syn-metamorphic Mnz constrains timing of S_1 at ca. 2.62-2.55 Ga.

The Upper Deck domain of the EAmt is locally underlain by Grt-rich, Sil/Ky ± Opx + Qtz + Kfs felsic granulite ribbon mylonite, interpreted as the restitic product of extensive melting of meta-igneous protoliths in deep continental crust. Locally, the dominant fabric is sub-horizontal and defined by recrystallized ternary feldspar, Ky blades, Qtz ribbons, and zoned Grt aggregates with grossular-rich annuli. Preliminary modeling suggests high-Grs Grt grew at pressures in excess of 1.4-1.5 GPa following near-UHT-melting at 1.0-1.1 GPa. Low-Th, Eu-enriched, and Ca-depleted Mnz included in high-Grs Grt rims directly date the time of partial melt extraction, breakdown of Pl, and growth of Grt during high-P metamorphism at ca. 2.58-2.5 Ga. Data are consistent with protracted partial-melting during injection of a mafic intra-plate and intense sub-horizontal fabric development followed by crustal thickening.

The early shallow fabric represents flow of lower continental crust beneath Laurentia in the Neoarchean. We speculate that

the fabric correlates with deep crustal reflectivity imaged by the Lithoprobe SNORCLE deep seismic reflection line in the southwestern Slave craton, dated at ca. 2.65-2.58 Ga. The overprinting of shallow fabrics by localized, NE-striking steep fabrics and shear zones point to rheologic strengthening of weak Laurentian deep crust syn- to post-2.5 Ga.

GIS-BASED TERRAIN ANALYSIS OF LINEAR INFRASTRUCTURE CORRIDORS IN THE MACKENZIE RIVER VALLEY, NWT

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Continued climate warming, and associated progressive thaw of frozen ground will have potentially serious implications for the structural stability and performance reliability of linear infrastructures traversing permafrost terrain. Of particular current concern are the long-term viability of existing and proposed pipelines and the extensive networks of seasonal and all-weather roads in the Mackenzie River valley. Access to suitably-scaled information about current and future terrain conditions, both local and regional, is of critical importance to engineers, regulators, and decision-makers responsible for the development and maintenance of these networks.

The Geological Survey of Canada is developing an ArcGIS-resident, multi-component terrain analysis methodology for evaluating permafrost terrain in terms of the probable geothermal and geomorphological responses to climate warming and/or antropogenic disturbance. A GIS-integrated finite-element transient ground thermal model (T-ONE) enables prediction of local-regional permafrost conditions (i.e. ground temperature, permafrost distribution and thickness, active layer development) and future responses of permafrost to climate warming. Analysis of topographic and topologic characteristics of terrain will clarify the influences of surface and channel hydrology on local erosion potentials. A weights of evidence-based landscape-process model, currently under development, will consider multiple terrain factors (e.g. geology, permafrost, topology and topography, surface hydrology) for identification and mapping of terrain with particular sensitivities and susceptibilities to various manifestations of terrain instability, including slope failure, subsidence, thermokarst, surface and bank erosion.

This terrain analysis methodology is currently being applied to a 2 km buffer spanning the proposed Mackenzie Gas Pipeline right-of-way, and along winter and all-weather road networks in the Mackenzie River valley, NWT. Initial ground thermal modeling completed within the buffer area has identified thermally sensitive terrain for which permafrost will either completely disappear or warm significantly to near isothermal conditions within the next 25 to 55 years. Ongoing development and application of the broader integrated terrain analysis package will facilitate the prediction of specific terrain units and/or localized areas that are particularly susceptible to terrain instability during the next century. This information will be of considerable utility to responsible agencies and stakeholders concerned with the long-term viability economics and of pipelines and roads in the Mackenzie River valley.

BUILDING STONE AS AN EDUCATIONAL RESOURCE

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Building stone is a resource long used at universities to describe rocks and minerals to students of geology. In Edmonton building stone fieldtrips (walking tours) are being used as an elementary and high school resource and are an enjoyable activity for the public including seniors and the physically disabled. Building stone brings regionally quarried rock samples to the mass of the Canadian population; with crystal clarity links science and technology (geology and stone dressing) with history and art (heritage buildings, design and architecture); and is readily accessible to everyone including inner city teachers or seniors with no funding for trips and the disabled who cannot travel to remote wilderness areas. Any geologist can be the catalyst to turn what occurs in our cities 'naturally' into a remarkable resource for teachers and the public and there are walking tour guidebooks for many cities in Canada. This common industrial resource will get even more exposure as an educational treasure in the Building Canada chapter of the proposed Geology of Canada book that is an initiative in support of the IYPE.

THE MAGMATIC "BAR CODE" RECORD FOR MAJOR CRUSTAL BLOCKS DURING THE PROTEROZOIC

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Precisely dated igneous event records, emphasizing short-lived magmatic events with potentially large footprints, provide "bar codes" that uniquely identify the ancestry of displaced fragments of crust. Comparison of such bar codes from now distant fragments of continental crust (e.g., Superior and Karelia cratons) is the key to identifying which crustal fragments may have been "nearest neighbours" and, if so, over what time interval(s) (e.g., Bleeker & Ernst, 2006, in Dyke Swarms: Time Markers of Crustal Evolution, Balkema, Rotterdam).

Herein, we compare bar codes of major Proterozoic crustal blocks around the world. The most detailed bar codes are those for Superior and Slave cratons of Laurentia, western Australia, and Karelia and Kola cratons of Baltica. Most other major crustal blocks have bar codes that remain poorly populated. A major geochronological campaign, coordinated globally, could quickly complete these bar code records, providing numerous tight, robust, constraints on pre-Pangaea reconstructions. Precise ages are both a catalyst and highly efficient filter to focus further work on those events that have maximum potential to test suggested correlations.

To systematically assess the likelihood whether certain crustal blocks were nearest neighbours, we present "correlation charts" in which we score the number of bar code matches, for particular time intervals, between all possible pairs of crustal blocks. Multiple sequential matches among two bar codes are of particular significance, as this greatly increases the chance that the matches reflect a "nearest neighbour" relationship rather than synchronous but distant events. Time intervals of particular interest are those that lead up to the breakup of significant continental aggregations through Earth history: large late Archean to earliest Proterozoic supercratonic landmass(es), e.g. Superia (see Bleeker, 2003, Lithos), Paleo- to Mesoproterozoic supercontinent Nuna (Columbia), and Neoproterozoic supercontinent Rodinia.

Some correlations are already compelling. For instance, the Paleoproterozoic pre-breakup bar codes for the Superior, Karelia, Wyoming, Hearne, Sask, and North China cratons show numerous matches, suggesting these blocks represent crustal fragments that trace their origin to a single contiguous landmass, potentially the late Archean supercraton Superia. Indeed, preliminary attempts at reconstructing Hearne, Wyoming and Karelia cratons along the southern margin of the Superior craton were published recently (Bleeker, 2004, Geoscience Canada; Bleeker & Ernst, 2006, see above).

For the interval 0.83-0.75 Ga, bar code matches between South China, western Laurentia, Kalahari, and west-central Australia support their proposed juxtaposition in Rodinia (Li et al., 2003, Precambrian Research, special volume on Rodinia, in press).

A TEACHING TOOL FOR EARTH SCIENCES EDUCATION

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The focus of this teaching tool is to foster an understanding of the scientific approach to the interpretation of the Earth's history and, therefore, provide insight into the discipline of geology. The exercise itself takes about one hour to conduct and requires a badminton court with regulation boundaries. Students perform mapping of an idealized geological terrain and utilize simple deduction to interpret observed data. Accurate data collection and application of geological knowledge leads to a reconstruction of a correct sequence of geological events. Coupled with a pre-activity and follow-up discussion, this activity can assist in satisfying a great number of expectations within a number of Ontario Ministry of Education curriculum documents, specifically:

Science Grades 11 and 12; Earth and Space Science, Grade 12, University Preparation (SES4U)
Science and Technology Grades 1-8; Earth and Space Systems, Grade 7, The Earth's Crust
History and Geography Grades 7 and 8, Grade 7 Geography
The Themes of Geographic Inquiry
Patterns in Physical Geography
Natural Resources

Through this exercise, students will directly witness how the application of knowledge can result in the valid interpretation and understanding of observed phenomena. The importance of geological mapping and the correct identification of rocks and minerals in the interpretation of the Earth's history are specifically brought to light.

GROWTH OF LAURENTIA FROM A PALEOMAGNETIC PERSPECTIVE: CRITICAL REVIEW AND UPDATE

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Paleomagnetic and tectonostratigraphic viewpoints on the pre-1800-Ma tectonic coherence of Laurentian cratonic elements have vacillated through the past three decades, ranging from an interpreted convergence of far-travelled cratons as young as 1800 Ma, to a more fixist perspective of tectonic unison with merely minor relative motions since the late Archean. Most of the more recent discussion has adopted the mobilistic model of late Paleoproterozoic ocean closure(s) in assembling Laurentia. The precise ages of various sutures can be estimated from geochronology of the relevant orogens, but complementary paleomagnetic estimates have been conflicting. In the year 2004, Ted Irving and colleagues' study of the Cleaver dykes provided a key datum demonstrating a unified Laurentia–from Labrador to NWT–at ca.1750 Ma. Here we address the preceding interval of 2000-1800 Ma, reviewing in particular the paleomagnetic data from Slave, Rae, and Hearne provinces. Most of the Slave data from this interval have been obtained from the East Arm stratified succession, all of which might be affected by regional vertical-axis rotations associated with the McDonald dextral shear system. More reliably autochthonous results have been obtained from the Wopmay and Thelon forelands. Combining previously published results from the Peninsular and Kilohigok (Mara Formation) sills, both intruding at about the same structural level in correlative sequences, we calculate a grand mean of ten sites at (23°S, 264°E, A_{95}=5°). Although the sills are not directly dated to our knowledge, they intrude foredeep sediments that are younger than 1882±4 Ma, and they are correlated to intrusions that are folded in Wopmay structures; therefore, the pole represents Slave craton at ca. 1870 Ma. This pole, and the ca. 1960-Ma paleomagnetic pole from the Rifle (previously Western River) Formation, are greatly different from penecontemporaneous poles of the Superior craton and indicate final closure of the Churchill Province oceans between 1870 and 1750 Ma. Pre-collisional Rae and Hearne poles are more sparse, but generally follow the Slave path rather than that of Superior. Sudbury should not be used as a key constraint on Superior paleogeography at 1850 Ma, because although the remanence direction is well defined, the overall tilt of the structure is unconstrained. Previous conclusions by Symons and colleagues, that the Manikewan Ocean remained wide at 1850 Ma, rely on the veracity of the Sudbury pole, and also on the application of U-Pb dates to the ages of magnetic remanence acquisition in the Trans-Hudson orogen. Recent Ar/Ar work across the orogen suggests substantially prolonged cooling that could have delayed remanence acquisition to as late as 1750-1700 Ma. Our new results from the Dubawnt Supergroup, straddling the Snowbird zone, provide refined poles for the combined Slave-Rae-Hearne craton at ca.1830 and 1755 Ma, and imply low paleolatitudes at both ages. The high-latitude poles from THO may indicate rapid poleward motion of the newly assembled continent by about 1700 Ma.

RECOGNIZING THE DISTINCT GEOCHEMICAL NATURE OF ANTIMONY IN THE AQUEOUS ENVIRONMENT AROUND THE GIANT MINE, YELLOWKNIFE, NWT

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Arsenic (As) has been the focus of environmental studies for decades with much less emphasis on antimony (Sb). Research on the environmental legacy of gold mining in the Yellowknife area has centered on As, but Sb is also present in the mine waste and was liberated during roasting. Like As, Sb is a recognized carcinogen and has been shown to adversely impact ecosystem health. Besides being commonly associated in gold ore deposits, As and Sb have similar electronic structures and form the same types of chemical bonds, hence they should behave geochemically similar. Results obtained through recent (2005 and 2006) sampling and analysis of surface water, pore-water, and sediment from sites near the Giant Mine provide evidence to the contrary.

Sediment pore-water was collected using in-situ dialysis arrays (peepers) that allow for sampling at the centimeter scale. Pore-water was analyzed for As(III/total) and Sb(III/total), Fe(II/total), anions and cations. Sediment cores were extracted adjacent to peeper sites, extruded at 0.5-1 cm intervals, and analyzed for cations. Arsenic and Sb respond differently to effluent treatment processes. In the NW tailings pond (water before effluent treatment) As and Sb concentrations range from 15.5 to 30.7 mg/L and 0.794 to 0.930 mg/L, respectively. In the settling pond (the first pond into which treated water flows) As concentrations are below detection (0.02 mg/L) whereas Sb varies from 0.171 to 0.181 mg/L. Arsenic appears to be much more affected by sorption onto hydrous ferric oxides than Sb. Another notable difference in As and Sb behaviour is their speciation in pore-water. For example, pore-water from the creek bed and a densely vegetated section within Baker Creek, the main conduit of mine waste to Yellowknife Bay, were analyzed for determination of Sb(T), Sb(III), As(T), and As(III). Results show that Sb(III) dominates in bottom water and pore-water near the sediment-water interface (SWI) and falls to below detection below the SWI where Sb(V) dominates. The opposite profile is

observed for As where As(III) is below detection and As(V) dominates near the sediment-water interface (SWI); As(III) increases to 0.330 mg/L at 27 cm below the SWI. Furthermore, the distribution of As and Sb in pore-water, and the observed relationships between the sediment and pore-water, are consistently different. Understanding that the geochemical behaviour of Sb is distinct from that of As, and more complex than previously assumed, has important implications as reclamation progresses.

ELEMENTAL PARTITIONING OF Mg, Al AND B BETWEEN TOURMALINE AND PRISMATINE-KORNERUPINE: POTENTIAL PRISMATINE-TOURMALINE THERMOBAROMETERS

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Kornerupine-Prismatine is a solid solution of magnesium iron boro-silicate hydroxides occurring in Boron-rich volcanic and sedimentary rocks subjected to high grade metamorphism with tourmaline as the most commonly associated borosilicate. Metamorphic conditions range from 540° to 840°C and 3 to 13 kbars. Little is known about the phase relations of prismatine and its compositional variability as a function of pressure and temperature in the presence of other Boron-bearing minerals. This study combining published compositional data for coexisting kornerupine-prismatine with extracted pressure-temperature conditions establishes usable elemental site-partitioning relationships as a function of pressure and temperature.

Prismatine and tourmaline data considered are from Ackermand et al. (1984), Lonker et al. (1988), Carson et al. (1995), Grew et al. (1995, 1997, 1998) and Darling et al. (2004). Kornerupine and tourmaline equilibria have been reported from Fiskenaesset,Greenland; Antarctica; Zambia; Tanzania; Tajikistan; the Adirondacks; Ontario; and Sri Lanka.

Major element analyses for prismatine and tourmaline were determined by electron microprobe. Be and B contents were calculated by stoichiometry, analysed by SIMS and/or wet chemistry. All Be and B values were used as reported in the literature. If B and H_2O compositions, were not reported, values were calculated based on ideal stoichiometry and weight-percent totals. Although prismatine and tourmaline occur in variable mineral assemblages containing cordierite, spinel, sapphirine, sillimanite, garnet, biotite, and other minerals, only data where prismatine and tourmaline were interpreted to be in textural equilibrium were used. Tourmaline data were normalized to 31 oxygens as per Grew et al. (1997, 1998) and Darling et al. (2004) via the formula (Ca, K, Na, ?)(Fe, Mg, Mn, Al, Cr)$_3$ Al$_6$(Si, Ti, Al)$_6$(BO$_3$)$_3$O$_{18}$(O, OH, F)$_4$. Prismatine-kornerupine data were normalized to 21.5 oxygens as per Grew et al. (1997, 1998) and Darling et al. (2004) based on the formula (Ca, Na, Mn, Li, Fe, Mg, ?)(Fe, Mg, Al)$_9$(Si, B, Al)$_5$O$_{21.5}$(OH,F).

Fe-Mg partitioning data used in thermobarometry shows no consistent trends in prismatine-tourmaline site partitioning. However, there are some consistent trends with respect to pressure and temperature. These include MgTur-3-site/MgKrn-9-site and Al Tur/AlKrn (for the 3 and 9 cation sites for tourmaline and kornerupine respectively) and the BTur-Krn sites. These yield the following thermobarometers:

B partitioning barometer:

P(kbars) = 2.0448 BTur/Krn -2.3589; R^2=0.8767

Mg partitioning thermometer:

T(°C) = -379.13 MgTur-3-site/MgKrn-9-site + 1613.1 R^2=0.5218

Mg partitioning barometer:

P(kbars) = -9.4547 MgTur-3-site/MgKrn-9-site + 29.34; R^2=0.289

Al partitioning thermometer:

T(°C) = 1131.6 AlTur-3-site/AlKrn-9-site + 435.0; R^2=0.5945

A MINERALOGICAL INVESTIGATION INTO THE POSSIBLE SOURCE ROCKS OF PLACER PLATINUM IN SEVERAL YUKON PLACER DEPOSITS

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Platinum group minerals (PGMs) have been historically reported in a number of placer deposits in Yukon, but have only been confirmed through scientific studies in a few of these locations. In addition, the potential source rocks for these placer platinum group minerals remain either unknown or poorly understood. The goals of the present study are: 1) to confirm the presence of PGMs in the placers with historically-reported platinum, 2) to determine which mafic/ultramafic rocks present in the area is the most likely PGM source, 3) to explain PGMs in the placers with no known ultramafic rocks present in the area. Towards this end we conducted a study of mineral assemblages and composition of heavy-minerals from placers with reported PGMs.

Heavy-mineral samples from twelve creeks in the South and West-Central Yukon were collected for this study. Mineral assemblages were examined optically under reflective light and with a scanning electron microscope. Mineral compositions of PGMs, chromite, ilmenite, olivine, clinopyroxene, orthopyroxene and garnet were determined by electron microprobe analysis. Major and minor-element compositions of all the studied placer minerals were compared to the mineral composition of the different types of platinum-bearing ultramafic rocks in the Cordillera and worldwide, as well as to the volcanic and intrusive rocks present in the studied areas.

Initial results show that the presence and abundance of olivine, pyroxenes and chromite vary significantly between the different samples. In the Kluane area, some creeks have a uniform population of chromite with a composition corresponding to the chromites of the adjacent Kluane-type intrusions. In other drainages, compositionally diverse chromite and ilmenite populations occur that might have been derived from several sources. The unusual composition of platinum-bearing heavy-mineral concentrates from Canadian Creek with no or very rare chromites, but common Sn, W, and Bi-bearing minerals does not exclude a possibility of hydrothermal origin for some of the PGM mineralization. The ongoing detailed study of mineralogy, composition of mafic minerals, oxides, and PGM grains will allow us to propose potential sources of platinum occurrences in several Yukon placers.

SUBSTITUTION OF CARBONATE INTO HYDROXYLAPATITE: BIOLOGICAL APATITE

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Substitution of the carbonate ion into the channel (A) and phosphate group (B) positions of hydroxylapatite [$Ca_{10}(PO_4)6(OH)_2$] has been investigated by FTIR spectroscopy and single-crystal X-ray structure, using apatite crystals synthesized at 1200-1500°C, 0.5-2.0 GPa. Three varieties of carbonate hydroxylapatite (CAp) have been synthesized: type A, type A-B and Na-bearing type A-B. The type A carbonate ion is oriented in the apatite channel with two oxygen atoms close to the c-axis, and the type B carbonate ion in A-B CAp is located close to the sloping faces of the substituted phosphate group, but inclined at an angle of 53° to the mirror plane (P63/m symmetry). In FTIR spectra, carbonate is indicated by characteristic doublet band(s) in the 1600-1400 cm^{-1} region, with absorption beyond 1500 cm^{-1} generally associated with the

presence of type A carbonate. For a series of Na-bearing type A-B CAp of general composition $Ca_{10-y}Na_y[(PO_4)_{6-y}(CO_3)_y][(OH)_{2-2x}(CO_3)_x]$, x = y <1, both FTIR spectra and X-ray structures show that structural accommodation of substitutions requires local coupling of Na and channel (A) and phosphate (B) carbonate ion defects. The type A absorption bands in these Na-bearing apatites are shifted to lower frequency: FTIR spectra have minimal asymmetric stretch absorption beyond 1500 cm^{-1} and dominant out-of-plane bending absorption at 873 cm^{-1}. Interestingly, these synthetic Na-bearing type A-B apatites (with a high content of type A carbonate) are similar in both chemical composition and infrared spectra to biological apatites. The latter were formally interpreted as type B CAp, but are presently reinterpreted as Na-bearing type A-B CAp with channel carbonate up to 50% of total carbonate.

A CAUTIONARY TALE OF SECTION PREPARATION ALTERING MINERALOGY PRIOR TO EXAMINATION

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Often, low-temperature chemical weathering and surface processes produce thin, discontinuous zones of minerals, or mineral assemblages, having limited stability (e.g. various states of hydration). These minerals can become unstable upon removal from their native environment. There have been a variety of attempts to study these systems without perturbing these fragile materials. One commonly-used method of preserving the texture and mineralogy of these materials is epoxy impregnation of the specimen, prior to polished or thin section preparation.

We report changes in mineralogy and hydration state for sulfate minerals in mineral crusts from sediments in the Haughton Impact Crater on Devon Island upon epoxy-impregnated section preparation. These crusts have formed from low-temperature, low-humidity oxidation of pyrite-rich layers in paleolake sediments of the Haughton Formation. Mineralogy of epoxy-impregnated polished sections has been compared with that in their respective hand samples (offcut slabs, bulk powders), using a Bruker D8 Discover micro X-ray diffractometer (μXRD). Minerals were examined in situ, using a 500 μm X-ray beam diameter in combination with a two-dimensional general area detector diffraction system (GADDS). In particular, all gypsum ($CaSO_4 \cdot 2H_2O$) in epoxy-impregnated polished sections has been partially dehydrated to bassanite ($CaSO_4 \cdot ½H_2O$) (but, interestingly, not completely dehydrated to anhydrite (CaSO4)). The soluble mineral rozenite ($FeSO_4 \cdot 4H_2O$) was found on the offcut slab but not in the polished section, suggesting that it had completely dissolved during epoxy-impregnated polished section preparation.

Changes in mineral hydration state, although not an important consideration for chemical analysis (e.g. electron probe micro analysis), can become important in the interpretation of subsequent optical and/or spectroscopic observations. Preparation-related phase transformations could lead to incorrect thermodynamic modeling of the system, which could have significant consequences. This has broad implications for the study of mine waste materials (for example, hydrated iron arsenic oxide minerals: kankite ($FeAsO_4 \cdot 3.5H_2O$) versus scorodite ($FeAsO_4 \cdot 2H_2O$)).

In the case of fragile mineral systems, minimal sample preparation is desirable. μXRD enables rapid in situ mineralogical identification in rock samples (having dimensions up to 10 cm) after little or no sample preparation. Thus, it is an ideal technique for mineralogical reconnaissance.

KIMBERLITES AS PROBES OF THE SUB-CONTINENTAL LITHOSPHERIC MANTLE

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Comparisons of mantle xenoliths and high-Mg lavas over geologic time indicate that there has been a temporal evolution in the composition of the mantle. Low-temperature harzburgite xenoliths from kimberlite pipes indicate that the sub-continental lithospheric mantle is highly refractory and Archean in age. But problems arise when attempts are made to relate this refractory mantle restite to the high-Mg lavas in Archean greenstone belts preserved at the surface. Archean komatiites and ferropicrites define an array that is displaced to higher Fe/Ti and lower Al/Ti ratios compared to Phanerozoic high-Mg lavas, and have Al/Si ratios that are too low for their compositions to be related to the Archean sub-continental lithospheric mantle - if their mantle source had a Primitive Mantle composition. The presently accepted composition of Primitive Mantle is tied to the compositions of mantle xenoliths from recent alkaline basalts, whose Re-Os isotopic systematics consistently indicate Proterozoic model ages, as opposed to the Archean ages obtained for mantle samples from beneath the cratons. Furthermore, the most fertile lherzolites, which constrain the presently accepted composition of Primitive Mantle, have Os isotopic compositions that are equivalent to those of modern MORB ($^{187}Os/^{188}Os$ ~ 0.13), and thus may actually represent stranded portions of the convecting upper mantle source for MORB that have accumulated around Archean cratonic nuclei. The compatible major, trace, and Os isotopic compositions of Proterozoic fertile mantle xenoliths and MORB suggest that the presently convecting upper mantle that produces MORB may have developed in the Proterozoic. The depleted mantle roots beneath continental cratons represent the refractory relicts of a more Si and Fe-rich Archean mantle that produced the distinctive Archean array of high-Mg lavas. Strikingly, kimberlites align with the enriched-end of the Archean array of high-Mg lavas, rather than that of Phanerozoic equivalents. The implication is that, despite conventional wisdom that kimberlites are sourced in the asthenosphere, kimberlites may actually sample pockets of carbonated fertile mantle in the Archean lithospheric mantle. Kimberlites essentially have the composition of fertile mantle mixed with variable proportions carbonate. They may represent the melting of fertile lherzolite regions in which clinopyroxene has been replaced by dolomite, while the harzburgite xenoliths they carry remained solid because they were clinopyroxene, and thus dolomite, free. The aerial distribution of fields of kimberlite and their aillikite cousins in the Superior Province suggests that there are regional variations in the Fe-content of these fertile pockets of Archean sub-cratonic lithospheric mantle.

CONSTRAINTS ON THE RELATIONS BETWEEN THE WYOMING AND THE SLAVE PROVINCES

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The Slave Province (SLP) and Wyoming Province (WP) exhibit many similar features suggesting they may have originally been part of single craton that has since rifted apart. These include:

1) Highly evolved $^{207}Pb/^{204}Pb$ isotopic compositions compatible with a Hadean-aged depleted mantle reservoir(s),
2) Rock ages = 3.5 Ga and detrital zircon ages = 4.0 Ga,
3) Similar 2.95-2.85 Ga trondhjemite-tonalite-granodiorite basement,
4) Similar stratigraphy, including quartzite, BIF, pelite and amphibolite in 2.86 Ga supracrustal sequences,
5) 2.01 - 2.00 Ga mafic dikes.

On the other hand, each province contains features that are not found in the in the other province. This includes:

1) 2.67 Ga Hi-P granulite metamorphism on western margin of the Wyoming Province,
2) 2.59-2.58 granite bloom across the Slave Province,
3) 2.62-2.64 accretion and calc-alkalic magmatism on southern margin of the Wyoming Province,
4) Ca. 2.3-2.0 Ga supracrustal belt on southern margin of the Wyoming Province.

Considering these restrictions, we recognize four possibilities for the relation between the Wyoming and Slave provinces.

1) WP and SLP are unrelated; the similarities are coincidental.
2) The WP and SLP developed together and rifted apart at 2.86 Ga, at which time the supracrustal sequence that occurs in both Provinces formed. After rifting the two provinces shared no common history. In this model, the similar-aged Paleoproterozoic dikes in the two Provinces are unrelated.
3) WP and SLP rifted apart at 2.86 Ga and were reunited during the 2.64-2.62 Ga accretion event on the southern portion of the WP. In this model the northern portion of the SLP lay against the southern portion of the WP. The provinces were then rifted apart again at 2.01 Ga. This model explains the similar ages of Paleoproterozoic dikes in the WP and SLP. However, if it is correct, then one must explain the lack of 2.58-2.59 Ga granites in the WP and the lack of correlative passive-margin sequence in the SP.
4) WP and SLP were united along the northern margin of the WP, but details of their mutual history is obscured by the lack of outcrops in the northern Wyoming province.

EARLY STRATIGRAPHIC RECORD OF THE BOWSER BASIN, NORTHWEST BRITISH COLUMBIA

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The Bowser Basin, located in northwest British Columbia, was deposited over the Stikine Terrane of the Intermontane Belt during a period ranging from the Middle Jurassic to Late Early Cretaceous. It contains approximately 6 km of marine to non-marine clastic sediments mainly assigned to the Bowser Lake Group but also includes sediments of the upper Hazelton Group at the base of the succession. Recent thermal maturation investigations have shown the existence of effective petroleum systems in the Bowser Basin but the later remains under-explored mainly due to its remote location and difficult accessibility in a sparsely populated area.

In order to investigate the subsidence history of the Bowser Basin, stratigraphic sections were measured in areas where the base of the succession is well exposed and constrained by paleontological data. Decompaction and backstripping analysis were then performed on those sections to explore different models for the tectonic evolution of the basin and understand how and when most of the accommodation space was generated.

Volcanogenic units of the lower Hazelton Group indicate that these rocks mostly accumulated in an oxidizing, subaerial environment. The transition from the volcanic arc assemblage of the lower Hazelton Group into a subsiding sedimentary basin can be traced above a regional unconformity surface. Above the unconformity, the deposition style of the upper Hazelton Group is variable on the basin scale. Depending on the paleotopography and the distance from active volcanic centres, the sediments incorporated more or less volcanic input and were deposited along with subaqueous and subaerial bimodal volcanic flows. Based on the observations made in measured stratigraphic sections, it appears that continuous sedimentation took place in a tectonically active, shallow marine basin on Stikinia from the Early Pliensbachian to Early Bajocian. Rapid lateral facies change and the variability of sediment thickness in the upper Hazelton Group are attributed to active normal faulting during an extensional back-arc stage that isolated multiple sub-basins. Following the end of rifting, thermal relaxation of the crust combined with eustatic sea-level rise generated new accommodation space in the basin where condensed sections of fine-grained deepwater sediments were deposited. The basin remained starved until the Bathonian when a new sediment source became available with the subaerial exposure of the Cache Creek Terrane and the Bowser Lake Group began to accumulate in the basin.

PETROLEUM RESERVOIR ROCK AND SOURCE ROCK POTENTIAL IN LOWER PALEOZOIC STRATA OF PEEL PLATEAU AND PLAIN, NORTHWEST TERRITORIES AND YUKON

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This poster presents some initial observations and analytical data from samples obtained as part of the multi-disciplinary and multi-agency "Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain" project (http://www.nwtgeoscience.ca/petroleum/PeelPlateau.html).

In the Peel Plateau and Plain (Peel area), early Paleozoic strata comprise Cambrian siliciclastic and evaporite rocks deposited in an epicratonic sea and uppermost Cambrian to Silurian carbonate rocks deposited on a passive continental margin. Platform carbonate deposition continued through the early and middle Devonian, with a transition to basinal shale at the west side of the Peel area. Finally, Middle to Upper Devonian shale was deposited in a deep marine basin.

A sample of Cambrian Mount Cap Formation sandstone had a porosity of 4.4%. Two shale samples from the same formation had a maximum of 0.21% total organic carbon (TOC), but higher values have been obtained in the region. Cambrian to Silurian Franklin Mountain and Mount Kindle formations contain locally coarse and vuggy dolostone (maximum porosity of samples 9.4% and 5.1%, respectively). Potential source rocks did not occur within this platformal succession. The age equivalent (Cambrian to Devonian) Road River Group basinal shale occurs in the western part of Peel area. Samples collected from this unit yielded values of 1.46 and 2.49% TOC.

Lower Devonian Arnica Formation dolostone is sucrosic in some sections, with porosity up to 6.1%. No potential source rocks were collected from within Arnica Formation, nor from underlying Delorme Group and overlying Landry Formation. Bear Rock Formation, which is stratigraphic equivalent to Arnica and Landry formations in eastern Peel area, however was locally oil stained at Powell Creek.

Middle Devonian Ramparts Formation includes a reefal member that is present in eastern Peel area. One sample from northeast Peel area yielded porosity of 10.6%. Locally black shale (Carcajou marker) beds underlie the reefal member and have high TOC values to 12.4%. Ramparts Formation is underlain by Hare Indian Formation shale, which includes a basal member that is a rich source rock (up to 10.1% TOC). Overlying Ramparts Formation is Upper Devonian Canol Formation, with up to 8.3% TOC.

Future work will focus on describing petroleum systems and plays in Peel area. At the outset, it seems that possible carbonate reservoirs (with the exception of Ramparts Formation) are stratigraphically isolated from prolific source rocks. This suggests that structural traps would be important.

A PALYNOLOGICAL RECORD OF POSTGLACIAL CLIMATE AND FOREST DYNAMICS FROM TINY LAKE, CENTRAL MAINLAND COAST OF BRITISH COLUMBIA

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Pollen preserved in sediments from Tiny Lake in the Seymour-Belize Inlet region of the central mainland coast of British Columbia document postglacial changes in vegetation and climate and succeeds previous research at nearby Two Frog Lake. Following deglaciation prior to ca. 12,000 yr BP (ca. 14,150 cal. yr BP), a pine woodland grew at Tiny Lake when the climate was cool and dry. At ca. 11,900 yr BP (ca. 14,000 cal. yr BP), the climate became moister, which permitted spruce and fir to grow locally. Younger Dryas cooling at ca. 10,400 yr BP (12,000 cal. yr BP) arrested successional trends and allowed pine to re-expand but comparison with the pollen record from Two Frog Lake indicates that this was a local response. By ca. 10,150 yr BP (ca. 11,700 cal. yr BP) the climate became warmer and supported western hemlock and alder on moist sites but by 8740 ± 70 yr BP (9740 cal. yr BP) wetter conditions permitted western hemlock and Cupressaceae to expand. The timing of early Holocene vegetation change at Tiny Lake and at Two Frog Lake preceeded change elsewhere in coastal British Columbia where a warm and dry climate persisted until ca. 7500-7000 yr BP (ca. 8200-7800 cal. yr BP) but it is not clear whether synoptic scale climate variability or factors particular to the Seymour Belize Inlet Complex were the proximate cause of change. At 6860 ± 50 yr BP (7692 cal. yr BP) Cupressaceae replaced western hemlock at Tiny Lake when a modern cool and wet climate was established. Neoglacial climate deterioration at ca. 3900 yr BP (ca. 4350 cal. yr BP) is registered at Tiny Lake when peak expansion of Cupressaceae was reached but it is not documented at Two Frog Lake. The differences in the timing and nature of vegetation change to post-glacial climate fluctuations within the Seymour-Belize Inlet Complex demonstrate that the response of coastal forests to climate change can be highly variable, even on small spatial scales.

PALAEOPROTEROZOIC GREENSTONES AND PELITIC SCHISTS IN THE NORTHERN NAGSSUGTOQIDIAN OROGEN, WEST GREENLAND: EVIDENCE FOR A SECOND SUBDUCTION ZONE?

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The collisional Nagssugtoqidian orogen in central West Greenland is an important component of the Palaeoproterozoic plate-tectonic collage of eastern Laurentia. In the northern Nagssugtoqidian orogen (NNO), detrital zircons in pelitic chlorite schist from the Isuamiut islands north of Aasiaat yield a Palaeoproterozoic depositional age of ca.1890 Ma. The schist is associated with tholeiitic pillow lava and sills, podded chert, banded iron formation and black chloritic shale at upper greenschist/lower amphibolite facies. Terrigenous clastic rocks are almost absent. Deformation is weak, with open upright folds. Other islands to the south consist of Archaean orthogneisses with a strong southward strain gradient into a major ENE-trending high-strain zone. Farther south on the mainland, the greenstones and chlorite schists correlate with the contemporaneous but intensely deformed Naternaq belt, which is separated from underlying Archaean orthogneisses by a folded thrust sole.

Still farther south, a stable block undeformed in the Palaeoproterozoic isolates the Aasiaat region from the central Nagssugtoqidian orogen (CNO) with its Palaeoproterozoic Arfersiorfik magmatic arc, relics of Palaeoproterozoic oceanic crust, and farther south the Sisimiut arc. The CNO has previously been proposed to host the suture of a former single south-dipping subduction system, which allegedly gave rise to the two magmatic arcs. However, this model cannot account for the position of the Arfersiorfik arc amidst the relics of oceanic crust that should have fed it.

We propose a new plate-tectonic model for the Nagssugtoqidian orogen with two south-dipping subduction zones instead of one. In this model a new, northern subduction zone with ocean-related supracrustal rocks seen at the Isuamiut islands fed the Arfersiorfik arc. The Naternaq belt represents the southern part of a related collisional flower structure in this region. SE-directed kinematic indicators have indeed been found in the Naternaq belt, although most early structures have been obliterated by intense late Nagssugtoqidian deformation. The suture of the proposed new subduction zone may be linked through Disko Bugt to a recently proposed suture at the Nagssugtoqidian-Rinkian boundary near Ilulissat, where ocean-related supracrustal rocks are lacking. Furthermore, the old problem of the position of the Arfersiorfik arc in relation to its subduction system is solved, because in the new model this arc was fed by the northern subduction zone. The model can also help to justify why the Nagssugtoqidian-Rinkian system is so wide, and can explain previously observed geochemical and Pb-isotopic compositional breaks in orthogneisses in the Kangaatsiaq region.

A RELICT ISLAND ARC COMPLEX IN WESTERN GODTHÅBSFJORD, SOUTHERN WEST GREENLAND: EVIDENCE FOR MID-ARCHAEAN SUBDUCTION AND CONTINENTAL CRUSTAL ACCRETION

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A relict oceanic island arc complex with a zircon U-Pb age of 3071 ± 1 Ma in the eastern Akia terrane, Godthåbsfjord, southern West Greenland, constitutes a magmatic and geotectonic link between tonalitic orthogneisses and enclaves of older supracrustal amphibolite. The arc is marginally older than the surrounding orthogneisses and is the first supracrustal unit within the Akia terrane from which a reliable depositional age has been obtained. It now forms isoclinally folded panels of volcaniclastic meta-andesite with major and trace element island arc signatures, intercalated with volcano-sedimentary schist, tholeiitic amphibolite and opx-rich cumulate rocks. The identification of the arc complex provides new insight into mid-Archaean continental crustal accretion in West Greenland, and substantiates previous ideas that the orthogneisses are products of slab melting in convergent plate-tectonic settings. The presence of the arc complex also implies that Archaean high-grade orthogneiss-amphibolite associations may not represent plate-tectonic environments distinct from granite-greenstone associations, but expose deeper sections of the same convergent systems.

The arc hosts gold mineralisation in andesitic rocks which have been thoroughly hydrothermally altered in a synvolcanic epithermal environment prior to their deformation and metamorphism.

THE TIMANIDE, CALEDONIDE AND URALIDE OROGENS IN THE EURASIAN HIGH ARCTIC, AND RELATIONSHIPS TO THE PALAEO-CONTINENTS LAURENTIA, BALTICA, AND SIBERIA

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Recent studies of structure, stratigraphy and isotope geochronology on Svalbard and East Greenland have provided a foundation for reconstructing the Laurentian margin of the Arctic segment of the North Atlantic Caledonides. The axial zone of the high Arctic, Barentsian Caledonides has been inferred to trend northwards through the Barents Shelf to the northern edge of the Eurasian margin between Kvitøya (easternmost Svalbard) and western Franz Josef Land, based on analysis of drill-cores that sampled the pre-Carboniferous basement beneath Alexandra Island. The deformation front of the Barentsian Caledonides has been inferred to trend northeastwards between Franz Josef Land and Novaya Zemlya. The North Kara Terrane, reaching from Severnaya Zemlya (SZ) and northernmost Taimyr in the east to northern Novaya Zemlya in the west, comprises the northernmost foreland to the Barentsian orogen. Four lines of independent evidence are presented here demonstrating that the North Kara Terrane is a direct northerly continuation of the Timanide domain, the latter composing the Neoproterozoic accreted margin of Baltica in the Timan–Pechora–Urals region. These lines of evidence, all from October Revolution Island (SZ), include: (1) a westerly source for Old Red Sandstones successions, with 'Caledonian' fish fauna and detrital muscovites yielding Ar/Ar ages of c. 450 Ma; (2) Ordovician igneous rocks containing c. 550 Ma xenocrysts; (3) Cambrian turbidites with c. 545 Ma detrital muscovites; (4) Cambro-Silurian fauna with many species shared with Baltica. In addition, the Neoproterozoic turbidites of northern Taimyr have been previously reported to contain c. 560 Ma zircon populations, a signature that has been recently found in similar lithologies from Bol'shevik Island (SZ). All these late Vendian ages are characteristic of the Timanide Orogen of the Timan–Pechora–Novaya Zemlya region and, together, indicate that the North Kara Terrane was not an independent 'plate' or 'microcontinent' in the Palaeozoic, as previously proposed, but an essential part of southernmost (Ordovician coordinates) Baltica. Comparability of the evolution of the Timanian margin of the North Kara Terrane with the contemporaneous Baikalian evolution of adjacent Taimyr, together with the lack of evidence of Palaeozoic oceanic rocks and Uralian collisional, high-pressure metamorphic assemblages in Taimyr, suggests that the palaeo-continents Siberia and Baltica were never separated by a major ocean in the high Arctic. These relationships deserve closer investigation. (from Geol. Soc. London, Mem.32).

HYDROCARBON-INDUCED DOLOMITE FORMATION ASSOCIATED WITH HORMUZ SALT PLUG IN THE PERSIAN GULF, IRAN

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Salt domes are common geologic features throughout the Persian Gulf region, both onshore and offshore. Hormuz Island is a salt plug in the eastern part of the Persian Gulf. The Hormuz complex formed during the early Cambrian constitutes the core of a number of these salt plugs. This complex composed of salt, gypsum, fetid limestone, dolostone, sandstone, shale and volcanics.

Large crystals of black, white and pink dolomites (up to 3 cm in diameter) associated with Hormuz salt diapir. Associated with the dolomites are pyrite, gypsum, anhydrite, apatite and iron oxides. Based on this investigation the dolomites are interpreted as hydrocarbon-induced products formed by oxidation of leaked hydrocarbons, with the CO_2 produced expected to have an isotopic signature similar to that of the leaked hydrocarbons.

The $\delta^{13}C$ values of black dolomite range from –1.43 to –1.94‰ VPDB, indicating that little if any of the carbon is derived from the oxidation of hydrocarbons. Sea water containing relatively ^{13}C-enriched bicarbonate probably was the carbon source for dolomite precipitation. The $\delta^{18}O$ values of these dolomites range from -12.61 to -15.20‰ VPDB.

The $\delta^{13}C$ values of the white and pink dolomites range from –18.66 to –21.40‰ VPDB, indicating that there is a large depletion in their $\delta^{13}C$ values. The source of isotopically markedly depleted carbon could have been from the oxidation of hydrocarbons due to thermochemical sulfate reduction. Assuming that the sea water was involved in white dolomite formation, the $\delta^{18}O$ values of these dolomites (-15.94 to -17.21‰ VPDB) reflect precipitation under high temperature regime. Steady cooling took place thereafter due to the continuing uplift salt plugs.

Pyrite crystals and sulfur scattered throughout the salt dome may have formed in a reducing environment where the source of sulfur was H_2S from petroleum or its oxidation near the surface. Sources of iron include iron oxide in the surrounding environment. Large pyrites precipitated at depth within the migration plume and later flowed to the surface. Hence, it is envisaged that hydrocarbon leaked up along the flanks of the salt dome creating a reducing environment that promoted the formation of various types of diagenetic minerals.

GRANULITE FACIES XENOLITHS FROM PRINDLE VOLCANO, ALASKA: IMPLICATIONS FOR THE NORTHERN CORDILLERAN CRUSTAL LITHOSPHERE

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Xenoliths collected from Prindle volcano, Alaska (Lat. 63.72 °N; Long. 141.82 °W) contain crustal and mantle-derived xenoliths. The crustal xenoliths include granulite facies metamorphic rocks and charnockites, comprising orthopyroxene (opx)-plagioclase (pl)-quartz (qtz) ± mesoperthite (msp) and clinopyroxene (cpx). Opx-cpx geothermometry yields equilibrium temperatures (T) from 770 to 1015°C at 10 kbar. Pl-cpx-qtz geobarometry yields pressures (P) of ~6.6-8.0 kbar. Integrated mesoperthite compositions suggest minimum temperatures of 1020-1140°C at 10 kbar using solvus geothermometry. The absence of garnet in these rocks indicates a range of maximum pressure of 5 to 11.3 kbar, and calculated solidi constrain upper temperature limits. We conclude that the granulite facies assemblages represent relatively dry metamorphism at pressures indicative of crustal thicknesses similar to present day (~36 km). Zircon separates from a single crustal xenolith yield mainly Early Tertiary (48-63 Ma) U-Pb ages which are considerably younger than the cooling ages of the high-pressure amphibolites exposed at the surface. The distribution of zircon ages is interpreted as indicating zircon growth coincident with at least two different thermal events as expressed at surface: (i) the eruption of the Late Cretaceous Carmacks Group volcanic rocks in western Yukon and adjacent parts of Alaska, and (ii) emplacement of strongly bimodal high level intrusions across much of western Yukon and eastern Alaska in a possibly extensional tectonic regime. The distributions of zircon growth ages and the preservation of higher-than-present-day (> 25 ± 3°C/km) geothermal gradients in the granulite facies rocks demonstrate the use of crustal xenoliths for recovering records of past, lithospheric-scale thermal-tectonic events.

BIRD RIVER GREENSTONE BELT IN MANITOBA – NEOARCHEAN ARC MAGMATISM IN THE WESTERN SUPERIOR PROVINCE

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The Bird River greenstone belt (BRGB) in southeastern Manitoba, located between the English River and Winnipeg River domains, is part of a 150 km long, east-trending supracrustal belt that extends east to Separation Lake in Ontario. The oldest rocks in the BRGB are ocean-floor or back-arc volcanic sequences (Lamprey Falls Formation). They occur north and south of a central unit of ca. 2.73 Ma arc volcanic rocks. The arc rocks are the main component of the BRGB and are separated into a northern and a southern structural panel by a fault-bounded, east-trending turbidite sequence (Booster Lake Formation; 2.712 ±17 Ma). Similar-aged fluvial-alluvial sedimentary rocks (Flanders Lake Formation; 2.697 ±18 Ma) overlie the arc volcanic strata at the east end of the BRGB. Arc volcanic rocks of the north panel are calc-alkaline and consist of a diverse sequence of massive to fragmental volcanic rocks in which mafic, intermediate and felsic types are of roughly equal abundance. Arc volcanic rocks of the south panel, which are slightly younger than the north panel rocks, are tholeiitic and include both normal and geochemically more evolved types. Contacts between these lithologically and geochemically distinct components are invariably faulted.

Volcanic rocks of the BRGB were likely emplaced concomitant with northward subduction of oceanic crust, during convergence of the flanking North Caribou (3.0-2.87 Ma) and Winnipeg River (3.4-2.8 Ma) cratonic terranes from the north and south respectively. Turbidite and fluvial-alluvial sedimentary rocks to the north in the English River Domain (2.727-2.704 Ma) are similar in depositional age to epiclastic rocks (Booster Lake Formation and Flanders Lake Formation) that overlie the arc volcanic strata in the BRGB. The sedimentary sequences in the English River Domain and BRGB may be stratigraphically equivalent but are discrete tectonic elements because their contacts are invariably faulted or obscured by plutonism. Emplacement of the epiclastic deposits in the BRGB was in part coincident with continental collision, uplift and granitoid plutonism in the contiguous Winnipeg River and English River domains. The supracrustal components in the greenstone belt were subsequently deformed and tectonically interleaved prior to extensive orogenic granitoid plutonism at approximately 2.66 Ma.

SOURCE OF RUBY AND SAPPHIRES IN ALKALI BASALT GEMFIELDS

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The genetic process for the genesis of BGY sapphires and rubies recovered in continental basaltic gemfields remains problematic. Their formation will be discussed on the light of their O-isotopic composition:

Sapphires: The $\delta^{18}O$-values for more than 150 BGY sapphires originating from 13 countries show a $\delta^{18}O$ range between 3.0 and 7.7‰ (mean $\delta^{18}O$ of 5.8 ± 1.2%). The restricted O-isotope compositional range for most of the BGY sapphires fall into the isotopic range defined for sapphires in syenites ($4.8 < \delta^{18}O < 8.3‰$), plumasites ($4.2 < \delta^{18}O < 7.5‰$), biotite schists in granulitic gneisses ($4.6 < \delta^{18}O < 9.0‰$), and skarns in calc-silicates and marble ($7.7 < \delta^{18}O < 10.7‰$). Only French sapphires from Beaune sur Arzon ($8.0 < \delta^{18}O < 9.2‰$) and Le Mont Coupet ($\delta^{18}O = 10.3‰$) fall outside this range.

a) *magmatic origin*: the presence in some of these sapphires of melt inclusions, solid inclusions as feldspar, zircon, baddeleyite, pyroxene, columbite, hercynite, uraninite, U-pyrochlore, and fine oscillatory zoning in the crystals are different arguments compatible with a magmatic origin and/or environments rich in incompatible elements and volatiles as found in alkali-magmas. It suggests a crystallization in evolved melts resulting from the fractionation of basaltic magma (with an O-isotope composition around 6 and 7 ± 1‰) contaminated by lower crust.

b) *metamorphic origin*: the sapphires called "metamorphic" have pastel (blue, pink, orange) colour, and contains solid inclusions such as chromiferous spinel, pleonaste, fassaite and sapphirine. Such sapphires are found in the Barrington ($4.6 < \delta^{18}O < 6.2$) and the Tumbarumba ($5.5 < \delta^{18}O < 6.4‰$) placer deposits in Australia. These isotopic ranges overlap the isotopic ranges of two possible metamorphic sources : sapphires in plumasites and biotite schists. Besides skarns in calc-silicates and marble area also a good candidate, compatible with the oxygen isotopic values found for sapphires from the Mont Coupet and Beaune-sur-Arzon.

Rubies: The $\delta^{18}O$-values for more than 62 rubies originating from placers in basaltic environments have an O-isotope composition in the range 1.3 to 5.9 ‰. In the exceptional primary ruby deposit of Soamiakatra associated with alkali basalts in central Madagascar, ruby is contained in clinopyroxenite xenoliths. Ruby has low $\delta^{18}O$ values between 1.3 and 4.7‰ that overlaps the range of ruby in mafic and ultramafic rocks ($1.25 < \delta^{18}O < 6.8‰$). Ruby in garnet pyroxenite is one verified source for ruby found in basaltic placers.

THE DEVELOPMENT OF A TEACHING MATERIAL (TV PROGRAM "MIRACLE AND WONDER OF MINERALS") FOR EARTH SCIENCE EDUCATION AND MINERALOGY

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I developed an innovative TV program for the earth science education for children at the ages of 13 to 15 years old in collaboration with the national educational broadcasting association. The TV program consists of mineral hunting, fossil and rock hunting. The TV program was broadcasted all over Japan for children's enjoying finding the beautiful mineral and studying in their local nature. They also include the core content, competencies, and habits of mind that environmental educations (EE) and education for sustainable development (ESD) should support. Children understand how to find minerals in their local nature and enjoy studying geology and mineralogy and work together to contribute to conservation and sustainability of nature through watching the TV program. After watching the TV program and acting locally through studying local natural resources, children can recognize the beauty and wonder of minerals and foster the environmental literacy including an understanding of the importance and development of natural resources, their life style and the care and stewardship for the earth. The TV program was very interesting and more than one million children watched these TV programs all over Japan and have also been used by many elementary and secondary teachers for their science lessons and outdoor or

environmental education all over Japan. I have also developed some curriculum by using one of the TV program and implemented it and evaluated the quality of the TV program, my curriculum and practice. I have also made use of them for in-service teacher's training workshops for novice science teachers in Japan. The TV program are evaluated very useful for children and teacher's education. I will have a presentation about TV program development for earth science education and environmental education, my educational practice with them and assessment of it.

MINERAL CHEMISTRY EVIDENCE FROM LASER ABLATION ICP-MS SUPPORTING VOLATILE-INFLUENCED DIFFERENTIATION IN A LAYERED ALKALI BASALT, PENGHU ISLANDS, TAIWAN

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A thin (~20 m), alkali basalt flow on the Penghu Islands, Taiwan, shows well-developed textural layering related to the formation of segregation veins, but there is chemical layering largely correlating with height in the flow. Igneous augite, plagioclase and olivine show major element (by electron microprobe) and trace element compositions (laser ablation microprobe - inductively-coupled plasma mass spectrometry) supporting a role for volatiles in the chemical differentiation of the flow. The distribution of elements defining the chemical stratification (K, Rb, Li, Na, Zn in minerals and whole rocks, C, Cl, S, As, Pb and Sr based on whole-rock data) does not fit a crystal fractionation model. These elements tend to be complexed and moved by volatiles in various geological environments. The new igneous mineral data show that the chemical layering is unlikely to reflect secondary (alteration) processes. The experiment supports a role for convection-related scavenging and concentration of selected elements by volatiles during cooling and solidification of the flow. Comparisons with lava flows from other localities indicate that the platinum-group-elements may be concentrated by volatile movement. Volatile movement of elements may be accentuated in deep submarine basalts where pressure can increase the concentration of volatile components soluble in mafic magma.

TECTONIC ACCOMMODATION AND ALLUVIAL SEQUENCE STRATIGRAPHY

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A model is discussed for alluvial sequence stratigraphy where discharge and sediment supply are considered boundary conditions, subject to feedback effects. Primary control on alluvial facies changes is attributed to the gradient of the alluvial plain. This gradient is determined by the “graded profile”, a topographic profile defined by a graded stream linking a sediment source region to a subaqueous basin. It is argued that coupled source uplift and basin subsidence provide feedback on sediment supply, grade, and flux that reinforce expected facies changes, in part providing justification of initial assumptions. The model provides a rationalization for a generally upward-fining alluvial sequence that is coeval with a general upward-fining to coarsening nearshore sequence, bridging the theoretical gap between subaerial and subaqueous sequences. It also provides an interpretation of basin-scale stratigraphy based on the tectonic evolution of sedimentary basins, in keeping with the models for how they form.

SEDIMENTOLOGY OF CRETACEOUS WAVE-DOMINATED PARASEQUENCES OF THE TREVOR FORMATION, PEEL PLATEAU, NWT

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The stratigraphic succession of Martin House, Arctic Red, and Trevor formations constitute the Cretaceous rocks of the Peel Plateau and Plain region at the front of the Mackenzie Mountains, west of Norman Wells. Martin House Formation is a transgressive marine sandstone. Arctic Red Formation is a thick succession of basinal marine mudstone.

Trevor Formation is subdivided into four facies: mudstone; interbedded sandstone and mudstone; amalgamated hummocky cross-stratified (HCS) sandstone; and parallel-laminated sandstone. Mudstone facies is composed of poorly indurated mudstone, siltstone, and very minor sandstone interpreted as offshore deposits. Interbedded sandstone and mudstone facies contains storm beds of HCS, parallel lamination and combined flow ripples that alternate with interlaminated mudstone and ripple cross-laminated sandstone. Interbedded facies is interpreted as transitional to lower shoreface. Superimposed storm deposits of HCS and parallel lamination comprise the amalgamated sandstone facies, interpreted as middle shoreface. Parallel laminated sandstone facies is dominated by horizontal parallel lamination with minor scours. The association of horizontal parallel lamination in fine to medium-grained sandstone is interpreted to represent a storm-dominated upper shoreface.

Trevor Formation parasequences, 20-60 m thick, are bounded by flooding surfaces commonly associated with a transgressive lag. A typical upward-coarsening succession is from mudstone, through interbedded sandstone and mudstone, to amalgamated sandstone facies. Associated HCS increases in wavelength from small (10-30 cm) to large scale (1-3 m). These parasequences record lower and middle shoreface progradation of fine-grained sand into an offshore mud-rich marine basin.

CANADIAN GEOSCIENCE EDUCATION NETWORK (CGEN) – CONNECTING THE COMMUNITY

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CGEN, the outreach arm of the Canadian Federation of Earth Sciences (CFES), is a collective of close to 200 individuals from all over Canada who work to promote geoscience education and public awareness of science. CGEN’s objectives are to: 1) facilitate communication and cooperation between organizations and individuals involved in outreach through the sharing of information, ideas and resources; and 2) encourage, support and coordinate the development of programs and projects that are of interest across Canada, but which also benefit from grassroots involvement in local communities. CGEN also encourages CFES member societies and organizations to support outreach activities through financial and in-kind contributions. Five programs form the core of CGEN’s current focus.

- The national *EdGEO* program (www.edgeo.org), initiated in the 1970s, supports earth science workshops for teachers that are organized by teams of local educators and geoscientists. Funding is provided by three CFES member societies, Canadian Society of Petroleum Geologists, Geological Association of Canada, and Mineralogical Association of Canada, and by CFES itself.
- *What on Earth* (www.whatonearth.org), a biannual national earth science newsletter established at the University of Waterloo in 1987, provides a wide range of earth science information for teachers in Canada and elsewhere.

- *EarthNet* (www.earthnet-geonet.ca) is a virtual resource centre tailored to the needs of Canadian earth science educators and students; it has a vast array of earth science materials for use in the classroom.
- For over 15 years, *Careers in Geoscience* has been an important resource for Canadian students and others seeking career information. It was available first as a booklet and then as a website (www.earth.uwaterloo.ca /services/geoscience/careers.html); an updated website is under development.
- *Geoscape Canada* and *Waterscape Canada* communicate practical earth science information to communities across Canada through a series of electronic and hard-copy posters and other resources (www.geoscape.nrcan.gc.ca). Sixteen Geoscape projects and four Waterscape posters have been completed. Current activities include *Northwest Territories Geoscape*, a northern British Columbia geological highway map, community guides, and educational resources linked to various posters.
- *Friends of Canadian Geoheritage* (http-server.carleton.ca/~jadonald/friends.html) is a new national program currently being piloted in the Ottawa-Gatineau area; it is working with municipal and other government agencies, schools, universities, and other community groups to help preserve, protect and promote Canada's rich geoheritage.

CGEN strives to strengthen the synergy between these five core activities and explores new links between these and other programs, including projects linked to International Year of Planet Earth.

PALEOMAGNETISM AS A RELATIVE CHRONOMETER OF DYKES WITHIN A SWARM: APPLICATIONS TO THE 2.1 Ga MARATHON LARGE IGNEOUS PROVINCE, NORTHERN ONTARIO

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U-Pb geochronology and paleomagnetism of the 2.1 Ga Marathon dyke swarm show that only one geomagnetic field reversal has taken place over a 25 m.y. time span. Older dykes of "*N*" polarity are dated from 2125 to 2121 Ma and younger ones of "*R*" polarity from 2112 to 2101 Ma. A single polarity reversal also characterises the 2171-2167 Ma Biscotasing dyke swarm. These results have helped place dykes within both swarms into older and younger sub-populations based on magnetic polarity. Geochemical analyses on dyke chilled margins show that older dykes within each swarm tend to be more enriched and more fractionated, in terms of incompatible trace element patterns, compared to younger dykes. This result may indicate progressive changes in the degree of crustal contamination and/or in partial melting of the source. The geochemical trend observed in the Marathon swarm is also seen throughout a large radiating dyke pattern, which comprises the Marathon, Kapuskasing and Fort Frances swarms. The youngest Fort Frances swarm (U-Pb dated from 2076 to 2067 Ma), shows on average the lowest trace element enrichment and fractionation. The Kapuskasing dykes remain undated but are probably of similar age to Marathon dykes because (a) they are intermixed with U-Pb dated Marathon dykes of similar trend, (b) they are geochemically indistinguishable from the Marathon swarm, and (c) like the Marathon swarm, they also show mixed polarities with *N* dykes on average having higher trace element enrichment and fractionation compared to *R* ones. Geochemical data from all three swarms together suggest a progressive geochemical evolution that genetically links them to a common mantle plume event about 50 m.y. in duration, the centre of which occurs at the focal region of the radiating dyke pattern. We refer to this magmatism as the Marathon Large Igneous Province. Independent estimates of the location of the plume centre using either the Marathon or Fort Frances swarms (both of which show a fanning pattern) place the centre in Wisconsin suggesting that throughout a period of 50 m.y. the plume remained stationary with respect to the lithosphere. This observation is compatible with paleomagnetic results which show a lack of polar wander during the time represented by the Marathon LIP.

VEIN RELATIONSHIPS AND MINERAL COMPOSITIONS AT THE HOIDAS LAKE REE DEPOSIT, RAE PROVINCE, NORTHERN SASKATCHEWAN

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Traditionally, economic concentrations of Rare Earth Elements (REE) predominantly occur in monazite-bearing placer deposits or are associated with carbonatites. Even for well known, and thoroughly researched, REE deposits conjecture still remains as to the details of the genesis of many of these unusual deposit types. The Hoidas Lake REE Deposit, in the Rae Province of northern Saskatchewan, is an interesting, potentially instructive and economic deposit. It is one of approximately 30 REE showings in the region which are spatially associated with a regional-scale fault system. The mineralized occurrences are concentrated along the Hoidas-Nisikkatch fault which parallels the Black Bay Fault system. The region has undergone significant internal deformation, plutonism, and metamorphism associated with the tectonic assembly of Laurentia during the period between 2.0 and 1.7 Ga.

Reconnaissance work has revealed that the Hoidas Lake REE Deposit is unique in its mineralogy, as the REE are hosted by allanite and apatite, as opposed to the more typical monazite or bastnaesite hosts. Detailed examination has defined an anastomosing, eastward dipping vein system adjacent to the Hoidas-Nisikkatch fault. The vein system is complex, hosting multiple vein generations with various mineralogical associations. Hyalophane-dominant veins are the earliest vein type with REE enrichment, followed by rather ubiquitous allanite mineralization which is often associated with diopside-rich intervals. Allanite can also be found throughout the various apatite vein generations. Currently, there are four visually distinct apatite generations which, although lower grade than the allanite, will provide the main source of REE due to the volume of apatite in the vein system. Overall, the Hoidas Lake REE Deposit is enriched in Light Rare Earths, specifically La, Ce, and Nd, with grades average from between 2% and 4% Total Rare Earth Oxide and a maximum grade of 26.9% in an allanite-rich sample.

The unusual mineralogy observed at Hoidas Lake, and the multiple vein generations, provides a valuable opportunity to enhance the available knowledge about the formation and evolution of REE deposits. Examination of this deposit through a combination of petrographic and microprobe analysis will be used to document mineralogical and geochemical changes between vein generations to provide constraints on the genesis of the Hoidas Lake REE deposit. In addition to its academic value, the Hoidas Lake REE Deposit has significant economic potential; should the site be brought into production it will be the only currently operating Rare Earth mine in North America.

NUNAVUT HAS IT ALL! EXPLORATION OVERVIEW, RESOURCE POTENTIAL AND TRENDS

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Nunavut is geologically diverse and this, coupled with increased commodity prices, continues to attract exploration companies. Nunavut's three regions from west to east are the Kitikmeot, Kivalliq and Qikiqtani. The Kitikmeot is underlain by rocks of the Archean Slave and Bear provinces, separated and overlain by Paleoproterozoic sedimentary rocks of the Wopmay Orogen. Paleoproterozoic inliers occur on Victoria Island, overlain by Paleozoic Arctic Platform sedimentary rocks. The Slave is separated from the Western Churchill Province (Archean to Paleoproterozoic) by the Paleoproterozoic Thelon Orogen that underlies much of the Kivalliq. Sedimentary Hudson Platform rocks are found on islands within Hudson Bay. In the Qikiqtani, most of Baffin Island, eastern Devon Island and eastern Ellesmere Island are underlain by the Churchill province while the northern Arctic islands are underlain by the Arctic Platform.

Exploration expenditures for Nunavut are at record levels with companies active in all three regions and reporting expenditures late-2006 of over $181 million, ranking Nunavut third in Canada. Gold and diamonds are the main targets with $70 million and $38 million, respectively, spent by companies. Nickel-copper-platinum group elements (PGEs), base metals, precious metals and uranium are all enjoying renewed interest.

There was a shift in 2006 from diamond exploration to gold re-emerging as the dominant commodity of interest. Two gold projects (Doris North, Meadowbank) are in the regulatory review process. Several other gold projects (George and Goose lakes, Meliadine West) are well advanced with projects developing in central Nunavut (Committee Bay) and central Baffin Island.

The opening of Jericho, the territory's first diamond mine, in 2006 represented an outstanding event for Nunavut. Other areas – the Kugaaruk area and between Rankin Inlet and Chesterfield Inlet in central Nunavut – have emerged as significant diamond districts, as well as the Brodeur and Melville peninsulas and Baffin Island of the Qikiqtani region.

High Lake (base metals) in western Nunavut is in the regulatory review process and Hackett River (Ag-Zn-Au-Cu-Pb) is advancing well. Ferguson Lake (central Nunavut) represents the territory's largest and most advanced Ni-Co-Cu-PGEs exploration project.

Nunavut's Proterozoic basins, the western Hornby Bay Basin and the central Thelon Basin, are re-attracting exploration interest for uranium. With a commodity price exceeding US$70/lb for U_3O_8, companies are re-examining these basins using exploration knowledge from Saskatchewan's Athabasca Basin. The Kiggavik and Sissons properties in the Thelon Basin represent Nunavut's largest known uranium resources (140 million pounds of U_3O_8) with associated Au-Pt mineralization.

With the increased value of iron, the Mary River project, northern Baffin Island, is attracting much interest with high-grade iron ore deposits. Southern Baffin Island has an emerging gemstone project with naturally-blue sapphires.

U-Pb BADDELEYITE AGE FOR OTISH GABBRO: IMPLICATIONS FOR CORRELATION OF PROTEROZOIC SEDIMENTARY SEQUENCES AND MAGMATIC EVENTS IN THE EASTERN SUPERIOR PROVINCE

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Otish Gabbro sills intrude clastic sedimentary rocks of the Otish Group in the southeastern Superior Province within 80 km of the Grenville Front. They were previously thought to have been emplaced at ca. 1730 Ma or later on the basis of Sm-Nd and K-Ar ages. In the present study, however, a much older U-Pb baddeleyite age of ca. 2169 Ma has been obtained from a sample originally collected in the paleomagnetic study by Fahrig and Chown (1973). The new age indicates that Otish sills are related to the giant ca. 2170 Ma northeast-trending Biscotasing dyke swarm to the southwest, and that the age of the Otish Group falls between ca. 2510 Ma, the age of underlying Mistassini dykes, and ca. 2169 Ma. This age bracket is only a little different from the ca. 2450-2217 Ma bracket for the Huronian Supergroup of the Southern Province based on the ages of underlying Matachewan dykes and intruding Nipissing sills, suggesting that the two sedimentary sequences could be coeval. Similarly, the Otish Group could be coeval with sedimentary rocks of the Sakami Formation to the north, which are cut by ca. 2216 Ma Senneterre diabase dykes. In contrast, a link with sedimentary rocks of the Richmond Gulf Group on the east coast of Hudson Bay is now deemed unlikely as this sequence is thought to be no older that 2025 Ma. Given the age bracket for the Otish Group, the presence of Nipissing-Senneterre age sills might also be expected in the Otish basin because Senneterre dykes have been observed to the southwest, northwest and northeast. The paleomagnetic work of Fahrig and Chown on sills in the Otish Group did not reveal the remanence direction that characterizes Nipissing and Senneterre intrusions, perhaps because only two or three distinct sills were sampled. The mean paleomagnetic direction that was obtained by Fahrig and Chown is about 15 degrees steeper than expected for Biscotasing age intrusions. This may reflect the fact that too few distinct sills were studied to average out paleosecular and (or) the likelihood that alternating field demagnetization in this early study failed to fully remove unstable magnetization components.

U-Pb GEOCHRONOLOGY OF THE WESTERN CHANNEL DIABASE, WOPMAY OROGEN: IMPLICATIONS FOR THE APWP FOR LAURENTIA IN THE EARLIEST MESOPROTEROZOIC

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The late Paleoproterozoic-early Mesoproterozoic apparent polar wander path (APWP) for Laurentia is largely undefined between ca. 1740 Ma, the age of the well-defined paleopole for Cleaver dykes of the Wopmay Orogen, and ca. 1460-1430 Ma, the age of well-established Elsonian pluton poles from Labrador. Sheets and dykes of Western Channel Diabase (WCD) occur principally around the eastern and northern arms of Great Bear Lake where they intrude the lower portion of the flat-lying Hornby Bay Group and deformed volcanic-plutonic rocks of the Great Bear Magmatic Zone. They crosscut and hence are younger than ca. 1740 Ma Cleaver dykes. Previously, their emplacement age was poorly constrained, although published Rb-Sr and K-Ar ages of ca. 1400 Ma have been interpreted as either emplacement or overprint ages. A paleomagnetic pole for the WCD from an early study by Irving et al. (1972) is based on the mean of remanence directions that may fall into two groupings with similar northerly declinations and mean inclinations of –36° and –56°, or are perhaps streaked between these directions. The WCD remanence is likely primary because it has been reported that a Cleaver dyke in the vicinity of WCD intrusions has retained a typical Cleaver paleomagnetic direction. Two samples from the archived paleomagnetic collection of W.F. Fahrig at the Geological Survey of Canada, one with the shallower remanence direction and another with the steeper direction, were used in the present geochronological study.

They yielded similar U-Pb ages of 1592 ± 3 Ma and 1590 ± 4 Ma. The explanation for the two directional groupings or directional smear in the paleomagnetic data is unclear. The paleomagnetic sites may represent a very limited number of individual intrusions whose directions do not average out paleosecular variation. Alternatively, the apparent streaking may indicate that a small viscous component was not fully removed at some sites. Although further work is needed to test these hypotheses, it is considered unlikely that the published mean WCD paleopole is widely divergent from the true paleopole. The WCD paleopole falls midway in time between Cleaver and Elsonian paleopoles, providing an important new constraint on the drift of Laurentia in the earliest Mesoproterozoic. A tentative comparison of paleopoles from Laurentia and Baltica at ca. 1840-1825 Ma, ca. 1590-1570 Ma and ca. 1270-1265 Ma suggests that Baltica may have been located close to eastern Greenland between 1840 and 1265 Ma.

REMOTE PREDICTIVE MAPPING (RPM) IN THE PHELPS LAKE AREA, NORTHERN SASKATCHEWAN

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Surficial geology mapping by remote sensing data has experienced remarkable development in the past two decades. Remotely sensed imagery, especially Landsat TM/ETM and RADARSAT-1 imagery, have been increasingly employed in surficial geological mapping. The Phelps Lake Area was chosen to test the application of remotely sensed imagery as a remote predicative mapping tool for surficial geology in northern Saskatchewan. The study utilizes Landsat TM/ETM imagery, airborne radiometric and magnetic data, DEM, RADARSAT-1 imagery, and recently published surficial geology maps.

The Phelps Lake region is largely underlain by Archean granitoid rocks. The terrain is gently undulating with generally 20 meters or less topographic relief. The area has extensive drift cover (>70%) comprised of till, boulders, organic, sand and gravel materials, interspersed with rock outcrops, boulder fields, vegetation, and water bodies. The diversity of the surface coupled with geological field mapping makes the area an ideal site to test the use of remotely sensed data.

The process of remote predictive mapping began with a generalized characterization of the region, through a classification of Landsat imagery. Six classes of image training areas were derived from the surficial maps to classify the Landsat data. The resultant imagery was integrated with DEM, airborne radiometric data, and magnetic data. This in turn will be combined with data from principle component analyses of RADARSAT-1 imagery to reveal surface geological features that are often masked by vegetation. The end product is a predictive GIS model that can be used as a mapping tool in this region. Subsequent testing of this model is proposed in adjacent mapped and unmapped regions to evaluate its efficacy.

It is anticipated that the use of this type of predictive model has the potential to assist in surficial geology mapping over large remote areas, where costs for field based mapping are high, often prohibitive, as well as labour and time-intensive. This model could become a very efficient and cost-effective mapping approach for remote areas of Canada.

ISSUES OF HUMAN RIGHTS ISSUES CONFRONTING CANADIAN COMPANIES OPERATING OVERSEAS

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A series of Parliamentary sub-Committee hearings were held on the activities of Canadian mining companies overseas and on the broader issue of corporate social responsibility concerning activities of Canadian mining companies in developing countries. These led to formal recommendations that the Government, inter alia "Establish clear legal norms in Canada to ensure that Canadian companies and residents are held accountable when there is evidence of environmental and/or human rights violations associated with the activities of Canadian mining companies." In response, the Canadian Government hosted four National Roundtables on Corporate Social Responsibility and the Canadian Extractive Sector in Developing Countries to provide input to its report back to Parliament. This paper summarizes published allegations presented to the Roundtables during 2006 and discusses measures to address these issues and attempt to avoid future occurrences.

MELT INCLUSION EVIDENCE FOR CONTRASTING METAL ENRICHMENT PROCESSES DURING MAGMATIC FRACTIONATION IN INTRUSION-RELATED GOLD DEPOSITS AT CLEAR CREEK, YUKON, CANADA AND FORT KNOX, ALASKA, USA

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Contrasting melt inclusion compositions in granitoids from Clear Creek ("CC"), Yukon and Fort Knox ("FKX"), Alaska may account for the differences in the style and extent of mineralization in these deposits. At both deposits, an early generation of coeval silicate melt and fluid inclusions of primary origin occur in magmatic apatite. Aqueous-carbonic fluid inclusions in apatite (CO_2 ~22-43 vol%) decrepitate near 400°C, but halogen exchange thermometry for apatite-biotite pairs shows that inclusion entrapment occurred at a minimum of 560-680°C at FKX, and 795-895°C at CC. LA-ICP-MS and SEM-EDS analyses show that "early-stage" melt trapped in apatite contained elevated F, Sb, and As. "Early" silicate melt inclusions also occur in magmatic titanite. Only at FKX do these early silicate melt inclusions coexist with trapped droplets of Au, Bi, As, Sb-rich sulfide melt.

Coeval aqueous-carbonic fluid and silicate melt inclusions of secondary origin also occur in magmatic quartz. These "late-stage" melts trapped in quartz were peraluminous, B-rich (400-4000 times chondritic), rhyodacitic liquids. LA-ICPMS analyses of the melt inclusions show that the late stage melts at CC and FKX were highly enriched in Au, As, Sb, Bi, Ga, W, Tl and Mo. Metal concentrations in the melt inclusions correlate with B and Cs concentrations, providing direct evidence that metal enrichment occurred via magmatic fractionation as the metals were excluded from crystallizing phases in the granitoids. However, the late stage melts at CC did not achieve the same degree of metal enrichment as at FKX. For example, Bi and Sb concentrations in the late stage melt inclusions are 60-100 times chondritic at CC, but reach concentrations of 540-4500 times chondritic at FKX.

The results of this study provide the first direct evidence that an aqueous-carbonic fluid phase separated from crystallizing granite at an early stage at both CC and FKX, and confirms an ultimately magmatic origin for the ore metals in these mineralizing systems. However, despite consistency in the type of fluid exsolved and the timing of this fluid exsolution, granitic melt at FKX reached a far more advanced stage of metal

enrichment than at CC. Different degrees of metal enrichment in evolving silicate melts may have influenced the relative amounts of ore metals that could be ultimately supplied to aqueous-carbonic magmatic-hydrothermal fluids responsible for ore formation. Identification of extremely metal-rich silicate or sulfide melt inclusions has potential to be utilized in determining pluton prospectivity in the Tintina Gold Province, Yukon.

GEOLOGY OF THE DO-27 KIMBERLITE PIPE

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The DO-27 kimberlite pipe is located within the Lac de Gras kimberlite province, approximately 30 km southeast of the Diavik™ diamond mine. It is one of the largest pipes in the Lac de Gras area, with a surface area of at least 8 hectares. The main pipe is steep sided with a shallower, complex lobe present in the northeastern area of the pipe.

Preliminary investigations suggest that the main vent comprises massive pyroclastic kimberlite (PK) with few internal variations and only very subtle bedding. There are no obvious variations in the proportion of single olivine grains versus juvenile lapilli, or in the types of juvenile lapilli present. This lack of variation suggests that there may only be one phase of kimberlite represented in the PK of DO-27. The most obvious variations within the PK are seen in the country rock xenoliths, which can be crudely summarized by granite xenoliths being most common towards the centre of the pipe, and shale xenoliths most common towards the pipe margins. The total dilution throughout the main PK remains <5%, and therefore does not have significant implications for diamond grades.

The northeast lobe of DO-27 is complex and contains many different types of kimberlite. Volumetrically, the northeast lobe is dominated by PK which has many similarities with the PK of the main vent, but also displays some subtle differences. Beneath the PK in the northeast lobe, the kimberlite geology is complex and includes volcaniclastic kimberlite (VK) units and VK breccia units that are highly variable and not continuous; these units have been modeled as a complex VK zone. In some areas, the northeast lobe is underlain by kimberlite characterized by a high proportion of pulverized, fine-grained granite fragments; this material is interpreted to represent early deposits related to pipe excavation. Beneath these units is a granite-rich (>25%) kimberlite that contains common fresh, coarse olivine macrocrysts, and is interpreted to be magmatic; this kimberlite may be related to the magmatic sheets common north of the DO-27 pipe. Drilling indicates that this is a large and complex kimberlite and more work is required to fully understand the geology of it.

GEOLOGICAL TIES AND SHARED RESOURCE POTENTIAL ACROSS THE NORTHERN BAFFIN BAY - NARES STRAIT REGION, NORTHERN NUNAVUT AND NORTHWEST GREENLAND

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Plate tectonics can be said to have been born with the recognition that the ancestral Greenland plate makes an obvious fit with the Labrador-Baffin continental margin. Alfred Wegener died on the Greenland Ice Cap trying to collect the geodetic proof. These plate motions necessitate the creation of new oceanic crust in Labrador Sea, and approximately 300 to 350 km of sinistral strike slip motion on the Wegener transform located in Nares Strait between northwest Greenland and Ellesmere Island. The problem with Wegener's model is that the Wegener Fault has not been proven to exist.

Eight of twelve geological markers of mostly Paleozoic age allow for between 65 and 75 km of Paleogene sinistral fault displacement and south-directed thrusting in the northern Nares Strait region. In contrast, eight of nine geological markers of Archean and younger ages from southern Nares Strait and northern Baffin Bay do not permit any significant faulting. The simplistic Wegener transform model is now replaced by one involving a series of distributed Late Cretaceous-Paleogene plate motions across the Innuitian Orogen. During this interval, part of Ellesmere Island lay on the ancestral Greenland plate. Three hundred and fifteen kilometres of sea floor spreading and continental margin extension in northern Baffin Bay are accounted for in the north by a series of contemporaneous tectonic motions. These include northeast-southwest extension in Cretaceous-early Paleocene time on Ellesmere and Axel Heiberg islands (30 to 55 km), north-south extension in Lancaster Sound and Devon Island (55 km) during the Eurekan Orogeny, dextral strike slip and extension in Jones Sound and on southeast Ellesmere Island linked to thrusting north of Bache Peninsula and sinistral strike slip on the JDFS (70 km) and, south-directed followed by southwest-directed shortening across the Sverdrup Basin (100km+35km). The latter deformation is attributed to counterclockwise rotation and escape to the west of a semi-rigid northern Ellesmere block during collision with the Greenland plate.

The close geological ties between northwest Greenland and Ellesmere and Devon islands in northern Nunavut are readily exploited for purposes of mineral exploration. Shared resource potential includes kimberlitic diamond and sediment-hosted deposits containing zinc, lead and precious metals. While petroleum potential is limited within correlated lower Paleozoic strata, significant new opportunities are now recognized for hydrocarbon exploration within the Cretaceous and Cenozoic sedimentary basins that have formed on the facing continental margins. The best opportunities lie in northern Baffin Bay and Lancaster Sound.

DAMTSHAA VERSUS ORAPA: A MINERALOGICAL COMPARISON OF INCLUSION-BEARING DIAMONDS FROM NEW AND OLD BOTSWANA MINES.

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The Damtshaa mine in northern Botswana consists of four kimberlite pipes and is part of the cluster of pipes which includes the Orapa mine, the second largest primary diamond deposit in the world. The present work details the mineralogy and chemical composition of syngenetic inclusions in a representative set of diamonds from these four adjacent sources and compares these results to similar information from the major regional mine.

Of the present diamonds, the eclogitic (E-type)/ eclogitic + peridotitic (P-type) abundance ratio is 40.0 against a value of 87.2 for Orapa. This significant difference arises because the biggest contributor to the Damtshaa production, BK15, has a distinct P-type diamond population. Sulphide-bearing diamonds are the other significant contributor at Damtshaa with 27% with a similar value of 20% at Orapa.

The chemical composition of the inclusions in Damtshaa and Orapa diamonds are generally similar, but distinctions exist. For example, among P-type inclusions at Damtshaa, i) an olivine with just over 0.2wt % Cr_2O_3 indicates a formation at temperatures higher than normal, ii) some garnets tend to be more harzburgitic, iii) spinels have lower Fe^{3+} contents and iv) one spinel has greater than 20wt % Al_2O_3, suggesting diamond formation in a regime of relatively low silica activity. The

principal distinction among Damtshaa E-type inclusions is that at least one garnet has an unusual level of Na_2O (0.38%), indicative of formation at greater depth for some of the diamonds. With the websteritic (W-type) inclusions at Damtshaa a garnet has a relatively low Cr_2O_3 content, whilst two clinopyroxenes are relatively high, compared to Orapa. Sulphide inclusions belong to both principal parageneses.

Of the physical properties of the diamond hosts, only nitrogen contents and aggregation states have been determined. Diamonds containing E-type silicates have the most nitrogen. Nitrogen ranges from zero to 1300 at. ppm, with higher total nitrogen broadly a function of greater nitrogen aggregation, which ranges between 10 and 85% Type IaA/B. Compared to Orapa, the present data would be hard to distinguish, but some E-type diamonds from Damtshaa have higher nitrogen with relatively lower nitrogen aggregation.

GROWTH OF AN EARLY ARCHEAN PROTOCONTINENT: NEW RESULTS FROM THE NORTHWESTERN SUPERIOR PROVINCE

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The Assean Lake complex (ALC), located at the northwest margin of the Superior Province in north-central Manitoba, Canada, hosts a Mesoarchean assembly of rocks that record a complex and prolonged crustal history dating back to at least 3.9 Ga. South of the ALC, the Pikwitonei Granulite Domain and associated Split Lake Block of the northwestern Superior Province are comprised of granulite, and partially retrogressed granulite rocks, respectively. Gneisses and migmatites of the Split Lake Block are dominated by tonalite and granodiorite. Unlike the ALC, sedimentary rocks are rare in the Split Lake Block, but sediments from both areas contain ancient ≥ 3.6 Ga detrital zircon grains. Hf isotopic analysis of Paleoarchean detrital zircon from the ALC indicates that the grains were derived from rocks which formed by reworking of significantly older (>4.0 Ga) crust. The youngest detrital grains in the Split Lake Block are ca. 2.7 Ga, whereas the youngest detrital zircons in the ALC are ca. 3.2 Ga. The presence of zircon detritus with diverse U-Pb ages is consistent with sediment derivation by erosion of continental-type crust.

Although sedimentary rocks in the ALC and Split Lake Block were deposited at different times, both regions share circa 3.16-3.20 Ga Mesoarchean plutonism. Clear contact relationships between the metasedimentary and granitoid rocks have not been identified, but these plutons are considered intrusive into the ALC supracrustal package, whereas they are considered basement to the supracrustal packages of the Split Lake Block. The >3.5 Ga TCR Nd model ages obtained for 3.16-3.20 Ga plutons in the ALC indicates that subduction derived melts mixed with ancient crustal material. The Paleoarchean component of the ALC acted as a protocontinent nucleus that underwent significant crustal growth in the Mesoarchean. Mesoarchean crust of the Split Lake Block may have formed contemporaneously to the ALC as a separate protocontinent or, alternatively, the Mesoarchean basement of the northwestern Superior Province may be an extension of the ALC. Regardless of their Mesoarchean origin, Neoarchean sediments in the Split Lake Block contain some ancient (≥ 3.6 Ga) detritus, and therefore the ALC and northwestern Superior Province likely amalgamated prior to 2.7 Ga. One puzzling question is how the ALC escaped the granulite grade metamorphism of the Split Lake Block and Pikwitonei Granulite Domain. The answer may be intimately tied to the reactivation history of crustal-scale shear zones at the northwestern Superior Province margin.

DEVELOPMENT OF A NEW TECHNIQUE FOR CLASSIFYING GARNET AND ILMENITE FROM KIMBERLITE, USING CRYSTAL STRUCTURAL INFORMATION

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The industry-accepted method for classifying kimberlite indicator minerals (KIMs) relies on electron probe micro-analysis (EPMA). Chemical composition is one of the major controls on crystal structure, and as such, crystal structure may be used as a proxy for chemical composition. The long term goal of this research is to use crystal structural information obtained by micro X-ray diffraction (μXRD) of both garnet and ilmenite obtained from various parageneses, to determine the diamond potential of kimberlites. Samples have been obtained from the following kimberlites: Bobbejaan, Premier, Sheiba, Jagersfontein and Roberts Victor (South Africa), as well as Aultman (Wyoming), Attawapiskat and Koala (Canada). These are kindly on loan from various donors.

Garnet initial results agree with crystal-chemical trends predicted from cation radii, showing a correlation between Mg - Ca substitution in the triangular dodecahedral site, and Cr - Al substitution in the octahedral site, where the larger cations (Ca and Cr) increase the size of the unit cell. Garnets from various parageneses have different trends. For example, there is a strong correlation (R^2 = 0.85) between variation in the unit cell size of Cr-pyropes from Attawapiskat (Ontario) and the mole fraction of both chromium and calcium. Closer examination of the relationship between Cr/(Cr+Al) and refined unit cell shows that the trend can be extrapolated down to the (Cr-free) pyrope end-member, and up to a nearly 50-50 knorringite-uvarovite solid solution. Similar trends are observed for plots of X/(Ca+Mg+Fe^{2+}) versus unit cell (where X = Ca, Mg or Fe^{2+}).

Ilmenite research is still in its initial phase. Previous research into the crystal structure of ilmenite has shown that it is more compressible along the c-axis than the a-axes at high pressure. This property can be measured using μXRD and is potentially useful as a geobarometer. In addition, the Fe^{2+} to Fe^{3+} ratio in an ilmenite crystal can be measured using X-ray photoelectron spectroscopy (XPS), and used to infer the oxidative conditions of the source region and/or the kimberlite melt which transported it to the surface. As diamond is only stable in a narrow range of redox conditions, this data has major implications regarding its preservation potential. The potential of μXRD to determine the Fe^{3+} content of ilmenite will also be examined. The goal is to establish a method for predicting the pressure at which an ilmenite grain formed, and whether or not its host kimberlite had the potential to sample and preserve diamond.

POTENTIAL ECONOMIC REE SOURCES IN CANADA

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Canada's potential rare-earth elements (REE) sources are contained in deposits occurring in numerous geologic provinces and depositional environments including igneous alkalic deposits, carbonatites, igneous affiliated deposits (including pegmatites and veins), iron oxide-copper-gold (IOCG) deposits, paleoplacers, and uranium deposits. Ten locations were selected for their greater potential for REE economic development. Various factors influence the economic viability of the Canadian deposits.

Estimation of the economic value of REE deposits is complex and may not be determined simply by grade and tonnage

estimates alone. More important factors are the REE mineralogy, mineral processing, and relative distribution of the REE between the light-group rare-earth elements (LREE) and the heavy-group rare-earth elements (HREE) in these deposits.

In this presentation, we attempt to show how REE occurrences may be evaluated based on a combination of mineralogy, grade, tonnage, amenability to mineral processing and, in particular, REE distribution in relation to current market demands for the individual REE.

Discussions include primary, hydrothermal, and supergene REE mineralization in the carbonatite at Oka, Quebec. Also evaluated are the paleoplacer at Elliot Lake (Blind River), Ontario; the McArthur River-Athabasca basin, Saskatchewan, uranium occurrences; the IOCG type REE-bearing deposit at Nipissis, Quebec; and the complex vein deposit at Hoidas Lake, Saskatchewan.

Canadian peralkaline granite and quartz syenites with attractive tonnage and distribution of REE will also be evaluated, with attention given to Eden Lake, Manitoba; Kipawa Lake, Ontario; Red Wine Lake, Labrador; Strange Lake, Labrador-Quebec; and Thor Lake, Northwest Territories.

Based on the factors above, Canadian deposits with the greatest potential, at current REE prices and demand, are those where REE can be produced as a byproduct; exhibit a reasonable ore grade with a REE distribution enriched in the higher-value HREE; allow ease of beneficiation; are amenable to separation of the individual REE; have infrastructure within a reasonable distance; contain naturally-occurring radioactive byproducts below acceptable limits; and generate a minimum disturbance to the environment.

GEOTECTONIC SETTING OF SLAVE PROVINCE DIAMOND DEPOSITS

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Kimberlitic primary diamond deposits worldwide are “on-craton” and located on or near Mesoarchean domains of Archean cratons. Diamond deposits of the Slave Province are no exception. With respect to its kimberlite occurrences, the Slave Province is a Type 3 kimberlite province (Mitchell, 1986) meaning that it contains kimberlite fields or clusters of several different ages and petrological character. So far, three clusters have yielded economic kimberlites. They belong to three different kimberlite age domains (Cambrian, Jurassic, Cretaceous-Eocene) but are all located in the NNW trending central corridor outlined by Stubley (2004). With respect to its geotectonic evolution, the Slave Province is a complex Archean craton with a centrally located composite Mesoarchean core (Central Slave superterrane) against which Neoarchean juvenile terranes have been accreted from the east and west. The central kimberlite corridor of Stubley lies adjacent to, and is approximately parallel with, the eastern boundary of the Central Slave superterrane, more or less coinciding with the Contwoyto terrane of Kusky (1989). Isotopic signatures of surface rocks and the kimberlitic mantle sample suggest that much of the central kimberlite corridor is underlain by Mesoarchean lithosphere. As seen from the kimberlitic mantle sample and diverse diamond budgets of kimberlites sampled to date, the subcrustal lithosphere throughout the Slave Province is heterogeneous. It has been suggested that at least three northeasterly-trending lithospheric domains can be distinguished that conform to trends observed in Neoarchean rocks, such as iron-formation-hosted gold deposits in turbidites and the distribution of Defeat magmatic suite intrusive rocks. By implication, diamond formation in the Slave Province would be Neoarchean. Contrary to this view, it is suggested here that crust-mantle coupling for harzburgitic P-type diamond host rocks was a Mesoarchean event. Distribution of such diamonds in the Slave Province is controlled by the extent at depth of remnants of Mesoarchean lithosphere which appears to be parallel to the NNW trending ca. 2660 Ma to 2655 Ma cryptic suture along the eastern margin of the Central Slave superterrane. This would hold true also for E-type diamonds predating or related to this suturing event. Later Neoarchean and Proterozoic tectonic and magmatic underplating events may account for extensive modifications of the earlier diamond budgets and may have locally added younger eclogitic diamonds.

PRELIMINARY INVESTIGATIONS OF THE ~1 Ga ST. IGNACE ISLAND COMPLEX, NORTHERN LAKE SUPERIOR, ONTARIO

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The St. Ignace Island Complex (SIC) is located along the northern shore of Lake Superior where it intruded the upper portions of Midcontinent Rift (MCR)-related, ca. 1108 Ma Osler Group volcanic rocks. The SIC is 5 to 8 km in diameter and consists of a gabbroic to anorthositic ring dyke, which encloses quartz-feldspar-porphyritic volcanic rocks. The pink to grey, rhyolitic rocks in the core of the SIC are dominantly quartz-phyric, with rare pyroxene and feldspar phenocrysts set in a fine-grained to glassy groundmass. They commonly contain wispy to amoeboid, mafic (basaltic?) inclusions, which are typically plagioclase-phyric. Geochemically, the quartz-feldspar-phyric rocks from the core of the SIC are dacites and rhyolites (62 to 74 wt% SiO_2) with elevated K_2O contents (2.3 to 4.8 wt%). The lower silica contents within the core of the complex are apparently associated with small mafic inclusions within the more felsic units. The sampled mafic intrusive rocks from the ring dyke are plagioclase- and pyroxene-phyric, coarse- to fine-grained gabbros to monzogabbros (53 to 58 wt% SiO_2). Epsilon Nd values for both suites are strongly negative ranging from -7 to -14.

The SIC samples yielded both zircon and baddeleyite. Subhedral baddeleyite grains from a rhyolite in the core of the SIC yielded a $^{207}Pb/^{206}Pb$ age of 1107.2±2.4 Ma, whereas zircons recovered from the rhyolite yielded a $^{207}Pb/^{206}Pb$ age of 1124 Ma. The fact that this latter age is much older than that of the Osler Group basalts that the SIC has intruded, combined with a lack of euhedral zircon and baddeleyite grains, suggests that these grains may be of xenocrystic origin. Gabbro from the margin of the SIC yielded a small number of zircon grains with baddeleyite cores. These grains yielded a $^{207}Pb/^{206}Pb$ age of 1089.2±3.2 Ma. The growth of euhedral zircon on baddeleyite cores occasionally occurs in mafic rocks and is interpreted to indicate increasing silica activity conditions during magma crystallization. This is consistent with field relationships, which suggest that rhyolitic and gabbroic magmas may have intermingled during emplacement. Consequently, the 1089 Ma age may represent the emplacement age of both the rhyolite and the gabbro and suggests that all dates obtained from the rhyolite are xenocrystic. This age is similar to that of other MCR-related intrusions in the area (e.g. Crystal Lake, Blake and Moss Lake gabbros; Arrow River dyke) that have intruded Paleoproterozoic rocks, older MCR intrusions and/or Osler Group volcanic rocks during the late stages of MCR magmatism.

REQUIRED DESIGN FOR CLIMATE WARMING IN PERMAFROST

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Climate warming has the greatest impact on Canada's permafrost region that covers about 50% of Canada. Air temperature records across northern Canada shows that permafrost will disappear across mainland permafrost regions within 20 to 100 years. This may have profound effect on existing structures and/or mine closures designs that are supposed to be stable for the '*long-term*'. Climate warming is already causing buildings supported on piles to settle and is disrupting pipelines in the eastern Russian permafrost region. It is imperative that the designs of structures, roads, pipelines and mine waste deposits in Canadian permafrost region take into consideration the warming/thawing of permafrost either or both during the operation phase and in the closure design to eliminate or minimize environmental problems when permafrost warms or thaws.

This paper reviews the measured air temperature warming trends across the Canadian mainland permafrost region and suggests air temperatures criteria for the operation and closure phase of structures and waste deposits. It provides an overview of how climate warming may affect structures and waste deposits in permafrost and what design could be employed to minimize/prevent problems due to the warming/thawing of permafrost. Design requirements have to consider that: a) buildings supported on piles founded in permafrost may settle, b) roads and pipelines may become unstable resulting in both physical instability and environmental detrimental erosion c) thaw of permafrost foundation under dams will initiate seepage that may undermine and wash out the dams and d) thaw of landfill and mine wastes that are or were based on permafrost encapsulation will release seepage with unacceptable water quality and may also become physically instable that may increase even further the environmental impact. Measures/designs are suggested that may be considered to eliminate/minimize environmental impacts when permafrost starts to thaw due to climate warming.

SYSTEMATIC AND INTEGRATIVE ORE CHARACTERIZATION OF MASSIVE SULFIDE DEPOSITS: AN EXAMPLE FROM THE VOISEY'S BAY OVOID DEPOSIT, LABRADOR

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This is a developmental method to quantify mineralogy and document textures in a systematic and consistent manner in order to evaluate potential mineralogical zonations and geochemical variations within an ore deposit. Quantitative mineralogical and textural data can then be integrated into 3D block models similar to any other parameter such as grade or density, and be examined in detail using visualization software. The method is built around an algorithm for translating large databases of whole-rock chemical assays into mineral abundances. Mineralogical domains defined by the algorithm are verified and further characterized by image analysis on key selected samples. The advantage of this method is that it can be used as a predictive tool to determine mineralogy from whole-rock geochemical assays utilizing thousands of samples virtually instantaneously. The method can be used to establish mineralogical zones or metallurgical domains, before a deposit is mined or processed and can aid in predicting how to mine the deposit or predicting potential processing issues that may ensue. Good quantitative mineralogical and textural characterization is also essential for evaluating the genesis of an ore deposit and may aid in improving ore recoveries, beneficiation, guiding exploration of economic metals, and targeting other potential mineralized zones.

In principle, this method can be applied to many different ore deposits. This study utilizes the Voisey's Bay Ni-Cu-Co massive sulfide Ovoid deposit as an example of quantitative mineralogical ore classification. The magmatic sulfide deposit, located in northern Labrador, was discovered in 1993 and contains an estimated 32 million tonnes of proven and probable mineral reserves consisting of 2.8% nickel, 1.6% copper, and 0.15% cobalt (Inco 2004 estimate).

Detailed textural, mineralogical, and geochemical classifications were determined by the method and then scaled up and integrated with ~3175 massive sulfide Ovoid deposit samples from Voisey's Bay Nickel Company Limited's Mine Exploration Borehole Sample (MEBS) database.

The method proved variations in mineral abundances spatially in the Ovoid deposit and was able to define three principle massive ore types. The results can then be used in a predictive manner to determine mineral distributions within the Voisey's Bay Ovoid. Verification of the model results and integration with additional mineralogical datasets was carried out using JKTech mineral liberation analysis software.

NWT MINING HERITAGE SOCIETY

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The mandate of the NWT Mining Heritage Society is to save, preserve and display the mining, geological and mineral exploration history of the NWT.

While it is important to save and preserve the history, it is the display part of the mandate that is the end product that the public sees.

The ultimate goal of our society is to create a "Mining and Geological Interpretive Centre" for the entire NWT located in Yellowknife at the Giant Mine site. It will house a number of displays and while we work towards that goal we are creating a number of other displays around town and are involved in numerous outreach projects.

Our most visible displays are at the Yellowknife airport, the Northern Frontier Visitors Center and an outdoor display of mining equipment at the city boat launch. Other projects such as the George Hunter Photographic show have a great appeal and to broaden the experience and reach a wider audience we created a catalogue or book to accompany the show. Projects we are working on include a Pictorial History Book of Con Mine and various power-point photographic shows and talks.

The displays are designed to be interesting, informative and accessible to everyone from people involved in the industry to tourists. To do this we try to add colour, humour and seasonal variations to the displays.

Our goals are to entertain people, to educate them and to build awareness. We want people to learn about the contributions that mining and mineral exploration, have made to the north. We also want people to learn about the importance and diversity of the geology and geography of the north.

THE FORMATION OF UNCONVENTIONAL DIAMOND DEPOSITS – A CASE STUDY ON THE CAROLINA KIMBERLITE IN BRAZIL

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The Carolina kimberlite is located in Brazil, a country with a long history of diamond exploration and mining. Between 1730 and 1870, Brazil was the world's leading diamond supplier with its production derived from alluvial deposits. The Carolina

kimberlite is located in the southeastern portion of the state of Rondônia. Here alluvial diamond deposits have been mined from the Pimenta Bueno and Comemoração rivers since the 1930s. Exploration for the primary source of these diamonds only began in 1974, with the Carolina kimberlite itself not being found until 2002.

Exploration for primary diamond deposits is based upon the assumption that diamondiferous kimberlites are associated exclusively with cratonic areas that have remained stable since the Archean (i.e. for at least the past 2.5 Ga). The South American platform, which underlies Brazil, is an assemblage of two cratons, the Amazon craton and the São Francisco craton. The Rondônia kimberlite province with the Carolina pipe is located on the Amazon craton within basement rocks of presumed Proterozoic age (1.8 to 1.2 Ga). This occurrence of a diamondiferous kimberlite within presumably Proterozoic lithosphere thus appears to contradict current thinking on the normal location of primary diamond deposits and is the premise for this research.

The Carolina pipe is an olivine phlogopite kimberlite, containing abundant garnet xenocrysts. It is these xenocrysts that have been the focus of study to date. The kimberlite is unusual through an overwhelming predominance of G9 (lherzolitic) garnets. 308 garnets analyzed so far have all been shown to be G9 in character. This lack of harzburgitic (G10) garnets is consistent with a post-Archean signature, which is in agreement with Proterozoic age dates for the Amazon Craton.

Heavy mineral concentrate from the Carolina kimberlite shows almost exclusively peridotitic garnets with <1% being eclogitic in nature. This indicates that the subcratonic lithosphere is dominated by peridotite, with only a very minor eclogitic component. The almost complete lack of eclogitic garnets appears to contradict diamond formation in a post-Archean subduction related setting (as observed e.g. for the Buffalo Hills in Alberta, Canada). The absence of G10 garnets, on the other hand, is unique amongst primary diamond deposits derived from peridotic mantle sources. A more detailed understanding of this setting may eventually reveal alternative target areas for diamond exploration in unconventional settings.

LANDSLIDE INVENTORY AND HAZARD MAPPING IN THE SOUTHERN MACKENZIE VALLEY TRANSPORTATION CORRIDOR

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Information on landslides is essential for development and management of natural resources, settlements and transportation infrastructure in northern Canada. The type, distribution, magnitude and frequency of landslide vary depending on local relief, geology, permafrost and groundwater conditions. Along the Mackenzie valley transportation corridor, active layer detachment slides, retrogressive thaw flow slides, debris flows and rotational slides, related to the thawing of ice-rich glacial sediments or the pressure exerted by groundwater confined by ground ice, dominate north of 65°N. South to 60°N, the number of landslide types increases to include episodic slides, slumps, flows, falls, avalanches, and mass-wasting complexes involving rock and debris that represent continuous activity over 1000's of years. The highest landslide densities occur on steep bedrock slopes with high relief in tectonically active mountainous terrain and deeply dissected intermontane plateaus; and in valleys and low-lying plains where ice-rich glacial deposits are exposed and eroded by river and wave action. Earth materials most susceptible to landslides are poorly indurated shale, siltstone and weakly cemented sandstone; and colluvium, till glaciolacustrine, alluvial and organic deposits containing permafrost.

DUFFERIN AGGREGATES EDUCATION AND OUTREACH PROGRAM

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The Dufferin Aggregates Education Program was implemented in 1995. The Program was established to encourage a better understanding and awareness of the aggregate industry, including geology, geography and site afteruse. The program involves site tours, and lectures at institutions. The program serves more than 3500 participants annually and offers learning opportunities for Primary through to Post-Secondary learners and educators, and members of the public. Local and regional institutions and organizations are served and provided both informal and formal science learning opportunities. The program is very well received and successful, in part, do to the partnerships it shares with these institutions and organizations.

Educational site visits usually involve tours of operations, including the extractive, processing and rehabilitated areas of the site. The focus of a tour varies depending on the interests and curriculum requirements of teachers and students. Visits to a quarry or pit can complement different grades, strands and topics in the Ontario School science and technology curriculum, including the Elementary Science and Technology Curriculum Earth and Space Systems Strand (Grade 3: Soils in the Environment, Grade 4: Rocks, Minerals and Erosion, & Grade 7: the Earth's Crust Topics), and the five Earth and Space Science Strands of the Secondary Science and Technology Curriculum. Post-Secondary curriculum interests include geology, mining, and site rehabilitation. Lectures are presented at Colleges and Universities. The public are provided with educational opportunities during Open House site visits.

Dufferin provides material in support to other institutions and organizations, including schools, The Prospectors and Developers Association Mining Matters Program, and, in 2004, the EDGeo National Earth Science Workshop Program held at Brock University during the GAC/MAC Conference.

The Education and Outreach program provides many benefits to the community. In addition to supporting geoscience education, the Program provides improved public awareness and understanding of the aggregates industry in general and Dufferin Aggregates specifically, provides a forum for feedback and dialogue, and provides exposure to the next generation of workers and decision makers.

SEISMIC/ERUPTION AND OTHER SOFTWARE FOR TEACHING HIGH SCHOOL GEOSCIENCE

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I will present the Seismic Eruption program as well as some other programs which I use regularly to support my teaching of Geology 12 in BC. Seismic/Eruption is an interactive GIS of volcanic eruptions and earthquake hypocentres which can be visualised in several useful ways. I will also demonstrate some programs by TASA Graphic Arts which I use regularly with my classes. I will also discuss the development of a Western Canadian database for use with the Seismic Eruption program.

ACTIVE-LAYER THERMAL REGIME OF THE EKATI DIAMOND MINE TAILINGS FACILITY

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Permafrost isolation is one method for securing mining waste from the surrounding environment. At Ekati Diamond Mine™ ,

processed kimberlite tailings (PKT) are continuously discharged as sand and silt slurry at discrete spigot points along the perimeter of containment cells. Cell B, the uppermost cell, began receiving PKT in August 1998 and reached maximum capacity in late 2003. Permafrost aggradation into PKT began the first winter following discharge. The thermal regime of the tailings was examined to provide projections of freezing rates, and ultimately model the thermal containment of the PKT. Near-surface ground temperatures were measured at six sites in Cell B from August 2003 to July 2004 to determine temporal and spatial variation in near-surface thermal regimes in the tailings. The temperature sensors were placed at the surface, 50 cm, 100 cm and 140 cm depths. Measurements of active-layer depth, snow cover, moisture content, and particle-size distribution were taken at each instrumentation site to complement analysis of temperature data. Active layer tailings at the perimeter were medium to fine sand size, with gravimetric water content less than 0.2 g/g. In the centre of the cell, the active layer tailings were finer and wetter; with fine sand to silt particle size and water content higher than 0.3 g/g. The differences in moisture and particle size across the cell cause variations in the near-surface thermal regime. The active-layer in the centre is at least 10 cm thinner than along the perimeter due to the higher energy required to melt the pore water. Surface temperatures towards the centre are warmer in winter but cooler in summer due to high moisture contents. Snow tends to be blown clear around the perimeter. Across Cell B, minimum mean surface temperatures ranged from -15.6 to -10.5 ºC in winter and maximum means in summer ranged from 3 to 11.9 ºC. At depth the greater influence of winter conditions on the ground thermal regime is evident. The annual mean ground temperatures at 100 cm depth were approximately -5 ºC towards the centre, and approximately -8 ºC around the perimeter. The near-surface ground thermal regime varies across the tailings facility at Ekati, suggesting that permafrost aggradation rates will also vary within the cell.

PHYSICAL PROPERTIES OF THE LAC DE GRAS KIMBERLITES AND HOST ROCKS WITH CORRELATION TO GEOPHYSICAL SIGNATURES AT DIAVIK DIAMOND MINE, NWT

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The geophysical response of a target is dependent on the physical properties of the kimberlite and the host rocks. The objective of this study is to develop an understanding of the geostatistical variations in the physical properties; specifically density, resistivity/conductivity, magnetic susceptibility and remanent magnetization. Geostatistical modeling of physical properties along with previously collected geophysical data can be used to interpret geophysical field data and to understand how it can be correlated with complex models.

Physical property data were collected from previous drill programs that took place on the Diavik property or on Diavik exploration properties. In total, 433 kimberlite and surrounding host rock samples were collected from 16 kimberlite pipes. Pipes were selected based on core quality, pipe location, and varying diamond content.

Statistical analysis is an integral component of the data interpretation process. Statistical methods are used to assess data quality and to determine the range and distribution of the physical properties based on depth and lithology. Statistical methods can also be used to understand how physical properties for various rock types compare between rock types in a single pipe, and between similar rock types from pipe to pipe. In addition to simple statistical measures such as means and standard deviations, more advanced statistical techniques such as multiple regression, including principal component and principal coordinates analysis have been utilized. The collected physical property data were then compared with geophysical survey data and were modeled to examine the various correlations.

BACKGROUND RESEARCH AND TRIAL REVEGETATION OF MINE TAILINGS AT INCO LTD., THOMPSON, MANITOBA

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The agricultural properties of pyrrhotite-rich exposed tailings and the state of plants colonizing them were determined on the exposed Ni-Cu tailings at INCO Ltd., Thompson, Manitoba, to enable optimum revegetation strategies to be devised and field trials implemented.

The Exposed Tailings have low Net Neutralization Potential (-1.3 to -244 kg $CaCO_3$ eq./tonne) and high salinity (2.6 to 19 dS/m) in the root zone. The tailings and the plants growing on them contain high Ni. Because of the high salinity and Ni content, a protective layer of waste rocks is necessary to prevent the contact of plant roots with the tailings. Waste rocks have high bulk density values and appropriate texture and although potentially acid producing, the acid could be neutralized with less lime than the tailings. The Ni content in waste rock fines is as high as in the tailings, but contamination of plants is limited by their low permeability. The protective layer also decreases the formation of windborne dust and the flow of oxygen to the tailings.

Sewage, animal manure, primary and secondary paper sludge and grass clippings were investigated as sources of organic material to provide growth media for the plants on top of the protective layer. From the measurements of seeded species which survived and developed normally, of Ni content in shoots, and of invasive species of plants and insects, the most successful organic material was sewage sludge. Primary paper sludge was unsuccessful as a soil layer but could be transformed into secondary in the field by adding a thin layer of sewage sludge or secondary paper sludge.

The most successful indigenous plant species were slender wheatgrass, Canada wildrye and common Kentucky bluegrass. Drill seeding was the most appropriate technique under the northern climatic conditions. Transplanting soil cubes with tree seedlings from the Boreal Forest increased the sustainability of the vegetative cover.

INITIAL CONSTRAINTS ON THE THERMO-TECTONIC EVOLUTION OF THE CENTRAL BEAVERLODGE DOMAIN, SOUTHWESTERN RAE PROVINCE

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The Rae Province in Saskatchewan is flanked by the Taltson Magmatic Zone in the west and the Snowbird Tectonic Zone in the east. In 2006, a well-exposed 250 km^2 area of granuilte facies rocks in the Beaverlodge Domain was mapped at 1:20,000 scale. The Beaverlodge Domain has a protracted geological history, including 3.0 Ga, 2.6 Ga, and 2.3 Ga granitoid plutonism, and ca. 2.3 Ga deposition of the Murmac Bay Group of siliciclastic and basaltic rocks. Mapping has also identified extensive pelitic paragneisses and derived diatexites of equivocal age, that appear to extend discontinuously eastward into the Tantato Domain. Systematic mapping, and subsequent analysis of data, has provided initial constraints on the nature of deformation and metamorphism, and their correlation with regional tectonic events. Activity at ca. 2.3 Ga is thought to mark the temporal end and perhaps the southern extent of the 2.45-2.3 Ga Arrowsmith Orogen, although an

associated structural fabric and metamorphic overprint is barely discernable due to strong overprinting of later fabrics, each accompanied by upper amphibolite- to granulite-facies metamorphism. A west-northwest trending fabric is roughly parallel to the known trend of 1.99-1.95 Ga arc-type rocks of the Taltson Magmatic Zone and the area south of the Athabasca Basin, and is therefore being tentatively attributed to the Taltson Orogen. A subsequent northeast-striking fabric is broadly parallel to the Snowbird Tectonic Zone, which is characterized by 1.90 Ga high pressure granulites in its hanging wall. A final north striking fabric may represent effects from the ca. 1.83 Ga Trans-Hudson Orogen. An ongoing petrographic and related geochronological study aims at constraining metamorphic conditions during each of these deformational events, and thereby testing aspects of the broad regional tectonic relationships outlined above.

A RECENT INCREASE IN THE RATES OF THERMOKARST SLUMPING IN THE CANADIAN WESTERN ARCTIC

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The aerial extent and growth rates of thermokarst slumps in the northwestern Canada have increased significantly since 1973 in concert with accelerated climate warming. More than 540 slumps were mapped in a 3739 km^2 study area primarily within ice-rich morainal deposits immediately adjacent to tundra lakes. There are significantly less slumps on the leeward side of lakes (SW, S and SE) suggesting that wave-induced erosion may contribute to slump initiation. To evaluate change over time, all slumps on 24, 49 km^2 study plots were mapped on 1950, 1973 and 2004 aerial photographs. The aerial extent of slumping relative to the disturbed area in 1950 had increased by 15% in 1973 and by 36% in 2004. The mean rate of slump growth from 1973 to 2004 was almost twice the rate estimated for the period from 1950 to 1973 and the mean maximum rates of headwall retreat have more than doubled. New slumps contributed only 9% to the total increase in disturbed area from 1973 to 2004, indicating that in future, most slumping will occur in association with pre-existing disturbances. As the frequency and magnitude of thermokarst disturbance increases with continued climate warming the effect of slumping on landscape evolution and soil and lake chemistry will likely magnify the direct effects of warming on terrestrial and aquatic ecosystems.

AN INTRUSION-RELATED GOLD SETTING IN THE 380 MA PERALUMINOUS SOUTH MOUNTAIN BATHOLITH, NOVA SCOTIA: EVIDENCE FOR MULTIPLE RESERVOIRS

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Intrusion-related gold (IRG) deposits constitute a significant deposit type globally, their contribution to the annual production of gold increasing annually. This deposit type shows spatial and temporal association to reduced felsic intrusions and covers a wide range in ages and setting. However, studies of a variety of deposit environments indicate that whereas there are similarities, differences occur regarding source reservoirs for fluids and metals. Here we examine a mineralized (Au-As-Bi-Sb; to 0.5 g/t Au) system within the reduced, peraluminous, 380 Ma South Mountain Batholith (SMB) of Nova Scotia that intruded at ca. 10-12 km depth. Field relationships along the eastern contact of the SMB (Lat. 44°35'09"N, Long. 63°32'40"W), where it is in contact with metaturbiditic rocks of the Meguma Group, reveal exposure of sheeted quartz veins in a two-mica monzogranite. The granite is uniform in nature, the only variation being local occurrence of aplite-pegmatite dykes and rare Qtz-Kf-Musc miaroles. The sheeted-vein system has the following features: (1) a N-S strike with 80-90° dips and a Reidel shear geometry; (2) a 250 m strike length and 130 m width; (3) consists of multiple extensional, fibre-textured quartz Asp veins of <1 m width; (4) intense development of fractures parallel to and adjacent the veins. Vein-related alteration marginal to the veins varies from absent to intensely developed such that multi-metre wide areas of massive muscovite Asp greisen occur; these greisen areas occur proximal (i.e., 30 m) a small pegmatite from which the sheeted quartz veins egress. Sampling of the veins for fluid inclusion studies and isotopic analysis indicate: (1) coexisting fluid inclusion assemblages reflecting fluid unmixing of a primary aqueous-carbonic fluid; (2) $\delta^{18}O$ values of vein Qtz of +13.3 to +17.8‰ (n=8) and greisen Musc of +9.7 to +11.2‰ (n=3); (3) δD for greisen Musc of -46‰(n=3); and (4) $\delta^{34}S$ of vein and greisen Aspy of +9.8 to +10.3‰ (n=5). The fluid inclusion and isotopic data, when compared to a large data base for barren and mineralized areas within the SMB and Meguma Group, suggest a non-magmatic reservoir, possibly the Meguma Group, contributed chemically (i.e., carbonic nature of fluid) and isotopically (i.e., ^{18}O, ^{34}S) to the vein-forming fluid. These conclusions are permissive with Au and other metals also being derived from a non-magmatic reservoir and, therefore, provide supporting evidence for similar mixed reservoirs in other IRG deposit settings.

ORIGIN OF MICRO-LAMINATED TEXTURES IN AURIFEROUS QUARTZ VEINS, MEGUMA GROUP, NOVA SCOTIA, CANADA

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Quartz veins in orogenic gold vein systems, particularly sedimentary rock-hosted, are often characterized by a laminated nature and occurrence of fibre textures. Whereas the latter texture originates as new minerals grow with vein extension, the former texture is rarely described in detail, and hence, its origin is poorly constrained. Here we focus on the occurrence of such laminated- or ribbon-textured veins, also referred to as crack-seal veins, in a well-studied gold province, the Meguma Terrane of Nova Scotia. In this terrane, all gold vein types formed during the latest stages of fold tightening. They include bedding-concordant, en echelon, and discordant types. Most veins, particularly concordant types, are composite with early, dark, laminated quartz enveloped by later, clear to milky white, crystalline quartz. Gold is preferentially confined to the later quartz. The laminated texture is sometimes seen in discordant veins with laminations perpendicular to bedding and cleavage fabrics in the wallrock. Although some columns of dark quartz within the veins have been interpreted as single crystals by previous workers, the shape of the columns is inconsistent with quartz forms. Detailed studies of laminated vein quartz reveals the following: (1) a range from wallrock inclusions to micro-laminated material of ca. 10's to 100's microns width; (2) both dissolution (i.e., porosity generation) and precipitation (quartz, muscovite, Fe-chlorite, tourmaline, apatite, K- and Na feldspar) textures; (3) possible inheritance of wallrock CS-type textures, as defined by the laminae; (4) common occurrence of Brazil twinning in clear quartz that extends into the dark laminated quartz; (5) abundance of fluid inclusions crowded with solid inclusions of residual wallrock origin in the laminated quartz, which contrasts with simple aqueous-carbonic inclusions in the enveloping clear quartz. The vein textures suggest two possible origins for the dark and clear quartz, but also a paragenesis whereby the two are related. Thus, we suggest that the veins are composite in origin with an early stage of silicification with

minimal extension to produce the dark laminated quartz. The range in textures of the dark quartz records partial to extreme replacement along with new mineral growth where an earlier planar fabric (i.e., cleavage) once existed. Subsequently, perhaps due to increased fluid pressure, extension gave rise to a second generation, clear crystalline quartz which dominates veins. This process is best preserved where the columns of dark quartz occur. The occurrence of visible gold in second generation quartz indicates that gold was introduced late in the vein formation.

P-T CONSTRAINTS AND MONAZITE GEOCHRONOLOGY FROM THE NEIL BAY REGION, NORTHERN SASKATCHEWAN: CONSTRAINING THE RELATIONSHIP OF THE SNOWBIRD TECTONIC ZONE AND WESTERN RAE DOMAIN

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The Snowbird Tectonic Zone has been documented as a major lithotectonic structure of the Canadian shield and is characterized by granulite facies deformation and metamorphism in both the late Archean and Paleoproterozoic. The roll of this structure in the evolution of the North American craton remains unresolved, in part due to the uncertain relationship between the Snowbird Tectonic Zone and rocks of the Rae domain to the west. The Neil Bay region (northern shore, Lake Athabasca) offers excellent exposures of granulite-facies mylonites in the western Rae domain, and provides insight on the extent and timing of uplift in deep crustal rocks west of the Snowbird Tectonic Zone.

Two main planar fabrics are present in the Neil Bay area: a moderately-dipping, NW-striking foliation (S_1), and a mylonitic, steeply-dipping NE-striking fabric (S_2) that transposes the less intense NW-striking foliation. A shallow, SW-plunging mineral lineation on S_2 surfaces suggests that dominantly strike-slip motion was accommodated in high-strain zones. Garnet-bearing orthogneisses in the region are locally migmatitic, and leucocratic melt segregations are continuous along both S_1 and S_2 surfaces suggesting a temporal link between the two fabrics. Peak metamorphic conditions associated with migmatite generation are calculated at ca. 0.9 GPa and 900°C based on Grt + Opx assemblages. Post-peak decompression and cooling is documented by cordierite overgrowths on garnet and orthopyroxene, yielding estimated retrograde conditions of ca. 0.6 GPa and 700°C. Reaction textures and P-T estimates are most consistent with a relatively rapid, hot decompression following high-pressure metamorphism.

Electron microprobe dating of monazite hosted by garnet and matrix grains in migmatitic regions indicates that peak metamorphism and associated strike-slip deformation on S_2 was syn- to post- ca. 1.9 Ga. Rims developed on matrix monazite grains yield younger ages that may correspond to regional exhumation of the Rae domain along the Legs Lake shear zone immediately east of the Snowbird Tectonic Zone. These observations collectively suggest that the Neil Bay region accommodated dominantly strike-slip deformation within the Rae domain that initiated approximately 50 million years prior to thrusting along the present Rae-Hearne boundary. The Neil Bay region shows no evidence of the ca. 2.6 Ga granulite facies deformation and metamorphism that impacted the Snowbird Tectonic Zone, but the similar Paleoproterozoic deformation, metamorphism, and uplift histories of these regions suggest that the Rae domain and Snowbird Tectonic Zone were closely linked by ca. 1.9 Ga.

CURRENT AND FUTURE CAPABILITIES FOR SYNCHROTRON-BASED CHARACTERIZATION OF DIAMOND INCLUSIONS AND KIMBERLITE INDICATOR MINERALS

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Kimberlite indicator minerals and mineral inclusions within diamonds have been used to provide information about the mineralogy, chemical composition, and thermal regime of the ancient Archean-Proterozoic lithospheric mantle and petrogenic origins for the diamonds themselves. In this study, the objectives were: 1) to develop quantitative analytical tools for non-destructive, in-situ identification and characterization of mineral inclusions in diamonds (DI) using micro-scale synchrotron x-ray analysis techniques (Fluorescence - μSXRF; X-ray absorption - μXANES; Diffraction - μSXRD), and 2) to qualitatively compare chemical spectroscopic edge shifts of elements (i.e. Al, O, Si, Ca Mg) within the kimberlite indicator minerals, particularly garnets, with known reference compounds and with their corresponding EMP analyses. The advantages of synchrotron x-ray analyses are the non-destructive capabilities, substantial x-ray penetration and high x-ray intensity and micron spatial resolution. The μSXRF and μXANES analyses were carried out at Argonne National Laboratories using the Pacific Northwest Consortium-Collaborative Access Team (PNC-CAT) synchrotron microprobe beam line (20-ID), Advanced Photon Source (APS). The bulk XANES (i.e. Al, O, Si, Ca Mg) analyses were carried out at the University of Saskatchewan using the soft x-ray beam line (SGM) at the Canadian Light Source (CLS). This presentation will highlight aspects of these analyses and also discuss analytical capabilities of the VESPERS beam line currently being developed at the Canadian Light Source, which will facilitate simultaneous x-ray diffraction and x-ray fluorescence analyses at a micron scale.

A STRATIGRAPHIC CONNECTION BETWEEN A DEVONIAN-MISSISSIPPIAN ARC COMPLEX AND THE ANCESTRAL PACIFIC CONTINENTAL MARGIN, SOUTHERN CANADIAN CORDILLERA

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In southern British Columbia, the main Cordilleran orogeny involved Jurassic to Cretaceous compression of Paleozoic and Mesozoic arc-related assemblages and continental strata at the ancestral Pacific continental margin. Assemblages of juvenile rocks have been interpreted as exotic terranes, however the applicability of terrane theory to this part of the Canadian Cordillera is being re-examined in light of new data.

Orogenesis formed an arcuate structural belt of tightly folded and faulted supracrustal rocks, called the Kootenay Arc, along the transition between arc complexes and continental margin sedimentary units (the miogeocline). Within the Kootenay Arc, a regional unconformity separates conglomerate and argillaceous units of the Mississippian Milford Group from the underlying lower Paleozoic Lardeau Group, which comprises deep water sedimentary and volcanic rocks that were deposited on the outboard edge of the Cambrian miogeocline. Approximately 100 km to the west, Devonian-Mississippian arc and back-arc units of the Eagle Bay assemblage are strikingly similar to the Milford Group, but they were deposited atop Devonian strata and Paleoproterozoic (and younger?) paragneiss of uncertain correlation.

The Devonian succession that conformably underlies the Eagle Bay assemblage has recently been recognized beneath a western component of Milford Group strata, and new mapping

has demonstrated that the intervening contact is conformable – a relationship that stratigraphically links the Eagle Bay assemblage to the Milford Group. Field relations support existing paleontological data which suggest that the Eagle Bay assemblage and the Milford Group record Devonian-Mississippian eastward transgressive onlap of back-arc basin sediments onto the distal continental margin. This stratigraphic connection augments the body of evidence that certain arc assemblages in the southern Canadian Cordillera were deposited onto their current basement and do not represent exotic terranes.

PETROLOGICAL AND CEOCHRONOLOGICAL INVESTIGATION OF LOWER CRUSTAL XENOLITHS FROM THE DIAVIK DIAMOND MINE, SLAVE CRATON, NT, CANADA

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As part of a study to investigate the lower crust of the Slave craton, we have collected a suite of 40 crustal xenoliths from the 55 Ma, A-154 kimberlite pipes of the Diavik Diamond Mine. Most xenoliths are mafic in composition, with a mineral assemblage of garnet, clinopyroxene and plagioclase ± orthopyroxene ± quartz. Also present are intermediate xenoliths, and xenoliths of metasedimentary origin that contain sillimanite or kyanite. Accessory minerals include ilmenite, rutile, titanite, apatite, and pyrite. Hydrous minerals such as amphibole and biotite are absent, or present only in minor to trace amounts. Minor alteration occurs in some xenoliths due to decompression or reaction with the kimberlite magma. The majority of xenoliths can be characterized as high-pressure mafic granulites, similar to the most abundant type of lower crustal xenolith reported from other diatremes from the Slave Craton and worldwide. Estimates of peak metamorphic pressure and temperature were obtained using mineral core compositions and TWQ multi-equilibrium thermobarometry. Temperatures are regarded as minimum estimates because of the possibility of Fe-Mg re-equilibration in garnet and pyroxenes during cooling, while pressure estimates are maxima due to an absence of quartz in most of the xenoliths. Metamorphic conditions in the central Slave lower crust were determined to be least 750-900°C at pressures of 9.5–11 kbar. These data confirm that the xenoliths are of lower crustal origin and indicate minimum thicknesses for Slave craton crust of 35-45 km at the time of metamorphism. U-Pb geochronology has been conducted on zircon and monazite grains in thin section using laser ablation multi-collector inductively coupled plasma mass spectrometry. Most zircon grains are round and likely metamorphic in origin. $^{207}Pb/^{206}Pb$ ages of concordant or near concordant analyses range from 2.51-2.56 Ga. Several zircons also contain zoned cores with ages of 2.6-2.62 Ga, which may be minimum igneous crystallization ages of xenocrystic or detrital grains. Monazite ages have a larger range of 2.4-2.55 Ga, and 2.6 Ga. Collectively, these age data partly overlap with, but in general are younger than high-grade metamorphism recorded in the Slave middle crust. Preliminary oxygen isotope analysis of plagioclase and pyroxene separates from mafic granulite samples yielded $\delta^{18}O$ values ranging from 6.5-8.6 ‰ relative to SMOW. These values are similar to those reported for mafic granulite xenoliths worldwide and indicate that the xenoliths have interacted with, or were themselves derived from, rocks that at one time resided near the Earth's surface.

PROBABILISTIC ORE SYSTEMS MODELING: A NEW TOOL FOR QUANTITATIVE RISK ANALYSIS AND DECISION-MAKING IN EXPLORATION

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Probabilistic ore systems modeling is a new method for translating ore deposit models into a flexible, probabilistic decision-making structure that is based on the critical processes of ore formation: (1) extraction of ore components from crustal or mantle sources, (2) fluid- or melt-assisted transport of ore components from source regions to trap zones, (3) formation of trap zones that can focus melt or fluid migration and accommodate large amounts of metal, and (4) operation of the physicochemical processes that promote and sustain the deposition of metal from fluids or melts passing through a particular trap site. Our modeling approach integrates these critical processes with concepts of probability theory and decision analysis, with the principal objective of making ore deposit models more quantitative, amenable for management of risk and uncertainty and suitable for communication of geological concepts to managers or financial stakeholders who do not have a geoscience background. We constructed probabilistic models for lode-gold, porphyry copper, stratiform lead-zinc and magmatic nickel-sulfide systems. These models are based on our assessment of the current state of knowledge and our personal views, prejudices and experience. However, users can easily modify the model templates to suit their own beliefs, knowledge or specific local circumstances. We do not imply that our modeling approach is superior to others, but simply that the resulting ore systems models are flexible, probabilistic and internally consistent, and structured according to previously published petroleum and mineral systems approaches.

APPLICATION OF HIGH RESOLUTION X-RAY COMPUTED TOMOGRAPHY TO GOLD ORE GENESIS AND PROCESSING INVESTIGATIONS

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High resolution X-ray computed tomography (HRXCT) is the industrial equivalent of medical CAT scanning and provides a powerful extension of traditional petrographic analysis allowing observations and measurements in three-dimensions of grain size, shape, and associations within rocks. The University of Texas HRXCT laboratory is a NSF-supported multi-user facility that has been used for the past decade to produce information for a wide variety of geological, biological, and material science problems. Descriptions of the facility, HRXCT principles, and examples of applications are available at http://www.ctlab.geo.utexas.edu/.

HRXCT produces two-dimensional images ("slices") that reveal the interior of an object as if it had been sliced open along the image plane for viewing. A HRXCT image is generated by differences in X-ray attenuation that arise principally from differences in atomic number and density within the scanned object. By acquiring a contiguous set of slices, a density map for all or part of a sample volume can be obtained, allowing three-dimensional inspection and measurement of features of interest. Because the HRXCT technique differentiates mineral grains largely based on their contrasting densities, these studies are particularly effective in the study of gold or PGE grains in contrast with typical rock-forming minerals and other metallic minerals. Comparative studies of synthetic cores that incase gold grains of known dimensions demonstrate that HRXCT volume determinations are accurate on grains with minimum dimensions of roughly 1/1000 of the imaging field diameter.

HRXCT is an effective technique for megascopic studies of gold distribution in fracture-controlled ores. HRXCT volumetric data for many hundreds of grains in high-grade Cripple Creek ore samples indicate a substantial percentage of the gold is contained in a small percentage of grains, e.g. on average 50% of the gold in the samples is derived from the largest 9% of grains. Conversely, the smallest grains that comprise half of the population of grains only account for 15% of the total gold concentration. Microfocal imaging of 1 cm diameter cores of typical stockwork ore from the Grasberg porphyry Cu-Au deposit has identified gold grains as small as 6.5 µm. All of the gold grains observed occur in contact with copper sulfides, providing support for models of gold exsolution from high temperature sulfides. These investigations suggest considerable potential for HRXCT studies to contribute to the understanding of ore-forming systems and to practical applications such as ore processing to maximize precious metal recovery.

COLD-CLIMATE CARBONATE PRECIPITATES: TERRESTRIAL ANALOGUES TO THE SEARCH OF WATER AND LIFE IN EXTRA-TERRESTRIAL EXPLORATION

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Since the discovery of carbonates globules within the c 4.5 Ga Martian meteorite ALH84001, carbonates located in Arctic regions have been receiving growing interest. Cold-climate carbonates are strong candidates to the search of water and life on extra-planetary bodies because their presence necessarily implies that water was present at some point in time, and potentially implies the presence of microbial life as they might have been biologically mediated. But before cold-climate carbonate precipitates can be used to determine the presence of life (microorganisms) on other planets, it is crucial to be able to distinguish between abiotic and biotic carbonate precipitates. In this study, the stable C-O isotope ratios of more than 30 types of both abiotically and biologically precipitated modern cold-climate carbonates are reviewed and the effect of physico-chemical and microbial processes on the stable C-O isotope composition of carbonate precipitates verified under controlled laboratory conditions. It was found that in modern carbonates, the $\Delta^{18}O$ and $\Delta^{13}C$ between calcite and water could effectively identify the process that led to their formation (abiotic or biotic). However, only a few types cold-climate carbonate precipitates have $\delta^{18}O$ and $\delta^{13}C$ values within the range of those measured in ALH84001, which includes cryogenic cave calcite powders, evaporative calcite crusts, both precipitated through kinetic physico-chemical processes, and endostromatolites, a biologically precipitated calcite deposits growing within fissures in bedrock outcrops. Laboratory experiments demonstrated that the freezing and evaporation of a calcium bicarbonate solution under non-equilibrium conditions produced calcite with an highly enriched ^{18}O and ^{13}C composition relative to that of the initial solution. By contrast, a series of closed-system incubation experiments using bacterial communities cultured from field material indicated that acetogenesis was the dominant microbial process at low temperature, and produced a Rayleigh-type ^{13}C enrichment on the ^{13}C of calcite, while no significant changes were observed in the ^{18}O signal. Although physico-chemical and microbial processes can be discriminated by analyzing the stable C-O isotope composition of calcite and source water, this discriminating tool cannot be employed for "fossil" and extra-planetary carbonate precipitates. Therefore, the stable C isotope composition of organic matter extracted from "fossil" calcite precipitates of known abiotic and biotic origin was also analyzed to develop "true" isotopic fingerprints of microbial processes. It was found that in "fossil" microbially-mediated carbonate precipitates, the difference between the ^{13}C of calcite and of the extracted organic matter yielded a unique signature that not only allowed to detect the presence of organic material, but also to determine that the precipitation of the carbonate was biomediated by microorganisms. The isotopic fingerprint is produced because microbial communities prefer to metabolize the isotopically light C during photosynthesis / acetanogenesis / methanogenesis, leading to a concurrent enrichment in the residual $^{13}C_{DIC}$ pool and calcite being precipitated.

REFINEMENTS TO THE STRATIGRAPHY, BIOSTRATIGRAPHY AND STRUCTURAL GEOMETRY OF THE DEVONIAN AND CARBONIFEROUS IMPERIAL AND TUTTLE FORMATIONS, EASTERN EAGLE PLAIN, NORTHERN YUKON

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New fieldwork was undertaken to clarify the stratigraphic relationships, map distributions and structural geometry of the Late Devonian and Early Carboniferous successions in Eastern Eagle Plain, northern Yukon. In this area, the Late Devonian Imperial Formation comprises a three-fold succession, with a sandstone-dominant middle member lying between two shale-dominant members. The overlying Late Devonian to Early Carboniferous Tuttle Formation comprises a succession of interbedded sandstone and shale units. In this area, distal from its depocentre, the coarsest part of the Formation is in the lower part. The upper part consists of thinner sand ribs embedded in dark grey shale with siltstone laminae. The Tuttle Formation grades upward and laterally toward the southwest into the Ford Lake shale. The base of the Tuttle lies immediately above a shale succession dated palynologically as late Famennian (Late Devonian) to Tournaisian (Early Carboniferous). Elsewhere, a shale within Tuttle strata yielded a similar flora. In the field area, the top of the Tuttle lies within a succession yielding Visean (Early Carboniferous) palynoflora.

In eastern Eagle Plain, Tuttle strata are juxtaposed against the Imperial Formation along the Deception Fault, a large west-directed thrust fault associated with uplift of the Richardson anticlinorium in Early Tertiary time. Although exposure is generally poor and the fault is not exposed at the surface, the sampling has helped to refine its approximate position. Thermal alteration indices (TAI's) of palynomorphs jump from 2 in the west, to 3+ in the east, indicating substantial vertical separation across this regionally important structure.

OPTIMIZING PHOSPHATE REMOVAL FROM TWO WASTEWATERS USING DISCARDED MAGNESIA BRICKS TO PROMOTE STRUVITE ($MgNH_4PO_4 \cdot 6H_2O$) PRECIPITATION

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Controlled struvite ($MgNH_4PO_4 \cdot 6H_2O$) precipitation in industrial and municipal effluents is being used to extract valuable nutrients (magnesium, ammonium and phosphate) from wastewater prior to its release into the environment. This alternative phosphate removal process replaces the need to bind phosphates with iron or aluminium salts. In turn, the harvested struvite crystals can be used as a slow release fertilizer, thereby closing the gap in the phosphorus cycle as well as reducing eutrophication problems. At present, the chemical input required for maximum phosphate extraction in the form of struvite from an effluent is very expensive given that the two limiting factors in most systems are i) insufficient soluble magnesium and ii) a pH that does not favour maximum struvite formation (ideally the pH should be around 9.0). It was

hypothesized that used magnesia (MgO) bricks from the steel industry contain enough soluble magnesium and can raise the pH sufficiently that they can resolve these problems in a cost-effective manner, provided that the transport distance is relatively short. In testing this hypothesis, two effluents were used to make struvite in bench-scale experiments: one was a dairy barn effluent from the Elora Research Station, north of Guelph, Ontario, and the other was a food waste processing effluent from the Dufferin organics facility in Toronto. Although struvite forms at a molar ratio of 1:1:1 (Mg^{2+}:NH_4+:$PO_4$3-), effluents rich in organic matter call for magnesium additions beyond what is stoichiometrically required because of the ease at which magnesium binds with organic material. Preliminary experiments were carried out to determine how much additional magnesium need be added to each effluent to overcome any magnesium deficiencies that resulted from magnesium binding with organic matter. Struvite chemical equilibria computer models were designed to predict outcomes, but were too simplified in comparison with the highly complex effluents. The phosphate removal efficiencies of the magnesia bricks were comparable to those resulting from the use of pure chemical MgO. Based on XRD analysis, compounds other than struvite also formed in both wastewaters with either type of magnesium input.

1.17 Ga MAFIC MAGMATISM IN THE CENTRAL SLAVE PROVINCE

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U-Pb geochronology confirms field observations that a distinctive 330 km long easterly-striking diabase dyke in the central Slave Province is younger than 1.27 Ga Mackenzie dykes. The strongly magnetic 50-70 m wide Munn dyke is sub-parallel to 2.19 Ga Dogrib and 2.21 Ga MacKay dykes. En echelon Munn dyke segments exhibit a change in strike at Beniah Lake. East of the lake the dyke trends ca. 082° and has right-stepping overlap-offset segments, whereas to the west, the dyke trends ca. 070° and has left-stepping segments. Dyke geometry indicates the subvertical dyke was emplaced in a regional stress regime with subhorizontal maximum and minimum stresses oriented at ca. 075° and 345°, respectively. The “bend” and reversal in en echelon pattern is coincident with the Beniah-Napaktulik fault zone, a north-south pan-Slave feature. Munn gabbros are composed of plagioclase, clinopyroxene, amphibole and Fe-Ti oxides. Interstitial quartz and quartz-alkali feldspar granophyres are associated with biotite, chlorite, apatite, sulfides, allanite, baddeleyite and zircon. Geochemically, the rocks are fractionated subalkaline basalts with low MgO and high K_2O. They plot as within-plate tholeiites. Ba, Rb, Th, and U contents are high, whereas metal values, in particular Cu and Ni, are unusually low.

U-Pb ID-TIMS and microprobe chemical U-Th-total Pb methods for dating baddeleyite were used to determine emplacement age. Although chemical ages are less precise than ID-TIMS ages, the method is useful when, as in this case, baddeleyite yields are low. Chemical ages of 1201+51/-52 Ma and 1171+70/-71 Ma for two samples are in agreement within the quoted uncertainties. Combined data yield an age of 1187±39 Ma. Eight tiny baddeleyite grains were recovered from one sample. Three single crystals, each <0.5 micrograms, yield near-concordant $^{207}Pb/^{206}Pb$ dates between 1148-1171 Ma. The weighted average $^{207}Pb/^{206}Pb$ age of 1167±11 Ma obtained for the two least discordant fractions is the best current age estimate for the Munn dyke. Nd isotopic data for whole rock samples have near-chondritic epsilon Nd (1170 Ma) values of -1.0 to -1.2. The Munn dyke defines a previously unknown 1.17 Ga mafic magmatic event in the central Slave Province. Dogrib dykes were first distinguished from MacKay dykes based on different paleomagnetic signatures. Significantly, paleomagnetic results from a dyke at Thistlethwaite Lake, interpreted as a Munn dyke segment, gave a direction distinct from either Dogrib or MacKay dykes. The direction is likely primary and new studies could establish a 1.17 Ga pole for North America.

ROCK-WATER INTERACTION AND CO_2 SEQUESTRATION ASSOCIATED WITH KIMBERLITE ORE PROCESSING

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The crushing and washing of kimberlite ore during diamond recovery results in rapid changes in the chemical composition of processing water. Alkalinity, pH, Mg, Ca and SO_4 all increase in processing water during the short time it interacts with the kimberlite. This is an important factor affecting the composition of pore water in the processed kimberlite fines stored in the impoundment facility. Post-depositional geochemical controls are thought to include evaporation and cation exchange. Reaction and inverse modeling suggest that the kimberlite-water interaction within the processing plant involves the dissolution of chrysotile, Ca-sulphate and $CO_{2(g)}$ and precipitation of silica and magnesium carbonate. An industrially-enhanced version of this process may represent an opportunity to sequester atmospheric CO_2 through mineral carbonation. Experiments designed to simulate conditions in the processing plant showed an increase in alkalinity, pH, and major elements in the aqueous solution over 30 to 60 minutes approaching concentrations in the plant discharge water. Saturation indices show oversaturation of carbonates (calcite, dolomite, and magnesite) in both processing plant solutions and experiment solutions. An increase of inorganic-C is noted from the kimberlite to the processed kimberlite in the LLCF indicating that carbonates may precipitate. Although the mineral carbonation process may be occurring spontaneously in the processing plant and the experiments, the amount of precipitated carbonate is likely small and has not been directly observed.

LATE ARCHAEAN AMPHIBOLITE FACIES METAMORPHISM IN THE KAPISILLIT REGION; INSIGHTS FROM NEW MAPPING IN THE SE NUUK REGION, SOUTHERN WEST GREENLAND

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The Nuuk region is considered to represent a Late Archaean terrane complex, which resulted in a final amalgamation event at ca.2720 Ma. The majority of work on the terrane development in the Nuuk region has been focussed in the Isua, Akilia and Tre Brødre/Færingehavn areas, leaving a dearth of knowledge regarding the south eastern part of the Greenlandic craton. We present new field, metamorphic and geochronological data from Norsanna and Tummeralik in the Kapisillit region of the craton, pertaining to the final event in this terrane amalgamation hypothesis.

We document a regionally significant high strain zone that separates two orthogneiss suites in the Norsanna area. Here a heterogeneous, highly deformed tonalite, with high grade metamorphism at ca.3550 Ma overrides a homogeneous tonalite/granodiorite with a magmatic age of ca.2820 Ma. The zone itself has been refolded into a gently SW-plunging open fold but reconstructions of the ~100m thick zone show the original strike to be approximately east-west. Within the shear zone, boudinaged units of pelitic material with a prominent

sillimanite-biotite LS-tectonite fabric preserve sillimanite pseudomorphs after kyanite. New LA-ICPMS zircon ages from orthogneiss entrained in the shear zone, syn-tectonic leucosome and monazite ages from semi-pelitic material give ages of ca.2720 Ma.

The Tummeralik area lies approximately 40km east of Norsanna, and is dominated by heterogeneous tonalitic to dioritic orthogneisses and highly tectonised supracrustal lithologies. The controlling structure is a km-scale, east-plunging isoclinal fold with boudinage of metasedimentary lithologies on the fold limbs. All pelites contain biotite-sillimanite fabrics, and usually preserve relict kyanite or kyanite pseudomorphs. The pelitic units are typically boudinaged and rotated, resulting in an offset in the orientation of peak metamorphic fabrics in some metasedimentary units.

The two areas exhibit very similar characteristics in terms of metamorphic and structural evolution, with peak conditions likely to exceed 650°C and 7kbar. Integration of the field evidence and petrology shows that peak pressures in the kyanite field were likely to occur prior to the boudinage event. Sillimanite formation is also interpreted to have developed prior-to and during boudinage, suggesting heating and/or decompression from the kyanite field. Based on this evidence, we can correlate the peak events at these two localities. Geochronology from Norsanna places an age constraint of ca.2720 Ma for upper amphibolite facies metamorphism, which is in agreement with the timing of the arguable final terrane amalgamation event observed elsewhere in the Greenlandic craton.

STRUCTURAL GEOLOGY OF SOUTHERN PEEL PLATEAU AND PLAIN REGION, NORTHWEST TERRITORIES AND YUKON

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Frontal structures of deformed belts throughout the world, such as the Alberta Foothills, are known to contain significant hydrocarbon reserves. Therefore, understanding the internal structure and kinematics of mountain fronts has direct implications for petroleum exploration. Peel Plateau and Plain lie within the Interior Plains exploration region of the Northern Mainland Sedimentary Basin in the Northwest Territories and Yukon; the area has a widespread hydrocarbon potential and has been identified by industry stakeholders as a high-priority exploration region, yet it is underexplored and its geological history remains poorly understood.

As part of the project "Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain, Northwest Territories and Yukon" of the Northwest Territories Geoscience Office (NTGO), in collaboration with the Geological Survey of Canada (GSC) and Yukon Geological Survey (YGS) (http://www.nwtgeoscience.ca/petroleum/PeelPlateau.html), fieldwork was conducted during 2006 in the southern Peel Plateau and Plain and northern front of Mackenzie and Franklin mountains. This work focused on reevaluating the geometry, kinematics, and timing of key Phanerozoic regional structures that underlie the area. The region is structurally complex where linear, narrow ridges and shallow thrust faults of Franklin Mountains meet broad, flat-topped anticlines with intervening narrow synclines, and deeper contractional structures of northern Mackenzie Mountains. The transition from shallow to deeper structures appears to coincide with the westernmost occurrence of Cambrian Saline River Formation evaporites; however, much work is needed to elucidate the surface and subsurface geometry at the transition.

Detailed structural mapping was carried out along major structures, such as 1) the Tabasco Fault, a north-northeast-dipping thrust fault interpreted as a major backthrust, akin to the triangle zone of the southern Alberta Foothills, 2) the Deadend Fault, a north-verging thrust, which defines the front of Mackenzie Mountains in the Arctic Red River area, 3) the Southbound Fault, a south-verging structure located where Franklin Mountains meet Mackenzie Mountains, and 4) the Imperial anticline, a northwest to west trending arcuate regional feature located between the Mackenzie and Franklin mountains. The Imperial anticline, in particular, has important petroleum potential implications, as its geometry allows for possible structural traps involving sub-Saline River Formation siliciclastic intervals. Reconnaissance work was also conducted west of the Cranswick River, within the organic-rich Canol Formation shale, a potential source rock. Our work has revealed several south-verging thrust faults, which structurally thicken the succession. Additional work is warranted to evaluate the regional significance of these structures.

EXPLORATION ADVANCES WITH ULTRAVIOLET LED TECHNOLOGY – BELUGA SAPPHIRE, NUNAVUT

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The Beluga occurrence, located near Kimmirut, Baffin Island, has produced high quality, colorless to naturally coloured, multi-carat gem sapphires. The Beluga sapphires are of world class calibre and comparable to quality sapphires produced from deposits in Sri Lanka, Thailand, Cambodia, Africa, Australia and China.

The Beluga sapphire exploration program is focused on calc-silicate targets hosting visible, colorless to deep blue, pink and yellow sapphire, and pervasive late metamorphic and hydrothermal replacement in outcrop, surface trenches and drill core.

Key to the regional and detailed exploration success is the application of ultraviolet light surveys to recognize one of the principal diagnostic indicator minerals, scapolite. The scapolite typically occurs in proximity to the corundum mineralization. Scapolite exhibits a wide range of textural types from lobate granular to coarse pegmatitic euhedra to 30cm in length. Trace sulphur contained within the scapolite crystal structure is the probable fluorescence activator.

The increased working distance of LED ultraviolet light technology, employing optimum wavelength selection enhanced by special filters, has permitted successful prospecting over large areas of the property during the Arctic twilight of the field season. LED surveys using hand-held lamps can sweep areas of up to 5 metres in diameter allowing rapid coverage of prospective geology. Routine ultraviolet study of sample pits, outcrops, drill core and heavy mineral samples is utilized as standard exploration operating protocol to identify prospective targets.

Prospecting, mapping, core logging and concentrate examination are influenced by the powerful application of the LED technology specifically tailored to the scapolites of the Lake Harbour group calc-silicate lenses. The developing application of LED technology to the Beluga sapphire exploration will be discussed.

INVESTIGATIONS OF THE CRYSTALLINE BASEMENT BENEATH THE MACKENZIE MOUNTAINS OF THE NORTHERN CORDILLERA, NWT

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The basement beneath a large portion of the northern Cordillera in northeastern BC, eastern Yukon and the southwestern Northwest Territories is referred to as the Nahanni domain. The age and composition of this basement is poorly known, as it is nowhere exposed. The aim of this study is to provide insight new into the tectonic, geochemical, and geochronological framework of the basement in part of the western Mackenzie Mountains. Initial fieldwork for the study was carried out in July and August 2006 in collaboration with the Sekwi Mountain Project funded by the Northwest Territories Geoscience Office.

The project comprises three separate research thrusts. First, representative samples were collected from seven mid-Cretaceous plutons in the study area that are thought to be crustally derived on the basis of mineralogy and geochemistry. Crystallization ages for the intrusions will be determined using in situ U-Pb zircon dating methods. Inherited zircon cores will also be dated and hafnium isotopic compositions of both cores and igneous rims will be determined using in situ methods. The age and hafnium isotopic composition of the inherited cores will provide critical information about the nature of the crustal material that was melted to produce the magmas (possibly including components of the underlying basement). Secondly, a comprehensive U-Pb detrital zircon study of 10 different clastic sedimentary units, which were stratigraphically sampled throughout the map area, will be used to constrain the age and provenance of the individual sedimentary units. These units may include components from crystalline basement in the region and may also be present as inherited zircon cores in the Cretaceous intrusions. Finally, a small number of xenoliths, which are thought to be derived from underlying crystalline basement, were identified in a ~450 Ma ultramafic lamprophyre pipe termed the Mountain Diatreme. The Mountain Diatreme is one of nearly one hundred such diatremes in the central Mackenzie Mountains, many of which will be sampled for basement xenoliths in the 2007 field season. These will be dated and examined petrographically and geochemically to provide direct evidence for the nature of the Nahanni domain through which the diatremes intruded. Collectively all three studies will provide critical new information regarding the nature of the underlying basement in the Mackenzie Mountains and more broadly the Northern Cordillera.

Initial U-Pb results and preliminary interpretations from the detrital zircon study as well as preliminary U-Pb age constraints from the pluton investigation will be presented.

A NEW MODEL OF VOLATILE BUBBLE GROWTH IN MAGMATIC SYSTEMS

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The nucleation, growth and, ultimately, coalescence of volatile bubbles in a silicate melt (magma chamber) may play a crucial role in the processes leading to volcanic eruptions. A new diffusion-limited growth model of volatile bubbles in such a system is proposed. In contrast to previously existing models, ours treats the competitive effects of the other (randomly located) bubbles on the growth dynamics in presence of a hydrodynamic coupling with the melt advection field and viscous resistance. Numerical results suggest that, for small volatile supersaturations and small times, bubble growth occurs essentially as in a dilute bubble system. However, for larger times, the influence of the other bubbles is important. It is found that the growth rate decreases exponentially with time. Also, for larger volatile supersaturations, the bubble growth is subjected to an inflationary regime, whereby its radius increases very rapidly during a small time interval. Finally, a decompression situation is treated, in which the fluid pressure is explicitly decreased in time, thus simulating a magma ascent. In this case, bubble growth oscillates between normal growth and inflationary regimes.

YUKON DIGITAL SURFICIAL GEOLOGY COMPILATION: CONSTRUCTING A NEW GEOLOGICAL SPATIAL DATABASE

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In an effort to make surficial geology baseline data more consistent and accessible across the Yukon Territory, over 150 regional surficial geology maps are currently being digitally compiled into a territory-wide spatial database. The maps provide 80% coverage of the territory at scales varying between 1:250 000 and 1:25 000. About 4/5 of the maps were published by the Geological Survey of Canada since the 1960s. Most of the remaining maps were published by the Yukon Geological Survey in the last 10 years. The wide variety of authors, map scales, and terrain within the territory have made standardizing the map legends a challenge. About half of the maps have been digitized from hard copy formats, while the other half have been converted from various digital formats into a single standardized ArcGIS geodatabase format. The database structure and legend coding is primarily based on the British Columbia terrain classification system, but will also be consistent with national standards. The end product will be a valuable data source for a variety of land-use applications in the territory, including: mineral and placer exploration, forest management, biophysical and ecological land classification, geotechnical engineering, infrastructure planning, granular resource assessments, permafrost modeling and agricultural assessments.

RECENT PERMAFROST-RELATED LANDSLIDE INVESTIGATIONS IN SOUTH AND CENTRAL YUKON

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A variety of studies have been undertaken at the Yukon Geological Survey in recent years to characterize and monitor permafrost-related landslides in south and central Yukon. This work has taken place largely in response to a growing concern for the potential effects of development and climate change on slope stability in permafrost terrain. The investigations have utilized a wide variety of techniques, including detailed field-based geomorphological studies, regional inventories, two-dimensional resistivity geophysical surveys, differential GPS surveys, and Interferometric Synthetic Aperture (InSAR) analysis. A selection of case studies are presented to illustrate the application of these techniques and emphasize various characteristics that are commonly associated with permafrost-related landslides, including their source area settings, triggers, mobility, longevity of activity, and impacts. The nature and distribution of the failures documented to date highlights a number of implications for development in discontinuous permafrost terrain, and well as the need for regional permafrost mapping and enhanced methods of permafrost detection in the territory.

NAHCOLITE ($NaHCO_3$) AND TRONA ($NaHCO_3 \cdot Na_2CO_3 \cdot 2H_2O$): LABORATORY PHASE RELATIONS AT MODERATE P-T AND OCCURRENCE IN NATURAL FLUID INCLUSIONS

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Nahcolite and trona are the dominant ore minerals for soda ash (anhydrous Na_2CO_3), one of the most widely used and important commodities in the United States. These two minerals occur variously in evaporites (e.g. Green River Basin, Wyoming), altered natrocarbonatitic lavas, and fluid inclusions in rocks of metamorphic/igneous origin.

We presently investigate for the first time the phase boundary for nahcolite coexisting with trona, vapor and fluid at moderate-to-high pressures, using cold-seal hydrothermal bomb and piston-cylinder techniques and forward and reversal experiments. The results for nahcolite/trona equilibria at moderate pressure are in excellent agreement with earlier 1 atmosphere (near-surface T) experiments of Eugster and theoretical calculation. The phase boundary in log (p_{CO2})-T space is linear, and defined by the equation $\log(p_{CO2}) = 0.02403(14)T - 9.800(56)$ (with p_{CO2} in bar and T in K). Using this regression equation and literature thermodynamic data, the entropy of trona at 298.15 K is constrained to be ca. 303.8 J mol^{-1} K^{-1}. Completion of the forward (nahcolite to trona) reaction was inhibited by encrustation of nahcolite by trona, permitting derivation of the activation energy of the nahcolite/trona phase transformation at different pressures.

According to this study, trona is stable up to ca. 10 kbar, and has a much wider P-T stability than indicated by earlier trona/thermonatrite ($Na_2CO_3 \cdot H_2O$) phase relations. Literature estimates of P-T conditions for the natural fluid inclusions lie either in the field of trona or on the nahcolite/trona phase boundary. Therefore, we suggest that trona is most likely the primary sodium carbonate-sodium bicarbonate phase in these fluid inclusions, whereas nahcolite is a daughter mineral which crystallized from the fluids as temperature decreased.

"WHAT DO YOU MEAN DIAMONDS AREN'T MADE FROM COAL?" – CONFESSIONS OF A HIGH SCHOOL GEOLOGY TEACHER

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Students in most schools across Canada have limited knowledge and exposure to Earth Science or Geology in their Science classes. There are several reasons for this. They include :

1) The number of elementary and high school science teachers who have no geologic knowledge or experience.
2) The low priority that geology has in the Science curriculum in elementary schools.
3) The scarcity of funding in Education for Science teachers to attend Geology related workshops or obtain supplies for the classroom.
4) The tendency to place students with weak academic skills in Geology based courses to obtain graduation requirements.
5) The lack of knowledge in the general public about natural phenomena.

Despite the challenges facing a trained geologist teaching in a Yukon High school, teaching Earth Science and Geology to students from grades nine to twelve can be a very enjoyable experience. This is because the majority of students, whose initial reason for enrolling in the course is often to "get a Science credit," soon realize they are able to do quite well knowing that their outdoor experience will help them with the course.

Generally, students enrolling in Earth Science 11 at our school are weak academically, on IEPs (which include poor memory, attention deficit disorder, weak readers and writers, dyslexic, FAS/FAE problems) have behavior and attendance problems, but are "hands on" learners and keen on the outdoors!!!

However, those that enroll in Geology 12 have stronger academic skills, as there is a provincial exam associated with this course and the students are more motivated, may have taken Earth Science 11, need an additional Science credit (don't want to take Physics or Chemistry 12) or sign up because it fits in their timetable.

As a teacher with these types of students "landing at the door" I find I need to be very resourceful at balancing how to get through the curriculum, while organizing activities that make aspects of geology more relevant and "real".

SYNSEDIMENTARY FAULTING DURING DEPOSITION OF THE NEOPROTEROZOIC MACKENZIE MOUNTAINS SUPERGROUP AND ITS EFFECT ON ECONOMIC MINERALISATION

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Striking lateral thickness and facies changes in formation- to sub-formation-scale units of the >6 km-thick, epicratonic Mackenzie Mountains Supergroup are evident from isopach maps and cross-sections, and were caused by syndepositional activity of deep-seated faults. The supergroup was deposited along the arcuate margin of an extensional basin that deepened to the WSW. Although isopach data for formation- to group-scale units conform to this pattern, isopachs for individual sandstone-dominated formation-scale units of the Katherine Group (lower MMSG) do not follow regular, craton-parallel trends, as would be expected in a quiescent passive-margin setting. Complex isopach patterns suggest that fluvial facies of the Katherine Group prograded into a basin whose bathymetry was influenced by the activity of large-scale transfer faults that divided the subtly extensional basin into bathymetrically delineated compartments up to 150 km along strike and 50-70 km normal to the basin margin. The overlying, shallow- to deep-marine Little Dal Group (upper MMSG) is less well documented, but nonetheless exhibits pronounced thickness and facies variability. Along-strike thickness changes are present in parts of the Basinal assemblage, and the presence or absence of the Gypsum formation appears to be syndepositionally controlled in the vicinity of inferred faults. The lateral facies transition from Basinal to Platformal assemblage, which is at a high angle to the basin margin, is best explained by syndepositional faulting. The deep-water reef tract in the Basinal assemblage is parallel to inferred extensional faults. The southern margin of one of the more prominent sub-basins, identified by Katherine Group isopach patterns and lateral facies variations in the subsurface between Norman Wells and Great Bear Lake, may have been a SW-trending transfer fault S of Norman Wells. Its northern margin may have been a fault that controls Gypsum formation depositional thickness at Gayna River, and possibly formed the main structural control on base-metal mineralisation at Gayna River. It is possible that the large number of economic mineral showings known from the area between these two faults, in both Proterozoic and Paleozoic host units, were generated by metalliferous fluids migrating through these deep-seated and repeatedly reactivated faults. Refining existing thickness maps for the Katherine Group by acquiring more data in critical areas, and augmenting the currently sparse stratigraphic data for the Little Dal Group, may help to refine understanding of these structures and their activity, and illuminate the nature of and controls on base-metal and other deposits of economic interest in the Mackenzie Mountains.

DEVELOPMENT OF THE NORTHWEST SKEENA FOLD BELT, NORTHWEST BRITISH COLUMBIA

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The Jurassic-Cretaceous Bowser Basin is located in a sparsely populated region of northwest British Columbia prospective for petroleum exploration, in an area traditionally dominated by mineral exploration. The Skeena Fold Belt is a widespread region of deformation with a distribution overlapping that of the Bowser Basin. Ongoing study of this enigmatic basin serves to improve understanding of potential petroleum systems in the marine to non-marine clastic fill of the basin.

The Skeena Fold Belt is structurally dominated by two regional fold sets. Folds trending northwest are most commonly located within the eastern two-thirds of the fold belt, whereas folds trending northeast are dominant in the western third of the fold belt. Normal, thrust, and strike-slip faults have been identified. Structural overprinting has been noted in all areas. Detailed structural mapping has been undertaken in order to resolve the timing relationships between these and other structures, and to develop a general history of shortening.

In the areas studied there are variable types of structural overprinting. The Iskut ridge area shows mappable deflection of north-trending folds by outcrop-scale southeast-trending folds. In the Cartmel Lake area multiple cleavage sets in outcrop and the lack of distortion of map-scale folds by intersecting faults interpreted to be unrelated to area folds suggests overprinting of these structures. The Sweeny Creek area reveals north-trending folds that increase in plunge northward, a result of overprinting by a kilometre-scale syncline. Structures in all three areas are consistent with early generally northwest-southeast shortening, followed by northeast-southwest shortening. Understanding the structural history of the basin has implications for delineating dome-and-basin interference patterns capable of trapping petroleum and for developing models of petroleum systems in the region.

HEAVY MINERAL PROVENANCE OF THE FLEMISH PASS AND ORPHAN BASINS, OFFSHORE NEWFOUNDLAND AND LABRADOR

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The Orphan and Flemish Pass basins are fault bounded rift-basins, located at the southern end of the Labrador Sea. They are deep water frontier exploration areas that potentially contain the next Canadian giant oil field discovery. They formed during Mesozoic intra-continental rifting associated with the breakup of Pangaea and seafloor spreading in the North Atlantic. Rifting of Orphan and Flemish Pass basins was prolonged due to its proximity to three main spreading centres in the north Atlantic: the Grand Banks-Iberian, the northeast Newfoundland-northwest European, and the Labrador-Greenland. Sources and paleotransport pathways of detritus into the basins are unknown, which limits stratigraphic correlations, hydrocarbon exploration and paleogeographic reconstructions. Possible sources include the North Atlantic Archean craton, Neoproterozoic Avalonia-Cadomian terranes and the Paleozoic Appalachian-Caledonide orogen.

Exploration of these areas over the past thirty years has provided strong evidence for the presence of a major petroleum system. The Flemish Pass Basin is known to contain good quality source and reservoir rocks. It is yet to be confirmed whether these strata continue into the East Orphan Basin; however, recent geophysical studies suggest that they do, and that periodic open seaway communication occurred between the Flemish Pass and Orphan basins throughout the Mesozoic.

This project will contribute to previous studies by determining provenance and attempting correlations. Four key wells in the area are the focus of this study: Panther P-52, Baccalieu I-78, Mizzen L-11 and Blue H-28. Baccalieu and Mizzen are located in the Northern Flemish Pass Basin, Panther is on the eastern Central Ridge complex, and Blue is located in the West Orphan Basin. Collectively, these four wells have good coverage of Late Jurassic, Cretaceous and Tertiary strata.

Analyses of detrital heavy minerals (Fe-Ti oxides, garnet, zircon, apatite, monazite, tourmaline, etc.) are used as a tool to determine provenance. Detrital heavy mineral assemblage characterization, selective heavy mineral geochemistry, U-Pb zircon dating, and qualitative zircon analyses are all methods used in this study to define heavy mineral assemblages and to identify sediment sources.

The objectives of this study are: (a) to determine if the Jurassic, Cretaceous and Tertiary sandstones contain specific heavy mineral characteristics, including specific mineral abundance ratios and zircon age and composition that can be used for correlation and provenance studies, (b) to determine the provenance of Tertiary, Early Cretaceous and Late Jurassic sandstones, and (c) to determine if correlations exist between age-equivalent units in the Flemish Pass and West Orphan basins, based on shared heavy mineral provenance.

THE SETTING AND ORIGIN OF MAFIC-ULTRAMAFIC MAGMATISM WITHIN THE CENTRAL AND NORTHEASTERN RAE DOMAIN

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New U-Pb age constraints indicate that all late Archean orthoquartzite-komatiite associated supracrustal belts within the central/northeastern Rae domain of Nunavut, including the Woodburn Lake group (WLg), PAg, and Mary River group (MRg) are components of a much larger, northeasterly-trending network (~1400 km long and up to ~400 km wide) of co-genetic, clastic-dominated supracrustal belts. The predominant mafic-ultramafic and associated felsic volcanism within these belts formed between 2735-2690 Ma and upon 2775-2870 Ma continental crust. Extensive detrital zircon age dating, however, indicates components of the Rae crust are much older, ranging between ~3.3-3.8 Ga. Nd isotopic data indicate this crust is marginal to the crustal corridor containing the supracrustal belts and to the west. The formation of these belts upon juvenile crust, adjacent to ancient components suggests a continental-margin setting. The focusing of magmatism/sedimentation along this crustal corridor for ~45 m.y. suggests the pre-existing lithospheric architecture and structures controlled the large-scale distribution of magmatism. Moreover, the initial "pulses" of magmatism began abruptly between 2735-2730 Ma, with no evidence for uplift or age progressions these data suggest active lithospheric extension preceded/facilitated its initiation. Within the PAg segment, this phase of magmatism is unusually well-preserved and characterized by a voluminous (> 300 km^2 and ~3 km thick) komatiite-dominated mafic-ultramafic volcanic succession. Exceptional major/trace element geochemical fractionations and their correlation with stratigraphic height require decompression melting of a single "parcel" of hot peridotitic mantle separated into two principal stages. Initial melting within the garnet-stability field generated a spectrum of HREE-depleted ultramafic magmas that pooled at shallow lithospheric depths and differentiated to form basalt. The continued rise of residues from the initial melting eventually began a renewed stage of melting. These low-density magmas traversed the crust rapidly and undifferentiated. The short time span separating the eruption of garnet-present and garnet-

absent melt products, and that maxima in melting were approached during both stages (~25-30 wt.%) requires pre-existing space to facilitate the upwelling. These data can be reconciled if mantle upwelling and melting were focused from beneath the thick, ancient Rae cratonic root toward its thin, juvenile margin. The origin of the thermally anomalous mantle described here is still somewhat enigmatic, however, the strong influence of the lithosphere in focusing and controlling the distribution of magmatism and that komatiite-dominated magmatism is long-lived within this crustal corridor suggests the possibility that melting anomalies may have an origin at lithospheric depths, and perhaps not the core-mantle boundary.

THE GEOLOGY, GEOCHEMISTRY AND MINERALIZATION OF THE NAARTOK GOLD DEPOSIT: HOPE BAY BELT, NUNAVUT TERRITORY

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The Hope Bay Volcanic Belt is an Archean greenstone belt within the Slave structural province, Nunavut. The belt is bordered to the north by the Arctic Ocean and to the east, west and south by younger granitoids also of Archean age. The Hope Bay Volcanic Belt (HBVB) comprises a north-south striking package of intercalated basalts, sediments and felsic lithologies which generally young towards the centre of the belt. The HBVB is prospective for gold mineralization, and to date three main deposits have been defined which collectively contain a resource of ~8.9 million ounces. Recent exploration success has dramatically expanded the Madrid system and advanced our understanding of the structural and stratigraphic controls on mineralization. The Madrid system is located in the northern portion of the belt and includes the Naartok East, Naartok West, Rand and Suluk deposits, which have similar styles of mineralization. The Naartok deposits are in the northern portion of the Madrid system. The geology at Naartok consists of a north-northeast striking package of pillow basalts, pepperites/pillow breccias and lenses of argillite that face and dip steeply west. Basalt units are divided based on geochemistry and grossly consist of high Fe-Ti Fe tholeiitic basalt (A-type) and normal tholeiitic basalt (C-type). The A-type basalts represent the most prospective rocks at Naartok and are also a first order control on the distribution of mineralization. The second suite comprises normal tholeiitic basalts (C-type) which exhibit normal chemistry and are usually poorly mineralized. Mineralization at Naartok is also strongly structurally controlled. The Naartok deposit lies in the hanging wall of a regional structure called the Deformation Zone (DEFZ) which possibly originated as a growth fault. The DEFZ is oriented approximately east-west at Naartok and truncates both the north-south stratigraphy and the mineralization. Mineralization is noted in lenses along the hanging wall contact of the DEFZ and as pods within the DEFZ, but has not been recognized in the footwall. Where lower angle splays from the DEFZ interact with favorable volcanic strata, the host rocks become increasingly altered and auriferous. The gold mineralization is most commonly concentrated where the volcanic strata are strongly altered and veined, and exhibit significant pyrite content. The alteration assemblage that commonly has the highest grade mineralization comprises Fe-dol/ankerite + sericite ± albite ± Si-flood, primarily when developed within A-type rocks or near the contact of A and C-type lithologies.

NEW K-Ar AGE DATA ON ALTERATION CLAY MATERIAL ASSOCIATED TO ARGILLIC ALTERATION HALOS AROUND SKARNS IN THE GASPÉ APPALACHIANS – EVIDENCE FOR MESOZOIC FLUID FLOWS IN PALEOZOIC FAULTS

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Orogenic and Carlin-type gold occurrences, and base metal skarns, are spatially associated with the Devonian Acadian dextral strike-slip Grand Pabos-Restigouche fault system in the Gaspé Appalachians. Base-metal skarns, as well as the Saint-André-de-Ristigouche gold prospect (SAR), are enclosed in large halos of argillic hydrothermal alteration. Herein, we present new K-Ar ages of alteration clay material (illite) associated with the Cu-skarns and the SAR along the Restigouche fault.

The alteration assemblages form zoned halos surrounding two Cu-skarns, by successively surrounded a chlorite zone, a smectite, a kaolinite+smectite, a kaolinite and an illite zone. The larger halo is truncated by the Restigouche fault. The SAR is found within the kaolinite assemblage, close to the kaolinite-smectite assemblage.

We have analysed four samples. SA03-17 was collected in direct contact with the SAR mineralized vein in the silicified host limestone. SA03-17B is located in the kaolinite assemblage about 5 m away from the mineralized vein. The two other samples were collected in the illite (SA03-15) and normal (SA03-01) assemblages, respectively. The K-Ar ages were obtained on the three size fractions, 5-15, 0.2-5 and <0.2 μm of each sample. The K-Ar ages of the three fractions of the normal assemblage (SA03-01) vary between ca. 431 and 447 Ma, which is close to the biostratigraphic age of the host rocks (Ashgillian to Llandoverian, 449 to 428 Ma). In the illite and kaolinite assemblages, the K-Ar ages of the 5-15 and 0.2-5 μm size fractions are still Paleozoic, but the finest <0.2 μm fractions are much younger with Mesozoic values (SA03-15, SA03-17 and SA03-17B). The K-Ar ages of the 5-15 and 0.2-5 μm size fractions vary from ca. 437 to 396 Ma, or from Early Silurian (Llandoverian) to Early Devonian (Emsian). The K-Ar ages of the <0.2 μm size fraction is Late Triassic in the illite (ca. 211 Ma, SA03-15) and kaolinite (ca. 222 Ma, SA03-17B) assemblages, and Early Cretaceous (ca. 130 Ma, SA03-17) close to the mineralized vein.

This is the first time that a Mesozoic geological event (fluid flows and formation of authigenic clay associated with argillic alteration) is reported in the Gaspé Appalachians. This suggests that hydrothermal fluid migrations occurred in the plumbing system of the Grand Pabos-Restigouche fault system during the Late Triassic and Early Cretaceous at the onset of the Atlantic Ocean opening. However, the K-Ar age relationship with the gold mineralization remains unclear and has to be established.

LUMINESCENCE PETROGRAPHY AND SPECTROSCOPY OF ROCKS AND MINERALS FROM THOR LAKE, NWT, CANADA

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The Thor Lake rare-metals deposit is predominantly characterized by fine-grained complex mineralization most of which is not amenable to identification using conventional petrography and ore microscopy. The scanning electron microscope with energy-dispersive x-ray detection capabilities has been largely used to identify and record the occurrence of the minerals pertinent to economic exploration programs. A valuable supplement to SEM-EDX is the utilization of cathodoluminescence (CL). The use of CL enhances the identification of obscure minerals and the differentiation of specific crystallization episodes associated with rare-element mineralization.

Minerals identified by CL include xenotime, zircon, phenakite, apatite, polylithionite, fluorite, calcite, feldspar and quartz. Radiation-damage α decay haloes in quartz adjacent to thorite and zircon further enhances the recognition of these minerals with the use of CL. Pseudomorphic replacement of earlier minerals by late zircon, fergusonite and rare earth-bearing minerals are vividly revealed with CL. Comparison of rock slabs under study is made using macrophotography with 1) normal light; 2) UV excitation; and 3) defocused-beam CL.

The major carrier of Y and HREE at Thor Lake is xenotime. This mineral is easily identified by its characteristic light-green luminescence. The CL spectrum for xenotime consists of narrow line emissions that occur at ≈~ 480 and 570 nm from Dy^{3+} activation, and 545 nm from Tb^{3+} activation.

MICROBEAM-BASED ANALYTICAL APPROACH TO DEFINE MELT COMPOSITION AND IDENTIFY TARGET ROCKS IN IMPACT MELT SHEETS: AN ANALOGUE STUDY FROM THE MISTASTIN LAKE IMPACT CRATER, LABRADOR

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The Mistastin Lake impact crater is an exceptional study area for analogue cratering studies of impact melt genesis and dating. The projectile impacted northern Labrador 35-40 million years ago in a Mesoproterozoic (ca. 1.4 Ga) stable craton and has not been considerably affected by successive metamorphism and deformation. The impact melt rocks are well exposed and the target rocks from which the impact melt was produced are thought to consist principally of anorthosite and mangerite (hypersthene monzonite). Because of its anorthositic target rocks, Mistastin may be the best terrestrial analogue for lunar impact melts.

Bulk analyses have been traditionally used to determine the composition and target rock sources of impact melts. This approach is indirect in that model dependent mixing calculations must be employed using assumed target compositions. Advances in microbeam technologies such as laser ablation ICP-mass spectrometry and automated scanning electron microscopy (SEM) provide more direct measurements and less ambiguous results. Xenocryst-free regions identified by automated SEM, are analyzed simultaneously for major and trace elements using laser-ICPMS. Xenocrystic material, particularly the refractory mineral zircon, is analyzed by EPMA and/or laser-ICPMS to determine the nature and composition of the target rock contributions to impact melts. Zircon are resistant to the effects of impact melting and contain distinctive inventories of trace elements. The age of xenocrystic zircon determined by U-Pb laser-ICPMS dating may be used as a further link to particular target rocks. Target rocks on the Moon and Mars have very subtle differences in chemistry and relating impact melt products to particular impact craters and target rocks can be difficult.

For Mistastin, we have determined that the composition of the glassy to fine-grained melt sheet is broadly andesitic with SiO_2 varying from 55.7 to 61.5 wt%; Na_2O from 4.6 to 5.1 wt% and K_2O from 1.2 to 3.7 wt%. Chondrite-normalized REE patterns are slightly light REE enriched with $[La/Sm]_n$ = 3.5 to 5.5. U-Pb geochronology indicates the presence of at least two populations of xenocrystic zircons with ages of 1382.2 ± 8.2 Ma and 1412.3 ± 5.6 Ma. Compositions of xenocrystic zircons define 3 populations: (1) small grains (45-80μm) with high $[Th/U]_n$ (0.606 to 0.809), (2) mixed-size grains with low $[Th/U]_n$ (0.207 to 0.331) – low $[Hf/Sc]_n$ (343.9 to 417.8), and (3) elongated, large grains (75-125μm) with low $[Th/U]_n$ (0.169 to 0.296) – high $[Hf/Sc]_n$ (482.7 to 564.7). The data suggest multiple target sources contributed to the Mistastin impact melt sheet.

STREAM SEDIMENT GEOCHEMISTRY AT BARROSO-ALVAO REGION (N PORTUGAL) AND ALMENDRA-BARCA D'ALVA REGION (NE PORTUGAL) AS AN EXPLORATION METHOD FOR LI-BEARING GRANITIC PEGMATITES

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The Barroso-Alvao region (BA) and Almendra-Barca d'Alva region (AB) have a high geological resources' potential, regarding LCT (Li, Cs, Ta) pegmatites. Both pegmatite fields are located in the NW part of the Iberian Peninsula. These veins are hosted in low- to medium-grade metamorphic rocks and surrounded by highly evolved synorogenic two mica granitoids.

BA region and AB region are known by their Sn, W and Li mineralization. The lithium mineralization occurs in pegmatite-aplite veins mainly as lepidolite, spodumene, petalite and accessories montebrasite-amblygonite, cookeite and eucryptite.

Geochemistry prospecting was carried out by Portuguese Geologic Survey (presently INETI) in both regions during different periods of the last century. Stream sediment geochemistry in BA was carried out in the 90's. During this campaign, 665 samples were gathered up within a 227 km^2 area. While the AB stream sediment campaign (accomplished during the 80's) was restricted to 100 km^2. During it the team decided to collect 335 samples.

In both surveying the -80 mesh fraction was analysed for major and minor elements and it was given especial significance to the chemical elements Sn, W, Ta and Li.

The obtained results were analysed using statistical methods. After that, it was possible to establish lithium anomalous zones (background of 99 ppm) representative of each drainage catchment basin. These anomalous zones were overlapped in the geological map and were used as a first approach in a pegmatite exploration survey at 1:10,000 scale.

The identification of almost one hundred lithium bearing pegmatite-aplite veins in the BA region and the recognition of petalite (unknown until that moment) were the main results obtained after using stream sediment geochemistry data.

Based on the successful results obtained in the BA region, the same methodology is now being applied in AB region. Until the moment, we were able to identify lepidolite, petalite and spodumene bearing pegmatite-aplite veins using the same approach as before.

PALEOCLIMATE AND BIOGEOGRAPHY OF THE EARLY EOCENE QUILCHENA FOSSIL LOCALITY, BRITISH COLUMBIA

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The Quilchena site in the southern interior of BC is one of several Okanagan Highlands (OH) fossil floras now known to date mostly to the Ypresian (Early Eocene). Quilchena is securely dated radiometrically at 51.5 mya, which places it at the beginning of the Early Eocene warm interval. Both leaf-margin analysis of dicot leaves and bioclimatic reconstructions using a nearest living relative (NLR) approach have determined that the paleoclimate of Quilchena was both the warmest and wettest of the OH sites of similar age. The OH floras are interpreted as having little temperature seasonality. While other fossil floras from this upland region are classified as microthermal (MAT < 13ººC), Quilchena is warmer and falls within the mesothermal category (~ 15°C). As chronologies of other localities become better constrained, it is hoped that a time series of climate and

vegetational changes will be developed that will assess the impact of the changes surrounding the warmest interval of the Cenozoic.

Quilchena is floristically and biogeographically an interesting fossil locality, with a rich flora of gymnosperms (15 genera, including the only confirmed record in OH of the thermophilic Keteleeria), and the only known reproductive structures (cone and seed) of Calocedrus and Taxodium staminate cones. Taxodium, Glyptostrobus and an abundance of Metasequoia foliage, combined with the presence of coal seams in the basin, suggests that the Quilchena locality was a shallow lake and swamp complex. The only recorded presence of Nyssa (a fruit stone of tupelo or black gum) in the OH further suggests similarities to modern swamp-forests of the southeastern American coastal plain. A large number of angiosperm fossils are also recorded at Quilchena, including thermophiles such as Eucommia (Chinese rubber tree), Dipteronia, and cf. Gordonia (Theaceae). Fish remains are also common at the site, and a fossil insect fauna is providing a secondary source of paleoclimatic information, with taxa ranging from tropical to temperate affinities.

A comparison of Quilchena with other OH floras such as Republic, Princeton, McAbee, Falkland, and Driftwood Creek constitutes an opportunity to better understand the long-term consequences of climate warming and cooling on ecosystems.

DOES KIMBERLITIC MAGMA DEGAS AT THE MOHO?

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Olivine macrocrysts from the A154 (Diavik) and Grizzly (Ekati) kimberlites were studied using electron microprobe and FTIR spectroscopy. Major element composition and Ni content allowed us to reliably separate phenocrystic olivines from olivines that were likely derived from disintegrated peridotitic material. FTIR spectra were used to calculate water concentrations in olivine phenocrysts and estimate pressure and silica activity of their crystallization. On the basis of these data, we propose that kimberlitic magmas may pool and undergo significant modification (olivine crystallization, fluid exsolution) at the Moho.

Forsterite content (Fo#) of the olivines varied from 88 to 94. The majority of high-Mg olivines (Fo#>90) also have high NiO content (>3400 ppm). Such chemical compositions are characteristic of peridotitic olivines from the lithospheric mantle. In less magnesian olivines, NiO systematically decreases with decreasing forsterite content, a correlation that is consistent with magmatic differentiation. Olivines with NiO less than 3200 ppm were considered phenocrystic.

All of the Diavik phenocrysts contained uniform and relatively high water concentration ~250 ppm. Such uniformity is remarkable considering that the water content in the rest of the Diavik olivines ranges from 5 to 360ppm. The intensities and wavelengths of the IR OH absorption bands measured in phenocrysts suggest moderate pressures of crystallization (<2GPa). The combination of moderate crystallization pressures and relatively high water content implies that water fugacity during olivine crystallization or equilibration was defined by an aqueous fluid rather than a melt. This explains why olivine crystallization did not affect water fugacity. Similarly, constant water fugacity implies that crystallization occurred at constant pressure, e.g. in a magma chamber. Possibly, ascent of the kimberlitic magma was interrupted at the Moho due to abrupt changes in rheology and density at the crust-mantle boundary. Interaction of kimberlitic magmas with the overlying crustal rocks increased the silica content of the melt, which in turn triggered aqueous fluid exsolution. The exsolved fluid may have assisted in further magma ascent through the lower crust.

Clearly olivine crystallization can also occur in a more typical environment, e.g. during kimberlitic magma ascent. Olivine phenocrysts from the Grizzly kimberlite contain only ~120 ppm of water. FTIR spectra of Grizzly phenocrysts are suggestive of relatively high crystallization pressures (>2GPa). Here water fugacity was controlled by kimberlitic melt and the magmatic system was aqueous fluid free.

Magma pooling affects diamond preservation and thus study of this phenomenon should enhance our ability to predict the diamond potential of a kimberlite.

MINERAL EXPLORATION IN HIGH METAMORPHIC-GRADE TERRANES

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High-grade metamorphic terranes were not generally considered prospective, because they rarely contain world-class deposits. However, as more major deposits are identified, and as world demand for metals increases, metamorphic terranes will become increasingly perspective. Exploration in these areas requires a new paradigm. Using detailed examples from Broken Hill, Challenger, and Hemlo, combined with recent experimental results, we outline processes that occur in partially melted ore deposits that geologists should keep in mind when exploring in such terranes.

Our research has shown that all sulfide deposits undergo partial melting during high-grade metamorphism and that the melts produced concentrate precious metals. This means that, whereas precious metals may be evenly distributed within an un-metamorphosed deposit their distribution in a partially melted body will be highly localized. Thus, assessment of the economic viability of a deposit in a high-temperature metamorphic terrane must take this into account. In such studies Economic geologists should: 1) drill into tensional areas (such as fold noses, tensional veins etc.); 2) drill through the body to assess whether metal-laden melts had migrated into the country rock, and; 3) carefully examine granitic leucosomes for entrained sulfide melts.

The Challenger Deposit, in South Australia, is a pre-existing gold deposit that has been metamorphosed to granulite-facies. Pre-metamorphic alteration can be seen in the gneisses immediately surrounding the ore zones. During peak metamorphism, both the host and the ore melted, which strongly localised Au into and around leucosomes. This, in effect, produced a smaller exploration target, although an As halo is still present around the ore.

At Broken Hill, Australia, during granulite-facies metamorphism, the pre-existing massive sulfide deposit partially melted. The now solidified, sulfide melts were enriched in Pb, Sb, As, Ag, Cu, and Au relative to the main loads. The silicates surrounding the ore were chemically altered as a result of their interaction with sulfide melt.

At Hemlo Ontario, the sulfide melts, which were rich in gold, were concentrated into dilational domains. This process extracted Au, with Sb and As, into small, high tenor zones. Without melting, this major Au deposit may have not been economic.

MISSION TO PLANET "METEORITE": RECONNAISSANCE SAMPLING OF THE SOLAR SYSTEM WITHOUT A SPACECRAFT

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Meteorites provide a readily available source of samples from Mars, the moon, and small bodies in the Solar System. Lunar meteorites greatly expand the range of samples that are available from the moon and Martian meteorites are still the only rock samples that we have from the red planet; other meteorites are thought to represent 4 Vesta and a few other bodies of the main belt asteroids. Most meteorites have no clear analogue or identified source body, but nevertheless provide clues for understanding processes in the early (and present!) Solar System. Meteorites can fruitfully be studied by non-destructive methods to obtain bulk properties such as density, porosity and magnetism to provide a foundation for understanding their record of the early history of their source bodies and also their behaviour during impacts, cosmic ray irradiation and delivery to the Earth as Near Earth Objects which ultimately impact or arrive as meteors. Meteorite mineralogy and textural relations can be assessed non-destructively via in situ micro X-Ray diffraction, providing rapid initial meteorite identification along with information on grain size and the state of impact shock metamorphism. These reconnaissance meteoritic observations complement spacecraft-based efforts to characterize the moon, Mars and small bodies in the Solar System, acting as an inexpensive preview of what might be recovered from future geological studies -in context- during missions to these bodies.

END OF THE GRENVILLE: A NEW LAURENTIAN PALEOPOLE FROM THE 974 Ma GILBERT BAY DYKES, SOUTHEASTERN LABRADOR

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Rodinia paleogeography during the Grenville orogeny remains poorly known, in part due to the paucity of high quality ca. 1000 Ma paleomagnetic results. The Gilbert Bay dykes of the extreme northeastern Grenville province in Laurentia have an emplacement age of 974 ± 6 Ma (U-Pb zircon) and postdated metamorphism or deformation related to the end of the Grenville orogeny. Ten Gilbert Bay dykes have been sampled to obtain a non-metamorphic paleomagnetic result for Early Neoproterozoic Laurentia. Stepwise demagnetization of 180 specimens reveals a dual-polarity characteristic remanence carried by magnetite and hematite. A positive baked contact test demonstrates the characteristic magnetization to be a primary thermoremanence of Early Neoproterozoic age. The resultant paleopole at location 18.3 N, 146.4 E, A_{95}=6.2 places Laurentia at equator at ca. 974 Ma, and is strikingly offset from published ca. 1030-900 Ma Laurentian paleopoles of the Grenville Loop whose ages of steep remanence acquisition have been interpreted to reflect Early Neoproterozoic post-orogenic cooling of metamorphic and intrusive rocks from the Grenville orogeny. The well-constrained magmatic result from the Gilbert Bay dykes implies that Laurentia's Grenville Loop apparent polar wander occurred rapidly prior to or after 974 Ma, or that the Grenville Loop may not have occurred at all and that the steep remanences which form the "Haliburton A" portion of the Grenville Loop may instead have been acquired later. Rodinian paleogeography based upon the matching of the Early Neoproterozoic apparent polar wander path loops for Laurentia (Grenville) and Baltica (Sveconorwegian) may need to be reassessed.

TREE RIVER QUARTZ PEBBLE CONGLOMERATES: A NUNAVUT ANALOGUE TO THE WITWATERSRAND?

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The Tree River Volcanic belt (TRVB) is located within the northwest corner of the Archean Slave Structural Province (SSP) of the Canadian Shield in Nunavut. The TRVB is composed predominantly of mafic to intermediate volcanics, but also contains a small belt of sedimentary supracrustal rocks. Of particular economic interest are a series of pyritic polymictic, and monomictic quartz pebble conglomerates (QPCs) and arenites within a turbiditic sequence that Strongbow Exploration Inc. (Strongbow) explored between 2002 and 2006 for QPC-hosted gold mineralization. It was thought that these conglomerates might bear some similarities to that of the Witwatersrand in South Africa.

The detrital heavy mineral assemblage includes pyrite, chromite/chrome spinel, monazite, zircon, ilmenite, and titanium dioxide. This mineral assemblage is simpler than that of the Witwatersrand, but comparable to other mineralized QPCs worldwide; this however may be a function of provenance. The authigenic ore mineral assemblage includes pyrite (both porous and compact varieties), galena, chalcopyrite, cobaltite-gersdorffite-glaucodot-breithauptite, arsenopyrite, monazite, sphalerite, and Pb sulphosalts. It is not clear if these mineral phases are exotic metals that have been introduced into the host rocks, or if they represent a local remobilization and redistribution of metals from detrital mineral phases. This 'hydrothermal' overprint is not unique because many QPCs are overprinted by later hydrothermal events, to the extent that some workers consider them hydrothermal deposits and not modified palaeoplacers.

Gold grades within the conglomerates are generally low (<0.1 g/t), however, bonanza grades (>50 g/t) are locally present. The origin of the gold remains unresolved at this time. While these gold grades are lower than those of the Witwatersrand, they are comparable to other auriferous QPCs worldwide.

Organic matter is present as individual bitumen nodules. These are small (<1 mm), spherical to lobate in shape, and contain micron-scale inclusions of U- and/or Th-rich minerals (oxides, phosphates). The shape, size, and morphology of the inclusions within the bitumen nodules are consistent with a hydrothermal origin, rather than brecciation of a pre-existing mineral phase. These nodules are the product of a hydrocarbon migration event that included polymerisation upon contact with a radioelement-rich fluid phase. This carbon-radioelement mineral association is a common attribute of mineralized QPCs.

The features described above indicate that the Tree River QPCs may, in many aspects, be considered a Nunavut analogue to the Witwatersrand in South Africa.

THE INORGANIC GEOCHEMISTRY OF 'ORGANICS': A POSSIBLE NEW GEOCHEMICAL VECTOR TO MINERALIZATION?

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'Organics' either graphite and carbonaceous matter (including hydrocarbons, bitumen) are commonly associated with many different styles of ore deposits globally (e.g. unconformity-type uranium, sediment-hosted base metal, and various gold mineralization styles). Indeed in many cases, the occurrence of these 'organics' have been linked to ore geneses. While there has been a vast amount of work devoted to their organic

geochemistry; little or no work, apart from the study of solid inclusion within them, has been dedicated to their inorganic chemistry. After all they are for the most part combinations of C-H-O±S. As part of our research into innovative method in applied geology, we have investigated the inorganic chemistry of organics from the basement rocks to the Athabasca Basin, Canada, using micron-scale, synchrotron-based XRF. The ultimate aim is to assess if this methodology can be used as an exploration tool.

Two-dimensional elemental distribution mapping and single point data analysis were undertaken at beam line L at the Hamburger Synchrotronstrahlungslabor (HASYLAB) in Germany using monochromatic light (28 keV). The data were processed using either the AXIL or GEOPIXE software packages.

The results indicate that the graphite and the carbonaceous matter examined are far from being composed of only C-H-O±S. Instead they contain a plethora of other elements, both common (e.g. Fe, Ti, V) and exotic (e.g. Nb, Mo, U, Br, Sr). To date 25 different elements have been identified.

Not only is the presence of these metals exciting, but also their distribution and association: many samples show significant inter-sample heterogeneity. Within the dataset, two main end-member styles of elemental occurrences are identified: discrete point sources or 'nano-particles' (e.g. Cr, Zr, Nb, Th, U), and wide-spread or diffusive (e.g. Ga, Rb). However, certain elements may occur in different styles within different samples. Some elements have a positive correlation and similar distribution, e.g. Ti & V, and Zr & Y. However, other 'expected' elemental associations (e.g. Fe, S, Ni, Co) display heterogeneous distribution. This is significant as it precludes the occurrence of pyrite 'nano-particles'.

This initial work on the identification and understanding of the inorganic geochemistry of 'organics' warrants further work in assessing its possibility as a new geochemical vector to mineralization that can be applied to a number of metallogenic systems.

MICROPHOSPHATE U-Pb GEOCHRONOLOGY: THE KEY TO DATING GEOLOGICAL EVENTS

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The development of in-situ ion microprobe techniques for U-Pb geochronology of REE-phosphate grains (xenotime and monazite) at the 10 micron scale has focussed attention on the formation of these minerals. Xenotime ([Y,HREE]PO_4) may form at "room temperature", below the seabed during earliest diagenesis, during burial diagenesis, low-temperature fluid flow events in many rocks, metamorphism from low to high grade, and magmatism. Monazite ([Th,LREE]PO_4) forms over a similar range of temperatures and environments. Importantly, both minerals robustly preserve formation ages, have high isotopic "blocking" temperatures, don't suffer metamictisation which plagues zircon geochronology, and typically have significantly more U-Th (and Pb) than coeval zircons. As such, they are the best minerals for the reliable geochronology of multiple events in any given terrane.

The main applications for microphosphate geochronology, so far, are: (1) chronostratigraphy in unfossilised (mainly Precambrian) sedimentary basins, where early diagenetic xenotime provides a proxy age for sedimentation; (2) geochronology of cement stratigraphy in sandstones; (3) detrital mineral geochronology in siliciclastic sedimentary rocks, where detrital zircons usually do not occur with coeval phosphates and hence are not represented in zircon-only provenance studies; (4) geochronology of hydrothermal ore deposits, in particular Archaean lode gold deposits where all deposits so far studied have monazite±xenotime in their ore or proximal alteration assemblages; (5) geochronology of unconformity-related U-deposits, where U-rich xenotime may form instead of uraninite in distal or low-grade mineralisation; (6) geochronology of metamorphic events, including fluid flow events (e.g. monazite overgrowths on detrital monazite grains) and metamorphic phosphate formation events (e.g. xenotime formation consequential to garnet destruction); and (7) magmatism of fractionated and some alkaline igneous rocks.

Although the applications and potential applications for microphosphate geochronology are seemingly boundless, there are some limitations, including: (1) the need for highly specialised analytical facilities, analytical procedures, isotopic standards and expertise; (2) finding suitable microphosphate grains in a range of rock types; and (3) resolving fine phosphate growth events using electron microscopy, and petrographically relating these growth events to the larger scale. Each of these limitations is a major obstacle to progress, and combine to make microphosphate geochronology a field where patience, time and support and required in large amounts to achieve success. This presentation will outline selected examples of Precambrian applications of microphosphate geochronology.

THE TIN CUP MOUNTAIN DEFORMATION ZONE: MORE EVIDENCE FOR LATE ARCHEAN LATERAL MOVEMENT ALONG THE SOUTHERN EDGE OF THE WYOMING CRATON

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The Granite Mountains in central Wyoming preserve some of the oldest rocks in the province. In the eastern Granite Mountains, the Sacawee block contains ca. 3.2 Ga gneisses with negative epsilon Nd values of ca. -10 at 2.63 Ga. The extent of the Sacawee block is unknown, however, and its relation to the rest of the Wyoming province is enigmatic.

Our mapping has revealed that the western Granite Mountains contain rock packages similar to those in the eastern Granite Mountains. In addition, a 4-km-wide zone of high strain is exposed in the western Granite Mountains called the Tin Cup Mountain deformation zone (TCMdz). Strain is partitioned among northeast-southwest trending rocks in the TCMdz, which is intensely folded, and includes mylonitized to undeformed supracrustal and granitic rocks. We have documented both extensional and contractional oblique-slip movement in the TCMdz. The TCMdz culminates at the Tin Cup fault, a ductile fault that separates a deformed porphyritic granite in its hanging wall from a deformed equigranular granite in its footwall, called the Footwall granite.

We have dated the porphyritic granite at 3232 ± 9 Ma (U-Pb SHRIMP), and multiple Nd isotope analyses have shown that its epsilon Nd is -10 or lower at 2.63 Ga. These data, along with mapping and petrography, establish that the Sacawee block extends to the western Granite Mountains. In contrast, the Footwall granite has epsilon Nd values of ca. -6 at 2.63 Ga and a U-Pb SHRIMP age of 2725 ± 7 Ma. The Tin Cup fault is intruded by a post-tectonic granite called the Camp Granite, which we have dated at 2628 ± 15 Ma (U-Pb SHRIMP). A preliminary LA-ICP-MS U-Pb zircon date of 2.65 Ga from a syn-tectonic leucogranite dike in the TCMdz brackets deformation in the TCMdz to ca. 2.65-2.63 Ga.

These data show that 1) The isotopically distinct Sacawee block extends to the western Granite Mountains, and reaches its northern terminus at the Tin Cup fault. Here it contacts the Footwall granite, which has a Nd isotope composition similar to the core of the Wyoming province. 2) Deformation in the TCMdz occurred between ca. 2.63-2.65 Ga. 3) The complex oblique-slip motion of the TCMdz appears to be synchronous with accretion of more juvenile, laterally accreted terranes in the southern Wyoming province, suggesting that the Sacawee block

was laterally accreted or translated along the southern edge of the Wyoming craton in Late Archean time.

KIMBERLITE PETROLOGY OF THE SNAP LAKE PROJECT, NWT, CANADA

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The Snap Lake kimberlite (~523±6.9Ma) sheet complex is located 220km northeast of Yellowknife, NWT and occurs in the southeastern part of the Slave Craton, intruding Archaean granitoids and metavolcanics. Drilling and underground mapping show the kimberlite consists of a single unit that splits into several sheets, potentially connecting down-dip or laterally along strike. The kimberlite sheets dip northeast at ~15° with a plan view area of 2x3km and an average thickness of 2.5m. Petrographic features supported by matrix mineral and whole rock compositions, show these rocks can be classified as Group 1, phlogopite-monticellite kimberlite.

The kimberlite is composed of xenolith-poor, coarse to very coarse-grained olivine macrocrysts (15-35 modal %), rare mantle-derived xenocrysts of garnet, olivine phenocrysts (<5 modal %) and less common phlogopite microphenocrysts set in a groundmass of monticellite, phlogopite, spinel, apatite, perovskite, serpentine and carbonate. The olivine and monticellite have been completely pseudomorphed by serpentine. Four types of phlogopite are recognized petrographically. Type I and II are macrocrystal and phenocrystal phlogopite, respectively. Type III groundmass phlogopite occurs as small, colourless, late-stage laths with straight and/or irregular step-like boundaries. Type IV groundmass phlogopite occurs as larger, colourless, elongate subhedral laths having a decussate texture, and they poikilitically enclose monticellite, spinel and olivine microphenocrysts. Type IV phlogopite occur mainly in the upper sampling tunnel while the Type III phlogopites occur mainly in the lower sampling tunnel.

The petrographically distinct Type III and IV phlogopites have contrasting compositions and zoning patterns. Type III and IV can be subdivided into two distinct groups based on TiO2 content, with Type III having 0.8-2.5 wt.% versus 0.3-0.8 wt.% in Type IV. Type III phlogopite grains show enrichment in BaO content from the cores (<1.0 wt.%) to the rims (1.5-5.0 wt.%). In contrast, BaO content of Type IV phlogopite grains have BaO-enriched cores (6.5-11.0 wt.%) with lower BaO rims (<4.2 wt.%). The Type III phlogopite grains often have high Cr2O3 cores (<1.7 wt.%), which do not occur in the Type IV phlogopite grains. The difference in the occurrence and composition of the late stage phlogopites would suggest the sheets encountered in the upper and lower tunnels could be separate phases. However, underground mapping does not support this theory as there are no contacts that separate the two petrographically distinct rock types. Further comparative studies of bulk and mineral compositions of the kimberlites are required to confirm or reject this hypothesis and consider alternative explanations.

THE BLENDE PROPERTY: A STRUCTURALLY CONTROLLED Zn-Pb-Ab DEPOSIT, WERNECKE MOUNTAINS, YUKON

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The Blende Zn-Pb-Ag deposit is located approximately 75 km northeast of Keno Hill, Yukon, within the southern Wernecke Mountains. Mineralization is hosted by a dolomitic siltstone of the lower Proterozoic Gillespie Lake Group, the uppermost unit of the Wernecke Supergroup. The Gillespie Lake Group is a shallowing upwards carbonate sequence exhibiting transition from a shale-dominated base to dolomitic siltstone with stromatolitic and oolitic layers within the upper sections of the formation. Middle Proterozoic diorite to gabbro sills and dykes of the Hart River Intrusive Suite cross-cut the Gillespie Lake Group.

Fieldwork was completed as part of a drill program during the summer of 2006 for Eagle Plains Resources Ltd., which consisted of 23 diamond drill holes (4230 m) and field mapping. The 2006 drilling added to 87 historical diamond drill holes (17,598 m), completed from 1988 through to 1994. Regional and detailed mapping shows kilometre-scale open folding has produced a steep southwest-dipping axial planar cleavage. The Blende is situated on a broad, upright, southeast-plunging anticline where mineralized breccias form an anastomosing fabric oriented parallel to the axial planar cleavage of the anticline, suggesting the cleavage acted as a conduit for the mineralizing fluids.

Epigenetic sphalerite and galena, with associated pyrite, form the main sulphide mineralization at the Blende. Silver values are variable throughout the deposit; Ag is hosted in accessory minerals such as tetrahedrite. Copper is also present in small amounts throughout the deposit and is found in tetrahedrite and rare chalcopyrite. Coarse-grained dolomite, quartz and minor potassium feldspar make up the major gangue mineralogy associated with sulphide mineralization.

Following early pyrite and minor sphalerite precipitation, the main phase of mineralization is represented by sphalerite and galena (± tetrahedrite) cemented breccias and veins. Mineralization is rarely disseminated into the wall rock and massive sulphide lenses are found locally. Early pyrite is brecciated and corroded by main-stage sphalerite and galena-bearing fluids. The final stage of the paragenesis is represented by cross-cutting quartz and carbonate veins containing only minor sulphides.

Preliminary consideration of field data and petrographic analysis implies a sulphide age that post-dates the last major deformation event. This conflicts with a previously published Pb-Pb date that suggests a lower Proterozoic age.

CRATER-INFILL AT DIAVIK: FACIES ARCHITECTURE, TEXTURES, VOLCANIC PROCESSES AND IMPLICATIONS

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Processes responsible for crater-facies kimberlite deposits remain poorly understood because there are few well-preserved occurrences globally. New open-pit exposures of the A154N kimberlite pipe at Diavik in the Lac de Gras region of the N.W.T. reveal well-preserved crater-facies deposits. Here, we describe the componentry, structures, and geometries of the deposits from the uppermost 150m of the A154N pipe. We then interpret the processes responsible for their emplacement on the basis of these properties.

Near the base, a poorly-sorted, magnetic, and primary massive volcaniclastic deposit (MVK) grades upward into a well-sorted pyroclastic kimberlite (PK2). The PK2 is overlain by ~65m of re-sedimented volcaniclastic kimberlite (RVK). The RVK is, itself, overlain by a moderate to well-sorted pyroclastic kimberlite (~40-50m) that is sourced from another kimberlite volcano (GK).

The PK2-RVK contact is sharp and marked by the onset of bedded grain flows, wedge-shaped volcanic debris, and large, anomalous blocks of mud-rich kimberlite. This interface

represents the end of a primary eruption, and the transition to episodic sedimentation from collapse of an unstable volcanic edifice into an open crater.

Sedimentation into the volcanic crater (RVK) shows vertical variations in component sizes & types and depositional style. Sediments grade upward from kimberlite-rich to mud-rich. Deposits change from large volume, high-energy, en-masse flows in a sub-aerial to shallow sub-aqueous environment at depth into smaller, lower energy, muds and grain flows deposited in deeper water. Late H_2O-rich fluid causes a serpentinization reaction front which crosses the stratigraphic contact between PK2 & RVK.

A deposit of graded pyroclastic kimberlite (GK) defines the top of the A154N pipe. This GK unit is laterally consistent, massive and structureless, except for a crude vertical grading defined by a steady upward decrease in grain and clast size. Contacts with underlying RVK are sharp and (sub)-horizontal. The GK shows a variety of textures on different scales which suggest a pyroclastic origin, including grading over a 40-50m scale, a grain and clast-supported fabric, and vesiculated juvenile pyroclasts. Grading in the deposit suggests hydraulic sorting of an en-masse collapse of pyroclastic debris into a deep water column.

We suggest that the GK unit likely represents pyroclastic material contributed to the A154N pipe from one of the many adjacent pipes in the Diavik area. The deposit, therefore, represents cross-fertilization of A154N by an "extra-crater" kimberlite deposit from a later-erupting pipe in the cluster. These observations have implications on kimberlite volcanic processes and grade distribution.

GEOCHEMISTRY AND PHYSICAL VOLCANOLOGY OF THE KIDD-MUNRO ASSEMBLAGE RHYOLITES: PRELIMINARY RESULTS

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The Kidd-Munro Assemblage of the Abitibi greenstone belt is a ~200km long volcanic sequence that consists of calc-alkaline mafic and intermediate rocks overlain by tholeiitic ultramafic, mafic and felsic metavolcanic rocks. The felsic rocks of this assemblage range in age from 2717 to 2710±2 Ma (U-Pb zircon) and host the Kidd Creek giant volcanogenic massive sulfide deposit north of Timmins, Ontario. In addition to Kidd Creek there are at least a dozen other base metal occurrences hosted in this assemblage. The focus of our research is to document the volcanology and its relationship to the chemical and thermal evolution of the Kidd-Munro assemblage and its contained mineral deposits.

Rhyolitic rocks of the assemblage in southern Munro Township have been extensively explored for VMS deposits in recent years. Our mapping demonstrates that the rocks include air-fall pyroclastic facies consisting of sorted pumice deposits and also beds of accretionary lapilli, proving that at least some of the rocks were developed in a subaerial environment. These results show that the entire Kidd-Munro Assemblage may not be prospective for VMS deposits.

At Kidd Creek the rhyolites throughout the deposit show a very narrow compositional range for Hf, Th and Ta. These elements do not show a fractionation trend and it has therefore been proposed that either they were erupted as superheated lavas, or that a high volatile content prevented crystallization. Previous work using zircon saturation thermometry interpreted many of the high silica rhyolites, and some of those within the Kidd-Munro assemblage to have been formed under super-heated conditions between 840-940°C. It has been recently shown that this method does not provide reliable results and our petrography of the Kidd-Munro rhyolites (from Prosser Township) revealed large phenocrysts demonstrating that the lavas were not erupted in a super-heated state, at least locally. Therefore the high silica magma forming the Kidd Munro Assemblage rhyolites may have had abundant volatile phases. Indeed we have found minerals containing up to 10 wt % fluorine.

The physical volcanology of this important assemblage suggests both subaerial and submarine environments whereas volcanogenic massive sulfide deposits are formed in submarine environments. The chemistry of these high silica rhyolites demonstrates that they contained a significant volatile phase shown by the presence of F-rich minerals.

AN IOCG - PORPHYRY COPPER - EPITHERMAL CONTINUUM REVEALED: POLYMETALLIC MINERALIZATION IN THE ECHO BAY ANDESITIC STRATOVOLCANO COMPLEX, GREAT BEAR LAKE, NORTHWEST TERRITORIES

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Exploration geologists and geoscientists have been perplexed by the variety of mineralization types found in the Echo Bay region of Great Bear Lake since the original discovery of radium and polymetallic veins in 1930 by Gilbert Labine. Within the same suite of volcanic and volcanoclastic rocks of the Echo Bay andesitic stratovolcano complex (ca. 1.8 Ga) it is possible to observe in outcrop: 1) IOCG, 2) porphyry copper, 3) polymetallic epithermal arsenide vein, 4) skarn, 5) epithermal silver and/or gold, 6) epithermal base and precious metals, and 7) epithermal quartz-carbonate-hematite-pitchblende vein styles of mineralization. All types of mineralization occur within large 2-5 km-scale hydrothermal systems associated with a contemporaneous suite of diorite to monzodiorite intrusions. Individual hydrothermal cells are characterized by: 1) magnetite-actinolite-apatite-Na feldspar cores, 2) kilometer-scale potassium feldspar and/or hematitic halos around the core, 3) an outer phyllic alteration halo, and 4) widespread distal propyllitic alteration. Alteration is so extensive that individual cells coalesce into continuous belts of hydrothermally altered and mineralized rocks that can exceed 20km in length (e.g. Contact Lake Belt). This metallogenic district displays remarkable overlap of IOCG, porphyry, and epithermal characteristics, which are all apparently associated with the large IOCG systems.

IOCG, PORPHYRY, SKARN AND EPITHERMAL STYLES OF MINERALIZATION IN THE ECHO BAY ANDESITE STRATOVOLCANO COMPLEX, NORTHWEST TERRITORIES

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Hydrothermal activity associated with episodic construction of the ca. 1.8 Ga Echo Bay stratovolcano complexes generated several variants of IOCG, porphyry copper and epithermal styles of mineralization. The mineralization is spatially, and most probably genetically associated with a suite of diorite to monzodiorite intrusions, that are intermittently exposed along linear belts and as individual stocks.

IOCG alteration ± Cu, Ag, U, Co, Ni, Au is quite evident as kilometer-scale and smaller zones of magnetite, actinolite, apatite and Na-feldspar ± sulphide veining and/or pervasive replacement of country rock. Porphyry style Cu ± Au, Co and Ag occurs as veins, veinlets, disseminations and crackle breccias in potassic, tourmaline, hematite and sulphide altered rocks that are peripheral to, and associated with, magnetite-actinolite-apatite cores. Phyllic and phyllic-potassic altered rocks host large zones of copper and/or silver mineralization in sulphide veins and disseminations. Cu-Ag-Mo-Zn-Pb-W polymetallic mineralization occurs in garnet-pyroxene-vessuvianite-epidote-K feldspar-Fe oxide skarn in laminated pyroclastic tuffs, and at the contact between monzodiorite and tuff, altered rocks are locally highly enriched in silver.

Different styles of epithermal mineralization include 1) polymetallic arsenide vein Co-Ni-Ag-Cu±U, 2) quartz-carbonate-hematite-pitchblende veins, 3) base and precious metal sulphide veins, and 4) replacement type Ag and/or Au mineralization.

The Echo Bay polymetallic belt is host to 5 historic mines that exploited some of the high-grade polymetallic epithermal veins, and is currently the target of belt-wide exploration for bulk tonnage and high-grade deposits by Alberta Star Development Corporation. Recent discoveries include bulk tonnage targets at K2 (Cu±Au-Co-Ag) and the Echo Bay south gossan (Ag), the Mile Lake skarn (Cu-Ag-Mo-Zn-Pb-W), and several high-grade U and Ag intercepts in the vicinity of the former Eldorado and Echo Bay mines.

MAGMATIC ORIGIN OF THE FURIKUSA SERICITE DEPOSIT, CENTRAL JAPAN: CONSTRAINTS FROM H-C-O-S ISOTOPE SYSTEMATICS OF HYDROTHERMAL MINERALS

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The Furikusa sericite deposit is located at the southern margin of the Middle Miocene Otoge volcanic complex (Valles-type caldera), central Japan. The Otoge volcanic complex consists of alkaline rocks and basaltic and/or andesitic scoria, and also includes dike and sheet swarms. The dike and sheet swarms, width of about 5m on average, are of trachytic andesite and are divided into the NS-trending dike swarm and EW-trending corn sheet in the Furikusa deposit. Sericite ore bodies in the deposit occur as pipe or pod at the intersection between the dike and the corn sheet, and extend from several to tens of meters along the dikes and corn sheets. The sericite ore is composed mainly of illite-2M with minor amounts of calcite and euhedral pyrite, arsenopyrite, and quartz.

K-Ar ages of 14.2±0.4 Ma and 14.7±0.3 Ma as well as Ar-Ar plateau age of 14.5±0.2 Ma for illite indicate that the Furikusa sericite deposit was temporally and spatially associated with the dike and sheet which have K-Ar ages of about 13 Ma and 15 Ma. The δD and $\delta^{18}O_{SMOW}$ values for illite (five samples) range from -41 ‰ to -46 ‰ for δD and +7.7 ‰ to +10.6 ‰ for $\delta^{18}O$. Calcite (eight samples) in the sericite ore has a range of $\delta^{13}C_{PDB}$ from -11.5 ‰ to -8.3 ‰ and a range of $\delta^{18}O$ from +12.1 ‰ to +17.1 ‰. Pyrite and arsenopyrite (each of four samples) have a restricted range of $\delta^{34}S_{CDT}$ from -1.5 ‰ to -0.33 ‰. Assuming the hydro-thermal activity occurred at 300°C in the Furikusa deposit, it is calculated that hydrothermal fluid respon-sible for formation of sericite ore has a range of $\delta^{18}O$ from +11 ‰ to +15 ‰ by using fractionation of oxygen for illite- and calcite-water pairs. Similarly, the δD of hydrothermal fluid is estimated to have a range from -10 ‰ to -15 ‰ based on the δD values of illite. These $\delta^{18}O$ and δD values for hydrothermal fluid are modified in active volcanic gas such as Satsuma Iwojima. In addition, vapor-rich inclusions are pronounced in quartz in the sericite ore. These multiple isotope data suggest that a magmatic-hydrothermal origin for these minerals in the Furikusa sericite deposit results from magmatic steam associated with the Otoge volcanic complex.

"FOUR BILLION YEARS AND COUNTING: CANADA'S GEOLOGICAL HERITAGE": 2007 PROGRESS REPORT ON A POPULAR BOOK PROJECT

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In 2006, the proposed multi-authored, popular book, "Four Billion Years and Counting" was accepted as one of Canada's primary contributions to International Year of Planet Earth (IYPE), focused on 2008 but extending from 2007 to 2009. Acceptance means that the Editorial Board aims to publish both English and French editions in August 2008. To make this possible, we have over 40 expert contributors, some of whom have already delivered preliminary drafts of chapters, all committed to highlighting Canada's amazingly complete and fascinating geological record. Canada has some of the oldest rocks on Earth, a record of the break-up and reassembling of land masses, and spectacular modern geological features such as volcanoes, faults susceptible to earthquakes and glaciers. Canada's prosperity depends heavily on its mineral and energy resources, and its future, like its past, will be influenced by climate change. The book's first few chapters (Sections 1 and 2) will explain such basics of geology as the setting of Canada within Planet Earth, geological time, how Earth works, and our fossil record. The eleven chapters of Section 3 outline Canada's geological evolution in a series of time slices rather than regionally. The last section looks at ways in which geology directly affects Canadians and covers mining and energy, health, and the future. "Four Billion Years and Counting" should appeal to the non-geologist, and also attract the attention of geologists interested in regions or topics outside their specialty. The book will include a number of "hooks" to capture potential readers' attention, such as attractive photographs, paintings and schematics, and an easy-to-read text that will have been reviewed by specialists (for accuracy) and non-specialists (for readability). It's an ambitious project but achievable if we have continuing community support, and it should be a worthy contribution to IYPE.

EARTH SCIENCE OUTREACH IN CANADA: A COTTAGE INDUSTRY FOREVER?

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Small scale production of high quality, hand-made products characterizes cottage industries. Generally also, production is low and the products are not widely distributed. This description perfectly encapsulates the state of Earth science outreach in Canada in the early 21st century. We have progressed from the early 20th century when it was essentially non-existent, through a period of peer sneer for those who undertook it, to an era in which most Earth science organizations support it. The level of effort and production has undoubtedly increased over the past 35 years. We do some wonderful things well: thousands of

teachers have taken EdGeo workshops and carried useful materials back to their classrooms. Many citizens have perused geoscape posters, brochures and magazines to learn more about how Earth sciences relate to their communities. Many interested Canadians have visited museums, science centres, parks and geoheritage sites or attended public lectures sponsored by earth science societies and learned something about Earth science. But the fact remains that few Canadians understand the significance of Earth science for their everyday lives. They don't understand that they would not have all their stuff without available natural resources. They remain largely unaware of Earth processes that may affect them. Based on a largely volunteer effort, the Canadian geoscience community is trying to reverse this situation. However, the many excellent products are available to few Canadians because of a lack of national distribution or advertising. The volunteer producers may (or may not) receive kudos from their employer, but seldom many resources. Recently there have been a few significantly funded initiatives but these are now terminated or back to begging for resources. There is no funded, active national inventory of resources for Earth science outreach. Is geoscience outreach to remain as a small cottage industry forever or can it aspire to move to the next level? These are questions we must ask of the main geoscience institutions: geological surveys, universities, science centres and resource industries. People need to know about the Earth to be responsible citizens of the planet. In addition, Earth science faces a big challenge because it is taught less in school than other sciences. If our profession is to rejuvenate and gain influence in society, we have to attract new people. To be attracted to our science, young people have to be aware of it.

CENOZOIC TECTONIC FRAMEWORK OF THE BAFFIN BAY - NARES STRAIT REGION OF ARCTIC CANADA AND GREENLAND

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During the Cenozoic evolution of the North Atlantic rift system, the independent movement of the Greenland Plate resulted in a complex tectonic history between Canada and Greenland with large oceanic rift basins to the south and apparent intraplate deformation in the high Arctic. Magnetic data and gravity data over central Baffin Bay have been re-interpreted, defining Paleocene seafloor spreading anomalies and Eocene fracture zones. New aeromagnetic data over northern Nares Strait provides offshore mapping of a NNE-trending fault-bounded (Tertiary) sedimentary basin. This transpressive bounding fault (Eurekan Frontal Thrust) represents the mappable edge of the undeformed Greenland plate. Magnetics data over Kane Basin map a Proterozoic dyke westward from an outcrop on Greenland close to the Ellesmere coast with no offset, suggesting that the plate boundary identified to the north does not extend as a continuous linear feature through Kane Basin and the crustal block of SE Ellesmere Island is part of the Greenland Plate.

Regional gravity modelling have provided estimates of crustal thickness, and used to explain elements of both compressive deformation and extension. Substantial crustal thinning beneath the Lancaster Sound sedimentary basin, which is interpreted to be a failed rift-arm of the Eocene Baffin Bay spreading system. Calculations of crustal thickness suggest that as much as 40 km of extension occurred, possibly enough to consider Ellesmere Island (and Devon Island) as a separate plate from North America during the Eocene.

A new plate kinematic model has been developed to define the motion of Greenland relative to Canada (North American Plate) constrained by the new geometry of the oceanic rift system in Baffin Bay. The model defines 175 km of NE-oriented Paleocene separation of Greenland relative to Baffin Island, which must be accommodated for between northern Greenland and the Arctic Islands. Traditionally, this has been explained by a single sinistral plate boundary along Nares Strait (Wegener Fault); however, new evidence suggests a complex intraplate deformation over a broad region. During the Eocene, the Greenland Plate moved northwest by approximately 250 km. Although this direction is consistent with the orientation of Eurekan structures, it is substantially more than observed within the deformation zone adjacent to the Eurekan Frontal Thrust. New ideas on the intraplate geometry and the plate kinematic model are used to produce a series of Eocene and Paleocene reconstructions to present a possible new configuration of rigid "micro-plates" and definable zones of deformation.

THE NEON PROJECT: AN OVERVIEW OF BASIN DEVELOPMENT AND PETROLEUM POTENTIAL OF THREE ARCTIC SEDIMENTARY BASINS, NUNAVUT, CANADA

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The Geological Survey of Canada has completed a four year project - New Energy Options for Northerners (NEON) - to evaluate petroleum potential of three frontier sedimentary basins in the Canadian Arctic: the Saglek Basin in northern Labrador Sea, the Lancaster Basin in northern Baffin Bay, and the Sverdrup Basin in the Canadian Arctic Archipelago.

In the Saglek Basin area, new wide-angle refraction data were acquired to produce a crustal-scale transect crossing the Davis Strait showing the distribution of continental and oceanic crust. Well cutting samples have been re-analysed for organic geochemistry and palynology. A Late-Cretaceous source rock has been identified and new high-resolution biostratigraphic events have been established. Legacy seismic data were interpreted to produce stratigraphic horizons tied to the exploration wells and integrated with newly acquired heat-flow data in a 4-D petroleum model. Radarsat data reveal multiple oil-slick features, indicating that the petroleum system is broadly distributed.

Multidisciplinary onshore/offshore activities in the northern Baffin Bay - Nares Strait region have provided improved constraints on the timing and geometry of the basin development around Lancaster Sound. Gravity models and plate kinematic constraints have identified a link between the Eocene oceanic rift system in central Baffin Bay and the development of the basin. A review of industry reports filed with the National Energy Board have resulted in a regional overview of fault systems and structural culminations (32 mapped closures totalling 580 km^2). At least seven seismic stratigraphic units are recognized in the absence of well control.

Landsat data over the Sverdrup Basin were compiled to produce a new 1:250000 scale reference base to support details of the geological mapping and improve spatial positioning. New mapping improved the understanding between salt systems and volcanic intrusives and their combined influence on the petroleum system.

The NEON project focussed on a comprehensive review of legacy geological, geophysical, and well-log studies to produce digital data bases. New field work was carried out, generally in collaboration with universities, international government agencies and industry partnerships, to address specific "knowledge gaps". This integrated approach has provided a modern context to improve the understanding of the development and petroleum potential of these basins, as well as develop GIS-enabled databases, which represents the foundation work for further detailed resource assessments.

CORUNDUM DEPOSITS IN ALKALI BASALT GEMFIELDS FROM MADAGASCAR

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The Blue-Green-Yellow (BGY) sapphires and rubies provide a major share of the gem trade in Madagascar. They are mostly recovered from alluvial deposits in continental basaltic fields and gem corundum deposits occur: (i) in Neogene-Quaternary alkali basalts in the Ankaratra mountains of central Madagascar, (ii) in the Ambohitra igneous province, which includes also the Nosy-Be archipelago in the North, and (iii) in the Vatomandry area at the east.

(i) The gem corundum deposits in the Ankaratra area close to Antsirabe city, are alluvial except for the deposit of Soamiakatra, where ruby is found in pyroxenitic xenoliths included in alkali basalts and the deposits of Kianjanakanga-Mandrosohasina, where "BGY sapphire" are contained in paleoplacers made of basaltic and phonolitic pebbles cemented by lateritic soils.

(ii) The sapphire placer deposits in the Antsiranana province are located in the Anivorano and Ambondromifehy area, and on Nosy-Be Island. The region is mostly covered by volcanic rocks that date from the early Tertiary period to the Quaternary. The volcanic flows are formed by successive eruption of basalts, tuffs, pozzolanas and pyroclastites which contain enclaves of peridotite. Sapphire-bearing alluvial materials were deposited in voids and cracks of a karst developed on Jurassic Ankaratra limestone and arenites that lie south of the volcanic massif of the Montagne d'Ambre. All gem-bearing sediments forming paleoplacers are cemented by secondary carbonates (deposits of Ambohangimamy, Maromokotra, Sanaderakely contained in limestones) or silica (deposit of Maventibao contained in arenites).

The conglomerates are composed of fragments of red to orange zircon, sapphire, angular fragments of limestone, rounded iron oxide and ferruginous pisolith and products originating from the stripping of a ferruginous cuirasse.

On the Nosy-Be Island, the "BGY-sapphires" of the Befotaka deposit are found in alluvial loess in a layer formed of basalt, pebbles located one meter above the granitic bed-rock. In the Andovokonko area on the Ambato Peninsua, sapphires are found on the basalt surface covered by calcrete crust, and in tidal flats.

(iii) The alluvial deposits of the Vatomandry area (Amfao, Ambodilalona, Amboditavolo) contained rubies and "BGY" sapphires accumulated in fans of the lower part of the rivers. The source of these corundum are paleoplacers found in the upper part of the alluvial basin. The paleoplacer contains pebbles of basalt, granite and pegmatite with rounded crystals of magnetite, orange to red zircons, gem corundum and other heavy minerals, cemented by a siliceous matrix.

A COMPARATIVE STUDY OF TERRESTRIAL AND MARTIAN METEORITE IMPACT STRUCTURES

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Meteorite impact structures are the dominant geological landform on the Moon, Mars, and other rocky and icy bodies in the Solar System that have retained portions of their earliest crust. Martian and lunar craters are more abundant and typically better preserved than those on Earth; however, information is only available about their surface properties. In contrast, the study of eroded terrestrial craters, combined with information from drill cores, offers insight into the 3-D structure of impact craters and provides the only ground-truth for planetary data. In this work, data from terrestrial impact structures, in particular the Haughton structure (Devon Island, Canadian High Arctic), has been synthesized with imagery from Mars, to provide a greater understanding of one key, but poorly understood aspect of impact cratering: the generation and emplacement of ejecta.

The ~39 Ma, 23 km diameter Haughton impact structure is one of the best preserved and best exposed mid-size impact structures (e.g., ~15–30 km) on Earth. Despite the good preservation state, much of the ejecta has been eroded away so that the initial distribution and morphology is unknown. One of the most interesting features of Martian craters is the presence of layered, fluidized ejecta deposits, comprising single (SLE), double (DLE), or multiple (MLE) layers of ejecta. These ejecta morphologies have been attributed to either (1) interaction of ejecta with volatiles derived from the, or (2) ejecta interaction with the atmosphere. Importantly, two principal proximal ejecta types have been recognized at Haughton: (1) pale yellow–brown allochthonous impact melt breccias and megablocks, overlain by (2) pale gray impact melt breccias. Haughton is thus a DLE structure using the terminology developed for Martian craters. Field, optical and analytical scanning electron microscope studies reveal that the groundmass of these ejecta deposits at Haughton comprises calcite, silicate impact melt glass and anhydrite, which represent a series of impact-generated melts generated from the volatile-rich target rocks. This suggests that there are two discrete episodes of ejecta deposition during the formation of complex impact craters, which provides a mechanism for generating multiple layers of ejecta on Mars and Earth. It is apparent that the relative abundance of volatiles in the near-surface region outside the initial transient cavity and in the target rocks within the transient cavity play a key role in controlling the amount of fluidization of Martian ejecta deposits. This suggests that a substantial amount of H_2O is present in the Martian subsurface.

GEOSCIENCE SKILLS DEVELOPMENT IN REMOTE NORTHERN COMMUNITIES: THE IMPACT OF DIAMOND EXPLORATION ON RESIDENTS OF THE HIGH ARCTIC

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Diamond exploration in the Northwest Territories and Nunavut has expanded beyond the Slave craton into more remote northern locales, in particular Baffin Island, Victoria Island, and Somerset Island in the High Arctic. Many residents of the tiny communities of Resolute and Arctic Bay are already familiar with exploration techniques for MVT-type Pb-Zn deposits such as Polaris (Little Cornwallis Island) and Nanisivik (Baffin Island). Despite the closure of these mines in 2002, local enthusiasm for mineral exploration is strong due to the discovery of diamondiferous kimberlite on the Brodeur Peninsula of Baffin Island. The Brodeur property of Diamondex Resources Ltd. covers an area of over 400,000 acres on the northern half of the Brodeur Peninsula, and is known to host three diamond-bearing kimberlite bodies: Tuwawi, Nanuk and Kuuriaq. Since June 2005, Diamondex has conducted till and stream sediment sampling programmes with the help of contract employees from Resolute and Arctic Bay. The integration of local traditional knowledge of the land with modern exploration techniques has proven valuable for both Diamondex and the communities. Contract employees have developed important geoscience

skills, including: 1) using a map, compass, and GPS, 2) techniques for geological mapping, 3) mineral identification, 4) recognition of kimberlite, 5) interpretation of magnetic/electromagnetic surveys, 6) gravity surveying, 7) grid sampling for soil chemistry, and 8) safety in both the camp and helicopter. These skills, combined with a natural inclination to explore and learn about the geology of northern Baffin Island, have encouraged several residents of Resolute and Arctic Bay to consider coursework at the Nunavut Arctic College in the area of mineral exploration. Partnerships between local communities and exploration companies are not formal education or outreach programs, but they can significantly increase the geoscience knowledge of community members. From Diamondex's perspective, local contract employees provided critical knowledge of: 1) polar bear migration patterns and safety, 2) weather patterns, 3) ice conditions, 4) edible plants, 5) river systems, and 6) unusual rock types on the property. Continued mineral exploration on the Brodeur Peninsula of Baffin Island, as well as on other Arctic Islands, will expose the residents of remote northern communities to further geoscience education and help develop modern skill sets for exploration techniques in the 21st century.

VARIATION IN CLIMATE, VEGETATION, SNOW COVER, AND NEAR-SURFACE GROUND TEMPERATURES ACROSS THE TREE LINE IN THE WESTERN ARCTIC, NWT, CANADA

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Winter conditions control near-surface ground temperatures across the subarctic boreal to low arctic shrub tundra transition in upland terrain east of the Mackenzie Delta, NWT. During 2004/2005 air and near-surface ground temperatures were monitored along a 90 km transect at six sites (T1 to T6) representative of conditions across this ecological gradient. Air temperatures decreased northward due to a coastal effect in summer and a spring difference in net radiation (Q*) along the transect, however, during winter air temperatures between sites were relatively similar. There was a northward decrease in vegetation height with the greatest changes occurring over a 27 km transition from subarctic boreal forest (T1) to shrub tundra (T4). End of winter snow depths were positively correlated ($r = 0.683$; $P < 0.001$) with vegetation height. Mean winter ground-surface temperature (MWGST) at the low shrub tundra site (T6) was 3.5°C colder than at the boreal forest site (T1). A 2.5°C decrease in MWGST between the shrubby tussock tundra site (T3) and the shrub tundra site (T4) located only 8 km to the north, coincided with 40% of the change in mean snow depths observed over the entire length of the transect. Patterns of variation in mean annual temperatures at the top of permafrost mimicked those of ground-surface temperatures, with most of the change occurring between the boreal forest site (T1) and the shrub tundra site (T4) in association with a decline in mean end of winter snow cover from 78 cm to 45 cm. The effect of the summer coastal air temperature gradient on summer ground-surface temperatures is moderated by an increase in the structural complexity of vegetation and an associated increase in the interception of incoming solar radiation south of the shrub tundra (T4). Our data show that the northward cooling of ground temperatures across treeline can be attributed to variation in winter conditions as dictated by snow-vegetation interactions. These results suggest that the proliferation of shrubs onto the tundra and the associated increase in snow cover could have a major influence on the future warming of permafrost in the low arctic.

QUATERNARY GEOLOGY OF THE VILLE-MARIE AREA, QUEBEC AND THE LOCATION OF POTENTIAL DIAMOND-BEARING KIMBERLITE TARGETS

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Understanding the Quaternary history of the Ville-Marie area of the Temiscamingue Region of southwestern Quebec is vital in utilizing drift prospecting as a tool to locate diamond-bearing kimberlites and other mineralization (i.e. Au) within the region. The main ice-flow (or multiple stages) within an area was estimated using striae orientations, till fabric, and paleocurrent analysis. There is a strong indication of a southwestward flow towards the eastern part of the region, shifting to a southward flow in the central portion of the region, then to a southeastward flow in the western portion of the region. The variation in ice-flow directions may indicate the formation of two distinct ice-lobes, retreating and re-advancing in different directions during deglaciation about 10.5 ka to 9.5ka. Ground-truthing during the summer of 2005 coupled with stereoscopic air photo interpretation has been interpreted to create a detailed Quaternary geology map of the Lac D'Argentier area. These Quaternary investigations can provide a sequence and relative importance of major iceflows in the area during the last glaciation, and may provide an indication of the deglacation of the area.

The kimberlite indicator mineral (KIM) counts recovered from 1200 overburden samples collected by Superior Diamonds Inc. have been interpreted to represent a number of KIM dispersal trains in the Lac D'Argentier area. The location of the KIM or Au dispersal trains, coupled with grain chemistry interpretation and a strong knowledge of the Quaternary history of the area will allow for recommendations to be made for localized potential kimberlite-target drilling programs and for further kimberlite and Au exploration within the area.

GEOCHEMISTRY OF 'KIMBERLITIC' ROCKS FROM THE OTISH MOUNTAINS OF NORTHERN QUEBEC

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The canonical view that diamonds are xenolithic passengers in their kimberlite hosts has lead to a neglect of the chemical composition of their host kimberlites. In an effort to pursue this, we have analysed the chemical composition of 42 hypabyssal kimberlite samples from the Ashton/SOQUEM Foxtrot Property of the Otish Mountains, Quebec. The kimberlitic intrusions of the Otish Mountains can be divided into four distinct groups on the basis of whole rock Fe and Si contents. The Renard pipes and Lynx dyke of the Foxtrot Property contain the lowest FeO (5-10wt%), TiO_2 (0.5-2wt%) and HFSE (e.g. Zr:35-75ppm), but define two distinct groups in terms of Fe versus Si. The Si-poor samples dominate the interior of the pipes and have contamination indices (C.I.) ranging from 0.8-1.2 (Clement, 1982), while the majority of the Si-rich samples are within 30cm of the contacts and have C.I.'s ranging from 1-2. The Si-poor samples of the Renard pipes and Lynx dyke are Group I hypabyssal kimberlites, whereas the high contamination indices of the marginal Si-rich samples indicate that they represent Group I kimberlite contaminated by crustal rocks. Float samples found on the surface are distinctly richer in FeO (13wt%) defining a 3rd group with affinities with aillikite rather than kimberlite and do not appear to be genetically associated with the Foxtrot intrusions. Kimberlite bodies reported in other areas of the Otish Mountains define a distinct 4th group with intermediate FeO (8-12 wt%) and much higher TiO2 (2.5-3.5wt%) contents than any of those from the Foxtrot Property.

The Si-poor Group I kimberlites are dominated by olivine and carbonate (85%) and exhibit an anticorrelation between MgO (40-20 wt%) and CO_2 contents (1-15wt%). Two distinct trends can be recognized in a plot of Mg versus C, one towards calcite and the other towards dolomite. A decrease in Al_2O_3 (3.5-1.5 wt%) with decreasing MgO requires that the anticorrelation between Mg and C is not produced by olivine fractionation. The observed decrease in both Al_2O_3 and MgO is, however, mimicked by partial melt experiments, although the Fe free experimental data does not closely reproduce our data (Dalton & Presnall, 1998). The trends could also however be reproduced by the mixing of carbonatite and fertile lherzolitic mantle.

METAMORPHICALLY-INDUCED PARTIAL MELTING OF SULFIDE-SULFOSALT ORE DEPOSITS: OCCURRENCE AND IMPLICATIONS

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Metamorphically-induced partial melting of sulfide-sulfosalt ore deposits has only recently been recognized, yet potentially is an important remobilizing process, especially for precious metals. Mineral assemblages in sulfide-sulfosalt ore deposits are examined together with experimentally determined phase relations to (1) assess the pressure-temperature conditions required for the onset of metamorphically-induced partial melting of sulfide and sulfosalt minerals, and (2) place constraints on the amount of sulfide melt produced. Deposits that contain sulfosalts or tellurides may start to melt at conditions ranging from lowest greenschist facies to amphibolite facies. Deposits lacking sulfosalts and/or tellurides may begin to melt once P-T conditions reach the upper amphibolite facies, if galena is present, or well into the granulite facies if galena is absent. The result is two broad melting domains: a low-medium temperature, low melt volume domain involving the melting of volumetrically minor sulfosalts and/or tellurides; and a high temperature, potentially higher melt volume domain involving the melting of major sulfide minerals. Epithermal gold deposits, which are especially rich in sulfosalts, are predicted to melt at the lowest temperatures of all sulfide deposit types. Massive Pb-Zn(-Cu) deposits may start to melt in the lower to middle amphibolite facies if pyrite and arsenopyrite coexist at these conditions, and in the upper amphibolite facies if they do not. Excepting sulfosalt-bearing occurrences, massive Ni-Cu-PGE deposits will show little to no melting under metamorphic conditions, whereas disseminated Cu deposits are typically incapable of generating melt until the granulite facies is reached. The volume of polymetallic melt that can be generated in most deposit types is therefore largely a function of the abundance of sulfosalt minerals. Even at granulite facies conditions, this volume is usually less than 0.5 volume %. The exception is galena-bearing massive Pb-Zn deposits, where melt volumes significantly exceeding 0.5 vol.% may be segregated into sulfide magma dykes, allowing mobilization over large distances.

NEW OPPORTUNITIES FOR MINERAL EXPLORATION IN NORTHWEST ALBERTA

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This presentation will highlight the results of indicator mineral and geochemical analyses conducted on glacial sediment samples collected in northwest Alberta (NTS map sheets 84L and M). The objective of this sampling program, part of a collaborative surficial mapping initiative was undertaken by the Alberta Geological Survey (Alberta Energy and Utilities Board) and the Geological Survey of Canada (Natural Resources Canada), was to evaluate the potential of this region to host diamond-bearing kimberlite and other mineral deposits. Additional funding was provided by the GSC's Targeted Geoscience Initiative-2. These results were recently published as Alberta Geological Survey Special Publication 77 and Geological Survey of Canada Open File 5121.

Of particular significance, and the focus of the recently released publication, is the discovery of a sphalerite dispersal train in the south-central sector of the Bistcho Lake (NTS 84M) and north central sector of the Zama Lake (NTS 84L) map sheets. This dispersal train consists of highly elevated concentrations of sphalerite grains with secondary galena (e.g., >1000 sphalerite grains in the 0.25-0.5 mm size fraction of a single 25 kg till sample). The presence of high sphalerite grain counts in eight samples situated within a geographically restricted area, and the fact that strongly elevated zinc concentrations are not found in the silt and clay-sized fraction geochemistry, would argue against long-distance glacial transport, comminution, and deposition of erratic material from Pine Point. Instead, these results favour a proximal unknown mineral source, potentially hosted within the Lower Cretaceous shales. If the source of the sphalerite is local, it suggests the potential for hydrothermal fluid remobilization of minerals from the underlying Pb-Zn bearing carbonate strata along deep-seated faults.

The bedrock source of the sphalerite remains unknown; additional chemical and isotopic analyses are being planned to help elucidate its origin. Given the geographically restricted presence of samples with sphalerite grains in the regional sample set (n=70), it may point to undiscovered sedimentary hosted zinc deposits in this region and, therefore, represents new opportunities for mineral exploration.

THE PEBBLE COPPER-GOLD-MOLYBDENUM PORPHYRY, ALASKA

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The Pebble deposit contains three contiguous zones. In the Pebble West Zone, granodiorite stocks intrude gently warped volcanosedimentary rocks that had been intruded by diorite sills and two felsic intrusion breccias. In the Central Zone, volcanosedimentary rocks are cut by large diorite and granodiorite sills; the latter are genetically associated with the granodiorite stocks. Widespread potassic alteration consists of brown biotite and K-feldspar, with abundant quartz-carbonate-sulphide vein stockworks. Chalcopyrite/pyrite ratios range from 2/1 to 1/20. Diorite hosts the highest-grade mineralization, with much of it being disseminated. Patchy, later sericite alteration is moderate and commonly depleted copper. The Pebble East Zone occupies the western part of a granodiorite stock and intruded host rocks below an eastwardly thickening wedge of barren Tertiary volcanic and sedimentary rocks up to 4000 feet thick. Brown biotite alteration and copper mineralization are intense, with chalcopyrite/pyrite ratios commonly over 1/1. Bornite-rich pyrite-poor zones exceeding 500 m in diameter coincide with higher copper grades. Mineralization is continuous to a depth of over 5000 feet below surface; some of the deepest zones contain some of the highest-grade mineralization. Later, weak to moderate sericitic alteration removed some chalcopyrite and locally remobilized gold. The Pebble West deposit (West + Central Zones) has a Measured/Indicated resource of 3 billion tonnes grading 0.28% Cu, 0.32 g/t Au and 0.015% Mo (= 0.5% copper-equivalent) and an Inferred resource of 1.13 billion

tonnes grading 0.30 g/t Au, 0.27% Cu and 0.015% Mo (0.55% copper-equivalent). The Pebble East deposit has an Inferred Resource of 2.13 billion tonnes grading 0.55% Cu, 0.34 g/t Au, and 0.037% Mo (0.97% copper-equivalent) including 947 million tonnes grading 0.77% Cu, 0.48 g/t Au and 0.04% Mo (1.28% copper-equivalent). All estimates used a cut-off grade of 0.30% copper-equivalent. The Pebble East deposit is open to the east, north, and south.

CARBONATE BIOMINERALIZATION (ENDOSTROMATOLITES) FROM THE HAUGHTON CRATER, DEVON ISLAND, NUNAVUT: ANALOG FOR LIFE ON MARS?

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Endostromatolites, which are secondary carbonate deposits that develop under anoxic water-saturated conditions, show evidence of biomineralization. Understanding the growth of endostromatolites has astrobiological implications since the environment in which they are found allows "life" to carry out metabolism protected from extreme temperature, desiccation and UV. These are criteria that resemble harsh conditions, such as those on Mars. In order to identify the potential role of bacterial communities in the formation of endostromatolites, samples of these concretions were collected within the Haughton impact crater, Devon Island, NU, part of the Canadian Analog Research Network sites. Results show that endostromatolites contain 2-5% organic matter and a fraction of silicate detrital grains. Although there is an absence of visible surficial microbial activity, the porous and finely laminated calcite lacks a contrast in phase densities and suggests a slow accretionary process. Preliminary isotopic data of the organic matter entrapped within the mineralized carbonate yielded $\delta^{15}N$ values in the -5 to +1.5‰ range. DNA extraction procedures under development have not yet yielded positive results. The micro-laminations within the rock are under investigation since changes in mineral structure and chemical composition could be indicative of a biotic-abiotic mineralization cycle. Overall, the results will improve our understanding of carbonate biomineralization in extreme environments.

DEVELOPING GEO-ENVIRONMENTAL ORE DEPOSIT MODELS TO FACILITATE FUTURE MINING PROJECTS

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Under the Canadian Environmental Assessment Act (CEAA) the objectives of Environmental Assessments (EA) of mining projects are to promote sustainable development, prevent environmental degradation, provide access to information and facilitate public participation. Federal technical reviews of EAs of new and historic mine projects require impartial expertise in many disciplines but especially in the fields of geology, mineral deposits, mineral processing, geochemistry, hydrogeology, geomorphic processes and hazards. This geoscience expertise is needed in all aspects of design, construction, operation, monitoring, remediation and eventual closure.

Over the past 10-15 years, the notion of using geo-environmental models of ore deposits to help guide future developments has become more popular and accepted. The underlying concept is that different genetic types of ore deposits possess distinct environmental signatures because of their composition, geographic and climatic setting. For example, in temperate climates, weathering of primary and secondary minerals such as sulphides can play an important role on the extent of mobility of metals and non-metals in the receiving environment. By characterising key environmental components regarding the deposit under study, models can be used to predict and assess any potential related geo-environmental effects and guide selection of the best technologies to prevent or minimize environmental degradation.

Currently geo-environmental ore deposit models have been developed by the US Geological Survey for most types of mineral deposits, excluding diamonds. Their models pertain mainly to deposits located in southern climates and may not apply to the Canadian North. Northern mines generally have different environmental signatures because of important or unique factors such as the cold climate and existence of permafrost. For example, weathering of primary and secondary minerals newly exposed to the surface during exploration and mining may occur during the short summers. Changes in permafrost conditions, due to construction or operational activities and/or climate change, may lead to unexpected environmental problems during and after development. Understanding the deep groundwater flow regime that extends beneath the permafrost and that connects taliks (unfrozen ground) beneath large lakes is critical for structural design. Freezeback of tailings, associated formation of ice lenses and expulsion of pore waters with high solute loads, need also to be considered.

This talk will detail what components are needed in developing geo-environmental ore deposit models with examples from southern (Nova Scotia lode Au, Cobalt Ag) and northern regions (Athabasca U, Keno Hill Ag). Development of these models will aid in future exploration, environmental assessments and their critical reviews.

SULFUR ISOTOPES IN UPPER DEVONIAN ANHYDRITES

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The evolution of sulfur isotopic composition of seawater sulfate is fairly discontinuous as far as time resolution is concerned and thus the Upper Devonian Prypiac' and Dnipro-Donets Basins of Belarus and Ukraine, with their multiple episodes of evaporite deposition and reasonable constrained age assignments, offer a possibility to construct the secular $\delta^{34}S$ curve for the major part of the Late Devonian times. A total of sixty new samples taken from the precisely-constrained evaporites, in terms of their stratigraphic position, were analyzed for $\delta^{34}S$ aiming to provide a detailed sulfur isotope record for the Upper Devonian of those basins. Those new $\delta^{34}S$ data from anhydrite laminae in halite, anhydrite in water-insoluble residue in halite and sulfate from massive sulfate units in evaporite sequences show that the mean $\delta^{34}S_{sulfate}$ is 27.6 ‰ ± 3.0 ‰ (n = 60) with a range from 21.9 ‰ to 35.6 ‰. The mean values for Frasnian and Famennian evaporites are similar: 27.5 ‰ ± 3.8 ‰ (n = 30) and 27.7 ‰ ± 1.9 ‰ (n = 30), respectively. The data reported previously by Makhnach et al. (2000) for the Upper Devonian are similar: the mean $\delta^{34}S_{sulfate}$ is 26.7 ‰ ± 3.8 ‰ (n = 48) with a range from 20.5 ‰ to 36.0 ‰ (Table 4), and the data characterizing Frasnian and Famennian evaporites which are 26.8 ‰ ± 4.2 ‰ (n = 18) and 26.7 ‰ ± 3.5 ‰ (n = 30),

respectively, as well as the stratigraphic trends are similar. Therefore, both data sets can be combined and applied in the interpretation.

The rocks formed in a restricted basin but its parent waters had a marine source. Bacterial sulfate reduction was the dominant process controlling $\delta^{34}S$ of Upper Devonian anhydrite and pyrite although also disproportionation processes and secular variation played an important role. Excluding $\delta^{34}S_{anhydrite}$ values outside the 1σ limits for individual units of the Upper Devonian Prypiac' and Dnipro-Donets evaporite basins, a range of ca. 24-29‰ is assumed to be representative for oceanic sulfate of Late Devonian time. In the Eifelian of the Prypiac' Basin, mean $\delta^{34}S$ value is 15.4 ‰, and assuming that this value is representative for oceanic sulfate of Eifelian time, it would implicate the increase of $\delta^{34}S$ values of oceanic sulfate by 12 ‰ during ca. 11 Ma. Subsequently, $\delta^{34}S$ values show high plateau of 27‰ during ca. 12 Ma (Early Frasnian to Late Famennian). Afterwards, during Tournaisian time, they slightly drop to ca. 24‰.

AFTER THE MINE: MODELING LONG-TERM IMPACTS OF MINE CLOSURES IN A RESOURCE-DEPENDENT ECONOMY (YUKON)

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Recessions caused by sudden downturns in the mining sector are frequent and unavoidable events in boom-and-bust resource economies, and present a serious challenge to sustainability in frontier mining regions. However, the links between mining closures and general economic crisis in resource peripheries are not well-understood. While the immediate output and employment losses receive much attention, the long-term effects of mine closures on community sustainability are frequently understudied. This paper argues that in the post-industrial settings, most devastating 'post-mine' impacts are found in a long-term erosion of consumption base and shrinking service sector. This study analyzes several scenarios to simulate short and long-term direct, indirect and induced effects of miming closures in Yukon in the late 1990s. The paper considers two post-mining stages: post-mine economic shock (immediate direct impacts) and post-mine syndrome (extended indirect and induced impacts of endogenous nature). To trace these impacts the study uses the input-output modeling framework, including the extended demoeconomic IO (DIO) model. The DIO model indicates impacts of the post-mining demographic shifts through analyzing changes in age-specific consumption. Models demonstrate that the major impact on regional economy is associated not with direct impacts of downturn in mining, but with induced effects related to the long-term economic and demographic shifts in the household sector and decline in local service economy. Yukon's economy is found most responsive (vulnerable) to the closure-induced fluctuations in consumption rather than to the mining production decline itself. High-tech and high salary industries and services (most favorable for the future of the region) suffer the most from the post-mine syndrome. Consequently, the extended consequences of mining closure, which undermine local economies and consumption base, are more significant than loss of industry itself. Lastly, the analysis considered scenarios involved immediate remedies to offset the decline in mining by increasing output in other sectors. Thus, the major strategy of sustainable economic development should target retaining the population base to maintain consumption levels. The strongest positive effect in job creation and output generation is delivered by investing in public sector, alternative more sustainable staple sectors (e.g. logging) and sophistication of services.

OXYGEN-ISOTOPE GEOCHEMISTRY OF LATE PROTEROZOIC PLUTONIC-VOLCANIC SEQUENCES OF THE MIRA TERRANE, CAPE BRETON ISLAND, NOVA SCOTIA, CANADA

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The Avalonian Mira terrane of Cape Breton Island, Nova Scotia, Canada is composed mainly of late Proterozoic volcanic-plutonic-sedimentary sequences formed in an arc setting proximal to Gondwana. Previous oxygen-isotope studies have showed that many volcanic and plutonic rocks from this terrane have low $\delta^{18}O$ values, which likely were acquired by interaction with low-^{18}O hydrothermal fluids. Here, we describe results for the Huntington Mountain granitoid pluton and the associated East Bay Hills volcanic rocks of the Mira terrane. An alteration assemblage dominated by K-feldspar, chlorite, epidote, sericite, quartz, calcite, ilmenite and pyrite characterizes these rocks. Whole-rock $\delta^{18}O$ values range from +1.0 to +7.6 ‰ for granitoid rocks from Huntington Mountain, and -0.1 to +6.9 ‰ for the East Bay Hills volcanic rocks. Minerals from the plutonic and volcanic rocks have $\delta^{18}O$ values ranging from -1.5 to +8.5 ‰ for quartz, +2.5 to +6.5 ‰ for feldspar, and -5.3 to +1.0 ‰ for chlorite. The abundance of ^{18}O-depleted rock and mineral samples, along with the strong variability in the $\delta^{18}O$ values of quartz, suggest that this plutonic-volcanic complex underwent significant (but incomplete) exchange with low-^{18}O fluids (e.g. meteoric water) at hydrothermal temperatures (~350-450°C).

Large base and precious metal deposits (e.g., porphyry Cu-Au and epithermal Au) are commonly associated with the interaction between cooling plutonic-volcanic rocks and hydrothermal-meteoric fluids. The source(s) of such hydrothermal fluids, and the timing of their movement, are likely very important in understanding mineralization in the Mira terrane, and closely linked to the tectonic history of this portion of Cape Breton Island.

AWARENESS OF SCIENTIST PARTNERSHIP FOR CLASSROOM TEACHERS WITH THE UNIVERSITY OF SASKATCHEWAN

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The University of Saskatchewan offers a partnership with classroom teachers. This program is set up to expand the teacher's awareness of scientists, what they do and have the opportunity to have one or more scientist present in you classroom ... free. Workshops are set up to define examples of topics that would be relevant to individual class levels. With this program we make arrangements for a scientist to come to the school and present, or we attend the colleges at the university, with out students, and use the equipment at these facilities. Topics at the grade 5/6 level in Saskatchewan are: chemicals and reactions, earth's climate, heat, earthquakes and volcanoes, ecosystems, matter and its changes and resources of our earth. My students have been inspired to demonstrate individual experiments, for their peers and teacher, in all of the above areas.

TYHEE DEVELOPMENT CORP'S YELLOWKNIFE GOLD PROJECT

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The Yellowknife Gold Project is located 90 km north of Yellowknife. A resource estimate published in December 2006 reported a combined Ormsby + West Zone Measured and Indicated resource of 6.149 million tonnes grading 3.47 gpt gold,

representing 687,000 ounces of gold. The 2006 exploration program focused on completing 29,000 m of surface diamond drilling.

Gold mineralization occurs as silicified domains of pyrrhotite, garnet, biotite and carbonate metasomatized hydrothermal breccias transecting Archean aged mafic metavolcanic members within the Discovery Shear Zone. The metavolcanics are in conformable contact with mixed greywacke and argillite units. The metasedimentary rocks are gradational with typical Burwash Formation. More recent mapping is interpreted such that the Discovery Shear Zone coincides with a regional antiform along which the metavolcanic bodies are exposed. The Discovery Shear Zone is considered to have provided the extensional stress regime that permitted movement of hydrothermal fluids and the deposition of gold mineralization into dilatant areas. Gold mineralization occurs over a 3 km strike-length and to depths of more than 700 m below surface.

LOWER TO MIDDLE PALEOZOIC STRATIGRAPHY AND PETROLEUM POTENTIAL, PEEL PLATEAU AND PLAIN AND NORTHERN MACKENZIE MOUNTAINS

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Stratigraphic and petroleum resource assessment work is currently underway in Peel Plateau and Plain, which lies in the northern Mackenzie Corridor. Peel Plateau and Plain has widespread hydrocarbon potential but there have only been about 70 exploratory wells drilled. Subsurface stratigraphic information is sparse for this part of the Northern Mainland Sedimentary Basin, but excellent exposures are available for study in the adjacent northern Mackenzie Mountains. A four-year project (2005-2009) entitled "Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain, Northwest Territories and Yukon" is a collaborative study among the Northwest Territories Geoscience Office, Yukon Geological Survey, and Geological Survey of Canada. The project objective is to improve and update knowledge of regional geology, including stratigraphic relationships, depositional and tectonic histories, basin evolution, and petroleum potential of several plays throughout the Phanerozoic succession.

Cambrian strata (Sauk Sequence) are restricted to the eastern part of the study area and comprise siliciclastic, carbonate, and evaporite rocks deposited in an epicratonic basin called Mackenzie Plain Depocentre. Uppermost Cambrian to Middle Devonian strata (Tippecanoe and Kaskaskia sequences) are carbonate-dominated and widespread in the study area, representing deposition within Mackenzie-Peel Shelf which deepened westward toward Richardson Trough (Richardson Mountains, Yukon). In the Givetian, the platform succession was drowned during a rapid rise in sea level.

Stratigraphic studies focus on several conceptual petroleum plays. These include basal Cambrian siliciclastics play (Mount Clark/Mount Cap Formation), Lower Paleozoic platform play (Franklin Mountain and Mount Kindle formations), Arnica/Landry platform play (Arnica and Landry formations), and Kee Scarp play (Ramparts Formation). Fourteen new Lower to Middle Paleozoic sections and key stratigraphic intervals from twelve stations were studied in 2006 and sampled for porosity and permeability, Rock-Eval/TOC pyrolysis, and conodont biostratigraphic data. Initial analyses of outcrop samples collected indicate good porosity in several units including Mount Cap sandstone, coarse dolostone of Franklin Mountain and Mount Kindle formations, fractured and brecciated dolostone of the Arnica Formation, and reefal limestone of the Ramparts Formation. Oil staining was noted in the Hume Formation and in the Bear Rock Formation, a facies equivalent to the Arnica Formation in the eastern part of the study area. Rock-Eval 6 / total organic carbon (TOC) analyses from outcrop samples ranged from poor in Cambrian shale (Mount Cap Formation; 0.21 % TOC) to excellent in Middle and Upper Devonian shales (Canol Formation, Bluefish Member, and "Carcajou" facies of Ramparts Formation; 8.3 to 13.3 % TOC).

LATE PALEOPROTEROZOIC INTRACONTINENTAL BASINS OF LAURENTIA - REVISITING 'HELIKIAN BASINS AND GEOSYNCLINES OF THE NORTHWESTERN CANADIAN SHIELD'

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Laurentia is an aggregate of several Archean cratons welded by orogenic belts representing collision between 2.0 and 1.8 Ga. Uplift and unroofing of these belts dispersed huge quantities of detritus across the newly formed continent, some of which was captured in intracontinental basins such as the Athabasca, Thelon, Hornby Bay and Elu that formed during late stages of this aggregation. Erosion and dispersal of sediment was facilitated by rigorous chemical and physical weathering in the absence of substrate-stabilizing vegetation. These basins exhibit comparable geometry, lithology, stratigraphy and overall paleocurrent patterns, which suggested to previous workers that they were initially co-extensive, and perhaps covered much or all of the areas between the preserved edges of the basins. Regional paleocurrents derived from crossbedded sandstones interpreted as braided river deposits are dominantly west–directed in all basins, with local variations, particularly in the lower parts of the stratigraphic successions. This led to the view of a paleogeography typified by broad fluvial sandsheets originating from sources within active orogenic upland belts. Subsequent work shows that this model may apply only to the intermediate to late stages of basin development. Early sedimentation in each basin was controlled by local faulting and accommodation as shown by field mapping, detailed paleocurrent analysis and detrital zircon provenance studies. Subsequent stages of basin evolution reflect intermittent marine or lacustrine reworking of fluvial and eolian deposits and ultimately complete marine transgression as recorded by successions of platformal stromatolitic carbonates, which are best preserved in the Hornby Bay and Elu basins. Small patches of volcanic rocks occur in all basins, but it is unknown if they are correlative. Conformable overlying flood basalts of the 1270 Ma Coppermine River Group show that the Hornby Bay Basin preserves a ~500 m.y. history that was punctuated by significant time breaks at several unconformities within this succession. Detailed studies, including field mapping and core logging, sequence stratigraphic and sedimentary facies analysis combined with geochronology, have documented three regional intrabasinal unconformities and more than 200 m.y. of depositional history in the Athabasca Basin. Similar work is ongoing and planned in the Thelon, Hornby Bay and Elu basins to bring our knowledge up to that of the Athabasca Basin. This stratigraphic and structural context is important for future exploration and resource assessment of unconformity-associated and sandstone-hosted uranium deposits.

URANIUM METALLOGENESIS IN THE PROTEROZOIC HORNBY BAY GROUP, NUNAVUT AND NORTHWEST TERRITORIES, CANADA: RELATION TO NEW STRATIGRAPHIC, LITHOLOGIC, AND STRUCTURAL DATA

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Sediments between Great Bear Lake and the Arctic coast comprise at least 8 stacked overlapping basins separated by unconformities and/or changes in basin tectonics: 1) volcanic arc-related McTavish Group basin, in places downfolded into a 5

km thick north-plunging syncline, 2) foreland Bigbear Basin, over 500 m of fluviatile fining up clastic cycles prograding to the east, 3) unnamed wrench-fault (?) basins, over 700 m deep, filled with largely eolian quartz arenites, 4) crustal contraction foreland (?) basin with basal Lady Nye Fm clastics prograding to the west, grading up into the East River Fm carbonates and terminating with the Kaertok Fm interbedded clastics and volcanics, 5) Dismal Lakes Group basin, itself possibly composite, with 5a) basal paralic quartz arenites showing southerly directed paleocurrents overlain by a 5b) clastic/carbonate sequence thickening to the west, 6) the Coppermine basin, containing a three km thick basalt and clastic sequence, interbedded with the underlying carbonates; it and underlying units are folded into an east-west syncline in the area, 7) passive margin (?) basin; Rae Group sediments deposited on a peneplain dipping shallowly to the north, the area of a postulated continental breakup, and 8) shelfal units of the Western Canada Sedimentary Basin, a passive margin basin related to continental breakup along the western margin of North America. The Hornby Bay Group of the literature comprises part of basin 1 and all of basins 2 to 4.

The clastics of these basins are largely feldspathic, except for thick, well sorted quartz arenites in the upper units of the Bigbear, the eolian sandstones, parts of the Lady Nye to Kaertok fms, and in the basal units (Leroux and Fort Confidence sandstones) of the Dismal Lakes Group.

Alteration (bleaching, clay alteration, anomalous uranium, dravite, barite and malachite) is more common in the quartzitic units and in major fault zones than in the clay rich, feldspathic or carbonate units.

Where quartzitic units overlie or are adjacent to reductive basement there is potential for unconformity U deposits; where they underlie reductive shales Gabon-type U deposits may develop, particularly near NE to N trending faults. These faults also host the most widespread U and Cu shows in the area.

Many of the region's U shows described in the literature are basement-hosted fracture and fault zones, suggesting the potential for Olympic Dam deposits. These type of occurrences may also provide U to post-Hornby Bay Group mineralizing processes.

"INTRACONTINENTAL" OR COMPOSITE? LONG-LIVED PROTEROZOIC BASINS: THE ATHABASCA, THELON AND HORNBY BAY BASINS

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The concept of intracontinental basins often assumes characteristics of young uneroded basins formed within a single tectonic framework confined to the continent on which they formed.

"Intracontinental" basins lasting for most or more than one continental cycle fit other patterns. They often are composite: stacked remnants each with a different structural setting that may include rifts, pull-aparts, back-arcs, passive margin, foreland, late orogenic contraction, and orogen-related dynamic subsidence. Lumping them with young intracontinental basins leads to their being regarded as "enigmatic" in origin and inadequately described.

Their understanding is improved by regarding orogenies as the deformation of the crust due to compressional plate interactions rather than just their positive surface-relief forms. Orogenies create basins as well as topographic highs and should be considered as lasting until the crust resumes acting as a single unit i.e. until the last fragments of the descending plate pass back into the mantle. Continents in a collision should be regarded as distinct until the crust below acts as a single unit. "Intracontinental" basins such as the Proterozoic Athabasca, Thelon and Hornby Bay basins lose their "enigma" when their composite nature is recognized and their constituent basins are related to their distinct tectonic origins.

The little metamorphosed sediments of the area between Great Bear Lake and the Arctic coast comprise at least 8 stacked overlapping basins: arc-related McTavish Group basin, foreland Bigbear Basin, so far unnamed wrench-fault (?) basins, contractional foreland (?) Lady Nye to Kaertok fms basin, Dismal Lakes Group basin, itself possibly composite, Coppermine volcanic basin, passive margin (?) Rae Group basin, and passive margin WCSB. These basins relate to one collisional orogen (Great Bear), a crustal contraction orogeny (Forward), and two continental breakup episodes (passive margin after continental breakup related to Coppermine volcanics – Rae Group, and later Windermere Group). The Hornby Bay Group of the literature comprises all or part of four of these basins.

Little and unmetamorphosed sediments of Saskatchewan and Alberta comprise 6 stacked overlapping basins related to two collisional orogenies, (Taltson-Thelon and Trans-Hudson/Alberta), two to seven craton-margin subduction orogenies (Yavapai, Mazatzal, Central Plains, Antler, Columbian, Laramide), and one continental breakup (Laurentia breakup – Windermere Group). The Athabasca Series of the older literature variously included all six of these stacked basins.

The Thelon Basin is much less studied, but available data suggest a similar complex history.

The complex history of these basins is reflected by their equally varied metallogenic history.

MAGMATIC FLUID COMPOSITIONS (F-CL-S) AS AN EXPLORATION TOOL FOR CRETACEOUS INTRUSION-RELATED MINERALIZATION IN THE SELWYN AND MACKENZIE MOUNTAINS, SOUTHWESTERN NWT

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We present preliminary F, Cl, and SO_3 concentrations in igneous apatite and biotite from 24 felsic intrusions as part of a comprehensive regional study of Cretaceous magmatism in the Selwyn-Mackenzie Mountains, NWT. The studied intrusions are representative of several plutonic suites with and without genetically associated mineral occurrences. The goal of the study is to identify and characterize magmatic fluid compositions in individual intrusions and identify those bodies that have exsolved a significant quantity of potentially metal-rich volatiles. F, Cl, and SO_3 concentrations measured in apatite in this study demonstrate: (1) F increases and Cl and SO_3 typically decrease with increasing degree of evolution and/or crustal contamination and with decreasing age of magmatism; (2) the youngest intrusive rocks (Tombstone suite) have detectable SO_3 and anomalously high F, which may reflect significant quantities of CO_2 in the magma; (3) intrusions with combined F + Cl concentrations of <3.75 wt% are hypothesized to have exsolved a significant quantity of volatile material and have a high potential for related mineralization; (4) most intrusions with related tungsten mineralization appear to have exsolved volatiles *after* the crystallization of apatite (i.e., at lower temperatures). The relatively low temperatures for intrusions associated with tungsten mineralization may reflect a greater degree of crystallization before volatile exsolution, which is generally described as a significant factor in the formation of large tungsten deposits. Therefore, we suggest that apatite with measurable depletions in volatile concentrations are indicative of intrusions that are *not* prospective for significant quantities of tungsten mineralization.

Marked depletions in the calculated HCl/HF activity ratio between early-forming apatite and later-forming biotite from individual intrusions may also indicate the release of significant quantities of potentially metal-rich volatiles during igneous crystallization. Recognition of such depletions would therefore constrain the relative timing and temperature of exsolution of a magmatic volatile phase, and could potentially identify intrusions likely to have exsolved a mineralizing vapour phase. Our work thus far demonstrates that measured depletions in HCl/HF activity ratios between apatite and biotite are present in most intrusions associated with known mineralization. We have also identified several intrusions with significant depletions but without known mineralization, and we suggest that potential for intrusion-related mineralization exists in the vicinity of these bodies.

REDESIGNING UNIVERSITY UNDERGRADUATE CLASSES TO IMPROVE THE STUDENT EXPERIENCE AND GEOSCIENCE LITERACY

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Many current social issues have a strong geoscience component. Organizations such as the United Nations, the National Science Foundation and the National Science and Engineering Research Council recognize that increasing the awareness and interest in geoscience issues is an important issue facing the scientific community. One venue that can be used to improve people's understanding and interest in geoscience is through undergraduate university courses designed for non-science majors. This venue can be an ideal way to reach thousands of students every year as many undergraduate programs in the arts, social sciences and business disciplines require students to take science courses as a degree requirement. Currently, many of these courses are perceived by students as fact-driven, and students finish the course without the desired 'science literacy' skills such as an awareness of relevant and current geoscience issues, an ability to evaluate scientific information on the basis of its source and method used and have the ability to describe, explain and predict earth science phenomenon.

Currently, we are in the process of evaluating the effectiveness of teaching practices and learning objectives in a large (300 students) second-year undergraduate geoscience course at the University of Calgary designed for non-science students (GLGY301) called "The Geology of the Mountainous Regions of Western Canada". With this course we are also in the process of developing an accurate picture of the current student experience and student perception of geoscience issues both before and after the course. This is being achieved through one-on-one interviews with select students during and after the course and survey questionnaires administered to all of the students after the course. We are also comparing student's understanding of the science concepts before and after the course in order to determine how well the concepts are understood and retained. Through the administration of a 'pre-course' test, we were able to determine what level of understanding of the core concepts the students already had, which we will compare to their results on the final exam administered at the end of the course. Our goals for this project are to find out what teaching practices should be employed in classes such as GLGY301, and other similar classes, to improve the student experience and their geoscience literacy. The results of this study will be used to implement course design changes that focus on achieving these goals.

SUSTAINABLE MINERAL RESOURCES DEVELOPMENT: CRITICAL ISSUES FOR CANADA'S NORTH

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Despite their physical separation and climatic differences, Canada and Australia share many attributes, including long indigenous and colonial histories, modern "western"-style government, resource riches, and vast areas of land occupied sparsely by aboriginal peoples. Both countries are considered to be "first world" and "developed", although unlike many other such countries, including the USA and much of Europe, Canada's and Australia's economies still derive significant benefit from resource extraction. In both countries, as proximal resources have become depleted, exploration and development has pushed further and further into "frontier" lands, such as Australia's interior, and Canada's North. Conflicts have not infrequently arisen between resource companies and aboriginal people who live in these remote areas and depend on their natural resources for the survival of their way of life. Companies have commonly found that what they consider to be fair exchanges for access to land, such as cash and infrastructure compensation, and some jobs, are not universally welcomed by local people. This reflects a disconnect in valuation by the two parties of not only the material value of the goods offered, but also the time-scale of the exchange. Industry's focus is on the rapid generation of wealth through resource extraction, with interest strictly limited to the duration of the mine, which may be only a few years. In contrast, the interests of local peoples focus on the long-term sustainability of their communities, environment, and way of life, as well as short-term benefits such as employment. The missing piece in the puzzle is how to convert those short-term opportunities and benefits afforded by mining into longer-term sustainable benefits for the community.

One middle-term solution is through education and training, particularly if mining is expected to expand in the North. But care should be taken to ensure that real qualifications (e.g., certificates, diplomas, degrees) are obtained (as opposed to on-the-job training with no certification), and that the skills taught are transferable to other industries and businesses (i.e., not dependent on a single industry or work type). This will require a significant investment in the educational system, which should be funded at least in part by direct re-investment of mineral royalties and other mining-related taxes into the host communities. Thus, governments at all levels, and especially Nunavut Tunngavik Incorporated (which represents the Inuit people under the Nunavut Land Claims Agreement) have a critical role to play in this wealth-to-sustainability conversion process.

THE SARI GUNAY EPITHERMAL GOLD DEPOSIT, NORTHWEST IRAN

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The Sari Gunay epithermal gold deposit is located in central northwestern Iran, ~60 km NW of the city of Hamedan. The deposit is hosted by an 11.7–11.0 Ma (Ar-Ar) volcanic complex, consisting of trachytic, dacitic, and latitic flows, tuffs, hypabyssal intrusions, and diatreme breccias. This complex forms part of the NW-trending middle Miocene Takab belt of mildly alkaline volcanic and intrusive rocks, which also host or are related to gold deposits at Zarshuran and Agh Darreh. The Takab belt is parallel to, but to the southeast of and slightly younger than, the main Urumieh-Dokhtar calc-alkaline magmatic arc, which hosts

several large middle Miocene porphyry Cu deposits. The Takab belt gold deposits are suggested to have been formed by syn-collisional, mildly alkaline magmas during closure of the Neo-Tethys ocean in central Iran.

Gold mineralization at Sari Gunay was first recognized by Rio Tinto exploration geologists in 1999, during inspection of the site of old antimony-arsenic vein workings and an old millstone quarry in silicified igneous rocks. A resource of 52 Mt of oxide mineralization containing 1.77 g/t Au (1.0 g/t cutoff) has been delineated. Gold is predominantly invisible, and is hosted by fine-grained arsenian pyrite and arsenopyrite in epithermal quartz-adularia-pyrite-stibnite veins, with late realgar, orpiment, cinnabar, and extremely rare wire gold. Fluid inclusion assemblages in these veins indicate trapping under boiling conditions at 199 ± 24°C, with liquid salinities of 3.6 ± 1.1 eq.wt.% NaCl, and traces of CO_2 in coexisting vapour-rich inclusions. Indicated pressures are very low (~15 bar), indicating shallow depths of formation.

Epithermal veins are structurally controlled by an earlier, barren quartz-tourmaline breccia system, which itself followed a SSW–NNE-trending diatreme breccia complex. Fluid inclusions from these veins record boiling conditions at 246–360°C, with hypersaline brines (34.4–46.1 eq.wt.% NaCl) coexisting with a low-density, CO_2-bearing vapour phase, suggesting shallow emplacement. Sericitic alteration of wallrocks around the quartz-tourmaline veins has been dated by Ar-Ar at between 10.8 and 10.3 Ma (best estimate ~10.7 Ma), indicating formation shortly after the main stage of volcanic and intrusive activity. Below 300 m-depth, sheeted quartz-sulfide-magnetite veins with weak potassic alteration and low grades of Cu and Au mineralization resemble banded quartz-magnetite veins from shallow porphyry Au deposits. Minor tourmaline in these veins links them to the later, shallower quartz-tourmaline veins, which together provide evidence for a transition from porphyry- to epithermal-style hydrothermal activity and mineralization.

SCALED ANALOGUE MODELLING OF BASEMENT-INVOLVED FOLDING WITH APPLICATION TO THE EASTERN PENOKEAN OROGEN AND THE SUDBURY IMPACT STRUCTURE, ONTARIO, CANADA

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Crustal-scale domes and basins are a ubiquitous, yet kinematically pooly understood structural elements in orogenic belts of all ages. In order to better understand large-amplitude, non-cylindrical folding, we conducted a series of scaled analogue experiments. The experimental set-up consists of a rectangular tank filled with layers of corn syrup, Polydimethylsiloxane (PDMS), PDMS blended with plasticene and various fillers, and granular materials with Mohr-Coulomb rheology. These layers represent respectively the lithospheric mantle, lower crust, middle crust and sedimentary cover rocks. Bulk horizontal shortening of the layers is imposed by piston moving at a constant rate.

The resulting models show that deformation style in orogens depends strongly on the distribution and thickness of sedimentary cover rocks, the mechanically strongest layer in the system. More specifically, the wavelength and amplitude of folds in the middle crust increase with decreasing thickness of the sedimentary cover. Thicknesses of cover rocks exceeding 10 km in nature significantly inhibit the formation of mid-crustal folds. Moreover, reverse faults and thrusts in the sedimentary cover nucleate in the hinge zones of mid-crustal model synforms.

The importance of sedimentary cover rocks in controlling the style of mid-crustal folds and the localization of thrust faults is clearly evident in the Paleoproterozoic Eastern Penokean Orogen of the southern Canadian Shield. Domes and basins of Archean basement rocks and sedimentary cover rocks of the Huronian Supergroup are characteristic of this fold belt. The fold belt hosts also the deformed central portion of the 1.85 Ga Sudbury Impact Structure, in which a large meteorite impact removed Huronian cover rocks, thereby exhuming mid-crustal granitoid basement rocks in a circular area ~ 130 km in diameter. Analogue modelling of post-impact deformation of the central impact structure and adjacent basement-cover assemblages generated remarkable geometric similarities with the natural prototype. These include the formation of a non-cylindrical basin consisting of a larger, shallowly dipping flank and a smaller, steeply dipping flank of the free surface of the model basement rocks. Furthermore, a prominent reverse fault nucleated in the hinge zone of the folded model impact structure and displaced the steeper flank over the shallowly dipping one. Finally, the geometry of higher-order discontinuities outside the central model impact structure corresponds well with mineral fabric and fault patterns in equivalent positions of the natural prototype. Our results indicate that scaled analogue experiments using viscous and granular materials provide a significant step forward in understanding the dynamic evolution of crustal structures.

TECTONIC SETTING OF THE OTTAWAN AND RIGOLET OROGENIC PHASES OF THE GRENVILLIAN OROGENY AND THE ROLE OF THE ALLOCHTHON BOUNDARY THRUST: TWO HIGH-PRESSURE BELTS IN THE GRENVILLE PROVINCE?

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On the basis of its > 600 km width, widespread high-grade Grenvillian assemblages, subhorizontal ductile fabrics, and the ca. 110 My duration of orogenesis from ca. 1090-980 Ma, the Grenville Province qualifies as part of a large, hot, long-duration orogen. Numerical modelling has shown that under conditions of moderate erosion at the orogen margin, the interiors of such orogens may be characterised by orogenic plateaus beneath which ductile rocks flow in a mid-crustal channel towards the erosion front under gravitational or tectonic forcing. This model fits the Ottawan (ca. 1090-1020 Ma) orogenic phase of the Grenvillian Orogeny very well. Ottawan metamorphic rocks were derived from the high-temperature orogenic hinterland and transported in a crustal channel above the Allochthon Boundary Thrust to the orogen margin. A range of levels of Ottawan crust is preserved, from ca. 50-60 km depth in the high pressure (HP) Belt, through 33-15 km in the medium to low pressure (M-LP) Belt, to <15 km depth in the Orogenic Lid. Peak Ottawan temperatures at 1000 MPa were ca. 800-850 °C, implying a relatively high geothermal gradient and were accompanied by extensive partial melting and a very ductile style of deformation, and the HP and MP Ottawan crust remained above ca. 500 °C for > 50 My after peak conditions.

In contrast, metamorphism during the ca. 1005-980 Ma Rigolet orogenic phase of the Grenvillian Orogeny took place beneath the Allochthon Boundary Thrust, peak P-T conditions preserve evidence for MP to HP metamorphism at ca. 20-50 km depth that took place under a lower geothermal gradient (peak temperatures at 1000 MPa were ca. 750°C), and the subsequent tectonic evolution involved rapid exhumation and cooling through ca. 500°C in < 20 My. Moreover, lithological correlations indicate that rocks metamorphosed during the Rigolet orogenic phase are parautochthonous and were derived from the orogenic foreland. There are thus two HP belts within the Grenville Province, and their back-to-back locations on either side of the Allochthon Boundary Thrust imply that the latter acted as a material focal plane, about which allochthonous Ottawan HP metamorphic rocks formed in the orogenic

hinterland and parautochthonous Rigolet HP metamorphic rocks formed from the former orogenic foreland, originally separated by several hundred km, converged and were exhumed.

ARCHEAN TO PROTEROZOIC EVOLUTION OF HIGH-GRADE TERRAIN IN THE BOOTHIA MAINLAND AREA, KITIKMEOT REGION, NUNAVUT

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The Boothia Mainland area in central Nunavut, Canada, is located in the north-central Rae domain of the Churchill province. The area comprises a high-grade gneissic terrain dominated by Neoarchean metaplutonic rocks, lesser Archean and Paleoproterozoic supracrustal sequences, and migmatitic gneiss. The Archean supracrustal rocks (Barclay belt) outcrop as narrow, northeast-striking belts of psammite, semi-pelite, metabasalt, ultramafic schist, and sulphide-bearing (lean) iron formation. Based on its youngest detrital zircon age of 2.76 Ga, the Barclay belt correlates with the pan-Rae Prince Albert Group. Granitic rocks, and their gneissic equivalents, are dominated by I-type, meta- to peraluminous, polyphase, commonly porphyritic bt-hbl monzogranite to granodiorite. U-Pb zircon ages indicate they are part of a 2.61–2.59 Ga pan-Rae magmatic event. Lesser 2.67–2.66 Ga plutonism represents a previously unknown age of magmatism in the Rae domain. Nd isotopes generally yield 2.85–2.70 Ga model ages for plutonic rocks and juvenile initial Nd ratios (+0.7 – +3.8), indicating interaction with a 100–250 m.y. older crust, possibly basement to the Barclay belt. These data are characteristic of the regionally delineated 'Committee Bay block'. Two smaller domains in the northeast and southeast yield 3.0–2.9 Ga model ages, potentially highlighting fertile tectonosphere for sourcing diamonds.

Small outliers of Chantrey Group, occur as complex infolds in the Archean rocks. Detrital zircon studies indicate a Paleoproterozoic age, consistent with other Rae domain cover sequences such as the Amer and Piling groups.

The area's structural grain is dominated by a moderately to intensely developed regional transposition foliation (S_2), which is folded about map-scale, northeast-trending Paleoproterozoic F_3 folds, doubly plunging about less pervasive north-northwest-trending F_4 folds. Linked thermobarometric and in-situ SHRIMP data unveil a complex tectonometamorphic history. The northern granulite belt records conditions of 6.3 kbar and 720°C at 2.6 Ga, accompanying burial of the Barclay belt, probable deformation, and emplacement of pan-Rae granitoids. 2.41 Ga rims on 2.6 Ga monazite are thought to reflect the 2.5 – 2.35 Ga Arrowsmith Orogeny. D_3 deformation at 1.83–1.81 Ga varied from upper amphibolite (7 kbar-720°C) in the northeast to lower amphibolite (4 kbar-530°C) in the southwest, considered to reflect a late stage of reworking associated with microcontinent collisions with Rae. Migmatization likely occurred at least during the 2.6 and 1.82 Ga events. The Paleoproterozoic component of this protracted tectonothermal history tracks into northern Baffin Island where a southward-decreasing gradient from granulite- to lower amphibolite-facies occurs at broadly the same scale.

A PROPOSED REVISED STRATIGRAPHIC-CHEMOSTRATIGRAPHIC NOMENCLATURE FOR DIVERSE PALEOPROTEROZOIC ALKALINE MAFIC TO FELSIC IGNEOUS ROCKS OF THE WESTERN CHURCHILL PROVINCE: LAMPROPHYRES, SYENITES AND HUDSONIAN GRANITOIDS

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In the western Churchill Province the interval 1840-1790 Ma is characterized by the contemporaneous emplacement of a diverse series of magmatic rocks that are exemplified by, and which nomenclature is largely based upon, extrusive units of the Christopher Island Formation (CIF). Within Baker Lake Basin the ca. 1840-1790 Ma Baker Lake Group is composed of four lithostratigraphic formations including, of major interest herein, volcanic and volcaniclastic rocks of the CIF.

CIF volcanism, which was active throughout the Baker Lake Group, can be subdivided into three distinct lithostratigraphic units. The first, locally overlying the unconformity marking the base of the Baker Lake Group, comprises K-feldspar- and phlogopite-porphyritic felsic minette (sensu-lato) flows and volcaniclastic rocks that form localized volcanic centres. The second, comprising minette (sensu-stricto) volcanic rocks, was extruded basinwide and composed a significant component of the basin fill. Felsite flows, locally K-feldspar-porphyritic, formed localized domes that comprise the third volcanic unit.

Regionally, hypabyssal dyke rocks of comparable age and petrology are considered as constituents of the CIF. Hollocrystalline plutonic units of similar petrology and age have, however, typically been termed as comprising the Martell syenites. Collectively, rocks of the CIF and Martell syenites include: minette flows, felsic minette flows, bostonites, felsite domes, syenite stocks, minette plugs and sheets, ocelli syenite dykes, minette and spessartite dykes and syenogabbro-pyroxenite sills and dykes. Significantly, sheet-like intrusions and domal masses of Hudsonian monzogranite overlap in both time and space with these alkaline rocks and commonly exhibit commingling with a number of hornblende-bearing end-members.

The present nomenclature for these petrologically diverse contemporaneous rocks is therefore inadequate and is largely a result of our poor understanding of the petrogenesis of the suites. We propose herein a new, more flexible lithostratigraphic and lithodemic nomenclature for these Proterozoic igneous rocks of the western Churchill Province. Our nomenclature is based upon detailed stratigraphic analysis of the volcanic and volcaniclastic rocks of the Christopher Island Formation along with examination of the geochronological, petrological and lithogeochemical relationships for hypabyssal and plutonic units cropping-out in the Hearne domain to the southeast and east of Baker Lake Basin.

UNIQUE GARNET COMPOSITIONS FROM THE MUD LAKE KIMBERLITE, SW SLAVE PROVINCE, NWT: AN OCCURRENCE OF RARE, HIGH Cr-Ca GREEN GARNETS

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The Ticho Diamond Project, operated by Snowfield Development Corporation, is located ca. 50 km south-southeast of Yellowknife on the eastern shore of Yellowknife Bay. Earlier

historical work in the area includes regional till sampling programs conducted by prospector David Smith, industry and the Geological Survey of Canada. This work reports significant new data from the diamondiferous Mud Lake Kimberlite Sill complex.

Regional till samples revealed elevated counts of kimberlitic indicator minerals and, during follow-up investigations in 2003, Snowfield discovered the Mud Lake kimberlite. The kimberlite comprises a NNE-trending, SW dipping sill-like body, generally continuous along strike for at least 800 m and, although bifurcating, ranges in thickness from <1 to 7 m. The freshest portions of the kimberlite consist of: abundant (45 volume %, ≤5 mm) serpentinized olivine grains along with less common, phlogopite (<5%, ≤5 mm) and picroilmenite (<2%, ≤5 mm) grains. Pyrope garnet, typically with kelypihtic rims, is common and set in a fine-grained groundmass of serpentine, carbonate and opaque minerals. Paragenetically late deposition of hematite and corresponding reddening of the kimberlite and country rocks is widespread. Locally, breccia zones are observed at the structural top of the kimberlite and contain up to 90% rounded to angular country rock xenoliths in a carbonate matrix. Caustic fusion analyses on drill core from the sill has, recovered promising macro diamond contents, the two largest stones being larger that 2 mm in their longest dimension.

Electron microprobe data for garnets from the kimberlite reveals a broad array of mantle-derived garnets with very common G9 (28.6 vol. %), G3 (19.5 %), G4 (15.6 %), rare G10 (1.8 %) and G0 (< 0.1 %) garnets along with a major proportion of G12 (34.4 %) garnets. A minor proportion of these G12 garnets are green, high-Cr_2O_3 and high-CaO grains with CaO ranging from 12.83-21.47 wt. % with corresponding Cr_2O_3 from (7.01-17.80) and plot in the miscibility gap between ugranditic and pyralspitic garnets. Three of the green garnets have unit cell lengths of a= 11.700, 11.710 and 11.771 Å (determined via μXRD) and similarly plot in the gap between known garnet cell dimensions along the solid solution (11.67-11.77 Å). There is a remarkable correlation of these green garnets and diamonds in every diamond bearing kimberlite were green garnets have been identified. Green garnets with these compositions have been found in several diamond bearing kimberlites that have been mined including Premier in South Africa and Udachnaya in Russia. These unique diamond indicator minerals from the Mud Lake kimberlite represent the first publicly known green, high-Ca-Cr garnets in the Slave Province from a bedrock source.

SECULAR AND SPATIAL VARIATIONS IN THE COMPOSITION OF PALEOPROTEROZOIC (2200-1950 Ma), "MANIKEWAN" BASALTIC SUITES OF THE WESTERN CHURCHILL PROVINCE: IMPLICATIONS FOR REGIONAL LITHOSTRATIGRAPHIC RECONSTRUCTIONS AND EVOLUTION OF MANTLE SOURCES

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Over the last decade, a significant body of new field, geochronological and geochemical data have become available for Proterozoic mafic rocks of the western Churchill Province (wCP) west of Hudson Bay and also in parts of the Trans-Hudson orogenic foreland on central Baffin Island. At least 10 suites of Proterozoic mantle-derived basaltic rocks are now recognized, occurring both as dyke-sill complexes that cross-cut older rocks and as pillow basalt-sill assemblages comprising integral parts of the Paleoproterozoic cover sequences. In order of decreasing known or presumed age, these suites include: 1) ca. 2450-2490 Ma Kaminak Dykes and Spi Group basalts of the Central Hearne subdomain; 2) the ca. 2190 Ma MacQuoid-Tulemalu dyke swarm of the NW Hearne subdomain; 3) the <2450>2111 Ma Happotiyik Member of the Ameto Formation in the Central Hearne subdomain; 4) undated basalts of the Ketyet Group, Woodburn Lake area, Rae Domain; 5) undated basalts of the Amer Group, Rae Domain; 6, 7, 8) three petrochemically distinct, ca. 2155 Ma pillowed basaltic rocks of the upper volcanic sequence in the Rankin Inlet Greenstone Belt (note: 6, 7 & 8 likely structurally overlie older Neoarchean rocks); 9) the 2111 Ma Griffin Gabbro sills of the Central Hearne subdomain and; 10) basalts of the ca. 1950 Ma Bravo Lake Formation of Baffin Island. Only the latter 9 suites are of interest herein.

Modern, precise lithogeochemical data are available for all but the Ketyet and Amer Group rocks. For the remainder, the older (>2150 Ma) suites consist of primitive tholeiitic basalts exhibiting major contributions from depleted (DM) or primitive (PM) mantle and likely sub-continental lithospheric (SCLM) mantle sources. Rocks of the younger sequences typically exhibit a decrease in the influence of SCLM sources, but increased contributions from plume-related, ocean island basalt (OIB)-type sources are readily apparent. The Bravo Lake Formation, exposed in the Trans-Hudson orogenic foreland of Baffin Island exhibits major inputs from OIB and DM sources, but apparently lacks an SCLM component. A better temporal and lithogeochemical understanding of these mafic rocks now permits evaluation of their compositional variation in time, and in their present-day spatial coordinates. These data suggest early suites sampled DM and SCLM sources beneath the wCP, marginal to the main southward-lying Manikewan rift during protracted extension of the wCP. Continued and perhaps enhanced extension during latter stages of active rifting resulted in a substantially thinned lithospheric mantle and an increase in the proportion of observed OIB-type magmas at surface. The precise timing and petrogenetic evolution of these Paleoproterozoic mafic suites therefore provides constraints on the nature and evolution of magmas generated in response to the protracted extension and rifting of the collective Rae-Hearne craton during the formation of the Paleoproterozoic Manikewan Ocean.

PETROCHEMICAL AND GEOCHRONOLOGICAL CONSTRAINTS ON THE ORIGIN OF THE RANKIN INLET GREENSTONE BELT, NUNAVUT: A PROTEROZOIC COLLAGE OF JUVENILE NEOARCHEAN INTRA-OCEANIC ARC-BACKARC AND PROTEROZOIC INTRA-CONTINENTAL BASINAL SEQUENCES

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The Rankin Inlet Greenstone belt (RIGB), exposed on the western Hudson Bay coast, contains the only past producing nickel deposit of the western Churchill Province. The belt, occupying a critical position along the inferred boundary between the Central and Northwestern Hearne subdomains, comprises two distinct assemblages of mafic volcanic dominated rocks, separated by a ca. 20m thick horizon of tectonized matrix supported polymictic conglomerate. Recently, via U-Pb SHRIMP dating of detrital zircons, the upper volcanic sequence (UVS) has been demonstrated to be younger than 2155 Ma and therefore likely represents a package of Proterozoic basinal rocks overlying the Archean substrate. The only constraints on the rocks of the lower volcanic sequence (LVS) indicates that these are probably ca. 2663 Ma in age.

Rocks above the conglomerate are typically pillowed, and are in stratigraphic and structural intercalation with quartzites, dolostones, wackes, sulphidic shales and pyroxenite-peridotite (host to the Rankin Inlet ore). In contrast, massive basalts, volcanogenic sediments, psammite and pelite, iron-formation, gabbroic dyke/sill complexes and rare felsic tuffs comprise the rocks below the conglomerate. Poorly delineated outliers of

presumed Proterozoic quartzite-polymictic conglomerate and plagioclase porphyritic basalts locally occur.

Modern lithogeochemical and Nd isotopic data for rocks of the Rankin Inlet belt support the two assemblage scenario proposed by earlier investigators. The LVS comprises tholeiitic basaltic lavas and tuffs having five distinct lithogeochemical affinities including: dominant MORB-like basalts, but abundant arc-like, back-arc-like and rare boninitic compositions. OIB-like magmas are very rare. These are all predominantly juvenile at 2663 Ma, although rare negative epsilon Nd_t values for these rocks may indicate evidence of contamination by older material. The diversity of magmas in the LVS of the RIGB attests to the heterogeneity of their Archean mantle source and suggests a petrogenetic link with Northwestern Hearne subdomain. The UVS basaltic rocks comprise three lithogeochemically distinct suites, all of which appear to include varying proportions of depleted mantle and sub-continental lithospheric mantle. The three suites are comparable, in terms of their lithogeochemistry and Nd isotopes, to the basalts and gabbros of the Happotiyik Member of the Ameto Formation exposed in the Central Hearne subdomain. The stratigraphically highest of the three suites exposed at Rankin Inlet, however, in contrast with the other two, exhibits clear petrogenetic evidence for generation via partial melting of OIB-type mantle as well as depleted and sub-continental lithospheric mantle sources.

PETROGRAPHICAL AND GEOCHMICAL CHARACTERISTICS OF ORGANIC MATTER IN RECENT LAKE SEDIMENTS; THE ENVIRONMENTAL IMPLICATIONS

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The relationship between the type of organic matter (as determined by Rock-Eval® Analyses and organic petrology) and the distribution of mercury is studied for the sediment profiles from the boreal eutrophic lakes in Central Alberta and the oligotrophic lakes from the High Arctic, Canada.

The results show that the total organic carbon (TOC) in sediments consist of various organic compounds, which play a different role in the distribution and accumulation of Hg. The strong correlations between the organic matter and the sedimentary mercury in the studied sediments arise mainly from the pyrolysable portion of organic matter related to aquatic source. These compounds primarily consist of easily degradable algal-derived geolipids and various pigments, which are dominantly present as soluble organic matter (SOM) in the sediments. The S1 is a good indicator of the labile portion of algal-derived organic matter, which is highly susceptible to the degradation exerted by selective diagenisis processes in the surface sediments. This is evident as the sedimentary profiles often show a rapid decline in S1 content from the top few centimetres downward to the bottom of the sediment column. The organic petrology of S1 revealed the “fluid-like”, amorphous nature of these compounds, which fill in grain cavities, coating the sediment particles and cementing the fine grain particles together. The physical-geochemical property of S1 compounds provides a suitable organic substrate with enormous surface area for Hg and other organically-associated trace elements since they concentrate on the finer sized fractions.

S2 corresponds to the H-C bonds released mainly due to the thermal volatalization of the hydrogen-rich aliphatic biomacromolecules forming the cell walls of algal matter. The higher temperature yield of S2 is capable of thermally cracking the more refractory portion of algal-derived organic matter in recent sediments, which may not easily degrade during early diagenesis processes. Therefore, the quantity of S2 is likely to remain constant with little degradation throughout the surface unconsolidated sediments. Since the quantity of aquatic organic matter in sediments is determined by the balance between primary productivity, the preservation during the early diagenesis, and inorganic dilution, the estimated S2 flux (corrected for inorganic dilution) may serve as a suitable indicator of primary productivity in the aquatic sediments.

COMPARATIVE WEATHERING PROFILES IN GRANITE *vs* SLATES AND SCHISTS USING SEISMIC REFRACTION IN CANELAS (NW PORTUGAL): PRELIMINARY RESULTS

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Canelas area is located in Penafiel, on the North of the Douro River margin, being composed by steep slopes, exhibiting more 55% of inclination in several areas, it has a long record of problems related to slope stability.

Material on most hillsides is permanently moving down the slope at rates that can vary from imperceptible creep of soil and rock to landslides and rockfalls, moving at high velocities. These rates may depend on several factors such as topography, climatic conditions, vegetation, presence of water, anthropogenic factors, and of course time and lithology including subsurface weathering and erosion that can either act by increasing driving forces or decrease resisting forces.

The region is mainly constituted by Hercinic granites and Ordovician slates and schists. As we know these rocks have very different behaviour when exposed to erosion and triggering mechanisms, which are reflected on their different weathering profiles.

Currently, we are performing standard seismic refraction tests, using vertical and horizontal sensors, non-uniform distributed way, in order to compare weathering profiles in granites and slates to obtain a better knowledge of the depth and proprieties of these layers. The results of the P wave refraction profiles gives estimates on the variation in depth of weathering and the combined P and S velocity results can yield the estimates of mechanical properties such as Poisson ration, Shear Modulus and Young’s Modulus. In turn this information can be quite valuable, especially to the study of the spatial distribution and better understanding of the instability of various lithologic formations.

U-Pb DATING OF STREAM SEDIMENT ZIRCON IN WEST GREENLAND.

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Continental age structure is usually inferred from mapping in conjunction with detailed geochronology of few well selected samples. The approach is well founded, widely used and has been highly successful. Here we present an approach whereby detrital zircon in stream sediments from West Greenland are dated to characterise the local age distribution of each catchment area. The purpose is two-fold; firstly it aims at obtaining an age map of the West Greenland basement that better includes relative abundances of different age peaks. Secondly, it forms a source component benchmark for sediment provenance studies off the Greenland coast. U-Pb data is obtained through laser ablation ICP-MS and we aim for approximately 100 zircon grains in each sample where >10% discordant data is filtered out in $^{207}Pb/^{206}Pb$ relative age distribution diagrams.

A sample subset that represents the basement between 65-72°N was drawn from a large collection of stream sediment samples systematically collected in a regional geochemical mapping and exploration programme from drainage basins covering 10-30 km^2. There are two available size fractions, <0.1 mm, which has been analysed for major and trace elements, and 0.1-1 mm. We have mostly worked on 50-300 g splits of the <0.1 mm size fraction, but we are currently examining possible grains size effects on selected samples from the 0.1-1 mm fractions.

Samples south of the Palaeoproterozoic Nagssugtoqidian orogen display tightly constrained $^{207}Pb/^{206}Pb$ age distributions representing single populations, while samples from within the Nagssugtoqidian orogen often display dual populations; one Archaean and one 1.9 Ga. Episodic lead loss due to the 1.9 Ga event occurs intermittently, presumably reflecting local fluid activity rather than thermal conditions. There seems to be a trend of increasing age complexity northwards and closer to the ice margin. The former is due to Precambrian sediments with mixed provenance ages, while the latter presumably is due to glacial input. In comparison to Cretaceous sediments on and offshore West Greenland, the abundance of >3.5 Ga grains is low, which hints to unrecognised Eo-Archaean basement, possibly located under the current inland ice cap.

Zircon U-Pb dating of stream sediment is a fast and accurate method of obtaining the age structure of an unknown area, and might be particularly useful in finding rare age components as each sample is drawn from a greater area than is covered by more traditional sampling.

NORTHWEST TERRITORIES GEOSCAPE POSTER: ROCKS AND RESOURCES

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The Northwest Territories has both exciting geology and a rich history of mineral and petroleum resource exploration. This geoscape poster captures geological landscapes in key resource-rich areas of the NWT.

The geoscape poster is an information source for the general public, and a visual educational resource for teachers. Using geological diagrams with a minimum of explanatory text, it is designed to get students to ask questions, and as a starting point for research projects.

A web-based teacher's guide to accompany the geoscape poster may be developed in the future. The guide will include ideas for research topics, and more detailed information about geology, and mineral and petroleum resources of the NWT.

THE QUEEN MAUD BLOCK – REFINING PALEOPROTEROZOIC ASSEMBLY OF NORTHWESTERN LAURENTIA

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The Queen Maud Block (QMB) of Arctic Canada is unique in its crustal history. Geochemical and isotopic data obtained for the QMB provide important new constraints for our understanding of the Paleoproterozoic assembly of northwestern Laurentia. These data indicate: 1) Widespread 2.46 to 2.50 Ga felsic to intermediate magmatism, the eastern limit of which defines the boundary between the QMB and adjacent Rae domain. Felsic rocks with these emplacement ages are not known in the Rae domain and are in fact rare in North America. We have also documented the co-existence at the outcrop scale of QMB aged (2.45-2.50 Ga) and Neoarchean igneous rocks. This finding corroborates our conclusion from Sm-Nd isotopic data that the QMB magmas were derived from Neoarchean source rocks similar to those that gave rise to the granitoids of the Rae domain. 2) An extensive ~NE-trending 2.44 to 2.39 Ga sedimentary belt, herein termed the Sherman Group, which is dominated by 2.45 to 2.50 Ga detritus. 3) Regional ca. 2.39 Ga granulite-grade metamorphism, with no evidence of metamorphic or magmatic activity concurrent with orogenesis in the adjacent Taltson-Thelon belt at 1.9 to 2.0 Ga. These findings are at odds with tectonic models that propose the Taltson-Thelon and Queen Maud Block represent a mountain front and orogenic plateau associated with collision of the Slave and Churchill Provinces at ~1.97 Ga. We propose that the eastern QMB was the site of an incipient continental rift at ~2.5 Ga. Evidence for rift-related magmatism includes a brecciated mafic dyke yielding an age of 2516 ±14 Ma which is within analytical uncertainty of the host ca. 2500 Ma granitic and charnockitic rocks. Exhumation of 2.46 to 2.50 Ga granitoids produced during the early stages of rifting provided detritus to a short-lived basin that closed and underwent granulite-grade metamorphism at ca. 2.39 Ga. The switch from extensional to compressional environments could be a result of a Slave and Churchill collision at ~2.39 Ga or may represent far-field triggers affecting an intracontinental environment within an already contiguous Slave / Churchill craton.

QUASI-CORRELATION BETWEEN CARBON AND OXYGEN ISOTOPE SIGNATURES IN ECLOGITIC DIAMONDS AND THEIR MINERAL INCLUSIONS

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The carbon isotope composition of diamonds and the oxygen isotope composition of coexisting syngenetic coesite inclusions have been determined for eclogitic diamonds from Guaniamo (Venezuela), Argyle (Australia) and Orapa (Botswana) and found to be anomalous relative to accepted values for typical upper mantle materials. Diamonds were analyzed by in situ ion microprobe and by conventional combustion techniques, and coesites were analyzed using ion microprobes, both in situ and on grains released from diamonds by breakage. Anomalously high oxygen isotope values of coesite inclusions ($\delta^{18}O$ = +10.2 to 16.1 per mil V_{SMOW}) in Guaniamo diamonds are correlated with anomalously low carbon isotope values ($\delta^{13}C$ = -11.3 to -22.3 per mil PDB) in diamond hosts. Similarly anomalous values were measured in Argyle diamonds ($\delta^{18}O$ of coesites in the range +6.8 to +16.0 per mil and $\delta^{13}C$ of host diamonds in the range -10.3 to -14.1 per mil). Coesite in an Orapa diamond has $\delta^{18}O$ = +8.5 per mil in a diamond host with $\delta^{13}C$ = -9.0 per mil. Although there is a clear correlation between the anomalously high oxygen isotope compositions of coesites and anomalously low carbon isotope compositions of host diamonds, the relationship is neither linear nor smoothly curving as might be expected if the two systems were behaving in concert, as a result of precipitating from fluids or magmas undergoing fractionation in the upper mantle. Instead, the data are those expected for materials resulting from the sea floor weathering and low-temperature hydrothermal alteration of ocean floor basalt subsequently emplaced, together with admixed biogenic marine carbon, beneath the continents by subduction into the field of diamond stability. A variation on this hypothesis, in which subducted meta-basic ocean floor rocks merely serve as a substrate for metasomatic deposition of diamond from fractionated mantle fluids is not supported by our data. In the

latter model, low $\delta^{13}C$ diamond should be associated with eclogites of any oxygen isotope signature, whereas they have only been shown to coexist with high $\delta^{18}O$ silicates. Significantly, such anomalous data have been obtained from diamond suites from three continents, indicating that such processes have been widespread in Earth evolution, and important in the growth of the continents.

MINERALIZATION AND FORMATION OF THE SCHAFT CREEK PORPHYRY Cu-Mo-Au DEPOSIT

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The Schaft Creek porphyry Cu-Mo-Au deposit is a major unexploited pre-accretionary deposit occurring in the Cordillera of northwestern British Columbia. The deposit is hosted in the Triassic andesites of the Mess Lake facies, which is part of the Stuhini group.

The Stuhini group volcanic sequence is in turn hosted within the Stikina terrane in the Intermontane belt. The volcanic pile that hosts the deposit is comprised of a complex package of subaerial tuffs and mafic lava flows which are basaltic andesitic to andesitic in composition. The volcanic rocks are strongly variable in texture with aphanitic to plagioclase- and/or pyroxene-phyric flows and pyroclastic deposits of tuff to breccia size fragments.

The Triassic volcanic rocks are bound to the west by the Hickman batholith, which is a complexly zoned Jurassic-aged intrusive of granodioritic to quartz monzonitic composition. Dyke-like apophyses of this batholith intrude the Triassic volcanic rocks from the north of the Schaft Creek deposit area. These dykes trend roughly south-southeast and are discontinuous from the northern Paramount zone through to the Main Zone of the deposit, where the dykes are narrower and less abundant.

These intermediate dykes locally grade into zones of intrusive breccia, which in turn grade outwards to zones of hydrothermal breccia within the andesitic volcanic rocks. During cooling of the system, multiple fluid overpressure events produced these numerous hydrothermal breccia zones. These hydrothermal breccia zones grade outward to form a complex system of cross-cutting veins. One of the last events was a large, fairly low-temperature hydrofracturing event which produced the West Breccia zone.

Mineralization at Schaft Creek is strongly controlled by pervasive quartz-carbonate veins of variable thickness (millimetre to decametre width) and intensity (sometimes greater than 100 veins per metre), as well as by the abundant intrusive and hydrothermal breccias. The dominant economic ore minerals are chalcopyrite, molybdenite, and bornite. Pyrite occurs extensively in the propylitic zone surrounding the deposit and notably in the West Breccia zone, but is largely absent in both the Paramount and Main zones. Molybdenite from a chalcopyrite-molybdenite-bearing quartz vein in the Main zone has been dated at 222.1 ± 1.5 Ma (Re-Os model age), which is interpreted to represent the best estimate of the age of mineralization for the system.

Following mineralization, the system was tilted steeply to the south-southeast and was partly eroded leaving a poorly-exposed cross-section of the lower portion of the porphyry system.

BIOGEOCHEMICAL BASELINE CHARACTERIZATION OF ARCTIC GRAYLING IN THE CONTEXT OF FOOD-WEB RELATIONSHIPS, FORTYMILE RIVER MINING DISTRICT, EASTERN ALASKA

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Analyses of metals and stable isotopes of C, N, and S from stream sediments, waters, aquatic and terrestrial plants, insects, and Arctic grayling (*Thymallus arcticus*) – an important nonanadromous sport fish and the dominant predator in the Fortymile River – were used to understand the potential bioaccumulation of metals. The area has experienced over 100 years of placer gold mining, some using mercury amalgamation, but to date no bedrock mining. The watershed is characterized by slightly alkaline pH (7.7 to 8.2), low TDS (< 175 mg/L), moderate hardness (74 to 220 mg/L $CaCO_3$) and alkalinity (48 to 450 mg/L $CaCO_3$), high DOC (16.6 to 19.9 mg C/L), and low concentrations of As, Cd, Cu, Hg, Pb, Se, and Zn in waters and stream sediments. The $\delta^{15}N$ values of grayling muscle tissue have a narrow range (7.6 to 9.9 ‰) suggesting a limited trophic position approximately 2 to 3 levels above primary producers. In contrast, muscle tissue has a wide range of $\delta^{13}C$ (-31.7 to -25.6 ‰) and $\delta^{34}S$ (-8.4 to 8.2 ‰) values, reflecting a diversity of food sources (i.e., aquatic and terrestrial insects, larval fish) from geologically distinct environments, consistent with stomach contents of the fish and the geology of the watershed. The $\delta^{13}C$ values of the stomach contents (-31.1 to -25.3 ‰) are similar to those in the muscle tissue indicating that the stomach contents are representative of the diet of the grayling; the $\delta^{15}N$ values of the stomach contents (-6.2 to 5.6 ‰) are lower than those in the muscle tissue, consistent with isotopic fractionation between consumers and their diets. Hg concentrations are low and partition subequally between muscle (0.13 to 1.42 mg/kg, dry basis) and liver (<0.02 to 2.14 mg/kg, dry basis) tissue. Pb concentrations are higher in muscle than in liver, whereas Cd, Cu, and Zn concentrations are higher in liver than in muscle. Stomach contents generally have higher concentrations of Cd, Cu, Pb, and Zn than muscle tissue, but lower concentrations of Hg, suggesting that the grayling are bioaccumulating Hg. With regards to potential future mining in the district, geochemical baseline characterization should include biota, such as grayling, in addition to more traditional media such as surface and ground waters and stream sediments. Geochemical signatures of biota are best understood in the context of food-web relationships.

CHARACTERIZATION OF ARSENIC SOURCES AND REMEDIATION PLAN FOR THE GIANT MINE, YELLOWKNIFE

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The Giant Mine near Yellowknife, Canada operated from 1948 to 1999, producing over 7 million ounces of gold from an extensive network of underground workings and shallow open pits. The majority of the gold was refractory, typically encapsulated by arsenopyrite and pyrite. Key steps in the recovery process included flotation of the sulphide minerals, roasting to liberate the gold, and then leaching by cyanide. Approximately 237,000 tonnes of highly soluble arsenic trioxide dust were produced during roasting process. The arsenic trioxide was collected and placed in chambers and stopes in the underground mine. Tailings were stored in surface impoundments or used as backfill in the underground mine.

INAC and SRK carried out detailed sampling programs to characterize the main sources of loading in the underground mine and surface facilities. Results indicated that seeps from the arsenic trioxide storage areas have arsenic concentrations

of over 4000 mg/L, accounting for over 95% of the arsenic load in the underground mine water. The other main sources of loadings within the underground workings are seepage from the Northwest tailings pond (7 mg/L), and the backfilled workings (5 mg/L). The main surface sources include the treated effluent, tailings, and mill area. The underground mine water and surface runoff are currently pumped to the Northwest tailings pond and treated prior to discharge into the environment.

An integrated remediation plan has been developed and will be submitted for regulatory review under the Mackenzie Valley Resource Management Act. The arsenic trioxide storage areas will be frozen to hydraulically isolate them from the post-closure groundwater system. The workings will then be gradually allowed to flood. On surface, contaminated soils will be relocated to the tailings area prior to covering the tailings. Some of the more contaminated soils may be relocated to a frozen zone within the B1 Pit. The tailings will be covered and reclaimed. Ongoing monitoring programs will continue to evaluate potential arsenic loading from flooded sources in the mine and the requirements for long-term treatment

VOLCANIC ARCHITECTURE OF A PART OF THE ARCHEAN HOPE BAY GREENSTONE BELT, NUNAVUT

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The Hope Bay volcanic belt is an Archean greenstone belt, in western Nunavut, that is part of the Slave structural province. This north striking greenstone belt is dominated by mafic volcanic rocks with lesser felsic volcanic and sedimentary rocks. Mapping of two transects across the Hope Bay Greenstone Belt subdivides the volcanic rocks into distinct suites, some of which can be correlated between the transects based upon field, petrologic, geochemical, and geochronologic criteria. The Flake Lake transect is underlain by and interlayer with mafic volcanic suites and felsic volcanic suites and a large gabbro; contacts between volcanic packages do not outcrop but are inferred to be structural and stratagraphic. The Flake Lake Felsic Suite (2716-2700Ma), on the east is dominated by tholeiitic rhyolite with flat REE profiles as well as highly variable Nd and Hf isotopic compositions. The calc-alkaline Windy Felsic Suite (2685Ma), ranges from dominantly sedimentary to more proximal volcaniclastic rocks and coherent rhyolite flows and has homogenous Nd and Hf isotopic compositions in the coherent volcanics. The mafic volcanic suites are dominated by a suite of pillowed normal tholeiites with a less common suite of unusual pillowed high-Ti basalts and a suite of LREE enriched basalts (La = X5). The high-Ti basalts are incompatible element enriched, and spatially associated with the Boston deposit in the south part of the belt. The Clover Lake Transect, located west of the Flake Lake transect has two mafic volcanic suites, a felsic suite, and a sedimentary suite. The mafic volcanic rocks includes a suite of normal pillowed tholeiites to andesites as well as a tightly folded suite of pillowed normal tholeiites contain minor volcaniclastic interbeds and syn-volcanic gabbro intrusions. Conglomerate to argillite of the Clover Sediments separates the mafic volcanic rocks. The calc-alkaline Koignuk Felsic Suite (2677Ma) is separated from the other volcanic rocks in this transect by a fault. This suite is dominated by coherent volcanic rocks with some minor volcaniclastic rocks that are texturally and isotopically homogenous. Together, these transects provide a view of the geological evolution of the Hope Bay Greenstone Belt.

GEOCHEMICAL CONSEQUENCES OF DIFFERENTIAL SETTLING OF GOLD TAILINGS

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Differential settling of sulfides and carbonates in the mill discharge, 70 years ago, resulted in lateral zoning across the tailings at the Central Manitoba Gold Mine site. Close to the discharge, sulphide rich tailings, with a negative NNP, have depleted acid neutralizing calcite resulting in a pH of ~3. Remote areas, which accumulated less-dense carbonate-rich sediments, now have a positive NNP and a pH of 7-8. This has produced a lateral colour zonation across the tailings with an active chemical front characterized by green bands which concentrate Cu rich minerals such as brochantite.

The tailings deposit contains two ponds, the barren Blue Pond located near the discharge point and the Green Pond 100 m north of the mill site. The Blue Pond is impacted by acidic drainage from carbonate-poor, sulphide-rich tailings, and characterized by a pH of 4.4±0.1. Further from the water source, the Green Pond is surrounded by tailings with higher carbonate than sulphide content, giving a positive NNP and a pH of 7.4±0.4. Aluminum and copper are dissolved from the acidic oxidized tailings, precipitated in slimes in streams and then washed into the Blue Pond, where dissolution of $Al(OH)_{3(s)}$, jurbanite and basaluminite maintain the constant pH.

ARSENIC MOBILITY FROM ARSENOPYRITE-RICH GOLD MINE WASTE, SNOW LAKE, MANITOBA, CANADA

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High concentrations of arsenic occur in one groundwater monitoring well (MW17) at the gold mine site in Snow Lake Manitoba. The likely source of As is an Arsenopyrite Residue Stockpile (ARS). From 1948 to 1959, 250000 tons of arsenopyrite concentrate were stored in a waste rock impoundment, which was capped in 2000 with layers of waste rock, clay and silt. Another possible source is the emergency discharge area for Nor Acme tailings, through which MW 17 is drilled.

Pore water in the unoxidized zone of the ARS contains up to 100 mg/L total arsenic (<25 mg/L As (III)) possibly remobilized from secondary phases, amorphous iron sulfo-arsenates, scorodite and jarosite formed prior to capping by oxidation of primary sulfide minerals. Hydrological modeling suggests that As is transported into the aquifer below the ARS by advection and diffusion. The concentration of arsenic in other monitoring wells within the aquifer in the vicinity of the ARS and the Nor Acme tailings is <0.1 mg/L, and in the pore water of the tailings <5 mg/L. This indicates that the tailings are unlikely to be the source of the contamination. Attenuation of As in surface waters appears to be adsorption of As(V) on Fe-oxyhydroxides such as ferrihydrite, although in the aquifer the majority of the As is the more soluble As(III). Snow Lake, the source of drinking water for the town of Snow Lake has very low concentrations of As.

LITHOSTRATIGRAPHY OF NIGERIA - AN OVERVIEW

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Nigeria lies very close to the equator (hot country) North eastern Africa between latitude 4°N and 14°N and longitude 5°E and 12°E. The country is located at the Northern end of the Eastern branch of east Africa rift system.

Nigeria geological set up comprises broadly sedimentary formation and crystalline basement complex, which occur more or less in equal proportion all over the country. The sediment is mainly Upper Cretaceous to recent in age while the basement complex rocks are thought to be Precambrian.

The studied area lies between latitude 12.4" and 11.11"W and longitude 13.81" and 14.13" S. The studied area is underlain by Precambrian basement complex of southern western Nigeria. The major rock in the area is charnokite and granite rock. The granite rock which are member of the older granite suite occupy about 65% of the total area. The principal granite is petrographic variety are recognized. The fine grained biotite-granite medium-coarse, non porphyritic biotite -hornblende granite and coarse -porphyritic biotite -hornblende granite. Also three main textural type of charnokitic rock are also distinguished are coarse grained, massive fine grained and gneissic fine grained. The mode of occurrence of rock is three (1) core of the granite rock as exemplified by study area and few smaller bodies (2) Margin of the granite bodies as seen in Ijare and Uro edemo-idemo Charnokitic bodies and (3) Discrete bodies of the gneissic fine grained charnokitic rock within the country gneisses as seen in Ilaro and Iju and Emirin village. All the charnokite in the region are dark-greenish to greenish-gray rocks with bluish quartz and greenish feldspar.

MINERAL CHEMISTRY AND CLINOPYROXENE Sr-Pb ISOTOPE COMPOSITIONS OF MANTLE ECLOGITE XENOLITHS FROM THE JERICHO KIMBERLITE, NUNAVUT

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We report new findings on mantle eclogite xenoliths recovered from the Jericho kimberlite, Nunavut, including major and trace element mineral compositions and Sr-Pb isotope results from clinopyroxene. This study builds on previous research of the Jericho eclogite xenoliths.

The Jericho eclogite xenoliths studied here are generally bi-mineralic (garnet and variably altered clinopyroxene with garnet:clinopyroxene proportions ranging from 25:75 to 70:30) but can contain accessory phases such as kyanite, corundum, rutile, apatite and olivine. Major-element compositional data have been obtained from microprobe spot analyses on fresh garnet and clinopyroxene and reveal large variations in mineral composition. Based on the major element composition of both garnet and clinopyroxene, the Jericho eclogite xenoliths in this study are dominantly Type B, with lesser Type C and only one Type A. Temperature estimates for 14 xenoliths based on the Ellis & Green and Ravna calibrations of the garnet-clinopyroxene thermometer are in the range 900-1070°C (calculated at 50 kbar) and one olivine-bearing eclogite xenolith records a temperature of 1140°C. Kyanite ± corundum-bearing eclogite yield calculated pressures from the Ravna and Terry calibrations of 35 to 40 kbar at 950°C. The equilibrium conditions calculated for Jericho eclogites in this study fall within the previously reported temperature range of 850-1180°C.

Based on laser ablation ICP-MS analyses, the garnet and clinopyroxene trace element data indicate REE profiles similar to Diavik eclogites from previous research. The isotopic results for clinopyroxene isolated from three Type B eclogites indicate moderately radiogenic Sr compositions ($^{87}Sr/^{86}Sr$=0.7043-0.7054) and relatively unradiogenic Pb compositions ($^{206}Pb/^{204}Pb$= 17.0, $^{207}Pb/^{204}Pb$=15.5). The Sr isotopic results do not indicate a depleted mantle origin, as would be expected if the eclogites originated as remnants of unaltered subducted oceanic crust, and overlaps the range of compositions reported for Jericho whole rock kimberlite. The Pb isotopic results are more radiogenic than values previously reported for Diavik eclogites. If these data have age significance then the Jericho eclogites in this study could be as young as ~1.0 Ga, indicating that Jericho eclogites have a range of formation ages.

PERMAFROST AND TERRAIN MONITORING IN THE MACKENZIE VALLEY – APPLICATIONS TO NORTHERN DEVELOPMENT AND CONTRIBUTION TO INTERNATIONAL POLAR YEAR

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The Geological Survey of Canada (GSC) has conducted a permafrost research and terrain monitoring program in the Mackenzie valley since the mid 1980s. A network of field sites in representative terrain types has provided valuable information to characterize the thermal state of permafrost and changes occurring over the monitoring period, facilitating investigations of the impact of climate change. Several study sites in the Norman Wells oil pipeline corridor have facilitated investigations of the impact of northern development on the surrounding permafrost terrain. The existing network has significant gaps, particularly in the northern portion of the region. In response to increased hydrocarbon development in the region, GSC has undertaken, in collaboration with other government departments, to conduct a major field program to establish new field sites to improve characterization of permafrost and terrain conditions.

Thermal data collected since 1984 at undisturbed sites indicates a general warming of shallow permafrost ranging from less than 0.01°C to 0.07°C per year with greater increases occurring in colder permafrost of the central and northern Mackenzie valley. This warming is consistent with recent increases in air temperature but changes in snow cover are also important. Beneath the Norman Wells pipeline right-of-way (ROW), shallow permafrost has warmed in response to clearance of vegetation with temperature increases of up to 2°C since 1984. Warming of permafrost beneath the ROW has been accompanied by increases in thaw depth and in ice-rich terrain this has led to considerable settlement of the ground surface (up to 1 m). The climate signal has largely been obscured beneath the ROW by the response of the ground thermal regime to the larger surface warming associated with clearing. However, distinct interannual variability in the ground thermal regime and thaw depth has been observed at some sites in later years indicating the influence of climate variability. These results indicate that climate warming and variability may be a factor in long-term performance of northern infrastructure.

In addition to providing information essential for infrastructure design and assessment of environmental impacts, the monitoring network provides information essential for understanding the role of permafrost and the cryosphere in the arctic climate system. This network will represent an important component of the Canadian contribution to the International Polar Year project on the thermal state of permafrost.

STACKED UPPERMOST MANTLE LAYERS WITHIN THE SLAVE CRATON OF NW CANADA AS DEFINED BY ANISOTROPIC SEISMIC DISCONTINUITIES

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A data set of 336 teleseismic events recorded across a 20-station POLARIS seismic array in NW Canada between 2001 and 2006 provided sufficient distribution in back azimuth and epicentral distance to characterize uppermost mantle discontinuities between depths typical of the Mohorovicic and Lehman discontinuities. Following wave field decomposition, groups of seismograms were source-normalized through

simultaneous deconvolution to estimate the near-receiver impulse response and thus detect major discontinuities beneath each seismic station. Stations within the Lac de Gras kimberlite field display an unusually strong negative impulse on the radial component within the NW quadrant and two moderate impulses on the transverse component. Forward modeling of these impulses suggests a mantle layer dipping at 22° to the southeast with a mildly anisotropic upper discontinuity at 120-135 km depth and another mildly anisotropic discontinuity at about 170 km depth. Superimposed on these layers is another, stronger anisotropic layer between 110 and 180 km depths that dips to the west. Stations outside of the Lac de Gras field, but within the southeastern Slave craton, display more numerous, but weaker impulses. The most prominent of these occurs at about 150 km depth on the transverse component and has opposite polarity to that observed further north. The prominent negative impulse on the radial component is interpreted to arise from structural-preferred orientation in the form of a stockwork of kimberlite dykes beneath the Lac de Gras field. Interpretation of the other layers in the context of known surface geology as well as xenolith petrology and garnet geochemistry of diamondiferous kimberlites favors previous suggestions that they represent 4000-2900 Ma depleted harzburgite and eclogite layers underthrust from the northwest at 2600 or 1880 Ma. The layer beneath the SE Slave has a similar, but distinct tectonic history of underthrusting associated with the 2635-2615 Ma Defeat Suite of plutonism. Taken together, these interpretations indicate that the Slave craton was assembled from at least four lithospheric blocks prior to its cratonization about 2580 Ma: each block is 90–120 km thick and abut across a near-vertical boundary beneath MacKay Lake in the central Slave craton. Significant amounts of carbon could have become incorporated into the central Slave mantle within the diamond stability field during the proposed underthrusting of lithosphere.

MARS (UTOPIA PLANITIA) ON EARTH: THE MACKENZIE RIVER DELTA AND TUKTOYAKTUK COASTLANDS

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Speculation concerning Mars having been warmer and wetter than it is today has been ongoing since the 1960s and 1970s, when the Mariner missions returned images of surface features whose morphology was consistent with the work of water. As the resolution of surface images has become increasingly fine, so have the hypotheses linking Martian landforms to the influence of water, either in a liquid, glacial or transient (periglacial) phase.

We have identified commonplace landforms in Utopia Planitia, one of the great northern plains of Mars, that point to the presence (possibly very recent) of ice-rich regolith (from the near-surface to depth) and of a dynamic environment consistent with the formation of periglacial landscapes. The landforms include: 1. small-sized, polygonal patterned ground; 2. depressions suggestive of drained thermokarst lakes (alases) and ponds; 3. gullies formed on or near the rims of impact craters (sometimes in the area of the alas-like depressions); and, 4. pingo-like mounds in various stages of evolution (on the floor of impact gullies as well as on the surrounding plains).

Possible periglacial analogues of these Martian features are found in the Canadian Arctic. This provides planetary scientists with the opportunity to study near-to-hand landscapes that have formed under conditions that could be mirrored on Mars at some high obliquities.

Here we focus on comparative planetary geology. First, we describe the landscapes suggestive of periglacial activity in Utopia Planitia and the obliquity-driven climate changes linked to their origin. Then we turn to the Canadian arctic. Specifically, we explore the geological and climatological history of the Mackenzie River delta and the Tuktoyaktuk coastlands where the possible periglacial analogues occur.

By means of this exploration, we suggest that the setting and evolution of the arctic analogues could run parallel to that of the Utopian landscapes. In so doing, we underline the important role played by water in the geological history of Mars, up to and perhaps including the recent past, and point to climatic conditions that could intermittently be much more amenable to the origin of primitive life than has been thought hitherto.

ONE YEAR OF GROUND TEMPERATURE MEASUREMENTS FROM BENEATH BOTTOMFAST ICE, BEAUFORT SEA, CANADA

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Measurements of temperature variations beneath bottomfast ice (BFI) are important for improving our understanding of the viability of permafrost and associated sediment properties in the nearshore. Thermistor cables were installed beneath BFI in 4 boreholes in a transect extending from a distributary channel in the Mackenzie Delta across a nearshore shoal. Each thermistor cable included 8 thermistors with a dedicated logger. The cables and loggers were installed in PVC casing to a total depth of approximately 10 m below the seabed. Temperature at each thermistor was logged every 3 hours from April 2005 to March 2006. BFI thickness above the top of the casing varied from 5 cm to 105 cm. Where BFI was thinnest temperatures varied from -25°C at the seabed surface to -6°C at the base of the borehole in winter (summer temperatures varied from +10°C to -4°C). Temperatures at the base warmed slightly and, at the surface a 1.2 m thick active layer developed between June and September. Where BFI was thickest, sub-zero temperatures were confined to a depth of 3 m below the seabed during the winter months with complete thawing of the frozen surface layer by August. Temperature variations in the boreholes where BFI thickness was 30-70 cm were transitional between these two cases. These results demonstrate that ice-bonded permafrost can be maintained or aggraded where BFI thickness is 70 cm or less, but at BFI thicknesses greater than 100 cm permafrost is likely to degrade if present.

PROVENANCE OF CRETACEOUS AND PALEOCENE SANDSTONES IN THE WEST GREENLAND BASINS BASED ON DETRITAL ZIRCON DATING

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The extensive and deep ?Jurassic/Cretaceous–Palaeogene sedimentary basins offshore West Greenland have significant petroleum potential; in particular the offshore region west of Disko and Nuussuaq where a live petroleum system has been documented for many years. However, the stratigraphic knowledge in this area is almost non-existant. We will present the results of a large zircon provenance study that constrains current depositional models on regional and local scale. 4262 grains in 65 samples were dated, and we use a >10% discordance criteria to filter out perturbed data. The remaining 2735 data display a relative age distribution that is in accordance with a local to regional derivation from the West Greenland Precambrian basement in a large deltaic succession that was fed from east-southeast. Furthermore, the age distribution patterns indicate temporal and spatial variation that

has bearing on transport paths. ~1.9 Ga ages are abundant in the Nuussuaq Basin, but absent in the Nuuk Basin, while seemingly coupled 1.1 and 1.6-1.7 Ga peaks are present in both basins. These two age components are not readily explained by a West Greenland source and indicate exotic components. Rocks within the East Greenland Caledonides are of these ages, but the lack of Caledonian (0.38-0.48 Ga) ages seems to exclude this source. The Labrador and Grenville orogens on the Canadian side do, however, fit the observations and we argue that this is a likely source of these components, in keeping with the predominance of these components in the westerly deep marine strata. These associated peaks in both the Nuuk and Nuussuaq Basins suggest syn-depositional interconnection, but the lack of the 1900 Ma components in the Nuuk Basin suggests unidirectional transport paths from the south.

A dramatic change in the depositional environment in the Upper Campanian to Paleocene period is demonstrated by the provenance of marine turbidite successions at Itsaku on Svartenhuk Halvø. A hiatus separates this succession from the underlying Upper Albian to Lower Cenomanian deltaic succession, which has provenance ages that are typical for the deltaic successions described above. The turbidite succession is characterised by a tight normally distributed peak that is centred at 1.87 Ga and a few grains scattering towards 2.7 Ga. We infer a single zircon source for these sediments and the 1.87 Ga Prøven Igneous Complex (PIC) to the north is the best candidate, which implies a change in the sediment source from east-southeast to a point source from the north.

AN OVERVIEW OF CURRENT MINERAL EXPLORATION ACTIVITIES IN GREENLAND

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Greenland has within the last three years experienced quite a boom in the activity level as for both oil and mineral activities. The increased interest from the industry has partly been driven from an intense marketing of the potential of the natural resources of Greenland and partly from a favorable price trend on oil, minerals and metals. By the end of 2006, 40 exploration licenses, 14 prospecting licenses and 2 exploitation licenses were granted (or under application). This is the highest number of licenses since 1997. To comparison by the end of 2002 17 exploration licenses and 6 prospecting licenses were granted. There were no active exploitation licenses in 2002. The exploration activities are especially turned towards gold, molybdenum, zinc, nickel, rubies and diamonds. The total exploration expenses have multiplied in the years from 2002 - 2005 and were as high as CAD $39 million in 2005. In addition CAD $71 million were used on development costs in connection with the construction of an olivine mine in Southwest Greenland. There has not earlier been registered such an extensive exploration activity in Greenland.

Today Greenland has two active mines that employ about 200 people; the Nalunaq Goldmine in South Greenland and the Seqi Olivine mine in Southwest Greenland. In order to get as much local employment in these mines as possible, a number of educational initiatives such as English language courses have been initiated to qualify locals to work in the mines. Besides these two active mines there are at least three additional exploration projects that within the next 3-5 years have a potential to develop into future mines. Among these are the molybdenite deposit at Mestersvig in East Greenland, the ruby deposit at Qeqertarsuatsiaat in Southwest Greenland and the reopening of the Black Angel lead-zinc mine at Uummannaq in Northwest Greenland. Additionally highly promising results from diamond exploration in the areas southwest of Kangerlussuaq has granted hope of the presence of commercial diamond deposits in Greenland.

CO-MINGLING OF IMMISCIBLE METAL-RICH MELTS AT BROKEN HILL, AUSTRALIA

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Sulfide melt inclusions (SMINCs) in quartz and garnetite adjacent to the Broken Hill orebody document the liquid line of descent of the sulfide melt that was generated during granulite metamorphism. Not only do SMINCs sample melts at a given moment during melt evolution, but once trapped, SMINCs continue to evolve in a manner similar to the main melt mass. Melt compositions inferred from SMINCs indicate that during differentiation the melt becomes depleted in Zn, Pb and S and enriched in Cu, Sb, As, Ag and Au.

The differentiating phases appear to have gone from sulfides (galena, chalcopyrite, pyrrhotite and sphalerite), to sulfosalts (arsenopyrite and tetrahedrite-tennantite), to sulfur-poor alloys and metals (dyscrasite (Ag_3Sb), kieftite ($CoSb_3$) and antimony). These relations are seen both within the main orebody and within individual SMINCs.

To further elucidate this process, a series of experiments were undertaken, in which a carbon capsule was filled with crushed quartz grains and a pressed pellet of a homogenous sulfide mix was placed on top. Upon heating, melt generated from the sulfide pellet trickled down through the crushed quartz, solidifying over a range of temperatures, from 820° to 380°C at 5 kbars. These polythermal isobaric quartz trap experiments demonstrate *in situ* sulfide melt evolution. In these experiments, melts evolved from sulfur-rich to metal-rich and appear to contain at least two immiscible melts: one dominated by galena and the other an alloy melt with Sb and As.

Based on these observations we contend that enrichment in Sb and As during differentiation, combined with cooling, caused the sulfide melt at Broken Hill to un-mix into two or more melts. This process of sulfide melt fractionation eventually leads to extremely high Sb, As and Ag contents in “dropper ores” and accounts for the very high Au grades (1 g/t) in the garnetites surrounding the Pb-lodes at Broken Hill. The common occurrence of low-sulfur ore minerals (such as antimoids and native alloys, is typical of metamorphosed ore deposits (for example, Sulitjelma, Tunaberg and Hemlo), which suggests that this process may be common in differentiating sulfide melts.

DOCUMENTING THE CHEMICAL, PHYSICAL, AND THERMODYNAMIC CHANGES ASSOCIATED WITH ALL POSSIBLE GEOCHEMICAL REACTIONS IN ROCKS USING GALE VECTOR SPACE: AN OLIVINE SERPENTINIZATION EXAMPLE FROM THE JERICHO KIMBERLITE

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Metasomatic reactions associated with many geological processes (e.g., hydrothermal alteration, diagenesis, weathering, etc.) are typically difficult to specifically define because some reactants and products (soluble species) may be added or removed by the fluid, and evidence for their involvement in a reaction may thus be absent from a suite of rocks. As a result, given a known (observed) reactant and product mineral assemblage, one is commonly able to identify a myriad of feasible geochemical reactions responsible for the observed mineralogic changes. Determining which reaction actually operated to produce the observed change in mineral assemblage may thus be intractable without other mineralogical, geochemical, physical, or thermodynamic constraints.

Matrices of row and column vectors may be used to describe both the compositions of minerals and aqueous species, and the coefficients of these minerals and species in geochemical reactions. As a result, a number of matrix operations can be undertaken to provide insight into the nature of geochemical reactions involving minerals and species. One important result is a geometric representation of the geochemical reactions in a multi-dimensional Gale vector space. This space hosts vectors defining all possible reactions among the minerals and species under consideration, and thus can be used to systematically describe the feasible geochemical reactions. Because changes to rock geochemistry (e.g., H^+, other soluble ions), physical characteristics (mass, volume, and density), and thermodynamic properties (ΔG_r, ΔH_r, ΔS_r) can be determined for each feasible reaction, Gale vector space can be used to conclusively identify all possible reactions consistent with observed or inferred constraints (e.g., constant volume, observed density change, adiabatic conditions, or isothermal reaction). As a result, investigation of geochemical reactions in a Gale vector space provides a comprehensive and systematic way to identify all feasible chemical reactions using such constraints.

An example involving the several olivine serpentinization reactions that have each occurred in the different intrusive phases of the Jericho kimberlite is used to illustrate the features and power of using a Gale vector space in this application.

KIMBERLITES, ULTRAMAFIC LAMPROPHYRES AND CARBONATITES IN WEST GREENLAND – AN UPDATE ON OCCURRENCES, AGES AND DIAMONDS

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Kimberlites, ultramafic lamprophyres (UML) and carbonatites are all potential carriers of lithospheric mantle material including diamonds. Their spatial and temporal distribution has, therefore, implications for diamond exploration as well as for the understanding of compositional variations within the mantle.

In West Greenland, increased exploration and research over the last few years have been rewarded with the discoveries of new kimberlite and UML dyke occurrences, some of which are diamond bearing. New age determinations have confirmed the spatial distribution of the Neoproterozoic Sarfartoq-Maniitsoq province, and have revealed one new carbonatite and several ultramafic lamprophyre occurrences of Jurassic age. The latter have enlarged the Jurassic province considerably and opened an entirely new area in southern West Greenland between 63° and 64° N as a potential UML province.

Abundant mineral analyses of groundmass and xenoliths have recently been carried out on samples from kimberlite-lamprophyre dykes within the Neoproterozoic Sarfartoq-Maniitsoq province. The data have greatly improved the classification of rock types present and they have indicated that the lithosperic geotherm was uniform over the province. By contrast, interesting variations in magma compositions over the province have been identified. The new rock data corroborate spatial variations identified in distribution patterns of indicator minerals in systematically collected till samples. Follow-up of samples with peridotitic and eclogitic garnets have lead to the discovery of more kimberlites in the Maniitsoq area, some of which have proved to be diamondiferous. This has strengthened the value of indicator mineral data from Greenland.

Seismic surveys and drilling by an exploration company have confirmed encouraging dimensions and grades of a diamondiferous kimberlite dyke in the Sarfartoq area. The company has also recovered the hitherto biggest stones found in Greenland.

Acquisition of new chemical and isotope data from the Jurassic and Neoproterozoic provinces is underway, allowing comparisons to be made with their Labrador counterparts. The new data will lead to a better understanding of carbonatite, UML and kimberlite genesis and provide new insights into the tectonic evolution of the easternmost Canadian-Greenland shield and thereby its diamond potential.

GEOLOGICAL ENVIRONMENTS, MINERAL DEPOSITS AND METALLOGENETIC MODELLING, GREENLAND

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Shield and cratonization formation occurred from Eo-Archaean to Palaeoproterozoic time typified by formation of continental and oceanic crust, amalgamation of oceanic crust and arc-formed crust by emplacement of TTG plutons. The oldest plate tectonic formation happened in the Isua greenstone belt where it is suggested that intra-oceanic subduction zone-like geodynamic processes were operating as early as 3.7–3.8 Ga and island-arc conditions are described at ~3.07 and 2.8–2.9 Ga. The various Archaean terranes in Greenland are amalgamated to the North Atlantic Craton ~2.7 Ga. Banded iron formation (BIF), mostly Algoma type, chromitite (±PGE), and gold mineralisation is typical for the Archaean greenstone belts.

The Palaeproterozoic time comprised several orogenic mobile belts (1.8–1.9Ga). The Ketilidian orogen is juvenile and is evolved during northward subduction of an oceanic plate under the Archaean craton and is famous for its gold metallogeny. Contrasting is the slightly older Nagsugtoqidian orogen where the convergence is a continent-continet collision. Recently, it has been proposed that the Nassuqtoqidian-Rinkian belt is one orogenic system comprising a passive margin with a sedimentary sequence (Karrat Group), which has been transported southwards during subduction. The Karrat Group carries the Black Angel Pb-Zn mine and the supracrustal suites in the northern Nagssugtoqidian orogen (1950–1920 Ma) contain syngenetic massive sulphide occurrences.

Rift environments (incipient rift and basin; rift margins) comprise the major magmatic complexes such as the Mesoproterozic Gardar Province (Nb-Ta, U-Th and cryolite), the Neoproterozoic and Phanerozoic carbonatite (Nb, REE, apatite) and kimberlitic rocks (diamonds), and the Palaeogene magma provinces of East and West Greenland. The Palaeogene comprises world class mineral deposits such as the Skaergaard (~55 Ma; Pd-Au) and Malmbjerget (~26 Ma; porphyry Mo).

Sedimentary rocks deposited in rift basins are registered in Greenland from Meosproterozic time to present. From a mineral deposit point of view the most important ore deposit types are sedimentary copper, SEDEX, MVT, evaporites and placer deposits. Sedimentary copper deposits in sandstone occur in the Mesoproterozoic and Neoproterozoic sediments, and as red bed type in Trias. Shale-hosted SEDEX deposit of Silurian age occurs in the Franklinian basin. The MVT-type deposits of Pb-Zn-Ba in carbonates are located in the Franklinian Basin and as veins (Cu-Pb-Zn) in Upper Permian – Lower Triassic basins together with evaporites and deposits of celestite and barite.

RESOURCE POTENTIAL: MULTIVARIATE DATA REFLECTING GOLD OCCURRENCES AND GEOLOGICAL ENVIRONMENTS IN THE NUUK REGION, SOUTHERN WEST GREENLAND

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Visual inspection and comparison of regional geoscientific data is a necessary way of interpreting geological features, metallogenic provinces and resource potential across poorly exposed or explored and/or remote regions. In mineral exploration, the data are scrutinized visually in order to identify anomalies, which may reflect mineral occurrences. However, visual inspection of data can easily overlook subtle deviations, and visual correlations between data are often limited to a few parameters and multi-variable relationships are easily overlooked, too complex or not deducible.

The talk presents results from the application of a statistical approach in the Nuuk region. It was investigated how areas with known gold showings are expressed in 68 different regional data sets (stream sediment geochemistry, aeromagnetic, aeroradiometric and lineament data). The objectives were to identify new areas with gold potential, and to quantify the multi-variable signatures of the gold mineralised areas.

The gold mineralised areas could be divided into three groups based on their multivariate signatures. All groups had high Ni/MgO and high Cs in stream sediment as a common feature, while signatures involving Cr, Fe_2O_3, La, MgO, Ni, Rb, Th and U in stream sediment and some aeromagnetic and aeroradiometric parameters were distinct among the groups. The characteristic signature for each group is used to predict sites with potential for gold mineralisation in areas without known showings. Fieldwork in some of the areas predicted most favourable have been carried out to verify and explain the obtained signatures and test the gold potential. Results from this work will be presented.

The results obtained in the first tests of the statistical method have been positive in the sense that areas with high probability for new gold occurrences were outlined in geological settings that would otherwise be regarded as prospective for gold. This has encouraged us to enlarge the area and identify multivariate signatures predictive of gold mineralised environments in most of West Greenland. The method has a potential to identify and map other kinds of mineralisation as well as specific litho-tectonic units in poorly known or poorly exposed areas, and can be used on local or continental scale depending on the resolution of the involved data sets.

INFLUENCE OF LANDFAST ICE ON THE DEVELOPMENT OF SEASONAL FROST IN THE NEAR-SHORE ZONE OF THE MACKENZIE DELTA

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In the near-shore zone of the Mackenzie Delta, the distribution of landfast ice plays an important role in the development of seasonal frost within sub-bottom sediments. In order to further understand the influence of ice conditions on the susceptibility of sediments to frost, Ground Penetrating Radar (GPR), drill core and ground temperature measurements were collected.

Over the winters of 2005 and 2006, the near-shore ice complex was classified into three zones which included 1) bottom-fast, 2) floating and 3) transitional ice. Significantly different thermal conditions occurred beneath each of these ice zones due to the presence of water or ice at the sediment bed. With the onset of Bottom-fast Ice (BFI), heat was readily conducted from the ground, whereas beneath floating ice, temperatures at the sediment bed were in thermal equilibrium with the water column. The loss of heat under BFI conditions was controlled by the Ice Contact Time (ICT) with the sediment bed. Beneath the BFI, seasonal ice bonding extended up to a depth of 3 m and in some cases permafrost was present. In contrast, less than 1 m of frost formed beneath the zone of transitional ice, due to a shorter ICT and a lateral flux of heat from adjacent regions of floating ice.

Over the two consecutive winters, ice conditions interpreted from GPR data indicated that the extent of BFI was less in 2006. The response to changes in ice conditions resulted in an increase in the extent of floating and transitional ice zones. Additionally, a shorter ICT was noted to occur beneath some zones of BFI. As a result, the penetration depth of seasonal frost was less and at some locations absent when compared to the pervious winter. Ice conditions in 2006 were also more conducive for the formation of suprapermafrost taliks, which were not observed in the previous winter. The data show that the development of seasonal frost in response to the timing and thickness of sea ice has an impact on permafrost conditions in the coastal zone.

CORRELATION OF ARCHEAN TO MESOPROTEROZOIC UNITS BETWEEN CANADA AND GREENLAND: THE ACCRETIONARY HISTORY OF TRANS-HUDSON OROGEN WITHIN AN ASIAN (HIMALAYAN) CONTEXT

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Based on available tectonostratigraphic, geochronological, and structural data, we propose the following sequence of tectonic events and correlations for Northeast Laurentia from the Archean to Mesoproterozoic: (1) Cratonization of upper-plate Rae craton by 2.7–2.6 Ga; correlation of Thule Mixed Gneiss Complex, Kap York Metaigneous Complex, and Melville Bugt Orthogneiss Complex (Greenland) with Rae craton (Baffin Island); correlation of Lauge Koch Kyst Supracrustal Complex (Melville Bugt) with Mary River Group (Baffin Island). (2) Deformation and magmatism along the northern margin of Rae craton at 1.96–1.91 Ga; correlation of metasedimentary rocks of Ellesmere-Devon terrane (Canada) with Etah Group (Greenland), and metaplutonic rocks of Ellesmere and Devon islands with Etah metaigneous complex (Greenland). (3) Accumulation of a continental margin sequence along the southern margin of Rae craton ca. 2.16–1.88 Ga; correlation of Piling and Hoare Bay groups (Baffin Island) with Karrat Group, Anap Nunâ Group, Naternaq supracrustal belt, and Nordre Strømfjord supracrustal suite (Greenland). (4) North-south convergence and accretion of Meta Incognita microcontinent to the southern margin of Rae craton ca. 1.88–1.87 Ga and correlation of Cumberland batholith (Baffin Island) with Proven igneous complex (Greenland). (5) Collision of upper-plate North Atlantic craton with the southern margin of Rae craton in Greenland ca. 1.86–1.84 Ga (Nagssugtoqidian orogenic belt), and with the eastern margin of Meta Incognita microcontinent in Labrador ca. 1.87 –1.85 Ga (Torngat orogenic belt); correlation of Archean orthogneisses and supracrustal units of Nain craton (Labrador) with those of North Atlantic craton (Greenland), the Ramah, Mugford, and Snyder groups (Labrador) with Maligiaq supracrustal suite (Greenland), and Burwell arc (Labrador) with Sisimiut charnockite suite (Greenland); (6) Establishment of an active (Andean-type) margin along the southern margin of the upper-plate North Atlantic craton in Labrador (Makkovik orogenic belt) and Greenland (Ketilidian orogenic belt) ca. 1.89–1.80 Ga; correlation of the Moran Lake and Post Hill groups

(Labrador) with the Vallen and Sortis groups (Greenland), and possibly Aillik Group (Labrador) with Julianehåb batholith (Greenland). (7) Accretion of Narsajuaq arc terrane to the southern margin of the composite upper-plate Churchill domain at 1.845 Ga, (no correlative in Greenland). (8) Collision of the lower-plate Superior craton with the Churchill domain ca. 1.82–1.795 Ga (no correlative in Greenland). (9) Accumulation of upper-plate Mesoproterozoic rift sequences and emplacement ca. 1.3 Ga plutonic suites; correlation of Borden and Thule basins of Baffin, Ellesmere, and Devon islands with that of north-western Greenland, and Gardar Igneous Province (Greenland) with Seal Lake Group and Harp dykes (Labrador).

ULTRAMAFIC ALKALINE MAGMAS (MEYMECHITES) FROM THE MID-ARCHEAN IVISARTOQ GREENSTONE BELT, SOUTHWEST GREENLAND

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A magnetite-rich, grey-green schistose layer, 10 to 50 m thick, in the composite Ivisartoq greenstone belt is interpreted as an ultramafic volcanic unit. This rock is exposed over a strike length of 8 km and is located between amphibolites with pillow lava structures in the northern part of the belt and intensely deformed banded amphibolites to the south. U-Pb zircon ages by laser ablation-ICPMS suggest that the unit and associated amphibolites are 3.1 Ga or older.

We mapped and sampled two detailed transects through the ultramafic unit. The mineralogy of the schists is composed of magnetite, chlorite, tremolite, phlogopite, talc and serpentine, overprinted by pyroxene and less abundant olivine porphyroblasts. The samples have very unusual but, despite the schistose nature of the rocks, remarkably consistent geochemical characteristics: high MgO (18-24.wt %), Fe_2O_3 (total) (17-22 wt %), Ni (450-1500 ppm), Cr (620-1560 ppm) and TiO_2 (1.1-3.4 wt %), and very low SiO_2 (mostly 41-45 wt %), Al_2O_3 (3.7-6.5 wt %) and Al_2O_3/TiO_2 (1.9-4.3). Incompatible trace element concentrations are highly enriched (Nb, La ~ 20 to 150 times primitive mantle values) and strongly fractionated ([La/Sm]pm=1.8-4.5; [Gd/Yb]pm=2.6-7.9). Primitive mantle normalized spider diagrams for the rocks do not have negative Nb-Ta anomalies, precluding significant crustal contamination of their parent magmas or subduction zone enrichment of their source regions. Initial epsilon-Nd values (3.1 Ga) range from -0.6 to +2.3, indicating both enriched and depleted mantle sources.

We interpret the protolith of the unit as the first reported occurrence of meymechitic volcanic rocks in the Archean. They formed by very small-degree melting (<5%) of the deep Archean mantle, either in the lower part of thick (200 km) subcontinental mantle lithosphere or in the asthenosphere below. The iron-rich nature of the Archean meymechites is strong evidence for the proposal that the Archean mantle was more iron-rich (chondritic) than the pyrolite composition of the present-day upper mantle. The Ivisartoq discovery also demonstrates that both enriched and depleted components occurred at great depths in the mid-Archean mantle, and could be tapped during the same melting event.

SEISMIC ANALYSIS OF UPPER CRUSTAL INTRUSIONS IN THE EASTERN ATHABASCA BASIN, NORTHERN SASKATCHEWAN, CANADA

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Regional and high resolution reflection surveys, in three separated areas of the Paleoproterozoic Athabasca Basin, identified zones of anomalously high reflectivity. These bright reflections extend through all the seismic profiles, some with lengths of over 160 km. The depth of these reflective bodies ranges from ~ 6 to 13.5 km (2.00 – 4.0 sec, TWT). In several locations, the reflector is offset by shear zones. In some localities these faults zones ascend near to the surface. The highly comparable seismic signatures of the isolated surveys, suggest that the tabular bodies extend over at least 25,000 km^2. The anomalous large amplitude of seismic signals indicates significant acoustic impedance contrast in a vertical zone of 50 to 150 m. The origin of these enigmatic sheet-like complex zones is not resolved. One suggestion is that they are sill-like bodies, subsurface expressions of the ca. 1,265 Ga (post-Hudsonian) Mackenzie diabase suite. Amplitude strength, instantaneous frequency, apparent polarity and other seismic signal attribute analysis; however reveal that a variety of geologically acceptable acoustic impedance contrasts, including remnant fluid inclusions, cannot be ruled out. The region of the anomalous subsurface reflectivity property is under extensive mining exploration; therefore resolution of the true nature of the complex geology interval of the upper crust has a major importance.

1:550,000 SCALE BEDROCK GEOLOGY COMPILATION AND REGIONAL SYNTHESIS OF PARTS OF THE HEARNE DOMAIN, WESTERN CHURCHILL PROVINCE, CANADIAN SHIELD, NUNAVUT AND MANITOBA, CANADA

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This digital compilation integrates recent and archived geology maps and provides a seamless bedrock geology map of a portion of the Hearne domain, west of Hudson Bay. Geochronology, geochemistry, thermobarometry, metallogeny, geophysical data have been incorporated, and collectively used to present a regional tectonometamorphic and metallogenic synthesis. Databases used vary from unpublished data maintained by an individual scientist to data captured from a national data warehouse. Digital data was originally compiled using FIELDLOG and AutoCAD, with final output generated with ESRI`s ArcGIS and ArcInfo software. The geochronology data are available for viewing and download from the National Geoscience Data Repository (GDR) website (http://gdr.nrcan.gc.ca/index_e.php).

The northwestern Hearne includes (1) Archean supracrustal and intrusive rocks of the MacQuoid Homocline, structurally overlain by (2) ca. 2720-2655 Ma, juvenile volcanic and ca. 2684-2655 Ma plutonic rocks; (3) ca. 2700 Ma Cross Bay plutonic complex. These are overlain by ca. 1850-1700 Ma intracontinental, supracrustal and intrusive rocks of the Paleoproterozoic Dubawnt Supergroup. The central Hearne is composed of Archean supracrustal sequences and granitoid gneisses, Paleoproterozoic cover-sequences, and ca. 1830 Ma granite intrusions. U-Pb (zircon/monazite) ages indicate formation of the Archean crust between 2711-2667 Ma. Geochronological and geochemical data suggest an extensional, oceanic supra-subduction setting for the development and evolution of the Archean supracrustal belt. The rocks within the northwestern and central Hearne domain record complex tectonometamorphic reworking at ca. 2.55-2.5, 1.9, 1.83, 1.75 Ga. The southern Hearne is comprised of Mesoarchean and Neoarchean granitoid gneisses, supracrustal rocks of uncertain age, and by Paleproterozoic intrusions. Its detailed tectonometamorphic framework remains to be established, but it appears to be distinct from the northern/central Hearne and may include gneisses older than 3.0 Ga.

The Western Churchill Province is host to a variety of mineral deposits and prospects associated with various lithostratigraphic sequences. Archean deposit types include VMS, iron-formation-hosted and vein gold, and PGE-Cu-Ni in mafic/ultramafic rocks. Proterozoic deposit types include unconformity type uranium mineralization, vein gold and iron-formation-hosted gold in Paleoproterozoic and Archean supracrustal sequences, paleoplacer gold in quartz-pebble conglomerate at the Archean-Proterozoic unconformity, sediment-hosted copper + silver, fracture-controlled uranium, sediment and volcanic-hosted uranium, U+Th+REE-bearing alkaline intrusions, diamonds associated with lamprophyre/kimberlite magmatism, granite-related polymetallic vein systems, and synsedimentary uraniferous phosphate. The gold-rich Kaminak greenstone belt with infolded Hurwitz Group rocks exemplifies the superposition of Archean and Proterozoic metallogenic processes. The diverse and complex expression of mineral deposit types reflects a protracted and overlapping Archean-Proterozoic thermotectonic evolution.

FLUORIDE IN GROUNDWATER OF THE TALCHER-ANGUL REGION, ORISSA, INDIA

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At concentrations above 1 mg/L, fluoride in drinking water can be dangerous to human health, leading to dental and skeletal fluorosis. According to UNICEF, fluorosis is endemic in 25 countries across the globe, afflicting tens, perhaps hundreds of millions of people. As there is no treatment for fluorosis, prevention is the only means of controlling the disease.

Previous studies have approached the problem of excess fluoride in drinking water in one of two ways: 1) researchers have attempted to provide an explanation for elevated concentrations of fluoride in groundwater, and 2) defluoridation strategies have been explored. While experimental work has shown, for example, that certain chemical species enhance fluoride sorption and removal from aqueous systems, it is the assertion of this paper that that information alone is insufficient for the development of appropriate remediation strategies.

This study takes a new approach to addressing the problem of defluoridation by investigating the geochemical relationships between fluoride and other groundwater constituents and conditions present in a contaminated area, and argues that understanding these relationships is integral to understanding how to approach remediation. Using data generated by fieldwork, this paper will probe the geochemical relationships that exist between fluoride and other parameters present in the natural environment, and will examine the complex relationship that obtains between those other parameters.

To provide the data necessary for the study, groundwater samples were collected from 93 sites in the Talcher-Angul region of Orissa, India, an area known for fluoride-contamination. *In situ* field analyses performed on the groundwater included pH, temperature, alkalinity, conductivity and fluoride and nitrate concentrations. Subsequent laboratory analyses were performed on 0.45 μm-filtered samples, collected at 52 of the sites, using Inductively Coupled Plasma - Atomic Emission Spectroscopy (ICP-AES) to determine metal concentrations and Ion Chromatography (IC) to ascertain anion concentrations in the groundwater.

Geochemical modeling was used to determine the major species present in the groundwater, as well as to identify the saturation indices for all possible minerals. Multivariate statistics, primarily principal components analysis (PCA), were then used to develop geochemical associations as well as to detect anomalies.

LITHOFACIES AND STRUCTURAL CONTROLS ON Zn-Pb MINERALISATION AT GAYNA RIVER, NWT

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Zn-Pb mineralisation at Gayna River, NWT is hosted by Neoproterozoic (ca. 880 Ma) carbonate rocks of the Little Dal Gp. (Mackenzie Mountains Supergroup; MMSG). Coarse red and green sphalerite and associated dolospar are predominantly void-filling and of presumed Paleozoic age. Most of the known mineralisation is in two stratigraphic units corresponding to the 'Grainstone formation' (informal GSC terminology). Surface exposures and drill-core data indicate that mineralisation (cumulative ~50 Mt over numerous zones; >5% Zn+Pb) is largely fracture-controlled and spatially associated with giant microbial reefs (>500 m thick; kilometres in diameter) of the underlying formation (the informal 'Basinal assemblage'), but the reason for and mechanics of this relationship have not been adequately explained.

Previous work illustrated a complex interplay between reef growth, reef-margin deposits, and off-reef sedimentation patterns. The geometry of the homogeneous, unbedded reef masses within the enclosing, compacted, layered Basinal assemblage and Grainstone formation was critical to focusing later fluid flow. The final phases of reef growth resulted in a sharp angle at all reef-top margins, where heterogeneous, interlayered, off-reef limestone, shale and dolostone units abut the rigid, lithologically homogeneous reefs. These inflection points formed a zone where stress was taken up by the more mobile, layered off-reef strata, both during burial compaction, and during later tectonism in the Phanerozoic. Brittle deformation of the carbonate units in response to these stresses was, therefore, most pronounced in haloes around reef-top margins, and the resulting fracture systems were subsequently filled by Zn-Pb sulphides. Detailed mapping of depositional lithofacies may provide a vector to as-yet unrecognised subsurface reef-margin zones favourable for Zn-Pb mineralisation. Mineralisation may also be present in the subsurface north and west of the known showings, where buried reefs may be present.

Mineralisation at Gayna River developed owing to the intersection of two structural features: the reef belt, and an inferred, underlying, deep-seated, repeatedly reactivated NE-trending transfer fault, identified from regional isopach and lithofacies patterns in the MMSG, which focused fluid flow into the reef-related fractures. Mineralisation is unknown from the same host rocks at any distance from the inferred fault, and absent where the same host units lack a reef association.

STRATIGRAPHY AND ECONOMIC POTENTIAL OF THE MESOPROTEROZOIC BYLOT BASINS OF ARCTIC CANADA AND GREENLAND

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The unmetamorphosed, ca. 1.2 Ga Bylot Basins span the Arctic islands from Somerset Island to northwestern Greenland and represent Mesoproterozoic aulacogens along Laurentia's continental margin. The basins have similar kilometre-scale stratigraphic patterns recording early to late rifting. The Bylot Supergroup of the Borden Basin (northern Baffin Island) is the thickest (~6 km) and includes an upper group, recording east-directed compression and basin inversion, which is absent from the other rifts. Post-Mesoproterozoic tectonic events were limited to the emplacement of 723 Ma Franklin dykes.

Carbonate strata of the Mesoproterozoic Uluksan Group, Bylot Supergroup, host numerous base-metal showings, including the

Zn-Pb-Ag deposit mined at Nanisivik (1976 - 2002). The timing of mineralisation is unclear: suggestions range from Mesoproterozoic to Ordovician. The main host rock is the Society Cliffs Formation (200 - >1000 m), which was deposited during ongoing, comparatively subtle extension. Historically, all dolostones at a particular stratigraphic position between shales in the Borden Basin were assumed to be the same unit, but it is now clear that the so-called Society Cliffs Formation comprises four distinct dolostone units with unique temporal and geographic distributions. A combination of structural (faults) and stratigraphic/lithologic conditions were prerequisites for mineralisation. Three distinct structural/stratigraphic settings for mineralisation correspond roughly to three geographic areas in the basin. Two of these showing types are hosted by deep-water carbonate laminite; the third is hosted by a shallow-marine ramp consisting of carbonates and interbedded terrigenous material, in the vicinity of major normal faults in basement.

Although carbonate rocks that correlate loosely to the Society Cliffs Fm. (*sensu lato*) are present in the other Bylot Basin aulacogens, base-metal showings are so far unknown. The Hunting Formation (>1000 m; Aston & Hunting Basin, Somerset Island) has limited geographic exposure, is largely peritidal, is not underlain or overlain by shale, lacks basinal laminite, is not exposed in proximity to major normal faults, and is unconformably overlain by Paleozoic rocks. The Narssârssuk Fm. (~1000 m; Thule Basin, Greenland) has extremely limited geographic exposure, and consists of predominantly peritidal carbonate and terrigenous lithofacies. Carbonates of the Fury and Hecla Basin (northwest Baffin Island) are sparse and poorly known. It is unclear whether or how the east-directed compressional event recorded in the Borden Basin was expressed in these other basins, and what role it played in mineralisation.

WATER CHEMISTRY AND NOBLE GASES IN PERENNIAL SPRINGS AT BEAR CAVE MOUNTAIN, FISHING BRANCH RIVER, YUKON

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The field site is located at Bear Cave Mountain on the Fishing Branch River in western Yukon near the Arctic Circle. This site is in the continuous permafrost zone and is underlain by Devonian carbonates. The focus of this work is on perennially flowing springs along the river by this mountain. Springs are between 5°C and 7°C, which is warmer than expected in continuous permafrost, and they prevent the river from freezing over. Salmon come up the river to spawn in the warmer waters from the springs. Many bears return to this area annually to feed off the salmon in the river. As of 1999 the area is part of the Fishing Branch Ni'iinlii'njik Park. The objective of this study is to understand the source of the springs and determine why the water is warm.

Results from the 2006 field season will be presented. In the field river discharge was measured and samples were collected of water and dissolved gas. Water samples are being analysed for dissolved ions, tritium, and isotopic analysis of oxygen, hydrogen and carbon. Water chemistry is being used to determine water sources and noble gases to calculate spring water mean residence time. Discharge was found to increase from 10.4 m^3/s to 24.3 m^3/s along the length of the mountain. Bedrock springs have a distinct $\delta^{18}O$ and $\delta^{2}H$ signature and are likely not as important to river flow as was originally suspected. Active layer melting is likely also a major contributor to river flow. Dissolved gas samples were collected and are being analyzed for noble gases.

For the 2007 field season further sampling will include more extensive flow gauging and sampling to better determine the contributors to river flow. This talk will outline the results of analysis that have been conducted as well as an outline of the 2007 field season.

EDGEO EARTH SCIENCE TEACHER WORKSHOPS: CURRENT SUCCESS AND VISIONS FOR THE FUTURE

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EdGEO is a national program, which supports Earth science workshops for teachers. Each workshop is organized locally by groups of educators and geoscientists, to provide teachers with geoscience information, hands-on activity ideas, resources, networking opportunities, as well as increased confidence and enthusiasm to teach earth science with their students.

Over the last five years EdGEO has supported 69 workshops for 1,284 teachers (growing from 170 in 2002 to 377 in 2006). The total cost per year has increased from $14,420 to $25,510. The focus of workshops depends on the local emphasis, and has ranged from understanding of regional geology and field trip based workshops (e.g. Nova Scotia, Drumheller, Burgess Shale), to curriculum based workshops (e.g. Calgary, Victoria, Vancouver, Ottawa, Manitoba). There have been Geoscape focused workshops, rock walks, workshops held together with the GAC-MAC National meetings (since 2003), and workshops held in conjunction with teacher conferences. The majority of workshops attract in-service teachers, however in 2005 and 2006, four workshops in Victoria were held specifically for pre-service teachers. While workshops in Alberta, Nova Scotia, Saskatchewan and British Columbia have formed the core of EdGEO for many years, regional coverage has increased with new workshops hosted in the NWT, Yukon, Ontario, Quebec, Manitoba, New Brunswick and Nunavut.

As we head into an IYPE in 2008, in a world ever more in need of Earth science awareness, EdGEO will encourage broader access to and participation in, Earth science workshops, by seeking opportunities associated with;

- Teacher conferences and professional development events, nationally, regionally and locally
- Collaborative initiatives between Faculties of Education and Departments of Earth Sciences at Canadian Universities and Colleges, targeting pre-service teachers
- Fostering links with other related areas of the school curricula such as Social Studies

EdGEO may also wish to consider establishing a program of 'packaged' curriculum linked workshops which could be carried out at schools requesting the program, by trained volunteers (e.g. graduate students, retired earth scientists). This would necessitate an influx of new funds to support both training and travel, as well as teacher resource costs.

GEOSCIENCE IN BRITISH COLUMBIA HIGH SCHOOLS: UNDERSTANDING THE STUDENT EXPERIENCE - UNIVERSITY STUDENT RETROSPECTIVES

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A survey of students in a first year Earth Science course at the University of Victoria was carried out in 2005 to gather information on the high school Earth science experience from a student perspective. Questions focused on the amount and type of exposure to Earth science, enjoyment and interest in Earth science in high school, as well as perception of the relevance of Earth science to society. Seventy percent of respondents attended high school in BC, 59% were female, 62% were aged between 16 and 20, and 26% between 21 and 25.

Over half of the students indicated they had not studied Earth science in Grade 10 and 61% of students estimated that Earth science occupied less than 15% of the overall time spent on

science in high school. Ninety four percent of students indicated that they never or rarely did Earth science lab work in high school, and 86% recalled never or rarely going on Earth science fieldtrips. In terms of interest, 83% of students rated Earth science 6 or more (on a scale of 1-10, 10 is most interested and 1 least interested), and 69% rated Earth science as 6 or higher for their personal enjoyment of the subject in high school. Written comments explaining these ratings suggest that interest and enjoyment of geoscience in high school are strongly influenced by;

1) Amount of time spent on the subject e.g. "I was really interested in the material but there was a minimal amount of time devoted to the topic"
2) The enthusiasm of the teacher e.g. "to be honest, I think my limited interest was greatly due to the lack of an inspiring instructor. In high school, the subjects I liked were because my teacher was passionate about it. This could include class, fieldtrip work, most importantly making it relevant to my life"
3) Teaching methods e.g. "no hands-on or experiments, just text work", "due to the fact that this is not a major subject in school, it was interesting but not well taught".

Eighty two percent of students agreed or strongly agreed that Earth science is relevant to society. The three most common explanations were a) how the Earth works and how processes impact us, b) awareness of disasters or hazards and prevention, and c) resources, sustainability and the environment. Smaller numbers of students cited knowledge of Earth's past, predicting future issues, global warming and weather.

CRUSTAL GROWTH AND TERRANE AMALGAMATION IN THE ARCHAEAN NORTH ATLANTIC CRATON OF SOUTHERN WEST GREENLAND

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The Archaean North Atlantic craton in the Godthaabsfjord region of southern west Greenland, has long been known as a region of terrane amalgamation. Two large Mesoarchaean blocks, the Akia terrane in the north, and the Tasiusarsuaq terrane in the south, bound a central zone of Palaeo- and Mesoarchaean gneiss complexes, including remnants of supracrustal belts, gabbro-anorthosite complexes and younger granitoid plutons. Four smaller terranes have previously been distinguished in the central zone. Recent work has highlighted the pre-algamation histories of some of these terranes, resulting in a picture of repeated crustal growth by subduction-related magmatism and deposition of supracrustal rocks in arc and back-arc settings, followed by complex deformation at amphibolite to granulite facies grade. The final amalgamation took place ca. 2.7 Ga in an overall NW-vergent overthrusting regime. In some cases obvious folded crustal-scale shear zones separate the terranes, but other terrane boundaries are cryptic. Although these six terranes form coherent, but deformed blocks, minor slices of rocks with distinct ages occur as well.

The structurally lowermost Akia terrane comprises a ca. 3.2 Ga core of mafic tonalitic-dioritic gneisses, surrounded by mafic supracrustal rocks including a ca. 3.07 Ga disrupted island arc complex and younger orthogneisses (3.05-2.97 Ga), metamorphosed at amphibolite to granulite facies around 2.98 Ga. The Tre Brødre and Færringehavn terranes are the structurally highest in the central zone and appear to be multiply interleaved. The former comprises 2.82 Ga arc magmatic orthogneisses, late Mesoarchaean supracrustal rocks and extensive anorthosites. The latter, together with its tectono-stratigraphically lower counterpart, the Isukasia terrane, contains early Archaean crustal components and remnants of supracrustal rocks. The Kapisillik terrane separates the Færingehavn and Isukasia terranes in the eastern part of the region. It contains crustal components similar to those in the Akia terrane, including the ca. 3.07 Ga Ivisaartoq supracrustal belt. The structurally highest Tasiusarsuaq terrane extends at least 100 km southwards, and contains 2.92-2.86 orthogneisses with ca. 2.8 Ga granulite grade metamorphism.

Large parts of the region have been affected by syn-post-collisional metamorphism at ca. 2.74- 2.62 Ga, with evidence for continued north-west vergent convergence at 2.62 Ga.

Gold mineralisation occurs in several of the supracrustal belts. In the southern part of the Akia terrane and on Storø, gold was introduced prior to deformation and metamorphism of the host rocks.

UPPER MANTLE XENOLITHS FROM THE CERTAC KIMBERLITE, EASTERN SUPERIOR CRATON

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Xenoliths and xenocrysts of mantle material from kimberlite dikes located underground at the Certac gold mine, Quebec, in the eastern Superior Craton, were studied in terms of major element composition of their constituent minerals. The kimberlite was dated at 1121±46 Ma by the U-Pb perovskite method. This suite thus provides a rare glimpse into the Mesoproterozoic mantle of the Superior Craton. Two parageneses of mantle material unrelated to the kimberlite occur: (1) An olivine-ilmenite (with or without magnetite) association characterized by relatively Fe-rich olivine (Mg/(Mg+Fe) = 0.68-0.84) and ilmenite enriched in Mg and Cr (4 to 13 wt% MgO, Cr_2O_3 up to 3 wt%) and (2) Peridotites characterized by magnesian olivine (Mg/(Mg+Fe) = 0.91-0.94). The Fe-rich association is interpreted as a magmatic cumulate unrelated to the kimberlite. The peridotite population is represented by nine xenoliths: a coarse harzburgite, a Mg-Al-spinel lherzolite, an altered chromite peridotite, two phlogopite lherzolites, a chromite dunite, two phlogopite chromite lherzolites, and a porphyroclastic harzburgite. The deformed harzburgite has relatively low Mg/(Mg+Fe) values for olivine and enstatite (0.83). No mantle-derived garnets occur in the xenoliths or as xenocrysts. The presence of Cr-rich spinels (Cr/(Cr+Al) = 0.84-0.98) from high temperature (850-920°C) chromite peridotites indicates bulk compositions too depleted in Al for garnet to be stable, although apparently derived from depths corresponding to garnet stability. Alternatively, the presence of phlogopite in two of the three high temperature chromite peridotites suggests the absence of garnet and depletion of chromite in Al may have been caused by metasomatism from a K-rich fluid that replaced garnet with phlogopite+diospideñchromite. Less depletion at shallower depths is suggested by a chromite (Cr/(Cr+Al) = 0.60) - olivine nodule that equilibrated at 785°C and a low temperature (625°C) Al-spinel lherzolite.

INFLUENCE OF GOLD ORE ROASTING ON THE SOLID FORM AND MOBILITY OF ARSENIC IN THE ENVIRONMENT

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Arsenic has been the focus of metallurgical and environmental studies at the Giant Mine near Yellowknife since milling began in 1948. Ore processing at Giant from 1949 included roasting of a sulfide concentrate to release submicroscopic Au locked in

arsenopyrite. By 1952 the mine had advanced from a 250 ton per day (tpd) operation with direct tailings discharge to Yellowknife Bay and no As gas emission control to an 850 tpd operation with on-land storage of tailings and desublimation of As trioxide with then state-of-the-art underground storage.

The oxidation of most of the arsenopyrite during roasting at Giant has played a fundamental role in the types of As-wastes produced and local geochemical behaviour of As. After 1951, arsenic not stored underground was released to the tailings in solid form as roaster-derived grains of As-bearing Fe oxides with some residual As-bearing sulfide. Synchrotron-based μ-X-ray diffraction and μ-X-ray absorption near edge spectroscopy on mill products and tailings confirmed that the roaster-derived Fe oxides are nanocrystalline composite grains of maghemite typically containing between 2 and 6 wt.% As (rarely hematite with less As) in a mixed oxidation state (As(III) and As(V)). The As(III)/As(V) ratios (typically between 0.1 and 0.8) were fixed by the partial pressure of O_2 at the reacting grain during roasting and have persisted in a subaerial (oxic) tailings environment for over 50 years.

The significance of roaster oxidized As is further highlighted by investigation of Yellowknife Bay sediments (up to 1300 ppm As). Multi-element porewater profiles collected using high-resolution dialysis arrays were compared to sediment core profiles. ^{210}Pb dating of core correlates with a Pb, Cu, Sb and Zn enriched layer exhibiting sharp increases in concentrations at 10 to 11 cm depth that corresponds to a date of 1956 (± 5 years). In contrast, the As profile exhibits a more gradual increase beginning at 20 cm depth and rising sharply at 12 cm depth (^{210}Pb date range of 1922 (± 12 years) to 1950 (± 5 years)). The observed As distribution in the solids suggests downward diffusion of As by post-depositional diagenetic processes (milling only began at Giant in 1948). This downward spreading is supported by porewater chemistry. Upwardly diffusing As was also measured in porewaters that rapidly attenuated in a thin Fe and Mn enriched oxic layer at the sediment-water interface. Arsenic mobility observed in this system would not be expected had As been deposited in unroasted sulfide form.

HIGH Ga SPHALERITE AT GAYNA RIVER CARBONATE-HOSTED Pb-Zn DEPOSIT, NORTHWEST TERRITORIES

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The carbonate-hosted Gayna River Zn-Pb showings are located in the Mackenzie Mountains 170 km west of Norman Wells, NWT. Several of the showings were drill tested by Rio Tinto Canadian Exploration Ltd. from 1975-1979. Over 100 surface mineral occurrences have been found on the property. Rio Tinto used a conventional MVT model for exploration but new work suggests a greater vertical component to the fluid system with higher temperatures hence the ore genesis model is being reviewed. Renewed interest in the Gayna property is created by: the recent shortages in world zinc supply leading to high zinc prices, high gallium values in the showings, and proximity to the improved transportation corridor associated with the proposed Mackenzie Valley pipeline.

The Gayna River deposits are hosted by the Neoproterozoic Little Dal Group carbonates which are dolomitized in the mineralized areas. The mineralization is dominated by sphalerite with minor galena and pyrite. The gangue mineralogy is composed of sparry calcite, dolomite to saddle dolomite, plus minor barite, quartz, pyrobitumen and rare fluorite. The sulphide mineralization often occurs as breccia cement where the sulphides are found in the breccia matrix as: discrete grains, fragments of sulphide aggregates, and rims around dolostone fragments. Sulphides are also found associated with sparry and saddle dolomite as fracture and vug infillings in the host dolostones.

The sphalerite at Gayna River ranges in colour from red, yellow, orange, green to brown. Microprobe analyses show an abundance of trace elements present in the sphalerite including selenium, cadmium, copper, cobalt, nickel, arsenic, gallium, iron, silver, and manganese (Carriere and Sangster, 1999; this study). Previous trace element studies failed to link sphalerite colour to simple elemental impurities. New microprobe data, recently collected at the U of A, reveal gallium values in orange sphalerite range up to 0.215 wt%. Mapping of individual sphalerite crystals shows that the gallium distribution is heterogeneous; some crystals show clear growth zoning with respect to gallium while others have uniformly low gallium concentrations. Copper values have a strong positive correlation with gallium in all crystals analyzed thus far. Research is underway on identifying the source of the gallium and other trace elements in the hydrothermal system by analyzing the nature of the mineralizing fluids.

SUSTAINABLE DEVELOPMENT AND MINING – OPPORTUNITIES AND RISKS FOR NUNAVUT

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Sustainable mineral resources development implies that non-renewable natural capital is converted into other forms of more durable human and social capital, or facilitative infrastructure. It also requires that no individuals, groups, or the environment are disadvantaged by resource extraction processes, and preferably should benefit. While mining companies are increasingly being expected to directly compensate affected communities and mitigate and remediate their immediate environmental impacts, the responsibility for managing longer-term impacts/benefits on communities and the environment must fall on governments. However, government revenues (e.g., royalties, taxes) are commonly funnelled into general revenue funds to finance current consumption instead of directing them towards longer-term investments in physical or human capital, which would ensure a stream of future benefits for generations to come. These non-hypothecated tax revenues make it impossible to track and hold authorities accountable in their commitments to sustainable development.

We have found that investors do not necessarily react negatively to high effective tax burdens where potential rewards are high (high geological potential) and financial risks are low (security of tenure, clear legislation, and stable fiscal policy). However, industry will be reluctant to invest in areas with poor governance, weak administration, unclear property rights, or ineffective law enforcement. For example, regions such as South and Western Australia have among the highest effective tax burdens in the world and have implemented tax instruments that shift the greatest amount of risk onto industry; yet they have high levels of mineral exploration and rank among the most favourable in terms of investment climate (according to the Fraser Institute's Annual Survey of Mining Companies, 2005/2006).

The key to sustainable development is good governance – a government that is accountable and committed to compensating affected communities, and investing resource revenues in alternative forms of physical and human capital. Returns on wise investments can be reaped by both current and future generations, whereas revenues spent on current consumption (such as the Alaska Permanent Fund and Alberta Resource

Rebates) do not generate the same longer-term (potentially sustainable) benefit streams.

Northern Canada, and especially Nunavut, faces similar challenges to those found in other resource-rich, but under-developed regions of the world. With the planned opening of several new mines in Nunavut in the next decade, a significant revenue stream will begin to accrue to the Nunavut government. How those revenues are handled and invested will be critical for the successful short-term and sustainable long-term development of the territory.

PALAEOENVIRONMENTAL ANALYSIS OF THE GRIMSBY FORMATION (LOWER SILURIAN) IN THE SUBSURFACE OF LAKE ERIE, ONTARIO

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Recent sedimentological investigation into the clastic Lower Silurian Medina Group, specifically the Grimsby Formation, combined with 3-dimensional modelling was carried out to further characterize the nature of this important hydrocarbon bearing deposit. This study examines 18 subsurface rock cores from a 1331 km^2 area located in Lake Erie, southern Ontario, southwest of Long Point.

Since production began, the Grimsby and Thorold sandstones have yielded considerable quantities of natural gas making the delineation of reservoir boundaries significant to hydrocarbon exploration and exploitation in southern Ontario, Ohio, Pennsylvania and New York. Determination of the depositional environment is critical for accurate prediction of the geometry of the deposit. Based on outcrops of the Grimsby Formation, proposed depositional models include a deltaic to sublittoral marine environment, a tide-influenced nearshore estuarine environment on a prograding shelf and a shoreline and shallow marine environment with some storm and tide influence. Multiple interpretations from geographically distinct study sites suggest spatially variability in the depositional environment of the Grimsby Formation.

Beneath Lake Erie, the Grimsby Formation primarily consists of interbedded very fine-grained crossbedded sandstone and mudstone. Analysis of cores reveals five recognizable facies: i) shales with minor very fine-grained sandstone interbeds interpreted as shallow marine sediments, ii) moderately bioturbated crossbedded, ripple cross-laminated and horizontally laminated very fine-grained sandstone with mudstone interbeds interpreted as shoreface deposits, iii) crossbedded very fine-grained sandstone with layers of mudstone rip clasts with little or no bioturbation interpreted as shallow tidal channels, iv) bioturbated mudstone with very fine-grained sandstone interpreted as tidal flat deposits and v) heavily bioturbated very fine-grained sandstone interpreted as sand shoal sediments. Ichnofacies are dominated by *Skolithos* assemblage traces, with rare occurrences of *Palaeophycus* and *Teichichnus* traces, indicate normal marine, higher energy conditions. The presence of mud drapes, flaser and wavy bedding, as well as minor hummocky cross-stratification suggest the influence of tidal and storm processes during deposition. Three-dimensional modelling of the Grimsby Formation reveals a northwest thinning trend of sand deposits and associated northwest thickening trend of finer-grained marine mudstones. The stratigraphy found in the cores is consistent with the previously documented regional regressive-transgressive cycle in a shallow marine environment. The proposed depositional model is broadly consistent with existing depositional models of the Grimsby Formation in southern Ontario.

LOW SULPHIDE MINERALISATION OF THE SUDBURY IGNEOUS COMPLEX, CANADA. NEW INSIGHTS AND POSSIBLE VECTORING TECHNIQUES

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The mines of the Sudbury Igneous Complex (SIC) represent the largest Platinum Group Element (PGE) producer outside Russia and South Africa. The PGE extracted to date from the SIC have been produced as a byproduct from traditional contact, footwall and offset Ni-Cu mineralisation. The recent discovery of Low Sulphide mineralisation in the footwall of the SIC has prompted an exploration rush with majors and juniors vying to discover this potentially valuable resource.

As the name suggests this new style of mineralisation does not present the high modal sulphide associated with the 'traditional' Sudbury ores, with the economic potential of the ore purely based on its PGE budget. The low abundance of sulphide also presents a serious problem, limiting the effectiveness of traditional geochemical and geophysical exploration techniques and the ability of geologists to visibly distinguish the mineralisation from barren rock. As such a new vectoring strategy is essential if more Low Sulphide mineralisation is to be discovered.

To date eight boreholes from three properties in Sudbury, totaling 3500 ft of mineralised and unmineralised core, have been logged and 779 samples collected. One hundred and ten samples have been subjected to transmitted and reflected light microscopy to ascertain variations in mineralisation and alteration style. Analysis has revealed two distinct sulphide generations: generation 1, dominated by chalcopyrite + pentlandite + millerite + magnetite + chlorite + amphibole ± pyrrhotite ± cubanite, and generation 2, dominated by chalcopyrite + pyrite + albite + epidote + amphibole + quartz + carbonate + chlorite ± bornite ± covellite. Both generations are preferentially hosted by Sudbury Breccia and precious metal bearing; however generation 1 possesses PGE grades an order of magnitude higher than generation 2. Analysis of PGE grade vs. weight percent sulphide has revealed that the mineralisation sampled to date reflects a trend between hybrid and low-sulphide mineralisation, with the bulk of PGE focused within a few massive sulphide veins. Once separated by generation it becomes clear that generation 1 represents a low sulphide trend, whilst generation 2 represents a trend similar to hybrid mineralisation. These results are in direct contrast to plots of modal sulphide vs. grade which show little correlation between sulphide abundance and PGE grade, a good indicator of low-sulphide mineralisation. Based on these results it is clear that a definitive classification of the mineralisation intersected to date remains uncertain.

The PGE resource is hosted in a number of Pd and Pt tellurides and Bismuthides, particularly Michenerite (PdBiTe), Maslovite (PtBiTe) Froodite ($PdBi_2$) and Moncheite ($PtTe_2$), hosted in sulphide and ferromagnesian minerals.

Selected samples have also been subjected to further investigation using SEM, precious metal assay, microprobe, XRF and fluid inclusion analysis to identify precious metal mineralisation and distribution, alteration and sulphide mineral major and trace element compositions, Cl/Br ratios and distribution, fluid temperatures and salinities. The above data are being combined with field and core observations to give new insight and discuss possible vectoring techniques for this new style of mineralisation.

A CRITICAL ANALYSIS OF K-10 EARTH SCIENCE IN BC

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Over the last three years there has been a complete overhaul of the K – 10 science curricula in British Columbia. Although the K – 7 documents have been out for a couple of years it was only late August 2006 that the Sc. 8 – 10 curricula were finalized with a three year phase in period, with Science 8 being implemented this current school year.

These new curricula have resulted in a reduction of the number of Prescribed Learning Outcomes which are now prefaced by the phrase ¨it is expected that…… ¨ rather than the traditional ¨students will…… ¨ Frequently these learning outcomes are written in such a way that the classroom educator is not being informed of their intent in terms of student learning. The prescribed outcomes therefore are expanded through a series of ¨Suggested Achievement Indicators ¨ that are intended to inform the educator of the actual scope of the curriculum with suggested time frames. According to the BC Ministry of Education these curricula have been developed to conform to the intent of the Pan-Canadian Science Framework, which at this point in time is already 10 years old. There has been no research in BC by the Ministry to evaluate these new curricula in terms of their efficacy at improving student learning. Without learning there can be no change in the long-term understanding of our inter-relationships with this planet that is our home.

The geoscience outcomes of these new curricula will be examined from the perspectives of age appropriateness, pedagogical appropriateness, and scientific accuracy in terms of student learning. The discussion will be framed through a definition of learning being the long-term change in knowledge and understanding rather than the short-term goal of passing a course. There will also be some discussion of the accuracy of the recommended texts for those curricula that have already been implemented. This analysis of the British Columbia curricula will give the geoscience community some baseline information and tools by which to evaluate other provincial curricula to develop a better understanding of the state of geoscience education in this country, particularly appropriate with 2008 being the International Year of Planet Earth.

THE NATURE OF THE SNOWBIRD TECTONIC ZONE IN THE ATHABASCA AREA: NEW CONSTRAINTS AND ON-GOING QUESTIONS

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The Snowbird Tectonic Zone (STZ) is a >2800 km-long, northeast-striking, geophysical lineament in the western Canadian Shield, historically used to separate the Rae and Hearne domains of the western Churchill province. It has alternatively been interpreted as an Archean intra-continental shear zone (possibly overprinting an earlier suture), a Paleoproterozoic intra-continental shear zone, or a Paleoproterozoic inter-continental suture. The STZ is superbly exposed in the East Lake Athabasca area (or East Athabasca mylonite triangle) where it is characterized by a diverse suite of HP-HT granulite-facies metamorphic tectonites cut by more localized mylonite zones. Three lithotectonic blocks have been distinguished: one dominated by Neoarchean gabbroic to granitic intrusive rocks, one by Mesoarchean tonalite and the 1.9 Ga Chipman dike swarm, and one dominated by Neoarchean migmatitic gneiss with thick sheets of mafic granulite. Combined thermobarometry, petrologic modeling, in-situ monazite geochronology, and high-resolution zircon geochronology document two events, Archean (2.6-2.55 Ga) and Paleoproterozoic (ca 1.9 Ga), of high-grade, deep crustal (> 1.0 GPa) tectonism. Archean fabrics are commonly shallowly-dipping and NW-striking. Paleoproterozoic fabrics tend to be upright, NE-striking (i.e. STZ-parallel), and more localized into regional and local shear zones. The 1.85 Ga Legs Lake shear zone accommodated W-side-up oblique thrusting of the high-grade terrane over the Hearne domain. The Cora Lake and Grease River shear zones are dominated by strike slip shearing, apparently within the hanging wall of the Legs Lake structure. The nature of the western boundary of the STZ is a matter of debate. High-P-T granulites persist well into the Rae domain to the west, but only Paleoproterozoic deformation has been solidly documented (west of the Grease River shear zone). Thus, the STZ is defined by two components: 1) a belt of HP-HT poly-metamorphic tectonites (with strong evidence for shallow Archean fabrics) and 2) NE-striking Paleoproterozoic shear zones that bound and locally cut the high-grade rocks. The ultimate (Archean and Proterozoic) geological significance of the STZ in the Athabasca region depends upon the explanation for the preservation of Archean tectonism in the East Athabasca blocks. The broader significance depends on the degree to which Archean and Proterozoic events can be correlated in other regions along and across the continent-scale geophysical lineament.

NANOMETRE-SIZED INCLUSIONS IN DIAMOND: FIB/TEM INVESTIGATIONS PROVIDE NEW INSIGHTS INTO DIAMOND GENESIS AND FLUID COMPOSITION

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Inclusions in diamond comprise valuable information. The peridotitic or eclogitic mineral inclusions generally contain information about mantle environment and the P-T conditions in which diamond has formed. The size of these inclusions is typically in the range of tens of micron up to several hundred microns. However, there are numerous sub micrometre- or nanometre-sized inclusions in diamond that contain solid phases + fluid and/or gas. So far, the investigation of such small inclusions was only possible with spectroscopic methods such as Raman or IR spectroscopy. In the past, transmission electron microscopy (TEM) studies of inclusions in micro diamonds and larger diamonds were nearly impossible because of specimen preparation problems. With the now available focused ion beam (FIB) specimen preparation technique it is feasible to prepare electron transparent foils with typical dimensions 15 × 10 × 0.150 μm or less. Investigation of such foils with TEM allows the identification of individual nanophases in inclusions in the range of 50 nm up to several hundred nanometre by chemical analysis in combination with structural analysis (high-resolution imaging, electron diffraction). Even a qualitative characterisation of the fluid phase in the inclusion is possible. The excellent electron transparency of diamond allows a greater thickness of the TEM samples (approximately 300 nm). Thicker foils render the occurrence of still closed inclusions in the foil more likely. After identification of the solid phases and EDX analysis providing the chemical composition of the solid phases + composition of the fluid, the inclusion is opened by drilling a hole with the focused electron beam thus releasing the fluid and the gas content into the vacuum. A second EDX analysis of the residuum provides an estimate of the fluid and gas composition inside the inclusion. However, not only the inclusions are interesting. The microstructure such as dislocation density, dislocation character, presence of low angle grain boundaries, planar defects, stacking faults might provide an idea about thermal history of the investigated stone.

DEPOSITIONAL AGE AND PROVENANCE OF THE PILING GROUP, CENTRAL BAFFIN ISLAND, NUNAVUT: IMPLICATIONS FOR THE PALEOPROTEROZOIC TECTONIC DEVELOPMENT OF THE SOUTHERN RAE MARGIN

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The Paleoproterozoic Piling Group on central Baffin Island, Nunavut, Canada, represents a continental margin succession originally deposited on the southern margin of the Archean Rae craton and subsequently deformed and metamorphosed within the ca. 1.8 Ga Trans-Hudson Orogen. It forms part of an extensive package that has stratigraphic correlatives extending from Melville Peninsula (Penrhyn Group), across Baffin Island (Piling and Hoare Bay groups), to western Greenland (Karrat and Anap Nunâ groups). We report SHRIMP U-Pb detrital-zircon ages from a stratigraphically representative suite of siliciclastic samples that constrain the age and provenance of this supracrustal succession and provide a better understanding of its depositional setting. Quartzite near the structural base of the lowermost shelf-margin assemblage contains detrital zircon grains solely of Archean age, whereas stratigraphically higher quartzite within the same unit contains both Archean and Paleoproterozoic grains. The distribution and age of detrital zircon grains indicate a gradual change in sediment provenance, from local Archean sources to wider, mixed Paleoproterozoic sources. The shelf-margin assemblage was deposited on the Rae craton sometime after ca. 2.16 Ga, during initiation of a continental passive margin. Rift-related mafic/ultramafic volcanism and associated sedimentation is dated at 1935 ± 25 Ma, based on the age of a feeder dyke. Both field observations and our SHRIMP data indicate a conformable relationship between the volcano-sedimentary succession and the underlying passive margin sequence. Rapid subsidence of the Piling paleo-basin and contemporaneous tectonic uplift(?) resulted in deposition of a thick turbiditic sequence during a short time interval between 1915 ± 8 Ma and 1897 +7/-4 Ma. Together with the detrital zircon age spectrum from a thin metasedimentary horizon collected near the top of the volcano-sedimentary succession, these data imply a rapid transition from near-shelf volcanism to deep-basinal sedimentation. Bimodal distribution of detrital zircon ages from the turbiditic rocks indicates a source region composed of Paleoproterozoic (2.03-1.91 Ga) and Archean (>2.5 Ga) rocks, and suggest that deposition of these rocks coincided with early amalgamation of Laurentia ca. 2.0-1.9 Ga. Overall, this study provides a quantitative record of the tectonic development of the southern Rae cratonic margin during the Paleoproterozoic, from a post-ca. 2.16 Ga passive margin, to a ca. 1.93 Ga rift basin, to a ca. 1.92-1.90 Ga turbidite fan.

OCCURRENCES OF INTRAPERMAFROST GAS HYDRATES AND SHALLOW GAS IN THE MACKENZIE DELTA AREA, N.W.T., CANADA

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In the Mackenzie Delta area, the thickness of permafrost (i.e. depth of the 0°C isotherm), and the associated deep geothermal regime have been strongly influenced by ground surface temperature history during the past several million years. Important considerations include periods of glacial ice cover, duration of post-glacial terrestrial exposure, and periods of marine incursions, all of which are known to have varied considerably at both regional and local scales. Permafrost conditions in the region are highly variable spatially, with areas having less than 50m of permafrost being in close proximity to terrain characterized by more than 700m of permafrost. Assuming normal geopressure conditions, stable Structure I methane hydrate can exist in locations where permafrost is greater than 250m in thickness. Conditions supporting the occurrence of intrapermafrost gas hydrate (gas hydrate within the permafrost interval) are therefore widespread throughout much of the coastal and offshore areas of the Beaufort Sea. Current research issues include the sensitivity of intrapermafrost gas hydrates to climate warming, and their potential as a geohazard for exploration drilling and hydrocarbon production. This presentation will review the geologic factors influencing the occurrence and stability of intrapermafrost and sub-permafrost gas hydrates, as well as the presence of shallow free gas within the gas hydrate pressure-temperature stability field. Evidence for the occurrence of intrapermafrost gas hydrate has been documented in laboratory tests of core samples recovered from a research well at the Taglu field, and inferred from surface geophysical surveys, well log assessments, and anomalous gas shows during exploration drilling. Finally, data from constrained laboratory experiments document the unique behavior of gas hydrate within sediment-gas hydrate-liquid water/ice systems.

A NEW EXPERIMENTAL CALIBRATION OF Ni-Mg EXCHANGE BETWEEN GARNET AND OLIVINE AT UPPER MANTLE PRESSURES – IMPLICATIONS FOR Ni IN GARNET THERMOMETRY

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Cr-Pyrope grains, recovered from heavy mineral concentrates during diamond exploration, contain records of the temperature of equilibration with olivine in the lithosphere. If the local geotherm at the time of kimberlite emplacement is known, temperatures obtained from garnet xenocrysts can be fitted to the geotherm allowing estimation of the extent of entrainment by kimberlites of material from the diamond stability field.

Garnet and olivine participate in T dependent exchange of M^{2+} cations (where M = Fe, Mg, Ni, Zn, etc). If the PT dependence of these equilibria can be calibrated, then the compositions of garnet and olivine coexisting in the upper mantle can be used to determine the temperature at which they equilibrated. Because the concentration of Ni in olivine is fairly constant at 2900±360 (1σ) ppm Griffin (1989), calibration of the olivine-garnet Ni exchange reaction is applied to single grain garnet xenocrysts, inferred to have equilibrated with olivine with this Ni content Griffin (1989), Ryan (1996).

Partitioning of Ni between olivine and garnet has been calibrated empirically, in reference to conventional multiphase geothermometers, for example, the “Ni in garnet” thermometers of Griffin and Ryan. An alternative approach is direct high-pressure experimental calibration. Canil (1994) experimentally calibrated the “Ni in garnet” thermometer at 6-7 GPa. Although, there was agreement within error between the experimental Canil and empirical Griffin and Ryan calibrations at T=900-1100°C, there were significant discrepancies outside this range.

We conducted an additional experimental calibration at 3.0-4.5 GPa, to check existing calibrations. The new formulation is $T(K)=(5{,}264\pm589)/(\ln K_d+2.065\pm 0.403)$ ($K_d=[Ni/Mg]_{ol}/[Ni/Mg]_{ga}$).

Whilst there was no resolvable pressure effect on the reaction within the pressure range of our experiments, when our data is combined with Canil’s higher pressure data, the reaction has a resolvable and significant pressure effect of approximately 6-8°C/kbar, agreeing with thermodynamic predictions based on molar volume estimates.

This compromises the empirical calibrations, which do not include pressure effects in the Ni exchange reaction. Application of empirical thermometery to single grain Cr-pyrope garnet may artificially extend the range of temperatures obtained from garnet xenocrysts, implying a falsely large sampling depth interval for individual kimberlites.

TURQUOISE DEPOSITS OF YUN GAISI AND MA ANSHAN

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Turquoise is one of the oldest gem materials known. Its use in jewelry and for personal adornment can be traced back 70 centuries, to ancient Egypt; also it was one of the most famous jade in ancient china for thousand years.

Yun Gaisi and Ma Anshan turquoise, which originate from Hubei and Anhui province, China, are well known throughout the world as their sky blue color and perfect texture. The Yun Gaisi turquoise deposit is located at intermediate latitude where humid and rainy seasons alternate with high temperatures and dry weather. This weather pattern is favorable for the weathering, leaching, migration, concentration and precipitation of metallogenetic elements. Some of them were developed in a lower structural level through bedding stratified shear deformation under conditions of high temperature and low strain rate. Turquoise also originates from ShanXi, HeNan, QingHai, XinJiang, JiangSu and YunNan provinces. From different origination, turquoise has its own different characteristics. For example, the color of Yun Gaisi turquoise is green, while Ma Anshan turquoise shows vivid blue or greenish blue.

But by the industrial developing and economic urge, turquoise deposit are depleting day by day recently. Its output from HuBei can reach nearly a hundred tons a year only several decades before, but dropped down sharply in recent years to no more than several tons a year, and most of them are poor quality of a material. Furthermore, because the supply of high-quality turquoise is limited, and because this material readily accepts many treatments, most turquoise is adulterated.

So, what should be done is not only protecting turquoise deposits, mining turquoise logically, but also cherishing turquoise as treasures.

MESO- TO NEOARCHEAN CRUSTAL GROWTH AND RECYCLING ON NORTHERN BAFFIN ISLAND AND CORRELATION OF RAE PROVINCE ROCKS ACROSS MAINLAND NUNAVUT AND GREENLAND

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The Rae domain of the western Churchill Province on northern Baffin Island contains an Archean rock record spanning more than 300 million years from ca. 3.0 Ga to 2.68 Ga. Delineation of distinct crustal domains is speculative, however, three broad areas may be distinguished using Nd isotopic data: 2.9 – 3.3 Ga domains to the northwest and southeast and a central, north- or northeast-trending 2.7 – 2.85 Ga domain. These domains may correlate, from west to east on mainland Nunavut, with the Queen Maude block (2.9-3.7 Ga), the Committee Bay block (2.7-2.85 Ga) and the Repulse Bay block (2.9-3.4 Ga). If our correlations stand, the Committee Bay block on northern Baffin Island likely represents thinned Mesoarchean crust on, and through which, new juvenile crust was generated. New and existing U-Pb zircon geochronological, Sm-Nd isotopic and lithogeochemical data, along with critical field observations, permits the subdivision of the supracrustal rocks into two temporally distinct lithostratigraphic assemblages: ca. 2829 Ma Mary River and ca. 2740 – 2720 Ma Prince Albert groups. The Mary River group, previously correlated with Neoarchean supracrustal sequences to the southwest on the basis of a single bulk separate U-Pb zircon age and similar lithostratigraphic assemblages, is now demonstrated to be significantly older, at ca. 2829 Ma. This is the oldest Archean supracrustal rock yet dated from the wCP. These rocks occur in the northwestern part of the study area, resting unconformably on ca. 2900 Ma granodiorite gneiss, and consist of quartzite, tholeiitic amphibolite, banded iron formation (hosting significant iron resources), and intermediate volcanic rocks. The Mary River group and surrounding plutonic rocks have Nd model ages ranging from 2.9 Ga – 3.3 Ga, typically enriched epsilon Nd values ranging from +1.4 to -3.6 (calculated at t=2.7Ga) both suggesting major recycling of older continental crust. The Prince Albert group is volcanic-dominated in the northwest consisting of tholeiitic and isotopically depleted (epsilon Nd: +4.0 – +0.9 and model ages of 2.7Ga to 2.85Ga) amphibolite with quartzite-komatiite, whereas further southeast, toward Eqe Bay, clastic sedimentary rocks predominate and are interbedded with calc-alkaline mafic and intermediate volcanic rocks. Supracrustal and plutonic rocks in the southeast are isotopically enriched (epsilon Nd: +0.9 – -4.0) having model ages from 2.9 to 3.2 Ga. Voluminous granodiorite, tonalite, and monzogranite underlie much of the map area. Reconnaissance geochronology broadly shows three age ranges for plutonism at ca. 2.9 Ga, 2.85-2.79 Ga and 2.73-2.68 Ga. Ca. 2.60 Ga plutonism, a major granitoid emplacement event throughout much of the Rae domain to the southwest has not been recognized. Equivalent rocks to the northeast on Greenland include Mesoarchean volcanic (ca. 2800 Ma Kangilinaaq belt) and plutonic rocks (ca. 2850 Ma) which contain older (>3.1 Ga) components and minor juvenile ca. 2.85 Ga crust. The ca. 2740 Ma Ikamiut belt and associated plutonic rocks have variable isotopic signatures suggesting a mix of crustal growth and recycling at ca. 2.7Ga.

PALYNOLOGY AND TOC/ROCK-EVAL OF LATE DEVONIAN IMPERIAL FORMATION, SOUTHERN PEEL PLATEAU AND PLAIN, NWT

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Late Devonian stratigraphy of the Peel Plateau and Plain is comprised of the upper portion of the Hare Indian Formation, the Canol Formation, and the Imperial Formation. The Imperial Formation is overlain unconformably by the Cretaceous Martin House Formation.

Field work conducted in 2006 consisted of measuring stratigraphic sections on Imperial River, Powell Creek, an Elbow Creek tributary as well as an Arctic Red River tributary. These sections occur on NTS map sheets 96 E/4, 106 H/5 and H/7, and 106 G/7. Samples were collected from Imperial Formation for analysis of permeability, porosity, palynology, and Rock-Eval/TOC. To enhance the regional picture of Imperial Formation additional samples for Rock-Eval/TOC and palynology were collected from map sheets 105P and 95M.

Imperial Formation is interpreted as a turbidite sequence that can be coarsely described as three, thick resistant cliff-forming sandstone units, which are separated by less resistant to recessive thick silty shale packages. Bioturbation decreases up section and sedimentary structures are better preserved. Imperial Formation sandstone is locally fossiliferous. Sandstone units at the Imperial River section are locally petroliferous. Recent palynology work indicates environment of deposition as marine in the more northern localities to terrestrial to near-shore marine in the south (105P and 95M). Thermal Alteration Index (3 – 4) and equivalent vitrinite reflectance (1.4 - 2.0%) both indicate postmature dry gas zone.

The sandstones of Imperial Formation are medium grey, green grey, and olive green in colour. The greyer sandstones occur in the basal sand unit in the Shortcut Creek and Monument section to the west. In these two sections there is a distinct lack of

green sand in the basal member. The western sections also exhibit a notable decrease in coral and shell abundances. This possibly indicates a movement away from a shelf edge bioclastic sediment source, which may correspond to a northern extension of the Jungle Ridge member recognized further south.

Initial results from 2006 field season yielded porosity values between 14 % and 25 % on sandstones from Imperial River Section. One sample of Imperial Formation on Powell Creek yielded TOC 3.6%, T_{max} 438°C, S1 0.83 and S2 9.42. These Rock-Eval results are well within the oil window and are excellent indicators of potential source rock, and provide direction for future field work.

HUDSON BAY BASIN, NE CANADA: LATE ORDOVICIAN – EARLY SILURIAN CONODONT BIOSTRATIGRAPHY, THERMAL MATURATION, AND IMPLICATIONS FOR HYDROCARBON GENERATION

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Hudson Bay basin is one of the largest Paleozoic sedimentary basins in North America. It was explored for hydrocarbon resources, at a broad scale, more than 30 years ago, although the exploration potential remains somewhat uncertain. The lower part of the basin succession comprises approximately 600 -1040m of Upper Ordovician (Bad Cache Rapids, Churchill River and Red Head Rapids formations) and Lower Silurian (Severn River, Ekwan River, Attawapiskat and Kenogami River formations) strata. These formations mainly comprise carbonate rocks consisting of alternating fossiliferous limestone, evaporitic and reefal dolostone, and minor shale.

A study of 4500 conodonts from 390 conodont-bearing samples from continuous cores and well cuttings, from six exploration wells in the Hudson Bay Lowlands (Comeault Province No. 1, Kaskattama Province No. 1 and Pen Island No. 1) and offshore area (Walrus A-71, Polar Bear C-11 and Narwhal South O-58) has revealed 50 species representing 28 genera. The conodont studies have significantly improved our understanding of the Early Paleozoic geology by providing:

1) Clear definition of conodont zones and their stratigraphic ranges. Seven zones are established for the Upper Ordovician - Lower Silurian interval, namely *Belodina confluens*, *Amorphognathus ordovicicus*, *Rhipidognathus symmetricus*, *Ozarkodina elibata*, *Kockelella*? *trifurcata* and *Distomodus staurognathoides* interval zones, as well as *Pterospathodus celloni-P. eopennatus* Assemblage Zone.
2) Precise biostratigraphic control for the different formations. Upper Ordovician formations are dated as late Caradocian - late Ashgill with the uppermost Ordovician (Hirnantian or Gamachian) missing; Lower Silurian formations are dated as early Rhuddanian - middle Telychian, Llandovery.
3) mproved biostratigraphic correlation between exploration wells.
4) Recognition of sea-level events based on the stratigraphic distribution and known ecologic partitioning of key conodont species in wells representing a shallow to deep gradient.
5) Definition of the position of the Ordovician - Silurian boundary, typically at the hiatus created by the terminal Ordovician glaciation.

Conodonts from the six wells studied have a Colour Alteration Index (CAI) value of 1, indicating little alteration of organic matter and that the strata have not reached burial temperatures greater than 80°C. The Late Ordovician Boas River oil shale, which is inferred to have significant potential as a source rock and occurs at surface along the northern part of the basin, does not appear to be represented in the wells.

Author Index – Index des Auteurs

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