

2014

Yellowknife Geoscience Forum



Abstract Volume

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Cover photograph

Granitic Gneiss in 2014 Burn
Taltson River/Tsu Lake, NWT

Luke Ootes, NWT Geoscience Office

Compiled by D. Irwin and P. Normandeau

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2014 YELLOWKNIFE GEOSCIENCE FORUM ABSTRACTS

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Abstracts - Oral Presentations

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DEVOLUTION - POST TRANSFER UPDATE

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Devolution of responsibilities for the management of land, minerals, petroleum and rights in respect of water occurred on April 1, 2014. The Government of the Northwest Territories has now been "at the helm" for almost 8 months. Representatives from the Departments of Aboriginal Affairs and Intergovernment Relations (DAAIR), Industry, Tourism and Investment (ITI), Environment and Natural Resources (ENR) and Lands will provide an update on the implementation of devolution and be available to answer questions.

AIRLANDER AIRCRAFT - AN INNOVATIVE NEW AERIAL PLATFORM FOR GEOSCIENCE SURVEYING

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The Airlander 10 aircraft combines the aerodynamic lift of an airplane, the vectored thrust of a helicopter and the buoyant lift of an airship to provide an innovative aircraft that is ideal for geoscience surveying. It can fly at speeds up to 80 knots or loiter, at low altitude and at very slow speeds (or airborne hover like a helicopter), to provide enhanced accuracy for geoscience measurements. It has up to 120 kW of electrical power available to drive sensing equipment including Electro-Magnetic coils which can have a cross-sectional area of approximately 300 square metres (mounted around the "equator" of the aircraft) to provide much higher ampere-turns and sensing capability than other aerial platforms. The fuel burn of this aircraft is only a quarter that of comparable airplanes or helicopters which enables the cost per flying hour to be approximately the same as for a helicopter undertaking the same task whilst providing a much greater sensing capability with a range and endurance that is an order of magnitude greater than is available for helicopters.

DEMCO - THE EXPERIENCE OF AN ABORIGINAL OWNED MINE EXPLORATION DEVELOPMENT COMPANY

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DEMCO was incorporated in May 2013 as a 100% Dene owned exploration and mining company created to find and develop mineral resource on Dene lands. Since its incorporation, DEMCO has acquired strategic properties with silver, IOGC, diamonds and gold potential. In the past year and half, DEMCO has been compiling and analysing existing data to plan future developments and acquisitions. Our experience in the high-risk, high reward sector of mineral exploration and development has been expensive, exhilarating and rewarding. We have received strong support from our Dene communities, the NWT mining community, and the federal and territorial Government, all who want us to succeed.

NUNAVUT CARVING STONE DEPOSIT EVALUATION PROGRAM: DEFINING THE SUPPLY SIDE FOR THE COMMUNITY COMMODITY OF ARCTIC CANADA

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The Government of Nunavut and the Canada-Nunavut Geoscience Office have been evaluating carving stone sites

throughout Nunavut since 2010. The primary goals are to verify the quality and size of traditional soapstone sites and identify new resources. Community carvers providing guidance to sites and artisan suitability assistance are key program components.

Gathering of carving stone is a legislated right in Nunavut. The word 'soapstone' is an art industry misnomer applied towards soft stone of any colour or composition. The bulk of Nunavut's carving stone is gathered from artisan serpentinite deposits and artisan marble deposits with some use of competent marble, dolomite and limestone; minor use of gypsum and meerscham; and no observed use of talcose soapstone.

A total of 94 carving stone occurrences have been categorized by artisan suitability, tonnage and composition. Nunavut's carving stone deposits range in size from tiny sites to undeveloped resources of 50,000 tonnes and greater. A small site holds 100 tonnes of carving stone sufficient for the careers of several full-time carvers. A community quarry typically contains 500 to 2000 tonnes, while a regional quarry is 10,000 tonnes or larger in size. The territory has eleven quarries and fifteen undeveloped deposits able to provide at least several decades worth of carving stone on behalf of the nearest community. Seventeen out of Nunavut's twenty-five communities have access to local carving stone resources adequate for their long-term needs.

Much of Nunavut's softest carving stone is seasonally gathered at its two largest quarries; both have been in operation since the 1970s. Cape Dorset's tidewater Korok Inlet quarry is the premier producer of carving stone for the south Baffin area, servicing the communities of Cape Dorset,

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Kimmirut and Iqaluit. The Korok Inlet quarry has supplied 450 tonnes per annum of excellent-quality artisan serpentinite to one-third of Nunavut's carvers. The tidewater Main quarry in the Belcher Islands has supplied Sanikiluaq carvers with 50 tonnes per annum of excellent-quality artisan marble. Hitherto undocumented reserves of 30,000 tonnes at Saniqiluaq's Main quarry are twice as large as Korok Inlet's total output. Four artisan serpentinite resources of similar to larger size have been confirmed; three deposits occur in the Qikiqtani region and a major deposit occurs in the northern Kivalliq region.

Soft stone sites from Alaska to Greenland have seen successful transition by Inuit from land-based traditional artifacts to community-based modern art industry. Artisan carving stone in Nunavut is now understood to be a long-term commodity hand-mined by many individuals from an abundance of surface-accessible deposits. Substantial high-quality resources await further study and future development.

KENNADY NORTH PROPERTY: 2014 GEOPHYSICAL UPDATE

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This presentation will provide an update of geophysical surveys performed in 2014. These surveys were undertaken to aid in the delineation of known kimberlites and discovery of kimberlite targets on Kennady Diamonds Inc.'s Kennady North Property.

Kennady Diamonds Inc. resumed exploration on this property in 2011 with the completion of an airborne gravity

gradiometer survey. The survey produced numerous geophysical targets, which were followed up with ground-based magnetic surveys. During this time, an examination of historical airborne magnetic and electromagnetic and ground-based magnetic, electromagnetic and gravity geophysical surveys was undertaken. This study indicated that resistivity was most useful in detecting the kimberlites. The study also showed that the sample density for the ground gravity surveys would have to be increased in order to accurately detect and model the anomalies. In 2012 & 2013, ground-based gravity and capacitively coupled resistivity (OhmMapper) surveys were conducted over the Kelvin kimberlite. The data collected were modeled using 2D and 3D software and was then used to successfully drill test larger zones in the Kelvin kimberlite.

In 2014, Kennady Diamonds Inc. expanded the use of the OhmMapper surveys to cover larger areas in the Kelvin-Faraday Corridor (KFC) and beyond. Many exploration targets were also surveyed with ground-based gravity using an increased sample density. Ground penetrating radar was undertaken in the KFC in an attempt to provide further information on the 'sheet' type structures that had been previously discovered. Extremely Low Frequency (ELF) surveys were also completed over the Kelvin and Faraday kimberlites, and the results were 3D modeled.

Late in the season, three separate boreholes were read with multiparameter IP and Resistivity probes. Each of these boreholes was used as downhole transmitter locations for various Induced Polarization (IP) survey tests. Additional IP tests were completed on surface, over the deepest portion of the Kelvin kimberlite.

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**THE GEOCHEMICAL
SIGNATURES AND ND-
ISOTOPES OF ARCHEAN
VOLCANIC UNITS AROUND
THE SLEEPY DRAGON
COMPLEX, SLAVE CRATON,
NORTHWEST TERRITORIES**

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The Neoproterozoic Cameron-Beaulieu volcanic belts wrap around the Sleepy Dragon basement complex in the south-central Slave craton. Detailed bedrock mapping, geochemical studies and Nd-isotopic analyses of these belts from Sharrie and Turnback lakes provide insight into their tectono-stratigraphic evolution. Previous bedrock mapping and geochemistry from volcanic belts across the Slave craton provides a baseline that can be used to compare geochemistry and stratigraphic relationships of individual belts to a regional perspective.

Two volcanic sequences have been identified in the Yellowknife volcanic belt; (1) the > 2698 Ma Kam Group, and (2) the ca. 2661 Ma Banting Group. The older Kam Group is predominantly mafic and the few rhyolites have a flat HREE signature with a notable negative Eu anomaly. The younger Banting Group is bimodal and the rhyolites have a distinct HREE depletion and lack any Eu anomaly. The majority of the volcanic belts across the Slave craton were deposited between ca. 2690-2670 Ma, with felsic

volcanic rocks having either Kam-like or Banting-like signatures, thus sparking an investigation into the extent of the Banting. Formerly called the Beaulieu Group, the ca. 2680.0 ± 1.2 Ma volcanic belts at Sharrie Lake and Turnback Lake have bimodal sequences akin to the Banting Group but Kam-like geochemical patterns in the felsic rocks.

Sm-Nd isotope data throughout the southern Slave craton reveals a wide range in values for felsic, intermediate, and mafic volcanic rocks, with little discrimination between rock types or age. Locally, however, volcanic units within individual belts may have smaller ranges in isotopic values allowing for differentiation between belts, such as at Sharrie Lake and Turnback Lake of the Cameron-Beaulieu volcanic belts. Nd-isotopes of volcanic packages differ between the two belts dependent on rock type. Mafic volcanic rocks from Sharrie and Turnback lakes have ϵ_{Nd}^T values between -1.07 to +0.76 and +1.03 to +1.48, respectively, indicating some crustal contamination at Sharrie Lake and a more juvenile origin at Turnback Lake. Felsic volcanic rocks at Sharrie Lake have a small ϵ_{Nd}^T range between -0.47 and +0.68, while Turnback Lake rhyolites have a much wider range in ϵ_{Nd}^T values from -3.21 to +2.96, suggesting a vastly different source with areas of greater crustal contamination. Despite their proximity and shared geochemical signatures, Sharrie Lake and Turnback Lake are isotopically distinct.

THE LAC DE GRAS PERMAFROST PROJECT

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Throughout the North, permafrost thaw – unprecedented in extent and magnitude – will become one of the biggest challenges for the planning and operation of infrastructure and, more generally, for the land and for the well being of northerners. The expected outcome of this project is reliable evidence of near-surface geotechnical and permafrost characteristics. This is important because it provides a basis for project development in an otherwise difficult environment. This will be achieved by leveraging the synergy of a diamond project for obtaining geotechnical, topographic and thermal information required at a density unprecedented, globally. To maximize benefits to stakeholders, data will be made publicly available following best practices at Canadian government agencies within the lifetime of the project.

This two-year project will examine the surface and subsurface characteristics of the tundra permafrost system in order to obtain quantitative data on terrain variability, and its relationship with patterns of ground temperature and ice content, and their changes through time. For this, we are developing a methodology for randomized sampling of the landscape to avoid perception bias in the selection of research sites and for quantifying the characteristics of ‘footprints’ in the landscape. Footprints, on the order of 10^2 to 10^3 m² in surface area, are the basis units of investigation, aimed at providing an interface with remotely sensed

data and with grid-based permafrost models operating on similar spatial resolutions.

A large number of 5 to 30 m deep boreholes will be drilled in 2015 within an area of approximately 250,000 km² in the context of diamond exploration. This is expected to yield dense data on till geotechnical properties and ice contents, as well as on permafrost and active layer geochemistry. 15-25 of these boreholes will be instrumented in this project for permafrost investigations. Additionally, surface and shallow ground temperature sensors, and climate stations will be deployed at many of these locations. Each site will be discretized into a sampling schema where precise vegetation, organic material, ground material and topographic information will be quantified. Innovative techniques for proper sampling at this scale will be developed and applied.

Within and beyond the project, these data will allow statistical analyses of how landscape variability differentiates permafrost characteristics, how permafrost thaw may affect nutrient availability and stream geochemistry, and support the evaluation and development of computer simulation tools to assess permafrost and its changes.

A TUNNEL TO THE FUTURE: THE PRELIMINARY GEOLOGY OF THE KELVIN KIMBERLITE

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The Kelvin kimberlite is located in the southeastern Archaean Slave Craton of northern Canada. Wholly owned by Kennady Diamond Inc., the Kelvin kimberlite lies 8 kilometres northeast of the DeBeers/Mountain Province Gahcho Kué Diamond Mine, which is scheduled to enter into production in 2016. The Kelvin kimberlite is significantly diamondiferous and characterized by a non-traditional pipe shape and complex internal geology. Diamond drilling to date shows that it has a sub-horizontal boomerang tube shape with a plunge of 15-20 degrees to the north-northwest. The known extent of the kimberlite pipe is 600 meters and remains open at depth to the north. It ranges in width from 30 to 60 meters and has a vertical thickness of 75 to 200 meters. Associated with the pipe is a lesser-explored sheet system that strikes south-southwest along the regional southwest-northeast structural trend and dips to the west. Observations of drill core, thin section petrography, and 3D modelling of the Kelvin kimberlite indicate that the internal geology comprises multiple phases of emplacement and a full range of volcanic processes. Hypabyssal kimberlite (HK), Kimberly-type pyroclastic kimberlite (KPK) and a spectrum of transitional textures between these two end members have been observed. Four internal geological domains associated with different diamond grades have been identified. These domains overlie one another sub-horizontally and

continue the length of the kimberlite pipe. Structurally controlled, the Kelvin kimberlite sits along a southwest-northeast trend that is host to the Gahcho Kué kimberlites as well as the nearby Faraday kimberlite. The Kelvin kimberlite, with its non-traditional shape and complex geology, challenges the conventional approach to kimberlite exploration in Canada's north, opening the door to new ideas, approaches and opportunities.

CANNOR - RESOURCE DEVELOPMENT AND COMMUNITY ECONOMIC OPPORTUNITIES

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Communities need to develop strategies and plan ahead for major resource development that may affect their communities. CanNor's Community Readiness Initiative (CRI) program is designed to help communities and Aboriginal groups to take advantage of economic opportunities arising through resource development that may affect their communities. The CRI program objectives will be outlined as well as implementation in the context of regulatory requirements for major resource development in the North.

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IOCG STYLE ALTERATION AND MINERALIZATION IN A PROTEROZOIC CALDERA, CAMSELL RIVER, NWT

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DEMCo (Denendeh Exploration and Mining Company), an aboriginal-owned, Yellowknife-based company, has recently acquired claims covering the former silver producing district on the Camsell River, near the southeast corner of Great Bear Lake. A program of re-evaluation of the silver potential and reconnaissance mapping and prospecting in the summer of 2014, has led to some novel conclusions about the geology and mineral potential of the area.

The Camsell River area lies in the 1.8 Ga Great Bear Magmatic Zone (GMBZ). Its geological evolution, based on excellent mapping by Hildebrand (1984) for the GSC, can be summarized as follows: (1) Extensive deposition of subaerial, intermediate Moose Bay Tuff, (2) a collapse caldera about 15 km in diameter, with initial deposition of lacustrine sediments (the Terra Formation) within the caldera, (3) the caldera was filled by the Camsell River Formation, a thick sequence of subaerial andesite flows, and compositionally related explosion breccias and debris flows, (4) the caldera was folded into an open, gently NW-plunging syncline and intruded by two thick sill-like bodies of monzonite (the Balachey and Rainy Lake plutons) as well as other minor intrusives, including a 7 km by 1 km body of augite porphyry, (5) the caldera was eventually

covered by later subaerial volcanics.

The entire caldera has been affected by a long-lived, areally extensive and extremely intense (“IOCG type”) hydrothermal alteration system, presumed to be related to an underlying magmatic heat source. There is a generalized zonation, upwards and outwards from the base and centre of the caldera, characterized by the alteration mineral sequence albite - K-feldspar - K-feldspar+magnetite - magnetite - pyrite - hematite - quartz. Alteration fronts have advanced preferentially through fragmental units and presumed faults structures. Extreme magnetite development has resulted in at least two massive “Kiruna-type” magnetite-apatite-actinolite bodies. Mineralization includes the well known Ag-Bi-Co-Ni-As veins that sustained silver mining from 1973 to 1985; these are concentrated at the southern edge of the caldera and may be related to leaching of metals from underlying supracrustal rocks. Widespread throughout the caldera, but particularly concentrated within the pyrite alteration zone, are occurrences of Cu-Au (\pm Fe \pm Ag \pm As \pm P \pm Ni \pm Pt \pm Sr \pm Ba \pm Mo \pm Zn \pm Pb) as veins and disseminations in fractures and breccia zones.

Two features that highlight significant economic potential for the area have emerged from the 2014 work. Resampling of a 1981 diamond drill hole yielded wide intersections of low-grade disseminated Cu-Zn-Pb-Au-Ag-Pt sulphides. Reduced to copper equivalent, the two successive intercepts in this deep surface hole were 42.1 m @ 0.49% Cu eq and 65.5 metres @ 0.51% Cu eq (including 29.0 metres @ 0.67% Cu eq). Second, modelling of archived airborne magnetic survey data has indicated the possibility of large (1 to 5 kilometre-scale) buried magnetic bodies. A

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gravity survey is planned to refine exploration targets.

ENVIRONMENT CANADA POLLUTION PREVENTION REGULATIONS THAT MAY AFFECT ACTIVITIES IN THE NORTH

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Environment Canada will provide information relevant to Northern activities including the pollution prevention provisions under the Fisheries Act and various regulations under the Canadian Environmental Protection Act, 1999, particularly the Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations, the Perfluorooctane Sulfonate and its Salts and Certain other Compounds Regulations, the Environmental Emergency Regulations, the Federal Halocarbon Regulations (2003), and the PCB Regulations.

ARSENIC GEOCHEMISTRY IN THE SUBAQUEOUS TAILINGS AT TERRA MINE, NWT

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Elevated levels of solid and dissolved arsenic (As) in the subaqueous mine tailings at the abandoned Terra Mine 390 km north of Yellowknife present a potential hazard to the local environment. The surface water of Ho-Hum Lake, where tailings were deposited, contains As concentrations between 50 and 80µg/L. It is believed that

the dissolved As is primarily sourced from the subaqueous tailings, but the geochemical processes releasing the As to the overlying surface water are not understood.

The complex mineral assemblage of the hydrothermal Cu-Ag-Bi deposit includes 13 As minerals, mostly Co, Fe and Ni arsenides and sulfarsenides. Ore processing and conditions in the post-depositional environment has determined the behaviour of primary As minerals and how they weather and release As to the overlying surface water. The primary As minerals are unstable in oxidizing conditions and stable under reducing conditions. Partial oxidation of the primary minerals during ore processing and in the post-depositional environment, coupled with the addition of ferric sulphate to the tailings lake during mine operations has resulted significant quantities of secondary As mineral precipitation, mostly in the form of Iron oxides. The secondary As minerals, in contrast to the primary minerals, are stable in oxidizing conditions and unstable under reducing conditions. Redox conditions are spatially variable within the lake bottom tailings and consequently the geochemical processes releasing As into Ho-Hum Lake also vary.

Following the two field programs in the summer of 2013, mineralogical work was conducted upon select samples to determine how and to what extent ore processing and the post depositional environment has altered primary As minerals to allow them to be released into solution, as well as identifying the secondary minerals present. Scanning Electron Microscopy (SEM) at Queen's University, synchrotron-based µ-XRD, XRF and µ-XANES at Brookhaven National Laboratory in Upton, NY, as well as bulk XANES at Argonne National

Laboratory near Chicago, IL was conducted to achieve these goals. This work will be used to estimate the future potential for further As dissolution and release to the surface water and local environment, as well as determine the quantity of As that is stable under current conditions and expected to remain sequestered in the tailings.

AN OVERVIEW OF NUNAVUT MINING AND MINERAL EXPLORATION ACTIVITIES IN 2014

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In 2014, deposit appraisals and mineral exploration expenditures in Nunavut are anticipated to reach \$166.5 million (Natural Resources Canada Mineral Statistics). This marks a significant decline from the estimated \$312.9 million (Natural Resources Canada Mineral Statistics) in 2013, but follows the worldwide declining trend of financing resource exploration activities. Fewer projects were active in the territory; however a diverse range of commodities, namely gold, iron, uranium, diamonds and base metals, continued to be attractive for on-going exploration programs. Actively held mineral claims, leases and prospecting permits on Crown land in Nunavut now total over 8.1 million hectares.

Nunavut presently hosts two active mines. In 2010, Agnico-Eagle Mining Ltd. opened the Meadowbank Gold mine in the Kivalliq region. The Mary River iron project in the Qikiqtani region began operations in the fall of 2014 under Baffinland Iron Mines Ltd. Other projects for gold, uranium and base

metals are advancing at various stages through Nunavut's regulatory process. The presentation will discuss the current status of these projects and highlight some exciting developments in exploration taking place during 2014.

OLIVINE AS A PETROGENETIC AND EXPLORATION INDICATOR IN LAC DE GRAS KIMBERLITES

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Olivine constitutes the most abundant mineral in kimberlite, yet its origin is still heavily debated. This is in part due to its simple mineral chemistry causing compositional overlap in major elements between potentially different olivine populations. New analytical technology, such as high-precision electron microprobe analysis (EPMA) and laser-ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), has made the minor and trace element composition of olivine more accessible, broadening its possible use in both petrology and exploration. A surge of new studies, have indicated that olivine in kimberlite has multiple origins and is characterized by a complex crystallization history.

We present new major and trace element data on remarkably fresh olivines from the EKATI diamond mine. The analyzed olivines define two distinct chemical trends: 1) a mantle trend with angular cores, showing low Ca (< 0.1 wt% CaO) and high Ni (0.3-0.4 wt% NiO) at varying Mg# (0.86-0.93), 2) a melt trend typified by thin (< 100 µm) rims with increasing Ca (up to 1.0 wt% CaO) and decreasing Ni (down to 0.1 wt% NiO) contents at constant Mg# (~ 0.915). These findings are in agreement with recent studies suggesting that virtually all kimberlitic olivine is composed of xenocrystic (i.e. mantle-related) cores with phenocrystic (i.e. melt-related) overgrowths.

The two main trends can further be resolved into sub-groups refining the crystallization history of olivine. The mantle trend indicates a multi-source origin that samples the layered lithosphere below the Slave craton, whereas the melt trend represents multi-stage crystallization comprising a differentiation trend starting at mantle conditions and a second trend controlled by the crystallization of additional phases (e.g. ilmenite and chromite) and changing magma conditions (e.g. oxidation).

These trends are also evidenced in the concentrations of trace elements not routinely measured in olivine (e.g. Na, P, Ti, Co, Sc, Zr). The trace element distribution between the two trends appears to be consistent with phenocrystic olivine overgrowths possibly originating from dissolved orthopyroxene, showing enrichment in Zr, Ga, Nb, Sc, V, P, Al, Ti, Cr, Ca and Mn in the melt trend. The distinctiveness of these two trace element trends offers a clear way to distinguish mantle olivine from “melt-derived olivine” in till samples.

We will present trace element data on olivine from diamondiferous and non-diamondiferous peridotites, comparing the element imprint with that seen in diamond-forming fluids. Ultimately we aim to establish major and trace element discriminators for kimberlitic olivine, mantle olivine and diamond-facies mantle olivine in exploration till samples that may help exploration efforts.

IMPLICATIONS OF RECENT ABORIGINAL RIGHTS COURT DECISIONS ON RESOURCE DEVELOPMENT

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Two recent Supreme Court of Canada decisions on Aboriginal rights bring implications to resource development in Canada. The decisions differ in that the Tsilhqot'in decision relates to lands in British Columbia that are not part of an existing Treaty or settled Aboriginal land claim while the Grassy Narrows decision involves Treaty lands in Ontario. Implications for the mining sector in regions outside of B.C. and Ontario (like the Northwest Territories) will be addressed in this presentation.

THE FUTURE OF ONSHORE SEISMIC EXPLORATION IN CANADA'S NORTH

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In recent years, there has been intensive focus placed on improving the efficiency,

safety and environmental performance in onshore seismic operations. Several recent technological innovations have provided the opportunity for a step-change in onshore seismic operations, particularly when properly integrated.

These include but are not limited to new seismic receiver technology and methods, new seismic source technology, remote sensing and imagery, drones, improvements in seismic sampling and the associated underlying computing power and integration of surface, sub-surface and environmental data via geographic information systems (GIS).

We will review these new technologies and their implications for northern onshore operations. This talk will be of particular interest to explorationists, regulators and community stakeholders.

A REMOTE SENSING-BASED METHOD FOR DISTINGUISHING IMPACTS OF INDUSTRIAL DEVELOPMENTS FROM THAT OF NATURAL FACTORS ON BARREN GROUND CARIBOU

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Natural resources form a cornerstone of the Canadian economy. Their development contributed ~15% Canada's GDP in 2011, and an even large proportion in Canada's North. On the other hand, arctic lands are the home of aboriginal peoples for thousands' of years. Wildlife (e.g., caribou) has played an important role in their economy, culture, health, and way of life. Therefore, one of the biggest issues in Canada's North is how to optimally balance resource developments and wildlife conservation.

Caribou are affected by many factors such as habitat, harvest, predators, diseases and parasites, extreme weather, climate change, industrial development, and pollution. To distinguish the impact of one factor (e.g., industrial development) from others has been a challenge. As documented in the 'Science and Technology Plan for 2014 to 2019' of the Canadian High Arctic Research Station (CHARS), companies have identified the capacity to distinguish project-specific environmental, social, economic, and health impacts from those that result from broader-scale changes such as global warming or from the cumulative effects of multiple projects in a region as a critical area for science and technological development to support resource development.

As a part of NWT CIMP, we have been working towards a solution to this challenge. By using historical time series of satellite data from the NOAA AVHRR (Advance Very High Resolution Radiometer) acquired and pre-processed by Canada Centre for Remote Sensing, we have estimated the forage availability and quality over the Bathurst caribou summer range since 1985. Community-based vegetation monitoring results from sites near Wekweètì in 2013-14 were used for calibrating these estimates.

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We calculated a summer range cumulative index (SRCI) to measure overall forage capacity by combining forage availability in early summer and late fall with forage quality at the peak of leaf biomass. By determining the upper envelope curve between SRCI and caribou productivity, we were able to quantify the impact of habitat changes on caribou for the first time at the population level. With SRCI, we explained 54% variation in the late winter calf:cow ratio of Bathurst caribou since 1985. Using the SRCI-caribou productivity relationship as an analogue, we could potentially estimate impacts of industrial developments on caribou's productivity and population changes. Initial results of such estimations will be presented. However, we emphasize that before this method can be adopted as an acceptable tool for environmental assessment there are many questions to be answered (e.g., similarity and difference between impacts of natural factors and industrial developments on caribou, buffer zone distance of developed areas, and validity of the SRCI-caribou relationship for other caribou herds).

MANAGING RISK IN THE EXTRACTIVES SECTOR

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Environmental Resources Management (ERM) works with mining and oil & gas companies at all stages of the project lifecycle to help them improve business performance and reputation by solving complex business challenges arising from safety, health, environmental (EHS), and social issues.

Drawing on a number of examples, ERM

would like to put forward a session that examines the way in which projects and operations can adopt a more informed approach to risk management.

We will identify risks common to the industry, and the potential profitability and reputational consequences that can result if they are not effectively managed. Thought-provoking questions will be posed and practical tools will be provided to assist organizations in characterizing their risk profile.

Ultimately, we are looking to help our audience answer the following key question: How comfortable are you that your organization is effectively managing risk?

LIABILITIES AND FINANCIAL ASSURANCES

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As a result of Devolution, on April 1, 2014 the Government of the Northwest Territories (GNWT) assumed regulatory authority for land and rights in respect of waters and subsurface, including minerals and oil and gas, from the federal government. As a part of this transfer of authorities the GNWT inherited environmental securities valued over \$500 million.

On September 12, 2014, the GNWT announced the creation of a Liabilities and Financial Assurances Division in the Department of Lands. The role of the Division will be to ensure a proactive and coordinated approach to the management of environmental liabilities and the management of financial assurances for the GNWT.

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The role of the Division and its initiatives will be discussed to provide participants with an understanding of the GNWT's approach to security management.

NATIONAL ENERGY BOARD IN THE NORTH

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The presentation provides an overview of the National Energy Board and its responsibilities for oil and gas exploration and production activities in post-devolution Northwest Territories, Nunavut, and the Arctic offshore. The NEB is a full cycle regulator with consideration for a project spanning application assessment and decision-making to operational oversight and compliance verification if approved, to abandonment and report review with focus on safety and protection of the environment. The Presentation would include an update on current and anticipated activities in the next several years in the North. The presentation concludes with an overview of how the NEB is preparing for future activities including some legislated changes.

MANTLE SOURCES AND LITHOSPHERIC LID THICKNESS DURING SVERDRUP BASIN VOLCANISM: PRELIMINARY RESULTS

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The Sverdrup Basin Magmatic Province (SBMP) is the highest volume component of the High Arctic Large Igneous Province (HALIP) that spans High Arctic Canada, Franz Josef Land, northern Greenland, and Svalbard. Magma from this basin, associated with Early Cretaceous rifting, outcrops as dykes, sills and lavas on Ellesmere and Axel Heiberg Islands, Nunavut. Considering the widespread volcanism, surprisingly little geochemical and isotopic data has been acquired for the SBMP. Several recent studies on the HALIP indicate a surge of interest in this understudied magmatic province, including: U-Pb geochronology of two intrusive complexes in northeastern Ellesmere [1]; Ni-Cu-PGE prospectivity of the HALIP [2]; and a geochemical and Sr-Nd study on lava flows in the Hassel Formation [3]. Despite this interest, there are no reported Sr-Nd isotopic signatures of the dykes and sills. Obtaining Sr-Nd isotopic data from all forms of magmatism in the SBMP is important because it may provide the ability to link the sources of the various dykes, sills, and lavas of the Sverdrup Basin Magmatic Province, if the effects of crustal contamination can be screened out.

This study presents preliminary Sr-Nd isotope and trace element results for twenty four dykes, sills, and lavas that extend the length of Eureka and Nansen Sound, on both Axel Heiberg and Ellesmere Islands. The geographic spread of this new data compliments the sample locations of the recent studies and aims to solidify the link between the abundant dykes and sills along the basin margins with the stacked lava flows on the basin axis.

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To complement the Sr-Nd data, this study will also use the rare earth element (REE) chemistry of the magmas as a proxy for the depth of magma generation during Cretaceous extension. Inversion of REE compositions yields a melting profile that provides the proportions of melt extracted in the spinel and garnet facies [4]. The depth of magma initiation gives a snapshot of how thick the lithosphere was at the time of magma formation. Using the existing REE inversion model on the SBMP and related nephelinites from Bathurst Island, a cross-section of Cretaceous lithospheric thickness can be created, pinned by the presence of thick cratonic lithosphere on mainland Arctic Canada and extended to the thinned lithosphere beneath the Sverdrup Basin on the northern tip of Nunavut.

Ultimately, we will be able to track magma source and lithospheric lid thickness changes through time by coupling the REE inversion modelling and the isotope systematics of the magmas with a combination Ar-Ar dating of the lavas and high precision U-Pb geochronology of the sills.

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**WHEN SECURITY IS NOT
ENOUGH: DIRECTORS AND
OFFICERS LIABILITY FOR
ENVIRONMENTAL DAMAGES
WHEN MINING PROJECTS
FAIL**

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Mining exploration and development are high risk enterprises. Environmental laws in the Northwest Territories (NWT) and Nunavut set out a framework intended to both protect the land and ensure that the taxpayer is not required to pay the cost of cleaning up abandoned mine sites. This regulatory framework provides for financial security for closure and reclamation of mine sites: But what happens when the security held is not sufficient to clean up the site?

This presentation will briefly review the legal framework for financial security to ensure closure and reclamation of mines sites in the NWT and Nunavut. We will identify challenges for both mining companies and regulators. We will then explore the law related to the liability of officers and directors of mining companies which fail and abandon sites before clean up is completed.

**RESEARCH PROGRESS ON
INTERPRETING HEAVY
MINERAL CONCENTRATES
AND SILT CHEMISTRY FROM
STREAM SEDIMENTS FROM
THE MACKENZIE MOUNTAINS,
NWT**

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Stream sediment sampling programs conducted by the Northwest Territories

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Geoscience Office (NTGO) and the Geological Survey of Canada are improving the coverage throughout the Mackenzie Mountains for an important geochemical dataset. Regional stream sediment surveys have historically been implicated in the discovery of many of the major economic deposits in the Canadian Cordillera. The contribution of these surveys towards economic development in hinterland regions has encouraged provincial and territorial governments to ensure nearly complete coverage for both British Columbia and Yukon. This year, stream sediment data for the headwaters of the Cranswick River (western half of NTS 106G and 106F) will be released. In addition, a new sampling program was undertaken to supplement previously-collected data in the Flat and Little Nahanni River Valleys (95E and 105I) adjacent to the Nahanni National Park Reserve.

Since 2003, a silt, water, and bulk stream sediment survey program has collected material and observations from over 9500 sites, including nearly 1500 heavy mineral concentrate (HMC) samples. These surveys are based on a grab sample of silt-sized stream sediment and a corresponding water sample, collected at a density of one sample per 13 km². The collection of coarser-grained and volumetrically-larger HMC samples for indicator minerals has been conducted at a lower density of approximately one sample per 26 km². The interpretation of the analyses has been assisted by two additional datasets. The first consists of the delineated 3rd to 6th order watershed outlines and the second is the publication of a digital geology compilation for the study area (NWT Open File 2014-01). The development of these two data layers has allowed for a more systematic interpretation of the geochemical results.

The results largely demonstrate agreement with the established regional metallogeny, but there is evidence for other potential mineral deposit types yet to be found. The known mineral deposit types which can be identified in the chemical data include: stratiform/stratabound Kupferschiefer-type Cu-Ag hosted in the rift-related Coates Lake Group, sedimentary exhalative (SEDEX) Zn-Pb that was deposited in shales of the Selwyn Basin during the Cambrian through Devonian. Greater than 200 mineral occurrences belong to the carbonate-hosted Zn-Pb (+base-metals) type, found in the carbonate Mackenzie Platform. Cretaceous intrusion-related W-skarn (proximal to intrusions), base-metal skarn (distal from intrusions), rare-metals and semi-precious tourmaline related to pegmatites, and vein-hosted emeralds, occur throughout the southwestern Mackenzie Mountains. Among the new deposit types recently discovered in the region, the stream sediment data has guided explorers towards an extension of the 'Carlin-style' Rau-trend gold play into the NWT.

2014 NORTHWEST TERRITORIES GEOSCIENCE OFFICE (NTGO) PETROLEUM GROUP RESEARCH AND SUPPORT ACTIVITIES REPORT

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The NTGO Petroleum Group activities report covers the period from November 2013 to November 2014. The group's activities fall into three categories.

1. Research projects completed by:
 - NTGO

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- NTGO and Collaborators
 - Affiliated and/or Contracted Groups
2. Government Departmental and Divisional Support
 3. Client Support

Our focus projects include:

- Mackenzie Plain Phase 1 (2009-2014) – Wrap Up
- Canol Shale Resource Assessment – Initiation
- Mackenzie Plain Phase 2 (2014-2018?) – Initiation
- Liard Basin Project (2012-2015?) – Ongoing Collaboration
- Prospect Summaries Project – Initiation

The Mackenzie Plain Phase 1 Project (Mackenzie Plain physiographic region) included a thorough assessment of the Canol Formation with respect to litho geochemistry, source rock potential and thermal maturation trends. Project data will be used in a new NTGO Petroleum Group collaboration with the National Energy Board (NEB) to evaluate the Canol Shale unconventional hydrocarbon resource potential in the mapped region. The Mackenzie Plain Phase 2 Project was initiated to extend the Canol shale evaluation beyond the currently mapped boundaries. The Liard Basin Project is an ongoing collaboration between NTGO, Yukon Geological Survey and British Columbia Ministry of Natural Gas Development. All three jurisdictions have expressed a desire to work with the NEB to produce an assessment of the unconventional resources associated with the Horn River/Besa River formations of the Liard Basin.

The Petroleum Group contracted one research study and contributed samples towards one affiliated study during the past year. AMEC Environmental & Infrastructure was contracted to produce a Central Mackenzie Valley subsurface groundwater baseline study. The purpose of the study was to produce an independent and integrated baseline hydrogeological interpretation of the groundwater monitoring programs data collected in 2013 by ConocoPhillips Canada, Husky Oil Operations Limited and MGM/Shell. This study is available for download from the NTGO website (NWT Open File 2014-07). An affiliated study was completed by Dr. Thomas Hadlari (NRCan Calgary) on dominantly Canol shale samples collected during NTGO's past field research activities in the Mackenzie Plain and Peel Plateau. The purpose of his study was to evaluate the porosity characteristics of the Canol shale. This completed study is currently under review for publication as an NTGO Open Report.

The Prospect Summaries Project was initiated to address a Government of the Northwest Territories need for basic play information pamphlets for distribution at conferences and trade shows. Petroleum plays will be summarized in text, maps and figures and prospective trends will be identified.

The Petroleum Group also provides support to clients and intergovernmental groups such as the Petroleum Resource Division and Office of the Regulator Oil and Gas Operations. A new petroleum regulatory geologist was recently hired to facilitate support for these groups.

2014 was a busy year for the NTGO Petroleum Group. We collectively published

three Open Files and three Open Reports and currently have one Open File and two Open Reports under review for NTGO publication. By the end of this forum we will also have collectively published 7 abstracts for six conference talks and one poster session.

DRAFT INTERIM DEHCHO LAND USE PLAN - GUIDELINES FOR ACTIVITIES

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The Dehcho Land Use Planning Committee will provide an update on the status of the draft Interim Dehcho Land Use Plan. The presentation will review the proposed guidelines for mineral, oil and gas activities in the Dehcho.

PUBLIC ACCESS TO NWT PETROLEUM GEOSCIENTIFIC INFORMATION POST- DEVOLUTION

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On April 1, 2014, the Office of the Regulator of Oil and Gas Operations (OROGO) assumed regulatory responsibility from the National Energy Board for oil and gas operations in the NWT onshore outside of the Inuvialuit Settlement Region and federal areas. With that change, OROGO became the custodian of access to important geo-scientific information including core samples and historic drilling results.

The presentation will examine current requirements and future plans for public access to these important information resources.

ICHTNOLOGICAL CRITERIA FOR DISCERNING MARINE PALEO HIGH-LATITUDE SETTINGS

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High-latitude settings show predictable trends in climatic conditions that influence the distributions, behaviors, and sizes in some groups of tracemaking organisms. Resolving this signal in the ancient record is challenging, owing to the interplay of numerous environmental parameters.

Cold water results in lowered metabolism and extended life spans in animals. Additionally, due to increasing gas solubility in cold waters, dissolved oxygen contents are much higher therein. The higher availability of oxygen in cold water has been positively correlated to animal size. These factors favor larger body size and are expressed in Timofeev's proposition: body sizes increase along a declining temperature gradient.

The distribution of trace-making animals is greatly influenced by the severe conditions of high-latitude intertidal and shallow-water environments. Intertidal settings tend to preclude crustacean-colonization, resulting in reduced occurrences of Thalassinoides and Ppsilonichnus in high-latitude tidal flats. Therein, Polychaete-generated structures are more common. The highest biomass in high-latitude settings resides on the mid / outer

shelf, a marked contrast to low and mid-latitude settings where biomass is highest in bays, estuaries, and the inner shelf. This results in the dislocation of the Cruziana Ichnofacies basinwards and suppresses the Zoophycos Ichnofacies. Regarding specific ichnogenera, *Rosselia* abundances and morphologic complexities are heightened in cold-water settings. *Macaronichnus segregatis* occupying 'toe-of-the-beach' positions occur in high-latitude locales. Basinward displacement of echinoids in cold water favors robust and abundant *Scolicia*. Finally, because high-latitude settings are prone to high-frequency storms, trace fossils such as *Rosselia*, *Lingulichnus*, *Diplocraterion*, and *Rhizocorallium* commonly show signs of re-adjustment.

2014 NORTHWEST TERRITORIES EXPLORATION AND MINING: A YEAR IN REVIEW

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For many years, the Northwest Territories has led Canada in diamond and tungsten production and this trend continues for 2014 (NRCan 2014). Current production has surpassed expectations from both the Ekati and Diavik diamond mines with Ekati producing 1.36 million carats in the first 6 months, and Diavik producing 5.69 million carats during the first 9 months. Development of Ekati's Misery pit; development approval for the Pigeon pit; and adding the Lynx kimberlite to the water license are part of the July updated mine plan with operation to 2020. Ekati's Jay project has open pit resource potential to extend Ekati's mine life by 10 years. NWT

diamond production figures were augmented by 0.9 million carats produced from Snap Lake in the first 9 months. Production decreased modestly at the Cantung tungsten mine, but exploration has extended the mine life to 2017.

On the exploration front, a resurgence of diamond exploration and investment this year is evident by: the advancement of the Gahcho Kué to a development project; 15,300m of delineation drilling from the adjacent Kennady Lake property; re-staking adjoining ground with established kimberlite targets; and news of the Munn Lake option hosting diamondiferous kimberlite. The resurgence of activity is apparent in the staking statistics which show, 393 claims (142,909 hectares) have been staked by mid-October 2014 in comparison with 120 staked by year-end 2013, largely for diamond exploration. Daily updates can be viewed on-line through the Government of Northwest Territories-Industry Tourism and Investment (GNWT-ITI) Mineral Tenure Map Viewer (www.geomatics.gov.nt.ca).

A highlight in metals exploration is the continuing advancement of Prairie Creek Zn-Pb project to the development stage with announcement of underground rehabilitation work. Despite a poor financial market for gold exploration, two projects had substantial drill programs: 7826 m of drill core from the Colomac Gold Project of the Indin Lake Property; and 4505 m of drill core from the Yellowknife City Gold projects was recovered to update and increase historic gold resources and zones.

The bad news is that the NICO Au-Bi-Co and Nechalacho REE development projects have been put on hold, lacking funds for construction and challenges over processing plants; while companies focus their

resources on southern projects. This is also the case for advanced projects such as the Ormsby and Courageous Lake gold projects.

Grass root projects have been on the decline, as evidenced by lack of Prospecting Permits issued for 2014, and are highly sensitive to the global economic climate. GNWT-ITI's Mineral Incentive Program (MIP), managed by the Northwest Territories Geoscience Office, was implemented to kick-start exploration in the NWT through financial assistance of competitive proposals. A total of eight projects were funded for gold, base metals, polymetallic (IOCG) and diamond exploration.

Further details of exploration and mining can be found in the November 2014 NWT Exploration Overview at www.nwtgeoscience.ca.

**THE SLAVE VMS PROJECT:
NEW U-PB AGES
CONSTRAINING THE
TEMPORAL EVOLUTION OF
NEOARCHEAN VOLCANIC
BELTS AND VMS
MINERALIZATION IN THE
SLAVE CRATON**

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Of the 20+ known volcanic belts exposed within the Archean Slave craton, we are re-examining, through the Slave VMS project, many of those localized in the Northwest Territories for their potential to host volcanogenic massive sulphide (VMS) base

and precious-metal deposits. A major aspect of this project is to establish new, precise chemical abrasion isotope dilution (CA-ID-TIMS) U-Pb zircon age constraints for many (principally) rhyolitic units both within and across greenstone belts in the southern Slave craton. These new ages are being determined in support of new, high-quality mapping initiatives, all of which are coordinated in parallel with detailed litho-geochemical and tracer isotopic studies (e.g. Nd). One of the principal early objectives of the project is to determine the timing of development of volcanic systems in belts that appear to have VMS deposit potential, and compare this to the age(s) of volcanism and mineralization in belts with established deposits. This presentation will provide a progress report on the preliminary U-Pb dataset.

The best available age constraints for significant VMS deposits in Nunavut suggest punctuated activity beginning at approximately 2705 Ma (High Lake), at 2680-2690 Ma (Hood, Hackett River, YAVA, MUSK), and youngest magmatism/mineralization at ca. 2670 Ma (e.g. Gondor). The older and younger events were recognized to have temporally equivalent deposits within NWT greenstone belts to the south, including Cycle I volcanic-associated deposits in the Courageous-MacKay Lake belt (2701 Ma DEB deposit) and VMS prospects in the Coppermine River belt (e.g. INC-10, ca. 2668 Ma). New U-Pb results for hanging- and footwall rhyolites in the south-central Slave craton reinforce the importance of this younger event: 2667 Ma (BB showing, Indian Mountain belt) and 2672 Ma (Old Canoe - Lac du Rocher belt). This can be extended to include near synchronous felsic magmatism in the Snare River/Indin Lake belt (2672, 2675 Ma). Moreover, rhyolitic

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flows and tuffs with local VMS prospects in belts around the Sleepy Dragon basement complex have now been dated precisely at 2680 Ma (Sharrie Lake), 2681 Ma (Lark prospect, Sunset Lake belt), and 2690 Ma (Fenton Lake, Cameron River belt), bolstering correlations with VMS-related magmatism in the Hood and Hackett River belts.

From a Yellowknife Supergroup perspective, the oldest regional Slave VMS deposits such as at High Lake and DEB would correlate temporally with felsic volcanism in the upper Kam Group, whereas most other deposits have ages that would imply equivalence with lower Banting Group volcanic host rocks. In the Yellowknife area, Banting Group coherent rhyolites and rhyolitic tuff breccias are dated at 2661-2663 Ma.

RESERVOIR MODELS FOR MIDDLE / UPPER DEVONIAN SHALE SUCCESSIONS IN WESTERN CANADA

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We are developing stratigraphy-based reservoir models for key Middle/Upper Devonian shale formations in western Canada: the Horn River reservoir in northeastern British Columbia and the Duvernay Formation in Alberta. These formations are time-equivalent to potential shale oil and shale gas reservoirs in the Northwest Territories, including the Canol Formation. Our models rely on detailed sedimentological descriptions of long cores, large geochemical data sets and

petrophysical data sets that are carefully tied to sedimentary facies and rock composition. The Horn River study enables us to build high resolution reservoir models that account for changing composition due to proximity to sources of carbonate and clastic sediment; the Duvernay study allows us to examine the effect of varying thermal maturity on reservoir properties.

Shale lithologies show systematic variation related to sequence stratigraphic systems tracts. Transgressive and early highstand deposits are composed of laminated to massive, organic-rich, siliceous mudstones. Highstand deposits show increases in bioclast- and intraclast-rich debris beds, shed from nearby carbonate platforms. Bioturbation is more common and TOC values are typically lower. Stillstand or lowstand deposits in the Duvernay are commonly composed of nodular carbonates with increased argillaceous content and show increased fissility, intense bioturbation, and substantially reduced TOC values; in the Horn River sequence, low stand deposits are reflected by clay-rich compositions. Geochemical redox proxies indicate that deposition of TOC-rich intervals was associated with more reducing conditions, although some relatively high TOC samples nonetheless display bioturbation; this suggests that anoxia was not required for the deposition of significant amounts of organic matter. SiO₂ varies inversely with carbonate content and is interpreted to be biogenic in origin.

Porosity generally falls in the range from 2 to 10% and permeability from 3 to 40 nd. Positive correlations are observed between porosity and TOC and between quartz content and TOC, indicating that organic matter content is a primary factor controlling porosity development and that supporting a

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biogenic model for the quartz. Negative correlations are observed between porosity and the carbonate and clay content. Shale intervals deposited during transgressions have higher porosity than intervals deposited during falling sea level stage, probably due to enhanced TOC deposition or preservation and associated porosity development.

THE NEOARCHAEAN BANDED IRON FORMATIONS OF THE SLAVE CRATON: INSIGHT INTO A TECTONICALLY ACTIVE MARINE ENVIRONMENT

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Banded iron formations (BIF) are iron- and silica-rich chemical metasedimentary rocks that span much of the Archaean and early Palaeoproterozoic rock record. Given that they precipitated out from the ambient seawater, they provide an important archive of Earth's ancient marine environment. The Yellowknife Supergroup consists of a craton-wide Neoarchaean greenstone belts with a depositional age ranging between 2740-2600 Ma. The belt hosts some of the largest and best-preserved Archaean turbidite dominated successions in the world, which is best exemplified by the well-known ca. 2680-2650 Ma Burwash Formation. Overlying the Burwash Formation is a package of younger ca. 2630-2610 Ma turbidites that, alongside the typical greywacke-mudstone sets, are characterized by interstratified BIF.

In this study, petrography, geochemistry were conducted on three BIF sequences from the western Slave craton (Slemon Lake, Damoti Lake and Point Lake), and on one BIF from the eastern part of the craton (Goose Lake). In addition, to constrain the depositional ages, LA-ICP-MS zircon U-Pb dating was carried out on an interbedded greywacke sample from Goose Lake and on a tuff bed within the Slemon Lake BIF. The maximum depositional age based on the youngest detrital zircon analysed for the Goose Lake BIF is 2621±18 Ma and the Slemon Lake tuff bed is 2620.4±5.7 Ma. This shows that these BIFs belong to the younger turbidite package.

The BIFs are predominantly composed of micro- and mesobands of quartz and magnetite, with various amounts of Fe-silicates. On a geochemical bulk rock basis, the iron content is relatively high with an average of 47.2 wt.% Fe₂O₃ while the average SiO₂ content is 49.1 wt.%. The Al₂O₃ content is highest at Slemon Lake, between 1.07-2.96 wt.%. These values are all slightly elevated relative to the classical definition of BIF, probably as a result of the high volcanoclastic input into the depositional basin. Despite this, the BIFs still record the seawater composition, which is best reflected in their shale-normalized (SN) enriched HREE pattern that shows Pr/Yb_{SN} values between 0.26-0.63. The Eu_{SN} anomaly ranges from 1.18-3.16 (average of 1.96), indicating that reduced Eu²⁺ was derived from the hydrothermal submarine fluids that influenced the seawater.

The intimate deposition of BIF and turbidites likely indicates a depositional basin influenced both by submarine hydrothermal activity and terrigenous volcanogenic sourced sediments related to

the ca. 2630 Ma Defeat magmatic arc. Moreover, at Damoti Lake, Point Lake and Goose Lake, cm-scale, dark volcanogenic derived beds dominated by amphibole and plagioclase fragments set in a chlorite groundmass are found interbedded with the BIF suggesting that mafic volcanism was ongoing at the time of BIF deposition.

A STORM-INFLUENCED SHOREFACE SUCCESSION WITHIN THE CAMBRIAN MOUNT CLARK FORMATION OF THE MACKENZIE MOUNTAINS, NORTHWEST TERRITORIES

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The Cambrian Mount Clark Formation forms a conceptual hydrocarbon reservoir within the Central Mackenzie Valley (CMV) of the Northwest Territories, Canada. This succession lies unconformably over Proterozoic rocks and represents a complex marine setting flanked by paleotopographic highs to the West (Mackenzie Arch) and East (Mahony Arch).

The Cambrian Mount Clark Formation has been reported by the Geological Survey of Canada and Northwest Territories Geoscience Office in regional studies, but detailed ichnological and sedimentological investigations have not been conducted. Depositional affinities are poorly understood with fluvial to shallow marine environments proposed within an existing lithostratigraphic scheme.

To produce a detailed sedimentary framework, four outcrops within the

Mackenzie Mountains were measured and photographed to describe ichnological assemblages and sedimentological fabrics. New observations and our interpretations include: (1) sharp erosional contacts separating highly bioturbated lower shoreface strata from hummocky and trough cross-stratified upper shoreface strata and the presence of a localized *Glossifungites* firm-ground suite, both of which are interpreted to represent demonstrable base-level changes; (2) attenuated bioturbation, locally massive bedding, and unburrowed mud beds that are indicative of a wave-dominated delta setting; (3) sharp-based, unburrowed, wave reworked strata that are interpreted as tempestite beds indicating a storm-influenced depositional setting; (4) poorly developed to non-existent post-storm tempestite colonization trace fossil suites that may have significance regarding the evolution of post-storm opportunistic colonization by marine invertebrates; and (5) a fair-weather trace fossil suite comprising *Skolithos*, *Palaeophycus Striatus*, *Planolites*, *Diplocraterion*, *Asterosoma*, *Phoebichnus*, *?Rosselia*, *?Rhizocorallium*, *Teichichnus*, *Phycodes*, and *Chondrites*, representing an archetypal *Cruziana* Ichnofacies associated with proximal offshore to inner shelf sedimentation under normal marine conditions. These newly identified components and interpretations reveal a complex depositional setting punctuated by base-level changes. Observations taken will aid in the correlation and exploration of Cambrian strata within the subsurface of the CMV where core control is non-existent.

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**PROVENANCE OF
PALEOPROTEROZOIC
FLUVIAL SUCCESSIONS:
GAMMA-RAY SPECTROMETRY
AND PALEODRAINAGE OF THE
1.9-1.6 GA ELU BASIN,
NUNAVUT, CANADA**

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We present new gamma-ray spectrometry and sedimentologic data from fluvial and eolian deposits of Elu Basin, Kitikmeot Region of Nunavut, Canada. Elu Basin consists of an underexplored, 100x30-km-wide belt of sedimentary rocks sitting atop the Archean Slave Province. The basin is one of several Proterozoic sedimentary basins of Arctic Canada, the fill of which has been subdivided in sequences with regional traceability and recording discrete stages of basin development.

The Slave Province is here represented by granitoid rocks and by a folded complex of metasedimentary and mafic metavolcanic rocks of the Hope Bay greenstone belt, a regional, N-S-trending regional feature that underlies the Elu Basin in its central sector. The lower portion of the Elu Basin fill consists of siliciclastic rocks deposited in alluvial to eolian environments, while shallow-marine carbonate rocks dominate the upper portion. The lower stratigraphic units, the subject of this study, are the unconformity-bounded Burnside River, Tinney Cove, and Ellice formations. The Burnside River Formation is composed of hematite-stained, coarse-grained sandstone with minor conglomerate. Paleocurrent

patterns in the formation are generally unimodal, toward the northwest. The Tinney Cove Formation is composed of a locally developed breccia derived from the lower Burnside River sandstone, and the chaotic fabric of the deposit hampers the collection of reliable paleocurrent indicators. The Ellice Formation is composed of pale yellow sandstone with minor conglomerate, with dispersed paleocurrent indicators directed between west-southwest and north-northeast.

Provenance studies for the Proterozoic basins of Arctic Canada were previously based on detrital zircon geochronology, supported by paleocurrent analysis of alluvial deposits. In this study, we introduce new inferences on provenance based also on the gamma-ray spectral signature of both basement rocks and the deriving siliciclastic rocks. We discuss total radioactive-dose rates, bulk contents of U, Th, and K, as well as K:U+Th ratios. Within the basement, granitoid rocks are characterized by higher K and lower U+Th when compared to metavolcanic rocks. Similar trends in the basin fill are interpreted to represent sourcing from distinct basement lithotypes. However, enrichment of U+Th is characteristic of surfaces of unconformity, as well as deep profiles of alteration. High content in K within sandstone units is also associated to marine influence, i.e. introduction of mud-sized sediment. Comparisons between litho-geochemical data and detrital-zircon geochronology are further explored. Litho-geochemical data are derived from bulk-rock samples of the Elu Basin fill, while detrital-zircon geochronological data are derived from correlative exposures of the Wellington Inlier on Victoria Island.

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MINERALOGICAL SPECIATION OF ARSENIC IN LAKE SEDIMENTS AND SOILS IN THE YELLOWKNIFE AREA

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Since 1999, Queen's researchers have been investigating tailings, soils and sediments and co-existing waters near Yellowknife to understand the geochemical and mineralogical controls on the mobility of arsenic (As) and antimony. This presentation will focus on As.

Ore roasting has converted most of the As in arsenopyrite to other forms. In the subaerial tailings, AsIII and AsV are mostly hosted in roaster-generated iron oxides and are stable in an oxidizing environment. However, evidence suggests that these iron oxides undergo reductive dissolution and release As from sediments under oxygen-deficient conditions.

Soils on the Giant property contain arsenic trioxide and roaster iron oxides from stack emissions which have persisted for approximately 65 years. Soil pore water extracted after precipitation events contains as much 2000 µg/L As. The bioaccessibility of arsenic from three soil samples was determined using synthetic body fluids to evaluate how much As might be dissolved if ingested or inhaled. Results indicate that 34% of the As is bioaccessible in gastric fluids (<250 micron fraction) and 18% is

bioaccessible in lung fluids (<20 micron fraction).

The sediments in Baker Pond contain up to 14,000 mg/kg total As and those in the vegetated area of Baker Creek outlet contain up to 3000 mg/kg. In these sediments, As is present as arsenic trioxide, roaster iron oxides and arsenopyrite and root plaque on *Equisetum fluviatile* (horsetails). A survey of sediments from regional lakes has shown that those closest to and downwind from the roaster contain arsenic trioxide.

A combination of micro-analytical tools enables the distinction between anthropogenic and natural forms of As and provides the opportunity to predict long-term stability and bioavailability.

GEOCHEMICAL CHARACTERIZATION OF OXIDE MINERALIZATION AT THE PRAIRIE CREEK DEPOSIT, NWT

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Prairie Creek is an unmined high grade Zn-Pb-Ag deposit in the southern Mackenzie Mountains of the Northwest Territories, confined within the boundaries of the Nahanni National Park. The upper portion of the primary quartz-carbonate-sulphide vein mineralization have undergone extensive oxidation, forming high grade zones rich in smithsonite ($ZnCO_3$) and cerussite ($PbCO_3$). This weathered zone represents a significant resource and a potential component of mine

waste material. This research is focused on the characterization of the geochemical and mineralogical controls on metal mobility at Prairie creek, with particular attention to the metal carbonates as a host for trace elements under mine waste conditions. Analyses were conducted using a combination of SEM, EMP, MLA, LA-ICP-MS, and synchrotron-based μ XRD and μ XRF techniques.

Results include the identification of previously unknown minor phases, including cinnabar (HgS), acanthite (Ag₂S), metal arsenates, and Pb-Sb-oxide. Anglesite (PbSO₄) may also be present in greater proportions than is suggested by previous work. Smithsonite consistently contains elevated concentrations of Pb, Cd, Cu, Fe, and Mn, while cerussite (expected to be removed as Pb concentrate) regularly hosts Zn, Cu and Cd. Variable concentrations of Fe, As, Sb, Hg, Ag, and Se are present in both, in approximately decreasing order. A significant proportion of the trace metals may also be attenuated by other secondary minerals. Processing into tailings will remove significant sources for these elements, however, smithsonite will subsequently remain as the major source for most of them. Significant Hg and Ag could remain in tailings from cinnabar and acanthite that is trapped within smithsonite grains.

In a mine waste setting, near-neutral pH will encourage precipitation and attenuation of trace metals. Regardless, oxidation, dissolution and mobilization is expected to continue at a slow rate, which may be slowed by saturated conditions, or accelerated by localized flow paths and acidification of isolated, sulphide-rich pore spaces.

AN ORGANIC GEOCHEMICAL INVESTIGATION OF THE PAKTOA C-60 OIL, BEAUFORT-MACKENZIE BASIN

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A 20°API gravity and low sulfur (0.15%) oil was recovered from the Tertiary Taglu Formation at 1293-1311.5m depth during #4 drill stem testing of Paktoa C-60 well in Beaufort-Mackenzie basin. Organic geochemical analysis performed on the oil indicates that it has experienced severe biodegradation. Its total hydrocarbon composition obtained from GC-FID analysis is dominated by a UCM hump with normal alkanes and acyclic terpenoids being absent. Diamondoids and bicyclic sesquiterpanes are found to be the most prominent peaks situated atop the UCM hump. GC-MS analysis of the oil shows that regular steranes and C₂₉-C₃₅ hopanes have been removed whereas the biodegradation-resistant diasteranes and C₂₇ Ts and Tm hopanes seem to have been unaffected by biodegradation. Moreover, 25-norhopanes, the biodegradation products of regular hopanes are found to be at high abundance in the oil. Furthermore, the highly bio-resistant biomarkers of angiosperm input such as oleananes and bisnorlupanes and some of their aromatized derivatives have also been detected at high abundance in the oil. Other than triaromatic steranes, most polycyclic aromatic compounds including C₀-C₄ naphthalenes and C₀-C₂ phenanthrenes have been totally or partially removed depending on their alkylation and isomer status. This biomarker assembly

indicates that DST#4 oil from Paktoa C-60 well has experienced severe biodegradation.

Despite having been exposed to severe alteration, thermal maturation and source information can still be inferred for the Paktoa C-60 DST#4 oil based its distribution of biodegradation-resistant geochemical molecules. The thermal maturity of the original oil or its source rock is estimated to be in the range of 1.3-1.6% Ro based on its methyl-admantane and methyl-diamantane distribution, thus the oil had likely originated as a high maturity light oil or condensate prior to biodegradation. An extremely high concentration of adamantanes (*ca* 1.4% of oil) leads to an estimate that as much as 70% of the original oil accumulation could have been lost to biodegradation. A dryness of $C_1/(C_1-C_4) > 99.2$ for the liberated gas is consistent with a biogenic origin. The absence of a significant gas accumulation indicates that majority of the gas from oil biodegradation was lost by leakage.

The abundant occurrence of higher plant biomarker oleananes, bisnorlupanes and tricyclic diterpanes does suggest a contribution of Tertiary deltaic sequences to the oil accumulation at Paktoa. Contradictory maturity signatures of the oil (i.e. high maturity indicated by diamondoids and low-to-medium maturity shown by oleananes and bisnorlupanes) suggests that the original Paktoa C-60 oil was sourced primarily from a deep buried source rock at late-oil-generation to early-gas-generation stage with minor contribution from shallower Tertiary sources. The upward migration of the high maturity oil may have extracted low maturity oils while passing through the Tertiary strata to the reservoir. The main (deeper) source rocks are likely of Cretaceous age considering the distribution

of the diasteranes that have survived biodegradation. Paktoa C-60 oil has a diasterane C_{27}/C_{29} ratio around 40%, similar to oils believed to be derived from Upper Cretaceous source rocks but much higher than that of the typical Tertiary sourced oils (<25%) in the Beaufort-Mackenzie basin.

**CONVENTIONAL AND
UNCONVENTIONAL
RESOURCE ASSESSMENTS IN
CANADA'S NORTH: A NEW
ESTIMATE OF DISCOVERED
CONVENTIONAL PETROLEUM
IN THE NORTHWEST
TERRITORIES AND NEB
METHODS FOR ASSESSING
UNCONVENTIONAL
RESOURCES**

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The National Energy Board has been assessing the amount of conventional natural gas resources available to Canadians for many years, but has only more recently started assessing the amount of unconventional petroleum resources. When it comes to the Northwest Territories, the Board is involved with both conventional and unconventional assessments. In its most recent study, the Board has estimated the amount of discovered conventional petroleum in the Northwest Territories. In partnership with relevant provincial and territorial agencies, The Board is also in the initial stages of determining the unconventional resource potential of the Liard Basin, the Cordova Embayment, and the Canol Shale.

The Board's assessment of discovered

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conventional petroleum in the Northwest Territories used a volumetric approach, where statistical distributions were applied to variables in volumetric equations for each pool. Monte Carlo simulations were then run to determine the low, expected, and high values on a pool by pool basis.

The Board also uses a volumetric approach when assessing unconventional petroleum resources, though includes an adsorbed gas component where necessary. Unlike conventional resources, which can be thought of as multiple discrete accumulations with limited geographic areas, unconventional resources are typically continuous accumulations of petroleum over a large geographic area. Thus, the Board treats the unconventional resource like one large pool whose reservoir characteristics vary across its areal extent. By incorporating map grids into the assessment to capture how the reservoir changes from place to place, the Board can then determine the total resource volume by summing the amount of petroleum at each point on the grid. Statistical distributions can be applied to the variables at each point to simulate uncertainty on a local level. Geological maps, however, are often a geologist's "best guess". Therefore, a single distribution can also be applied to an entire map grid to simulate a suite of geological maps that range from pessimistic to optimistic. Where data is too limited to create a reliable map, a distribution can be applied across the entire map area instead. In this way, the Board can estimate low, expected, and high values for unconventional petroleum resources both locally and across the entire play.

NORTHWEST TERRITORIES GEOSCIENCE OFFICE - A YEAR IN REVIEW

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The Northwest Territories Geoscience Office (NTGO) experienced a number of significant changes during 2014. Prior to devolution on April 1, 2014, the NTGO was a partnership between the Government of the Northwest Territories (GNWT) Department of Industry, Tourism and Investment (ITI) and the Federal Department of Aboriginal Affairs and Northern Development Canada. With devolution on April 1, the NTGO became a division of ITI. NTGO staff largely continue in their pre-devolution roles but are now all GNWT employees. Devolution also yielded two new NTGO positions - a Manager of Geoscience Information Services and a Petroleum Regulatory Geologist. These positions were staffed in June 2014. The NTGO now has 25 staff members consisting of a Director, an Operations and Finance Officer, and five working groups: Petroleum Geoscience, Environmental Geoscience, Mineral Deposits and Bedrock Mapping, Geoscience Information Services, and Geomatics and Information Technology.

Introduction of the GNWT's Mineral Development Strategy during 2014 generated additional changes at the NTGO. Two term positions (a Surficial Geologist and a Geophysicist) were created and staffed and two high-impact geoscience projects were funded. A new Mining Incentive Program was also rolled out. In its first year, this program, which is administered by the NTGO, allocated almost \$400,000 to two

prospector applicants and six corporate applicants to support their grassroots exploration programs. Mining incentive programs are common to jurisdictions that encourage mineral exploration and provide an important means of supporting sound and innovative exploration approaches.

As 2014 draws to an end, additional NTGO changes are anticipated. These include: (i) re-profiling a vacant position to an Industrial Minerals Resource Geologist position; (ii) launch of a new NTGO website, and; (iii) a possible name change to the Northwest Territories Geological Survey. Two other major initiatives will be announced in the near future.

Despite all of these changes, NTGO staff managed to carry out a large number of project and client service activities both in and out of the field. Many of these projects will be described during the Geoscience Forum.

The NTGO looks forward to opportunities stemming from ongoing relationships with the Geological Survey of Canada, the Canadian Northern Economic Development Agency, numerous universities, and other partners and funding agencies. A new collaboration with the Canadian High Arctic Research Station was also initiated during 2014.

HOPE BAY GOLD PROJECT - NUNAVUT, EXPLORATION AND PROJECT UPDATE

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TMAC Resources Hope Bay Gold Project is located approximately 685 km northeast of

Yellowknife, in the Kitikmeot region of Nunavut. TMAC Resources Inc., a privately held exploration and development company, completed the acquisition of the Project from Hope Bay Mining Ltd., a subsidiary of Newmont Mining Corporation, on March 12, 2013. The project consists of proposed exploration, development and underground gold mining within the Hope Bay greenstone belt. The Hope Bay belt is a 2.65 billion year old, Archean age greenstone belt covering an extensive area of approximately, 80 km by 20 km. The belt has experienced considerable exploration and development spending over the past twenty-five years by previous operators, including BHP, Miramar, and Newmont. Currently three known gold trends exist on the property, Doris, Madrid and Boston. Combined mineral resources total 8.2 Mt, grading 10.6 g/t Au, containing 2,788,000 oz Au within the Measured and Indicated categories and 5.1 Mt, grading 10.9 g/t Au, containing 1,786,000 oz Au within the Inferred category.

The 2013 work program was focused on re-opening the camp facilities, environmental monitoring and regional exploration in the northern third of the belt. The 2013 program resulted in completion of a Preliminary Economic Assessment (PEA), authored by Roscoe Postle Associates Inc. and released on December 31st, 2013. The PEA demonstrated the significant positive economic potential of the project. TMAC resources closed a \$78 million financing on April 28th, 2014 to continue to advance the project towards production.

Aspects of the 2014 work program included diamond drilling in the Doris and Madrid trends, environmental compliance monitoring and permitting, infrastructure maintenance and commissioning and re-

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opening of the underground infrastructure at Doris. Approximately 67,000 m of diamond drilling was completed in 2014 to upgrade mineral resources classification and build on the existing mineral resource base, thereby further de-risking the project. TMAC Resources intends to complete a Pre-feasibility Study (PFS) on the project by the end of Q1 2015. The PFS will support project financing and development of the project to production.

2013 GEOTECHNICAL INVESTIGATION AT THE LONG LAKE CONTAINMENT FACILITY, AT EKATI DIAMOND MINE

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A winter 2013 geotechnical investigation was completed at Long Lake Containment Facility (LLCF). The primary purpose of the investigation was to determine the in situ conditions of the slurry deposited processed kimberlite at the Long Lake Containment Facility (LLCF). The drilling program required the drilling of 7 holes, a cone penetration test, coring of the frozen materials, sampling and laboratory testing of the unfrozen materials and lake water, and the installation of geotechnical instrumentation to support future monitoring. The subsurface conditions at boreholes comprised layers of processed kimberlite and ice over lake bed materials and till. In six of the boreholes the processed kimberlite material was frozen. A layer of unfrozen kimberlite was found in one borehole at the south end of the LLCF.

Successfully completing a winter drilling program in the north is always a challenge and extensive planning was required to safely execute the 2013 winter investigation. This presentation will discuss the geotechnical results of the investigation and also what is required for completing a successful northern geotechnical investigation

EVALUATION AND STABILIZATION OF A SLOPE FAILURE AT LIARD HIGHWAY NO. 7, KM 5.9

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The Liard Highway (NWT No. 7) was constructed between 1969 and 1984. In summer 2007, the road was reconstructed at km 5.9, raising the vertical alignment. A fillslope failure occurred later that summer. The Government of the Northwest Territories, Department of Transportation, reconstructed the fillslope, and installed a French drain in the ditch to intercept groundwater flow. The repairs performed adequately until 2010, when the slope failed again.

Tetra Tech EBA Inc. evaluated the site and designed the stabilization works in 2010-2011. Vital to the evaluation and stabilization of the slope was developing an understanding of road embankment behaviour as related to the underlying glacial deposits and post-glacial geomorphology. Recognizing the presence of till-like colluvium and peat over glacial till, understanding the likely pre-development topography and stratigraphy,

and noting the past and present pathways for high groundwater inflow from upslope, helped in explaining the complex site stratigraphy and artesian groundwater pressure near the toe of the slope. Stabilization works included a longer, deeper French drain along the ditch, and two counterfort drains across the road. The gradient of the upper fillslope was reduced to mitigate surface ravelling of the road embankment. Follow-up monitoring suggests that slope stability has improved, but surface water erosion remains an issue.

CORRIDORS FOR ENERGY AND COMMUNICATIONS IN NUNAVUT, NORTHWEST TERRITORIES AND YUKON

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To address the need for energy and communications in the North, we propose a number of corridors that host small diameter natural gas and liquid fuel pipelines accompanied by high-speed fiber optics communications. The liquids pipeline would be designed for batching to allow diverse and multiple fuels to be pumped.

Three such corridors would form the basic infrastructure from which future exploration and development growth would evolve. An eastern corridor would run north from Manitoba into Nunavut; a central corridor would extend from northern Alberta to Yellowknife, NWT and mineral rich areas to the north and in Nunavut; a western corridor would transit through the western NWT to Alaska. The project has been divided into logical segments for organic growth and lateral pipes connecting towns, mines camps, etc. would extend services to more

distant consumers. These corridors are a flexible design concept which can be quickly and simply installed and commissioned to meet northern needs and provide the backbone to invite future development.

MAPPING HYDROTHERMAL FOOTPRINTS: CASE STUDIES FROM THE BIF-HOSTED MELIADINE GOLD DISTRICT, NUNAVUT

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The geochemical and mineralogic signature, or hydrothermal footprint, of ore deposits has great potential as an exploration tool. In some cases, hydrothermal footprints can be mapped up to several kilometers beyond the economically viable portion of the deposit and thus offers the potential to vector from sub-economic mineralization towards higher-grade ore from district- to deposit-scales. Conventionally, hydrothermal footprints are mapped using some preferred threshold concentration for each pathfinder element, or ratio, of interest. The results are then generally portrayed as stacked geochemical traverses adjacent to known ore bodies. However, the conventional approach inadequately accounts for the multivariate nature of ore processes and the inherently imprecise boundary between barren and mineralized rock. In this contribution we explore alternative methods to define and map the hydrothermal footprint at six gold

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deposits and ore zones within the Meliadine Gold District (MGD), Nunavut.

MGD host rocks are variably altered (silicified ± sericitized ± sulphidized ± carbonatized ± chloritized) adjacent to BIF-hosted replacement-style gold mineralization and auriferous greenstone-hosted quartz (± ankerite) veins cutting mafic volcanic, interflow sediments and turbiditic successions. Robust principle component analysis defines key element assemblages (Au-Ag-As-S-Te-Bi-W-Sb) that are associated with gold and are enriched from 10s to 100s of meters adjacent to ore zones. We integrate and map pathfinder element enrichment and quantified measures of hydrothermal alteration intensity using a hybrid fuzzy- and conditional probability-based model (weights of evidence) in an effort to further highlight the complementary nature of multivariate datasets and to define fuzzy footprints. The available whole-rock data suggests that multi-element anomalies are, in some instances, better suited for defining broader geochemical anomalies than was apparent from analysis of individual pathfinder elements. We emphasize that samples containing pathfinder element concentrations in excess of some preferred threshold are akin to conventional definitions of geochemical anomalies, but in this case occur primarily in the ore zone and are thus of limited use for vectoring. In contrast, fuzzy footprints delineate the simultaneous occurrence of favourable pathfinder element enrichment and hydrothermal alteration for samples that would have been excluded following the conventional approach. These samples occur in hanging wall and footwall rocks devoid of gold (< 5 ppb), and thus provide a possible vector to high-grade gold ore.

PROTRACTED PALEOPROTEROZOIC GOLD HISTORY AT THE ARCHEAN BIF-HOSTED MELIADINE GOLD DISTRICT, NUNAVUT

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The Meliadine Gold District, Nunavut, represents one of Canada's largest emerging greenstone- and BIF-hosted gold districts (reserves of 2.8 Moz Au, plus indicated and inferred resources of 5.8 Moz Au). Most known gold deposits are co-spatial with the Pyke Break, which cuts Meso to Neoproterozoic (ca. 2.66 Ga) supracrustal and igneous rocks and represents an E-W trending fault associated with a NE-SW trending trans-cratonic fault network. The latter cuts the Western Churchill Province and records a complex and protracted reactivation history that spans at least four Paleoproterozoic orogenic episodes. Gold occurs as inclusions within idioblastic arsenopyrite crystals, at sulfide crystal boundaries and/or as sulfide fracture fills. Arsenopyrite crystal boundaries and domains adjacent to late fractures are variably recrystallized and relatively enriched in precious- and base-metals. In contrast, inclusion-free arsenopyrite crystals and overgrowths along with arsenopyrite domains devoid of fractures are relatively gold-poor. Clusters

of gold and galena that correspond with recrystallized arsenopyrite domains and at contacts between disparate arsenopyrite generations suggest that sulfide recrystallization liberated gold and was remobilized, at least locally, into low-strain micro-textural sites along with precious- and base-metals during late fluid-assisted and deformation/metamorphic-driven remobilization. New U-Pb xenotime ages at ca. 1.86 Ga, coupled with previously reported U-Pb hydrothermal monazite ages, post-date arsenopyrite recrystallization, which suggests that gold remobilization was concomitant with the Trans-Hudson orogeny (1.9–1.8 Ga). New Re-Os arsenopyrite model ages range from 2.3–1.8 Ga and document a hitherto unrecognized and complex pre-1.86 Ga hydrothermal and sulfide history. The range of Re-Os model ages tends to support partial open-system behaviour and/or mixing of disparate arsenopyrite generations that are evident from micro-textures and in situ element mapping. Replicate analyses of the two most Re-rich and homogeneous arsenopyrite samples yield Re-Os model ages at ca. 2.37 and 1.90 Ga, which are broadly concurrent with the Arrowsmith (2.4–2.3 Ga) orogeny and the earliest phase of the Trans-Hudson orogeny (known locally as the Snowbird orogeny; ca. 1.9 Ga), respectively. These Re-rich samples also tend to be gold-poor and likely yield ages that pre-date gold remobilization and subsequent enrichment along arsenopyrite crystal boundaries and fractures at 1.86 Ga. We speculate that the bulk of the gold was initially introduced at 2.37 Ga and/or 1.90 Ga along with idioblastic arsenopyrite crystals and was subsequently re-mobilized, coupled with arsenopyrite recrystallization, during the Trans-Hudson orogeny.

REMOTE SENSING AS A TOOL TO ASSESS AND MONITOR RECLAIMED AREAS: A MULTI- SENSOR, MULTI-DATA APPROACH

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Not long ago, the objective of reclamation was often to cover the bare ground as quickly as possible, usually with agronomic grasses so as to reduce erosion. Often, there is little if any pre-disturbance information. There is a pressing need to monitor reclamation and re-vegetation, both locally across large sites and regionally at many sites across broad areas. Regulation in certain jurisdictions requires forestry, oil and gas, and mining companies to return disturbed land as closely as possible to the requirements of the permit upon completion of their activities in an operating area.

As climate in the north continues to change, and resource exploration and extraction activities increase, mapping the changing landscape becomes key for the conservation and sustainable management of resources. Monitoring of reclaimed sites is a complex, interdisciplinary undertaking, especially in large, disturbed areas with difficult access. In that context, remote sensing is a unique and valuable tool that provides a synoptic view of an entire reclamation program and its progress over time, extending the more detailed but sparsely distributed in situ monitoring.

Through the analysis of remote sensing data, we can create maps that provide easily

understood information about a site's vegetation history, and whether or not it has reached and maintained the requirements of the permit. These maps are produced at various scales, are Geographic Information Systems (GIS) compatible, and often provide data for remote, inaccessible locations or for locations where historical data are missing. This information can help decision-makers focus remediation efforts on specific locations most needing it, rather than making unnecessary and potentially costly changes to entire sites. The maps are useful, not only in reclamation and multidisciplinary studies, but also in public demonstration of industry's progress towards reclamation goals.

In this paper, we present examples of long-term remote sensing monitoring at mine sites undergoing reclamation in Canada. Other applications of remote sensing are also discussed, such as the generation of habitat maps for wetland monitoring at reclaimed tailings ponds in support of wildlife habitat or biodiversity studies. An overview of an ongoing project recently funded through the Earth Observation Application Development Program of the Canadian Space Agency is also provided, which will integrate optical and RADAR imagery with in situ data for the purposes of developing more robust strategies for Earth Observation-based reclamation monitoring.

INNOVATIVE PROCESS TO STABILIZE SUBSURFACE AT GIANT MINE SITE

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The former Giant Mine is one of Canada's largest contaminated sites, now under the control of Aboriginal Affairs and Northern Development Canada (AANDC) on behalf of the Federal Government. A key component of mine closure is to provide structural support in underground voids to prevent collapse in the mine that could cause immediate harm or lead to failure elsewhere. In the case of the Giant Mine site, there is the additional risk of mine flooding from surface water that needs to be mitigated. Due to this and the presence of arsenic trioxide dust in underground stopes this has severe environmental consequences as well as safety considerations. In order to mitigate high risks related to the stability of the mine site due to underground openings, an innovative advanced remediation program is underway while the overall remedial approach is being developed.

AANDC engineers working with Public Works and Government Services Canada (PWGSC), and industry leaders in mine closure, developed an innovative approach to stabilizing the voids using unique paste mixtures. Paste is commonly used to backfill underground voids by pumping via boreholes. In this situation, the project team proposed using a portion of the thousands of tonnes of mine tailings deposited on the site as the primary paste ingredient. This would allow for the removal from the surface of tailings, as well as save significant amounts of money by not requiring importing other paste material to the site.

Using a small amount of cement as binder, testing was undertaken to determine if the required strength properties for structural fill could be achieved using the on-site tailings as the primary paste material. This is critical to minimize the potential for failure of the underground, especially for the stopes at the

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site, which either contain arsenic or are adjacent to arsenic stopes. Testing of the paste mixtures did not take place until late 2013, so the cold weather and dark days were an added challenge to the process. Paste backfill was produced by extracting frozen tailings and using a mobile paste production system, which had not been done under these conditions before. The paste delivery approach also had to meet stringent specifications from the permits and emergency water license issued for the program.

The logistical challenge to deliver the program considering drilling requirements, underground conditions, ongoing monitoring, health & safety, and other site activities, along with the technical challenge of finding the right paste mix and delivery conditions took significant effort by the project team to overcome.

This presentation will describe the process to design and deliver the stabilizing paste, and the lessons learned in undertaking this innovative approach in a unique operating environment.

A STRUCTURAL MODEL FOR HOWARD'S PASS PB-ZN DISTRICT: LET'S START FROM SCRATCH

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Zinc and lead mineralization was discovered at Howard's Pass in Silurian shale of the Selwyn Basin in the 1970's. It is considered to be a classic example of a sedimentary exhalative (SEDEX) deposit. The existing structural model for Howard's Pass holds

that mineralized sediments were deformed, while still water-saturated, during a period of local compressional tectonism speculated to have interrupted the extensional regime in the Silurian. According to this model, later Cordilleran-wide orogenesis produced further folding, low-grade metamorphism and minor remobilization of sulphide along cleavage, but did not significantly affect sulphide textures and distribution.

New insights from recent detailed surface bedrock mapping indicate that an alternative interpretation is required to explain the distribution of the strata and mineralization. We propose that the existing distribution of rock types is primarily controlled by thrusting, forming a duplex structure, not simply by folding. Northeast-verging thrusts are proposed to root into a flat-lying detachment surface that forms the floor thrust of the duplex, termed the Howard's Pass décollement. The Howard's Pass décollement displays significant ductile strain. Above the décollement, a series of imbricated thrust faults disrupt mineralization and stratigraphic succession. Sulphides (galena, sphalerite, and pyrite) are concentrated and remobilized along a pressure solution cleavage, well developed in zones of high-strain. The duplex is capped by a flat-lying detachment that is the roof thrust, above which less shortening has been accommodated. We suggest that the duplex and associated fabrics (pressure solution cleavage, transposition, folds and faults), which control the distribution of the mineralization, formed 250-300 Ma after deposition of sediments.

Field evidence supports a structural interpretation where the Howard's Pass district is subjected to layer-parallel shortening during Jura-Cretaceous collisional deformation of Cordilleran

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orogeny resulting in a regional-scale duplex structure. The duplex and its flat-lying bounding décollement surfaces can be traced, at the same stratigraphy levels, for hundreds of kilometers in the Selwyn Basin. The bulk of the deformation is Jura-Cretaceous, not Silurian in age.

Recent studies on the depositional environment of the Selwyn Basin host rocks reach contradictory conclusions. Some research shows that there is little evidence for exhalation and that the bulk of the Pb-Zn sulphide minerals precipitated below the seafloor in an intermittently oxygenated environment, while other research suggests exhalation in conditions of extreme basin restriction. These studies, together with our proposed structural re-interpretation of Howard's Pass, highlight the need to re-examine the currently accepted model for the district, as well as other 'SEDEX' deposits in the Selwyn Basin.

NWT PETROLEUM RESOURCES POLICY AND REGULATORY PRIORITIES

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The Petroleum Resources Division is a new Division within NWT's Department of Industry, Tourism and Investment that was formed as a result of devolution of natural resources, land and water management authority from the federal government to the Northwest Territories on April 1, 2014.

The presentation will outline the current and upcoming policy and regulatory project priorities for the Petroleum Resources Division, such as the development of an

NWT Oil and Gas Strategy, hydraulic fracturing regulations and governance of the Environmental Studies Research Fund, as well as operational responsibilities in managing oil and gas rights in the onshore NWT.

MAPPING HUMAN DISTURBANCE IN THE BATHURST CARIBOU RANGE USING PERMITTING REGISTRY INFORMATION AND REMOTE SENSING TOOLS

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A detailed geospatial database of current and historical human activity was developed for the range of the Bathurst caribou herd to provide a standard, robust and validated dataset for use by industry, wildlife management agencies, co-management boards and land use planners in cumulative effects assessment and cumulative impact monitoring.

Mapping human disturbance in the range of the Bathurst caribou presented unique challenges as standard remotely sensed mapping techniques are less effective north of treeline, where habitat alteration is not as obvious. A multiproxy approach using existing geospatial datasets and permitting records from regulatory agencies in the Northwest Territories and Nunavut were used to identify and locate historical activities in the study area. Additional information for each activity was then gleaned from permitting records, so that the

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database contained detailed attributes for each activity. The location of these data was validated using a combination of remotely sensed imagery and hard copy maps that were submitted as part of the permitting processes. The resulting database includes information on the timing, location, extent and nature of more than 260 human activities within the range of the Bathurst caribou herd between 2000 and present. A separate dataset is also scheduled for completion to augment this information by mapping other significant disturbances on the landscape that are not reflected in the permitting records. Although this supplemental dataset will lack detailed attribute information, it provides a more comprehensive picture of the current human disturbance footprint to include major disturbances that were either not permitted or were present prior to year 2000. The vast majority of validated features produced from this project are accurate at a scale of 1:100,000 (or +/-100 metres of their true location). The few features not able to be validated for their precise location are noted as such. Lastly, features were captured as polygons when possible. Some linear features were captured as polylines with specific attribute information to denote the average width of the footprint. A small number of features were captured as points due to their small footprint or a lack of detailed information to delineate a true representation of the disturbance. In these cases, the documented area of the feature is included in the attribute information. As such, all features can be combined for spatial analysis purposes within a GIS and represented as polygons through the use of buffer tools to develop a single polygonal dataset. This polygonal dataset can then be used to calculate more precise area statistics for the cumulative disturbance footprint.

Datasets such as this are critical as resource managers and industry are increasingly responsible for determining and estimating cumulative effects of human and natural disturbance on wildlife and other valued parts of the northern environment. The intention is to further refine this pilot study based on feedback from data users and then apply the methodology to other priority areas in the NWT.

STATE OF NORTHERN KNOWLEDGE IN CANADA: RESEARCH GAPS, GAINS AND OPPORTUNITIES RESPECTING NORTHERN RESOURCE DEVELOPMENT

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The North's resource development industry operates in an environment of significant change driven by a number of complex factors, with overlapping consequences for Northern industry, communities and cultures, natural and built environments, northern economies and Canada as a nation. In April 2014 the Canadian Polar Commission published a report on the 'State of Northern Knowledge in Canada' which presents significant research gains made since the beginning of International Polar Year in 2007 and identifies key knowledge gaps most critical to Northerners and the Canadian North in order to prepare for large-scale resource development; increase community sustainability; strengthen resilience; and understand environmental change. Respecting large-scale resource development, the report identifies research gains and gaps relating to employment and training, understanding and mitigating

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negative impacts, public governance, and mapping and surveys. Respecting community sustainability gains and gaps are identified under the headings of housing, infrastructure, transportation, energy security, food security, supporting local and regional economies, and health care systems, each of which are fundamental to the social and economic context within which northern resource development occurs. The 'State of Northern Knowledge in Canada' report is built on semi-structured interviews with 114 northern researchers and practitioners, two-thirds of them resident in Canada's North. Interview input was corroborated through an extensive survey of peer-reviewed and grey literature and reinforced by further expert consultation. The full report including references is available on the Canadian Polar Commission's website:

http://www.polarcom.gc.ca/sites/default/files/snk_report_english.pdf.

A WATERSHED-SCALE SAMPLING PROTOCOL FOR DISTRIBUTION AND TREND ASSESSMENTS OF STREAM SALMONIDS IN THE NORTHWEST TERRITORIES

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Understanding the conditions that limit the distribution and abundance of species is a primary goal of ecologists. This complex question becomes even more challenging for species found in remote locations. Salmonids are top predators in stream networks and integral to ecosystem functioning, yet are highly sensitive to disturbance. This inherent vulnerability makes them a resource management concern but also ideal indicators of aquatic ecosystem health. The purpose of this project was to develop a scientifically defensible and practical protocol for monitoring the abundance, distribution, and habitat use of stream salmonids in the Northwest Territories (NWT). These species include chars (*Salvelinus* spp.), graylings (*Thymallus* spp.), and whitefishes (*Prospium* spp.), and are all important subsistence and recreational fishes. Conventional monitoring based on site-level abundance is not well suited for these species because they naturally occur at low densities and use spatially distinct habitats across large river networks. Alternative monitoring strategies based on spatial and temporal patterns of species occurrence have recently been developed that require less intense sampling at individual sites, yet provide powerful and accurate trend detection across broad areas.

A research project was developed to explore application of distributional monitoring techniques to streams in the NWT. A persistent data gap has been our understanding of juvenile fish ecology. Since juvenile salmonids spend some period after emergence in natal spawning streams, occupancy in streams can be used to identify rearing habitat and also as a proxy for spawning habitat being nearby. High

occupancy by juveniles of streams across a watershed can, additionally, be used as a surrogate for the presence of healthy salmonid populations.

In 2012 a pilot study was implemented to test this approach on Bull Trout in the Prairie Creek watershed. Streams that possessed suitable spawning and rearing habitat were identified and a sub-set of these streams were surveyed. Occupancy and detection efficiency of juvenile Bull Trout was highest in second order streams and lowest in high-gradient first order streams. In 2014 this stream sampling method was implemented in two additional systems - Little Nahanni and Rat River watersheds - to assess the transferability of this method to Arctic Grayling (*Thymallus arcticus*) and Dolly Varden (*Salvelinus malma*) respectively. Initial results indicate that this method works well for northern stream salmonids. Using this method we can collect data more efficiently to improve our knowledge of northern stream salmonid ecology and biophysical thresholds that limit occurrence. Further, data acquired can be used to: 1) build robust models to map spawning and rearing habitat over broader regions, and 2) describe baseline conditions which can be used to assess cumulative impacts and monitor population trends over time.

**NEW IDEAS ON THE
ARCHITECTURE AND
ECONOMIC POTENTIAL OF
THE WESTERN RAE CRATON
AND ITS BOUNDARY ZONE
FROM THE GEM-2 CHANTREY-
THELON PROJECT**

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Following a 550 km-long, GEM-sponsored, reconnaissance-scale geological transect across western Nunavut in 2012 (McMartin et al., 2013; Berman et al., 2014; Davis et al., 2014), the Chantrey-Thelon project was initiated to further advance geologic understanding and attract mineral exploration to this underexplored, frontier region spanning the Thelon tectonic zone, Queen Maud block, and adjacent Rae craton. The two main areas of focus in 2014 were the Thelon tectonic zone (Ttz) and Montresor belt.

Within the Ttz, bedrock mapping along two transects of NTS map sheet 76H revealed the lithologic and structural continuity of nine, roughly N-striking, belts with distinct aeromagnetic characteristics. Boundary zones are strongly tectonized and have steep dips that preliminary magnetotelluric models show extend to mid-crustal levels.

Belts of ca. 2.0 Ga plutonic rocks are prominent in the western part of the transect and age equivalent plutons are recognized significantly further east than previously known. The eastern plutonic belt comprises more mafic compositions than the western belts and includes migmatitic Fe-rich metasedimentary rocks. S-type granite separates this plutonic belt on both sides from monzogranite to quartz diorite domains that yield Mesoarchean ages, but the

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relationship between the two Mesoarchean domains is currently unknown. The western boundary of Mesoarchean crust is marked by a 10 km-wide aeromagnetic low dominated by S-type granite, potentially derived from melting of continental margin sediments. Poorly exposed monzogranite gneiss to the west of the aeromagnetic low is dated at ca. 2.6 Ga and may represent Slave crust. The relationships described above suggest the Slave-Rae suture may occur 40-50 km further east than previously considered.

A 1-2 km wide belt of low-grade mafic to intermediate metavolcanic rocks does not have contacts exposed with basement or with a package of metasedimentary rocks of unknown age. Significant geochemical anomalies (Cu, Pb, Zn, Ag) and sulphide grain concentrations, determined by a stream sediment survey in 2012 (McCurdy et al., 2013), appear to coincide with the volcanic belt. Geochemical analyses from 2014 till and stream sediment sampling, as well as from 8 newly recognized gossans, are in progress to further define exploration targets in this region. Mineral prospecting in the more heavily till-covered areas will be assisted by 2014 surficial mapping results that indicated the predominant ice-flow direction to the north-northwest shifted northwesterly during deglaciation.

Fieldwork in the Paleoproterozoic Montesor belt, 300 km east of the Ttz, revealed a significant metamorphic discontinuity near the base of the belt due to detachment along a post-1.85 Ga extensional fault. At the southwestern end of the belt, a 500 m-thick stratiform zone of brecciated, altered and mineralized rocks (returning 1600 ppm Cu, 1700 ppb Ag), as well as likely igneous precursors, are exposed for >4 km and marked by a prominent negative

aeromagnetic anomaly. The anomaly can be traced for >20 km and may continue on the northern limb of the Montesor syncline, comprising a 50-km-long target corridor for gold-silver-copper mineralization. Future work will include additional assays, geochronology and geophysical modeling.

References are to GSC open files 7418, 7471, 7652, 7698.

KENNADY NORTH PROPERTY: 2014 FIELD SEASON UPDATE

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The Kennady North Property, wholly owned by Kennady Diamonds Inc. is located 300 km northeast of Yellowknife adjacent to the DeBeers/Mountain Province Gahcho Kué Property. Exploration on the property dates back to the early 90's, during which time several kimberlites were discovered. Since 2012 Kennady Diamonds has completed a number of geophysical, RC till sampling and diamond drill programs. Work completed during the 2014 season significantly expanded the tonnage of two of the kimberlite pipes and identified several new exploration targets.

The 2014 field season started in January with a four month ground geophysics program that included 1,763.0 line-km of capacity coupled resistivity (Ohm mapper), 265.5 line-km of ground penetrating radar (GPR), 759 Extremely Low Frequency (ELF) stations and 6,175 ground gravity stations. The winter-spring drill program commenced at the beginning of February and ended in May. Drilling delineated the Kelvin kimberlite beneath and near the shore

of Kelvin Lake and explored other areas of the property. A 25 tonne mini bulk sample from the southeast portion of the Kelvin kimberlite was collected using two diamond drills (HQ core). A third diamond drill (NQ core) was used to delineate the Kelvin kimberlite, continue testing the Faraday kimberlite, and test a geophysical target in the central area of the Kennady Diamonds Inc. land package. This program was followed up by a six week RC till sampling program during which 267 holes were drilled and 889 till samples were collected and processed. The summer drill program was initiated using two diamond drill rigs; a third diamond drill rig was added in early August. The summer drill program ran from the beginning of July to the end of October and focused on further delineating the Kelvin kimberlite to the northwest as well as the Kelvin sheet structure at depth to the south of the Kelvin kimberlite pipe. During 2014, a total of 10,450 meters of HQ drilling and 16,317 meters of NQ drilling were completed on the Kennady North Property. A total of 47.5 tonnes of kimberlite was collected for dense media separation (DMS) and another 6.35 tonnes of kimberlite was collected for caustic fusion analyses. Saskatchewan Research Council in Saskatoon, Saskatchewan completed the majority of the analyses. A smaller portion of the caustic fusion sample was submitted to Rio Tinto Canada's Mineral Processing Laboratory in Thunder Bay, Ontario.

Kennady Diamonds Inc. is very encouraged with the exploration results to date and anticipates a successful and exciting 2015.

INNOVATIVE SOLUTIONS FOR OPERATING ON ICE COVERS IN NORTHERN CANADA

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The purpose of the presentation is to provide innovative solutions for using ice covers safely within a reduced operational window. Ice covers had been used successfully as temporary working platforms within the resource industry for transportation and operational purposes in Northern Canada. Mining companies and remote northern communities rely heavily on accessing sites and remote villages for the supply of consumables and equipment via winter roads during the winter months. Increasing ambient temperatures reduce the operational window. The future challenge is to carry out the same amount of work and to transport material within a shorter time period. Advanced construction methods and the application of analytical models are presented to effectively access and operate at remote places in northern Canada within changing environmental conditions.

ASSESSING THE NI-CU-PGE POTENTIAL OF THE CARIBOU LAKE GABBRO THROUGH ANALYSIS OF SILICATE AND SULFIDE MELT INCLUSIONS

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The Caribou Lake mafic-ultramafic intrusion (CLI) comprises the western intrusive suite of the Early Proterozoic Blachford Lake Intrusive Complex, which intrudes sedimentary rocks of the Archean Yellowknife supergroup, the Morose granite, and the Defeat granodiorite. The CLI is located approximately 90 km southeast of Yellowknife, NT, along the Hearne Channel, Great Slave Lake and lies at the southern margin in the Slave Province of the Canadian Shield.

Magmatic Ni-Cu-PGE mineralization consists of disseminated to massive pyrrhotite+magnetite+ilmenite+chalcopyrite+pyrite+pentlandite. Accessory phases include glaucodot-gersdorffite, galena, melonite, electrum, nickeline, molybdenite, sphalerite, and unidentified Pb-Te (altaite?), Bi-Te, and Pb-Se-Te inclusions within glaucodot-gersdorffite. Metal grades within the CLI are subeconomic, with the highest Ni and Cu values at ~1.7 and 1.4 wt%, respectively (in massive sulfide) and enrichments in Pt+Pd up to ~150 ppb (in a fine-grained gabbro containing minor disseminated sulfides).

Small ($\leq 30 \mu\text{m}$), secondary sulfide melt inclusions are preserved as trails within plagioclase and apatite and in olivine and ilmenite as large ($\leq 500 \mu\text{m}$) primary inclusions. The sulfide melt inclusions (SI) are polyphase, consisting of pyrrhotite (91-99%), chalcopyrite ($\leq 6\%$), and Co rich-pentlandite ($\leq 3\%$). LA-ICP-MS analyses indicate that individual SI have low PGE and Au contents and base metal concentrations of 1900 ppm Co, (n=67), 1870 ppm Ni, (n=46) and, 7000 ppm Cu, (n=65). Occasionally Zn, Ag, Pb, and Bi are present at ppm concentrations. The occurrence of these inclusions within high temperature cumulate minerals, their mineralogy, and bulk chemical composition suggests an early sulfide liquid that was poor in ore metals. Sulfur isotope analysis of the pyrrhotite phase in SI trapped in olivine and ilmenite ($\delta^{34}\text{S} = 0.2 \pm 0.5\%$; n=15), reveal compositions consistent with a mantle S source but not ruling out contamination by the Yellowknife supergroup sediments ($\delta^{34}\text{S} = 0.2 \pm 0.4 \%$; n=10).

Primary silicate melt inclusions (SMI) are preserved within cumulus apatite in a medium-grained gabbro. SMI range in size from 5–100 μm and typically form elongated inclusions with negative crystal shapes, aligned parallel to the c-axis suggesting a primary origin. Minimum trapping temperatures were determined by measuring the final melting temperature of solid phases within the inclusions. This occurred between 1100–1150°C, indicating that the SMI formed close to expected liquidus conditions for the enclosed melt composition (~1170°C). LA-ICP-MS analyses of SMI indicate that they trapped an Fe-tholeiite with Ni and Cu generally below detection limits (<60 and ≤ 40 ppm), and Zr (100 – 400 ppm), Nb (15-60 ppm), and Ta (≤ 3 ppm)

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enriched relative to MORB, suggest the intrusion was heavily contaminated by local crustal material. SMI have base metal tenor well below MORB values, consistent with other indications that the melt was metal depleted at the time of entrapment in primocryst apatite (e.g., olivine depleted in Ni). Whether this indicates that the original silicate magma was initially depleted in metals, or a sulfide liquid had already separated at the time of melt entrapment is unclear, but metal tenors within silicate and sulfide melt inclusions are consistent with the subeconomic nature of mineralization.

**APATITE AS AN INDICATOR
MINERAL TO IOCG DEPOSITS
IN THE GREAT BEAR
MAGMATIC ZONE,
NORTHWEST TERRITORIES,
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Apatite-amphibole-magnetite assemblages are a signature alteration product in iron oxide alkali-alteration systems that can host iron oxide-copper-gold (IOCG) deposits. The distinct apatite chemistry that evolves within these systems makes apatite a potential indicator mineral to IOCG deposits in glaciated terrains. As part of the GEM-1 IOCG-Great Bear Project, the mineral chemistry of apatite picked from till samples and disaggregated bedrock samples from the Great Bear magmatic zone (GBmz), as well

as from thin sections from the Sue Dianne and Fab IOCG systems were examined. A variety of possible substitutions within the apatite structure (e.g. Na⁺, Sr²⁺, Mn²⁺ or a Rare Earth Element (REE)³⁺ for Ca²⁺, and Si⁴⁺ for P⁵⁺) were investigated in light of the major and trace element budget of alteration facies of the studied systems. As observed at Fab, REE-rich apatite forms during high temperature alkali metasomatism, as temperature declines and the fluid chemistry evolves. Localized REE leaching takes place within apatite and leads to secondary REE-bearing minerals. Such apatite characteristics have been observed both experimentally and in several iron oxide-apatite deposits (e.g., Kiruna district in Sweden, Baqf district in Iran).

Dark irregular zones observed under SEM backscatter images relate to lower REE contents, confirmed through electron dispersive spectroscopy and laser ablation inductively coupled plasma mass spectrometry, as well as dissolution pits, and in some rare cases, the presence of secondary REE-rich mineral inclusions. Some apatite crystals from IOCG systems have a contrasting blue or blue and green zoned cathodoluminescence (CL) response associated with irregular zonation in REE. Apatite crystals from the least altered host rocks and apatite crystals from other alteration facies in the studied IOCG systems have green or green and yellow CL responses.

Apatite is commonly present in till from the GBmz in amounts ranging from trace to over 2 wt.% of the non-paramagnetic (1>amp) heavy mineral concentrate within the 0.25 to 0.5 mm fraction (separated at SG>3.2). The 0.5 to 1 mm fraction also contains apatite grains, but in minor amounts. Coarser grains (1-2 mm) are

locally present as well. While dissolution pits and irregular zonation (visible in shades of green and yellow CL response) are widespread, blue CL response and the REE-rich mineral inclusions are generally associated with grains collected either down-ice (< 1 km) or directly over the Sue Dianne deposit. These characteristics can be observed in grains picked under CL before or after the grains are mounted in epoxy stubs, highlighting potential to discriminate apatite related to IOCG systems from background apatite. Further work is ongoing to develop this method. The picking process was shown to induce an artifact: apatite grains, both from till and disaggregated bedrock samples were commonly coated by Ca-rich mineral rosettes, likely produced by a surface reaction during oxalic acid wash prior to hand picking. However, this surface reaction did not modify the CL response of apatite or its REE-rich mineral inclusions.

NEOARCHEAN VOLCANIC BELTS IN THE SOUTHERN SLAVE CRATON: REGIONAL CORRELATIONS AND VMS MINERALIZATION

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The NWT Geoscience Office initiated the Slave VMS (volcanogenic massive sulphide) project in order to re-examine Neoproterozoic volcanic belts in the southern Slave craton using new bedrock mapping and supportive geochemical and geochronological investigations. The project aims to highlight

volcanic belts that contain hallmark features indicative of VMS-type mineralization, construct new high-quality bedrock maps of well-exposed belts at finer resolution than were previously available, and provide insights into the overall evolution of the craton during the period 2700 to 2660 Ma. Almost all of the volcanic belts in the southern Slave craton have been mapped at 1:50,000 scale, however, in producing VMS districts such as Flin Flon, MB, it has been demonstrated that higher resolution mapping (e.g., 1:10,000 scale or better) is required to delineate favourable stratigraphic horizons and resolve volcanogenic complexities. To accomplish this scale of mapping, we have chosen areas that have had forest fires within the last 20 years that 'cleaned' the bedrock exposure. A positive consequence from the destructive 2014 forest fire season is that these fires burnt areas with known VMS prospects, providing a number of new areas to conduct bedrock mapping in future years. In volcanic belts that remained unaffected by fires, the previous 1:50,000 scale mapping generally remains satisfactory.

Detailed mapping, geochemical studies, and U-Pb zircon dating has been conducted at the Snare River, in the Burnt Inlet area of the Indin Lake volcanic belt, and south of the Sleepy Dragon basement complex at Sharrie Lake. Known VMS deposits, such as Sunrise at Sunset Lake, and BB near Indian Mountain Lake have been dated and their host-rhyolites geochemically characterized. Detailed geochemical transects have been completed across a number of other volcanic belts including the Courageous-Mackay Lake belt and Old Canoe-Lac Du Rocher belt (see Berger et al., Hamilton et al., Jackson et al., and Williams et al., this volume).

During the course of bedrock mapping and reconnaissance investigations, three new prospective VMS horizons were discovered. These include two Zn occurrences with grab sample values of 0.4% and 4.3% Zn, and one Cu+Zn occurrence with three grab samples with 0.15% to 0.3% Cu and 0.25% to 0.35% Zn, and is located ~15 km from winter road access. While the project definition was not VMS-exploration, these results demonstrate that many Slave volcanic belts remain under-evaluated for their VMS potential. Locations and results will be presented, along with highlights from new mapping, associated value added studies, and forward looking statements as to where future opportunities could exist for both mapping, and exploration.

CUMULATE PHL-CPX-HBL-OL- OPX-CHR-PO INTRUSIONS IN THE WOPMAY OROGEN BACKARC, NWT: LATE OROGENIC MELTING OF SUBDUCTION MODIFIED LITHOSPHERIC MANTLE

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At the Slave craton – Wopmay orogen boundary zone there are numerous small diameter peridotite intrusions. As these intrusions are mantle-derived, petrological details can provide significant insight into crust and mantle processes at the time of

their formation. Their mineral chemical characterisation is important for deciphering their potential input to the ultramafic mineral inventory of till exploration samples.

Field observations have been made on six of these plutons that intruded Paleoproterozoic and Archean rocks east of and parallel to the Wopmay fault zone over a 100 km north-northwest strike length. The plutons are ovoid bodies, <4 ha in diameter and composed of medium to coarse-grained ultramafic rocks with only minor evidence of more fractionated marginal phases. Some of the intrusions underwent brittle deformation along Wopmay fault zone, but most were not affected by the ca. 1860 Ma regional ductile deformation, supporting ⁴⁰Ar-³⁹Ar phlogopite ages between ca. 1870 to 1850 Ma.

Detailed petrological work has been undertaken on two intrusions, at Arm and Labrish lakes. Petrographic observations indicate a crystallization sequence of Ol+Chr-Cpx±Opx-Hbl-Phl with minor interstitial sulphides (Po±Ccp-Pn). Mineral chemical data indicate olivine has low Mg# (0.75-0.8) and 500-1000 ppm Ni, consistent with bulk rock data, and indicating that these olivines are a cumulate phase in the pluton. Chromite grains are <100 µm and are intergrown with Ol, with average Cr# 0.71 (n=82; std. dev. = 0.08) and average Fe# 0.83 (std. dev. = 0.05). In a Cr# -Fe# plot, the Arm chromites parallel the global CrAl trend and likely reflect Chr-Opx Al-exchange, albeit with much higher Fe# than typical chromite from all environments. Orthopyroxene is absent from Labrish samples which contains chromites that overlap Alaskan-type trends. The high Fe# nature of the chromites could be a function of Fe-Mg exchange with host olivine, and

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the chromite compositional trends therefore are best explained by exchange with co-existing phases during fractional crystallization and cooling. In-situ LA-ICP-MS data characterize the trace-element composition of each of the silicate phases and support that much of the REE are hosted in Cpx and Hbl, where Cpx has depleted LREE/HREE and Hbl has elevated LREE/HREE. Olivine has concave REE patterns, with very low concentrations (up to 100x subchondritic) and Phl has extremely low REE with the exception of Eu. The LILE and Nb-Ta are elevated in Phl and Hbl, compared with Ol and Cpx.

Mineralogy and bulk rock geochemistry support that these rocks are best characterized as the crystallization products of lamprophyric magmas. Normalized trace-elements indicate elevated LREE/HREE, and negative Nb, P, Zr, and Ti. They have Th/Yb-Nb/Yb ratios consistent with magmas derived from a metasomatized (subduction modified) mantle wedge. $\epsilon_{\text{Nd}}^{1850}$ values of -2 to -4 indicate either contamination by Archean crust or these were primary melts from subduction-zone enriched Archean mantle. In time and space, and petrologically, these rocks appear to represent hydrated cumulate magma chambers that intruded during the latest-stage development of Wopmay orogen and were possibly derived from a subduction-modified lithospheric mantle related to underthrust oceanic crust of the Nahanni Terrane.

OVERVIEW OF THE SECOND PHASE OF THE GEOLOGICAL SURVEY OF CANADA'S GEO-MAPPING FOR ENERGY AND MINERALS PROGRAM

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The Geo-mapping for Energy and Minerals (GEM) program advances and modernizes geological knowledge in the North to set the stage for long-term investment in responsible resource development.

The GEM program was first launched in 2008 as a five-year, \$100 million initiative to produce new, publically available, regional-scale geoscience knowledge in Canada's North. In 2013, the GEM program was renewed until 2020 with an additional \$100 million. The public geoscience produced by the program supports increased exploration for new mineral and energy resources. This new knowledge will also enable northern communities to make informed decisions about their land, future economy and society.

In its first five years (2008–2013), Geo-mapping for Energy and Minerals program undertook:

- 20 field projects in the three territories and the northern parts of six provinces (Ontario, Quebec, British Columbia, Saskatchewan, Manitoba, and Newfoundland and Labrador),
- Completed 35 regional geophysical surveys,
- Released over 840 open files of new geoscience maps and data, published on the Natural Resources Canada Website, and
- Delivered more than 800 technical information sessions at venues frequented by industry, government and NGOs.

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Taking into account remaining knowledge gaps where modern geological mapping is most needed, both onshore and offshore, the GEM program defined the following six regions of interest: the Mackenzie Basin region, the Northwestern Cordillera region, the Rae Craton region, the Baffin Island region, the Hudson Bay / Ungava region, and the Western Arctic region. Key activities of the GEM program involve on-the-ground field observations, the assessment and analysis of legacy samples and data, targeted airborne geophysical surveys and remote sensing, and advanced laboratory investigations.

In 2014, the GEM program launched its new research program with 14 activities that were initiated following extensive consultations with provincial and territorial counterparts. The program also engaged Northerners and their institutions to seek input on how the program's research activities can benefit Northerners.

THE CONCENTRATION OF ARSENIC IN LAKE WATERS OF THE YELLOWKNIFE AREA

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The Cumulative Impact Monitoring Program is currently collaborating with several university and government partners in a multidisciplinary research program designed to gain a better understanding of the nature, extent and fate of legacy contamination in

the Yellowknife area. As part of this project, two lake surveys were conducted in fall of 2012 and 2014 to establish a broad understanding of the limnology and geochemistry of local lakes. Surface water and lake sediments were collected from approximately 100 lakes within a 30 km radius of Yellowknife in the two sampling periods. Lakes across a range of size, landscape position (i.e. lake order, connectivity to other lakes and streams), bedrock and surficial geology unit, and catchment type were selected.

Water chemistry results from the survey indicated higher concentrations (140 - 1010 ppb) of dissolved arsenic (As) in surface waters within 5 km, and to the west and northwest of the historic roaster stacks at Giant Mine than in the rest of the study area. Median dissolved As in surface waters from the entire study area was 9.8 ppb (mean = 49.0 ppb; max = 1010 ppb; min = <0.5ppb). The distance and direction of lakes from the historic roaster stacks was clearly associated with the concentration of As in surface waters in the area. However, within the area of elevated As there was substantial between-lake variation in water chemistry, suggesting that within-lake processes and lake and watershed characteristics also drive differences in As concentrations in these water bodies.

This study provides important information on how the legacy of arsenic contamination interacts with our ecosystem and the data will inform future risk assessments to local ecosystems and human health. This large dataset also provides important baseline information for future development in a region influenced by 60+ years of mining.

**PRELIMINARY ANALYSIS OF
THE DISTRIBUTION,
MINERALOGY, AND
PETROGENESIS OF GOLD
MINERALIZATION IN THE
CANTUNG W-SKARN DEPOSIT,
NORTHWEST TERRITORIES**

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The Cantung mine is a world-class W-skarn deposit, located just east of the Yukon border in the Selwyn Mountain Range of the Northwest Territories. The extensive W skarn at Cantung was developed by predominantly supercritical magmatic fluids with homogenization temperatures ranging from 270-500°C. Mineralization is dominantly calcic exoskarn replacement of a clean limestone and lower grade replacements in a calc-silicate/chert unit exploited from an open pit and underground mine (the E Zone). In addition to its tungsten wealth, the deposit location is within the southern extent of the polymetallic Tintina Gold Belt, which has many notable intrusion-related Au deposits and reports of trace gold. This has encouraged the examination of the deposit for concentrations of the precious metal.

The main sulphide is pyrrhotite, which is abundant in all skarn facies. Scheelite and chalcopyrite are dominant and there is locally abundant sphalerite. Native Bi exhibits textures indicative of forming later than the silicate assemblage in the paragenetic sequence, and is decorated by

bismuthinite, Bi tellurides, Ag tellurides, and Bi selenides. Tungsten and Cu are the main mine products, but the Au potential of the deposit merits further investigation.

This study characterized the distribution, mineralogy, and petrogenesis of Au by examining five skarn samples with bulk rock Au assay values >0.5 ppm taken from the E Zone. No free gold or electrum was identified petrographically or by SEM and FEG-SEM analyses. A positive correlation (Spearman's Rank, r') of Au with Bi (0.76), Ag (0.70), Fe (0.64), Cu (0.64), and Mo (0.60) was identified using the bulk rock geochemical data ($n = 48$). The strong correlation between Bi and Au is suggestive of a liquid bismuth collector mechanism for Au enrichment; however, LA ICP-MS analysis of native Bi and Bi alloys failed to reveal significant Au predicted by the liquid bismuth collector model. In contrast, the highest Au concentration was encountered in hessite (Ag_2Te) and other tellurides. Nano-inclusions within chalcopyrite and silicate minerals were also investigated using the FEG-SEM for their Au content, but the nano-inclusion were composed purely of native Bi. The decoration of native Bi by bismuthinite, Bi tellurides, Ag tellurides, and Bi selenides provides evidence for a late stage S-, Ag-, and Te-rich fluid. This fluid is thought to have remobilized the Au and deposited it as lattice bound invisible Au within the tellurides. This new data constrains Au exploration targets at Cantung to areas of altered skarn or where there is a presence of telluride minerals.

CENTRAL MACKENZIE VALLEY (CMV) SUBSURFACE GROUNDWATER BASELINE STUDY

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A CMV baseline groundwater study was commissioned by the Northwest Territories Geoscience Office (NTGO) in February of 2014 and is now available for download from the NTGO website (NWT Open File 2014-07). The purpose of the study was to evaluate data collected during subsurface groundwater monitoring programs initiated in 2013 by ConocoPhillips Canada, Husky Oil Operations Limited (Husky) and MGM/Shell. The study objective was to produce an independent and integrated baseline hydrogeological interpretation of all the data submitted to the Sahtu Land and Water Board (SLWB) by the operators. Although monitoring programs are ongoing, this study focused on operator program reports and data submitted to the SLWB during 2013. The rectangular study area is defined by the following coordinates: 64 degrees thirty minutes 22 seconds N / 125 degrees 27 minutes 29 seconds W (south-east corner) and 65 degrees 13 minutes 11 seconds N / 127 degrees 16 minutes and 37 seconds W (north-west corner).

Fresh water aquifers were identified in the study area. These occur within the uppermost sandstone bedrock units of the Late Cretaceous Little Bear and Summit Creek Formations in the western and eastern portions of the study area, respectively. Husky and MGM/Shell reported hydrogeological investigations that included

aquifer tests to assess the capabilities of the identified bedrock aquifers.

Groundwater chemistry results were compared to the Canadian Council for Ministers of the Environment Water Quality Guidelines for Protection of Aquatic Life (CCME). Guideline exceedances were observed in both deep and shallow groundwater for some metallic elements such as aluminum, iron, and cadmium and some petroleum and aromatic hydrocarbons. Such results could be due to anthropogenic activity, most likely during establishment of the monitoring wells. They also may be due to interaction of groundwater with natural bedrock sources of metals and hydrocarbons such as might be found in nearby Cretaceous shale and coals. Ongoing collection of water well geochemical data will help to distinguish between these possibilities.

Husky and MGM/Shell also reported on the isotope geochemistry of groundwater samples from their monitoring wells. Husky wells MW-09A and MW-09B have oxygen and hydrogen isotopic fractions that are depleted compared to local surface water and precipitation values, indicating a colder climate at the time of groundwater recharge. A lack of tritium in the samples indicates that groundwater at these locations has not come into contact with the atmosphere in at least 50 years. The samples also showed depletion in sulphur-34 relative to modern sea water, suggesting a long residence time and interaction with shale formations. Radiocarbon age dating of groundwater samples from these wells indicates an age of approximately 20,000 years.

Groundwater samples from MGM wells showed oxygen and hydrogen isotope fractions close to the local meteoric water line with only a slight depletion compared to

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local precipitation and surface water. Depletion of heavier carbon isotopes relative to other bedrock groundwater samples was also observed. These data favour a relatively young age for groundwater in the MGM monitoring wells.

**ARCELLACEANS (TESTATE
LOBOSE AMOEBAE) AS
INDICATORS OF ARSENIC
CONTAMINATION AND
GEOCHEMICAL BASELINE IN
THE BAKER CREEK
WATERSHED REGION,
NORTHWEST TERRITORIES,
CANADA**

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Gold mining in the Yellowknife area, which commenced in 1938 with the opening of the Con Mine (1938-2003), and followed by several other operators, principally the Giant Mine (1948-2004), contributed tremendously to the economic development of the region. Unfortunately, ore processing resulted in contamination of local soils and waterways through the emission of arsenic trioxide (As_2O_3) and other metals. Before the installation of efficient scrubbers as much as 10,000 kg of As_2O_3 was released into the atmosphere per day in the early 1950s, resulting in considerable environmental degradation. In research carried out in the Cobalt mining area of northeastern Ontario we have previously demonstrated that Arcellacea (well preserved shelled protists) can be used as sensitive bio-indicators of metal contamination in mine influenced lakes. To test their efficacy as bioindicators in the

Yellowknife area we carried out a Detrended Correspondence Analysis (DCA) and Redundancy Analysis (RDA) on the distribution of arcellaceans, water property data, and ICP-MS metal analysis results from 61 area lakes. Preliminary analysis indicates that in this region the As concentration in lake substrate has the greatest influence on arcellacean distribution (10.7% of variance). Stress indicator taxa centropxyid-type arcellaceans correlate most closely with lakes with higher As concentrations, while uncontaminated lakes in the area are dominated by Diffflugid-type arcellacean faunas. Based on this success a more detailed analysis of the distribution of arcellaceans in 90 area lakes is underway. Elevated concentrations of As and other metals of concern (e.g. Al, Cd, Cu, Hg) in lakes could be the result of natural weathering, past mining activities, or a combination of both. In order to conclusively determine the influence that mining has had on area lakes it is critical that geochemical baseline and past land-use impacts on the sediment quality be defined. It is nearly impossible to differentiate between baseline, past, and future land-use impacts on area lakes using technologies currently employed for environmental monitoring due to the very slow sedimentation rates within northern lakes. We have developed a technique where sediments are frozen in situ with a freeze corer and extracted, thus reducing disturbance of lake sediments caused by traditional coring devices. Sediments are then analyzed geochemically and for biological proxies at mm-resolution using a custom designed freeze core microtome. Preliminary high-resolution analysis of freeze cores from Pocket Lake, adjacent to the Giant Mine, and further north at Matthews Lake, adjacent to the former Tundra (1964-1968) and Salmita (1983-

1987) mines indicates that our high resolution analysis approach can provide site-specific environmental monitoring and remediation targets that can be used to account for sources of natural variability. This data can then be used as a yard stick to measure future chemical change and land-use impact on sediment quality.

FLUID SOURCES OF ULTRA-DEEP DIAMONDS

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Sublithospheric diamonds that sample the transition zone and uppermost lower mantle provide a unique view into the deep Earth. In order to investigate the origin of diamond-forming C–H–O–N fluids within the deep mantle, within the framework of the terrestrial deep volatile cycle, we conducted a $\delta^{13}\text{C}$ – $\delta^{15}\text{N}$ –[N] micro-analytical study, by secondary ion mass spectrometry, of five Kankan diamonds from the asthenosphere/transition zone and the lower mantle.

Abrupt and large changes in $\delta^{13}\text{C}$ within KK-99 (up to 10.2‰) and KK-200A (up to 6.9‰) illustrate distinct episodes of diamond growth, involving different fluids, possibly during transport of diamond to deeper mantle depths from the asthenosphere/transition zone into the lower mantle. Despite limited variability of $\delta^{13}\text{C}$ within individual samples, diamonds KK-200B, KK-203, KK-204 and KK-207 display systematic $\delta^{13}\text{C}$ – $\delta^{15}\text{N}$ –[N] co-variations which can be modelled as a single diamond growth episode in a Rayleigh process from fluids/melts. These data constrain the carbon isotopic fractionation

factors to be both negative ($\Delta\text{C} = -0.9\text{‰}$ for KK-200B and -2.0‰ for both KK-203 and -207) and positive ($\Delta\text{C} = +1.0\text{‰}$ for KK-204), consistent with equilibrium between diamond and oxidised (CO_2 or carbonate) and reduced (CH_4 or carbide) fluids respectively. The modelling of $\delta^{15}\text{N}$ –[N] systematics suggests that the diamonds are depleted by $\sim 4\text{‰}$ (KK-200B) and $\sim 0\text{‰}$ (KK-204) relative to the oxidised and reduced sources respectively. Modelling the co-variation indicates a compatible behaviour of nitrogen in diamond relative to the growth medium ($\text{KN} = 4\text{--}16$), independent of the redox state. The parental fluids to the ultra-deep diamonds exhibit geochemical characteristics ($\delta^{13}\text{C}$ – $\delta^{15}\text{N}$ –[N]– KN – ΔC – ΔN) comparable to fluids thought to form lithospheric diamonds, suggesting a common mechanism of diamond genesis.

The metaperidotitic parageneses and the slightly negative $\delta^{13}\text{C}$ signatures for both KK-204 and KK-207 are consistent with their formation in the lower mantle by fluids that originate either from mantle or subducted carbon sources. A carbon flux from subducted oceanic lithospheric mantle may be important in the latter case. The strictly positive $\delta^{15}\text{N}$ signatures found both in KK-200B ($\delta^{13}\text{C} > 0\text{‰}$) and KK-204 ($\delta^{13}\text{C}$ slightly negative) illustrate that surficial carbon and nitrogen are potentially recycled as deep as the asthenosphere/transition zone and the lower mantle. Calculations of the diffusive relaxation of carbon isotope heterogeneity indicate that these ultra-deep diamonds may have a relatively young age and/or experienced rapid vertical movement to shallower mantle conditions, possibly by plume-related mantle.

The significance of ultra-deep diamonds within the NWT diamond production will be examined.

DEVONIAN AND CRETACEOUS HYDROCARBON SOURCE ROCKS, CENTRAL MACKENZIE VALLEY, NWT

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In the mainland sedimentary basins of the Northwest Territories, there is potential for the discovery of new shale oil and gas reserves (unconventional shale plays) where known high quality, mature source rocks are present. A second phase of the Mackenzie Plain Petroleum Project has been initiated this year by the Northwest Territories Geoscience Office Petroleum Group. The study builds on phase one of the project that coupled field-based stratigraphic research with data from subsurface exploration wells in order to expand the petroleum geoscience information for the Central Mackenzie Valley. A main focus of the project continues to be on hydrocarbon source rock characterization of the organic-rich Devonian Horn River Group (Hare Indian, Ramparts, and Canol formations) that is potentially a self-sourcing reservoir.

During the 2014 field program, Horn River Group strata were described and sampled from three sections and one station in Mackenzie Plain area. In addition, five previously measured sections and stations were re-visited to fill in data gaps including conodont biostratigraphy and detailed measurement of a proposed type section for

the upper Hare Indian Formation (Bell Creek member) at the Carcajou River section. At the Hume River outcrop, the organic-rich, basal Imperial Formation overlying the Canol Formation was sampled for total organic carbon (TOC) and lithogeochemistry data in order to differentiate the two units here. These data will be integrated with spectral gamma ray measurement from both units which contain strata with a petroliferous odour at this site. Chemostratigraphy is a robust tool that aids in differentiating the visually homogenous Devonian shale packages. In addition, four sites with Cretaceous outcrop (Slater River Formation) were also sampled to evaluate source rock potential (TOC and thermal maturation trends).

During the initial phase of the project, it was determined that the Horn River Group contains organic-rich shale intervals with fair to excellent source rock potential (average TOC values greater than five weight percent). The Canol Formation is a known source rock for the conventional oil reservoir at Norman Wells, NWT and its high silica content may enhance its ability to be fractured hydraulically as a shale reservoir. Thermal maturation data for the Canol Formation suggest strata are within the oil window through much of Mackenzie Plain; however, data gaps exist to the west and northwest of Mackenzie Plain (within the Peel Plain area), and in the southern part of Mackenzie Plain. Information from outcrop studies will be integrated with forthcoming subsurface data from exploration wells to improve mapping of thermal maturation trends through the Central Mackenzie Valley.

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RECONNAISSANCE MAPPING AND THEMATIC STUDIES OF NORTHERN BROCK INLIER

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The Brock Inlier project is an activity within the GEMII-Mackenzie, Shield to Selwyn geo-transect whose goal is to upgrade geoscience knowledge of a large window of mainly late Mesoproterozoic to early Neoproterozoic sedimentary rocks with affinities to the Minto Inlier on Victoria Island and the Mackenzie Mountains to the southwest. The inlier overlaps the eastern edge of the Darnley Bay geophysical anomaly, which has long-been speculated by the mining industry as being due to a deeply buried Ni-Cu-PGE magmatic sulphide deposit on the scale of Sudbury or Noril'sk. Our work is, in part, intended to decrease potential exploration investment risk by increasing the level of detail of scientific information in the surrounding region.

Prior to the 2014 field season, our intention was to: 1) Acquire magnetotelluric data along an E-W transect to see how strata exposed in the Brock Inlier continue westward into the region over the geophysical anomaly, which is covered by younger sediments. These data would also potentially image the top of the anomaly, thereby providing a more accurate assessment of its depth. 2) Measure and describe unstudied stratigraphic sections of the Rae Group along the Brock River. Such stratigraphic information will contribute greatly to our understanding of geological

linkages between, and evolution of the Mackenzie Corridor and Arctic Islands. 3) Assess the accuracy and density of previous geological mapping/observations in the Brock Inlier and address the feasibility of mounting a field mapping program there for 2015 and 2016.

Stratigraphic and Sedimentological studies

Strata of the Mikkelsen Islands Fm., measured in detail along ~13 km of the Brock River canyon, attain a thickness of approximately 575 m. The lower third of the section comprises dolostones featuring tractional sedimentary structures and intraclast layers indicating storm influence in shallow water. The upper two-thirds consist of cyclically alternating, microbially laminated and mechanically laminated dolostone with rare chert and stromatolites indicating deposition in quieter water.

Strata of the Nelson Head Formation are exposed along a 3 km-long segment of the canyon, immediately to the west of the Mikkelsen Islands Formation, which it sharply but conformably overlies. The lower Nelson Head Formation is a ~150 m section comprising 2 to 8 m thick bedsets of coarse-grained, trough crossbedded, tan-yellow sandstone alternating with subordinate, plane-parallel-stratified, maroon silty sandstone. Deposition was by sinuous and braided streams with paleoflow varying from northwest to northeast with high dispersion. The upper Nelson Head is finer grained with thinner bedding, exhibiting more plane-parallel stratification and ripple crosslamination than crossbedding. Paleoflow is toward the north-northwest with low dispersion.

Reconnaissance Geological Mapping

Reconnaissance geological mapping of NTS 97A revealed that there are areas along the Amundsen Gulf coast between Albert Bay and Dease Thompson Point that are mis-mapped as belonging to the Shaler Supergroup. Via comparison with strata recently mapped on Victoria Island, the region mapped as Nelson Head and Aok formations is largely underlain by strata of lower Cambrian age. Similar relationships and stratigraphic mis-assignments were observed in the vicinity of the Roscoe River canyon to the southeast.

**SOURCES AND
METALLOGENIC
SIGNIFICANCE OF EARLY TO
MID-CRETACEOUS
MAGMATISM ACROSS THE
SELWYN BASIN: INSIGHT INTO
THE AGE AND COMPOSITION
OF CORDILLERAN BASEMENT**

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The Selwyn Basin is host to five, mainly crustally derived and high-K calc-alkaline, Early to 'mid'-Cretaceous plutonic suites forming a broad curvilinear belt across the Selwyn Basin. The geochemical and isotopic compositions of these intrusive rocks provide some of the only information on the composition and age of the underlying basement.

The oldest magmatism is represented by two back-arc batholithic plutonic suites of supracrustal origin. The Anvil (112–106 Ma) plutonic suite was derived by low-temperature anatexis of a mainly pelitic lithology deposited distal to the ancestral

continental margin, in the southwest Selwyn Basin. Farther to the east, the Hyland (106–100 Ma) plutonic suite was generated by higher-temperature partial melting of a more proximal, compositionally variable lithology (e.g., greywacke). Even farther to the north and east, a post-arc 'mid'-Cretaceous array of batholithic intrusions belonging to the Tay River plutonic suite (99–96 Ma) was emplaced across Selwyn Basin. These intrusions were likely derived from high-temperature partial melting of a homogeneous metaigneous basement of intermediate composition (60–65 wt.% SiO₂). Magmas derived from the same (or similar) infracrustal rocks also characterize plutons of the temporally and spatially overlapping Mayo (98–95 Ma) and Tungsten (98–95 Ma) plutonic suites, both of which are associated with late shoshonitic dykes. The Tungsten suite plutons comprise either highly fractionated equivalents to the Mayo plutonic suite, or smaller-fraction partial melts from the same protolith. The latest and most 'inboard' (north and east) of the 'mid'-Cretaceous intrusions in the Selwyn Basin belong to the high-K calc-alkaline to peralkaline Tombstone plutonic suite (94–89 Ma), originating from two parental magmas: (a) an alkaline (shoshonitic) and LILE-rich magma derived in an enriched lithospheric or upper mantle; and, (b) a high-K calc-alkaline magma derived from partial melting of infracrustal rocks of intermediate composition. Notably, the supracrustally sourced intrusions are associated with proximal W ± Mo, and distal Pb–Zn–(Ag) occurrences, although few (if any) appear to be of economic significance. Infracrustally derived intrusions also have a strong base metal signature (e.g., W, Pb, Zn), and—unlike the supracrustally derived rocks—the Tungsten suite plutons are associated with several significant W–Cu

deposits and occurrences in the eastern Selwyn Basin.

The change from supracrustally to infracrustally derived magmatism from southwest to north and east suggests either a major change in the composition of mid- to lower crustal rocks across the Selwyn Basin, or that more 'inboard' post-arc anatexis occurred deeper in a crystalline lower crust. Furthermore, despite geochemical similarities for the high-K calc-alkaline magmas of intermediate-composition infracrustal origin, different basement domains are apparent in magmatic isotopic datasets. Whereas an isotopically evolved basement (e.g., a continental magmatic arc) may underlie the southeast Selwyn Basin, oceanic island arc rocks (lacking input from isotopically evolved crust) may underlie the northwest Selwyn Basin. The western and northeastern Selwyn Basin appear to be underlain by the oldest basement, which was apparently metamorphosed early in its history. These regional variations may have important implications with respect to inter- and intra-suite metallogenic potential across the Selwyn Basin.

LITHOGEOCHEMISTRY AND DISTRIBUTION OF 4.0 - 3.4 GA UNITS WITHIN THE ACATA GNEISS COMPLEX, NWT, CANADA

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The Acata Gneiss Complex (AGC) has long been known to contain rock units with crystallization ages close to 4.0 Ga [1,2] making them the oldest known evolved rock units in the world. However, the AGC has

experienced a long and complex history with multiple periods of igneous intrusion, deformation and metamorphism. Indeed, previous workers have demonstrated that orthogneisses within the AGC have igneous ages ranging from ~4.03 to ~3.4 Ga [3]. This large range in crystallization ages gives us the opportunity to investigate the evolution of Earth's earliest known continental crust through a period of greater than 600 million years.

Recently we published work documenting a distinctive 'Iceland-like' geochemical signature in one of the oldest known rock units present within the Acata Gneiss Complex [4]. The geochemical signatures present in this rock unit are distinct from the TTG suite of granitoids, a suite of rocks commonly thought to represent significant growth of continental crust in the Archean [5]. Archean TTGs are formed by deep-seated melting of a hydrated basaltic precursor in the presence of significant garnet, potentially in a subduction-like environment.

Here we present an updated geologic map of key areas within the Acata Gneiss Complex in which we delineate units based upon age as well as composition. We also discuss recently acquired whole-rock geochemistry, LA-ICP-MS zircon U-Pb geochronology and SIMS O-isotope analyses of zircons from a large suite of key samples. These data are used to evaluate the evolution of igneous rock types and tectonic environments within the AGC from 4.02-3.4 Ga.

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KENNADY LAKE LUE T'E HALYE (FISH-OUT)

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De Beers Canada Inc. has received permitting approval for the construction and operation of the Gahcho Kué diamond mine located about 280 kilometres northeast of Yellowknife. The Mine will take about two years to build, which includes time for dewatering approximately 659 hectares of Kennady Lake so that workers can safely access and mine the diamond-bearing kimberlite ore that lies under the lake. Prior to construction and dewatering of the lake, efforts to remove the fish from Kennady Lake were required under the Project's Fisheries Act Authorization. In advance of the fish removal effort, the program was named Lue T'e Halye by the Aboriginal communities, which is a Chipewyan phrase meaning fishing with nets (pronounced schlway te hallyay).

We will discuss the both the innovative approaches to communication and community involvement that led to the success in 2014, as well as the results of the fish removal and distribution. The Lue T'e Halye will comprise two Phases, Phase I being completed in 2014 and Phase II,

which is being planned for 2015. In communication with DFO, and following guidelines and principles from the 'General fish-out protocol for lakes and impoundments in the Northwest Territories and Nunavut (Tyson et al. 2011), fish catch and depletion protocols and targets were set and agreed upon by DFO. Phase I objectives included 1) targeted removal of fish using small and large mesh broad-scale monitoring gill nets; 2) engage local communities; and 3) allow fish harvested to be utilized by traditional resource users.

Phase I of the Lue T'e Halye program was completed in 2014 over 11 weeks from July through September. Fishing effort and data collection were led by Golder Associates Ltd. with assistance provided by local Aboriginal fishers hired by De Beers through Khione Resources. Overall results for Phase I of the fish out included removal of 13,608 fish weighing 3,408 kg. A total of 2,931 gill net sets were completed, with 36,592 net-hours of sampling completed over the course of the summer. Approximately 1,000 kg of processed fish were provided to local communities, with attention paid to targeting important dates and cultural events. Constant communication of ongoing results from the fishing performance with DFO was an important aspect of the program. By providing data in near real-time, we were able to accurately ensure compliance with the completion targets for Phase I in 2014.

Innovative approaches that took place during Phase I included fish processing, fish distribution, and data management. Prior to intensive fishing effort, De Beers hosted a Blessing the Water and Respecting the Land Ceremony at Gahcho Kue. Chiefs, councillors as well as elders from the Deninu kue Lutsel K'e, and Yellowknives

Dene First Nations lead the ceremony. The primary objectives of Phase I were successfully met in that removal targets were achieved, local communities were engaged and actively involved in the fishing and processing effort, and fish were successfully distributed to local communities.

NORTHWEST TERRITORIES PETROLEUM RESOURCES DIVISION & 2014 PETROLEUM INDUSTRY ACTIVITY OVERVIEW.

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With Devolution, the Department of Industry, Tourism and Investment (ITI) assumed responsibility for mineral and onshore petroleum resources management, including the Oil and Gas Operations Act, the Petroleum Resource Act and the Mining Regulations. The Office of the Regulator of Oil and Gas Operations (OROGO) is responsible for safety, the conservation of petroleum resources and environmental protection. The offices that now fall under ITI are; Mineral Resources, Mining Recorder's Office, Petroleum Resources, Financial Analysis and Royalty Administration, Office of the Regulator of Oil and Gas Operations (OROGO), Client Services and Community Relations, Industrial Initiatives, Northwest Territories Geoscience Office (NTGO), and the Mackenzie Valley Petroleum Planning Office (MVPPO).

Oil and gas activity in the Northwest Territories since October 2013 has been limited to the central Mackenzie Valley

(CMV) and the southern portion of the territory. There was no activity in the Mackenzie Delta or the Beaufort Sea. Two exploratory wells were drilled in the CMV by ConocoPhillips. Both of these wells were hydraulically fractured. A total of five wells were re-entered. Two wells were re-entered by ConocoPhillips in the CMV and three were re-entered by Strategic Oil & Gas in the Cameron Hills area.

During 2014, production operations were focused in the Norman Wells and Cameron Hills regions. Operators for these production regions include Imperial Oil Ltd and Strategic Oil and Gas, respectively. Oil and gas production for Norman Wells from January to August 2014 are 426,818.6 m³ of oil and 57,847,700 m³ of natural gas. Oil, gas and condensate production for Cameron Hills for the period April to August 2014 are 4,957.1 m³ of oil, 14,566,200 m³ of natural gas, and 160.4 m³ of condensates.

In October 2014, the Petroleum Resources Division of ITI commenced the petroleum and natural gas rights issuance process. This process is comprised of a "Call for Nominations" followed by a "Call for Bids" for selected regions of the Northwest Territories. This entire process is expected to be completed by April 2015. Lands in the Mackenzie Delta/Arctic Islands and the Central Mackenzie Valley will be made available for nominations.

Upcoming industry oil and gas activity in the Beaufort offshore region centres on The Beaufort Sea Exploration Joint Venture between Imperial Oil Ltd., ExxonMobil and BP. Chevron Canada also has plans for a Beaufort Sea drilling program. Both projects are in the regulatory phase with the National Energy Board (NEB) and Inuvialuit Environmental Impact Review Board

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(EIRB). The NEB has allowed both project groups to submit same season relief well (SSRW) alternatives for their proposed exploration wells. Both projects plan to commence exploration drilling in 2020 after NEB regulatory conditions have been satisfied.

SOURCE ROCK CHARACTERIZATION OF THE CARBONIFEROUS GOLATA FORMATION AND DEVONIAN BESA RIVER FORMATION OUTCROPS, LIARD BASIN, NORTHWEST TERRITORIES

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The evaluation of regional stratigraphic relationships and geochemical characteristics of Devonian to Carboniferous age shales in the Liard Basin area of the Northwest Territories is necessary for the assessment of shale gas exploration potential for this region. Field studies of the Golata Formation were conducted at the Etanda Lakes (60°50'46"N, 124°22'30"W) and Sheaf Creek (61°12'23"N, 124°33'32"W) sections in 2012 and 2013, respectively. Besa River Formation field studies were conducted at the Nahanni River section (61°15'19"N, 124°37'14"W) in 2013. Completed studies on the Golata and Besa River formations samples include: 1) Rock Eval/Total Organic Carbon (TOC), 2) vitrinite reflectance (VR), 3) inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectroscopy (ICP-ES).

The Golata Formation at Etanda Lakes and Sheaf Creek is characterized by relatively low uranium abundance (average 2.46 ppm), moderate levels of terrigenous input and detrital clays, and relatively high silica content (average 57.6% and 65.6%, respectively). In conjunction with outcrop observations, these data support the interpretation that the Golata Formation was deposited in a prodelta environment. Rock-Eval and TOC data from Etanda Lakes and Sheaf Creek indicate that the Golata Formation is a fair (1 to 2 weight % TOC) to good (2 to 5 weight % TOC) source rock. Vitrinite reflectance results show that Golata Formation shales are mature for gas at Etanda Lakes (1.71-1.85% R₀) and immature to early maturity for oil at Sheaf Creek (0.51-0.65% R₀).

The Besa River Formation at Nahanni River is characterized by enrichment in uranium (6.6 ppm average) and vanadium, a relatively low level of terrigenous input, and high silica content (80.2%). These data indicate that the Besa River shales were deposited in a reducing, anoxic, low energy environment. Rock-Eval and TOC data indicate that the Besa River Formation is a good source rock. The shales of the Besa River Formation are overmature at the Nahanni River section (2.23-2.66% R₀). The results of this work will be used to facilitate the evaluation of unconventional hydrocarbon resources in the Liard Basin.

**GEOTECHNICAL ASSESSMENT
AND MONITORING OF
RUNWAY 14-32, MERLYN
CARTER AIRPORT, HAY
RIVER, NT**

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A geotechnical evaluation and engineering assessment of runway 14-32 was undertaken in an effort to characterise the current soil subgrade and ground geothermal conditions and to develop recommendations to stabilize the runway. Consolidation of soils in the past and ongoing unstable permafrost and active layer conditions have led to continuous surficial distress in the runway that requires repairs every 3 to 5 years.

The site investigation included drilling and sampling, in situ testing and a geophysical investigation. Instrumentation was installed to measure the ground temperature profile and groundwater levels.

The site is in the zone of sporadic, discontinuous permafrost. The findings from the investigation supported the probable presence of discontinuous permafrost under the runway. It is believed that the site conditions are marginal for sustaining permafrost, which suggests its occurrence is intermittent. The recommended approach to stabilization is to change the energy balance in the ground by installing insulation to inhibit the presence and development of permafrost.

**YELLOWKNIFE CITY GOLD
PROJECT**

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TerraX's 93.5 sq km Yellowknife City Gold Project (YCGP) is underlain by the prolific Yellowknife Greenstone Belt immediately north of Yellowknife. The YCGP covers 15 strike km of the northern extension of the shear system that hosts the high-grade Con and Giant gold deposits. It also contains multiple shears that are recognized hosts for gold deposits in the district.

The Yellowknife Greenstone Belt is analogous to the Abitibi Greenstone Belt in Ontario/ Quebec. It contains metavolcanic rocks of the >2.70 Ga Kam Group and 2.69 to 2.66 Ga Banting Group, intruded in the west by 2.63 to 2.608 Ga granites, and overlain to the east by 2.661 Ga turbidites. The Kam and Banting groups are separated by the Hay-Duck Fault, which is a major crustal fault, typically an important feature of mesothermal gold terranes. The sedimentary Jackson Lake Formation occurs proximal to the Hay-Duck Fault; it is considered an analogue to the Timiskaming Conglomerate of the Abitibi Greenstone Belt. The Con and Giant deposits are hosted by Kam Group dominantly mafic rocks, as are most important targets in the YCGP.

Most known gold mineralization in the YCGP occurs in north to northeast-trending structures. This includes TerraX's two main areas of focus, the Crestaurum and Barney shear zones. The northeast-trending, ~45°SE-dipping Crestaurum Shear hosts the Crestaurum deposit and drill intersections as high as 5.00 m @ 62.9 g/t Au.

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Mineralization consists of pyrite, arsenopyrite, visible gold, stibnite, sphalerite and galena, hosted by quartz ± ankerite vein arrays that pinch and swell along strike and down-dip. Preliminary work suggests that the relative abundance of arsenopyrite and stibnite might provide vectors toward higher grade mineralization. The shear has only been drill tested to a vertical depth of 120 m.

The north-trending, subvertical Barney Shear is traceable over the entire YCGP, and is mineralized over ≥ 600 m strike length, including intersections as high as 22.4 m @ 6.35 g/t Au. Mineralization typically occurs in multiphase, deformed quartz-ankerite veins, locally with significant pyrite and/or arsenopyrite, and lesser galena and sphalerite. The highest grade mineralization encountered to date is at a vertical depth of 240 m. TerraX is confirming and expanding upon historical Crestaurum and Barney results, and has also encountered abundant high-grade mineralization on numerous north to northeast-trending structures.

TerraX has delineated five new NNW-trending quartz veins with grab sample values up to 812 g/t Au, several of which contain visible gold. These veins are proximal to the Crestaurum Shear and their intersection with the latter may influence the distribution of mineralized lodes within the Crestaurum deposit. TerraX also discovered molybdenum-rich quartz veins (best grab sample 6.32% Mo) close to the 2675 Ma Ryan Lake Pluton, 500 m west of the Crestaurum Shear. This pluton was intersected at a vertical depth of ~500 m immediately west of the Barney Shear, at which point it contained anomalous molybdenum and gold, and adjacent volcanics contained anomalous copper. TerraX is starting to factor this apparent porphyry style mineralization and the NNW

trending vein system into ongoing exploration strategies.

SEISMIC MONITORING IN THE CENTRAL MACKENZIE VALLEY, NWT

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In 2011 and 2012 five petroleum companies purchased exploration rights to fourteen contiguous license blocks in the Central Mackenzie Valley. Collective work commitments of over \$600 Million were promised to test the tight oil potential of the Devonian Canol Shale.

In the winter of 2012, Aboriginal Affairs and the National Energy Board visited Sahtu communities of Norman Wells, Tulita and Fort Good Hope to provide information about hydraulic fracturing. Members of those communities expressed concerns about the impact this technology could have on the region. Community members asked specifically about whether hydraulic fracturing could cause earthquakes and discussion indicated a desire to gather baseline data to help inform these concerns.

In collaboration with the Natural Resources Canada, the Northwest Territories Geoscience Office installed four new seismic monitoring stations on either side of the Mackenzie Valley near Norman Wells to supplement one existing Canadian National

Seismograph Network (CNSN) station located in the Norman Wells quarry.

The new seismic monitoring stations are small installations with $<2 \text{ m}^2$ footprints consisting of a battery and solar charger power source, GPS antennae, seismic recorder and seismometer in a protective vault. A Nanometrics Taurus recorder stores the data from three seismic channels as well as state-of-health information onto a memory chip. Extended bandwidth seismometers are used, the best of these sense seismic waves with periods of 0.12 up to 120 seconds (0.005–50 Hz).

The new stations were sited on bedrock to provide the best coupling to basement rocks, and greatest sensitivity for the highest frequency waves needed to most precisely determine earthquake epicenters. The stations were installed within line-of-sight from Norman Wells to facilitate future near real time monitoring via the CNSN.

Seismic data have been analyzed and located from installation to the end of November 2013. Using the new array, 137 earthquakes were located and assigned magnitudes ranging from 1.7 to 4.6. In comparison, during this same period, the CNSN reported 13 earthquakes to a minimum magnitude of 2.4. The newly installed local array detects all events reported by the national network, but also about nine times as many within a radius of 400 km from Norman Wells. Hydraulic fracturing activity near the array began in March 2014; analysis of the data from that period is currently underway and the results will be made available once the analysis is finished.

While set up to monitor potential induced seismic activity the network should also aid understanding the tectonic stress regime in

the CMV, and may identify tectonically active basement structures beneath the CMV which may pose a hazard for future fluid reinjection. Establishing this closely spaced seismic network prior to hydraulic fracturing activities in the area also enables the collection of baseline data before, during and after development in the area, should the Canol tight oil play proceed.

LITHOSPHERIC STRUCTURE AND DIAMOND POTENTIAL OF NORTHERN CANADA

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After over ten years of acquiring geophysical, geochemical and geological observations, we are able to compile a fully 3-dimensional model of the subcontinental mantle lithosphere of the Slave and Rae cratons in northern Canada. This model has benefited from the wealth of samples of mantle rocks and diamonds produced by mineral exploration to date, and supports future exploration in northern Canada for diamonds, and other commodities. These cratons have undergone over a two decades of intense diamond exploration, and superior collections of mantle xenoliths, xenocrysts and derivative observations, and models now exist. The Slave craton hosts four diamond mines and its exploration-driven petrologic database is now comparable with the Kaapvaal, Zimbabwe and Siberia cratons.

The resolution of the seismic-wave velocity model was greatly improved by increased coverage of recording stations deployed by the POLARIS consortium over the past decade. This station coverage is not as

uniform or dense as that of USArray in southern North America, but is sufficient to provide new insights into mantle structure within focus areas such as the Slave and Rae cratons. In addition, the POLARIS stations have been active for sufficient periods (3-8 years) to enable their recordings of earthquakes as 3-dimensional 'cones' that demarcate local discontinuity surfaces. The Moho is the most prominent discontinuity surface, but several intra-lithosphere surfaces are also observed. Conductivity is being modelled in 3-D on a regional scale for the first time, using newly developed algorithms for linear arrays or grids of magnetotelluric soundings acquired over the past two decades.

A number of kimberlite pipes have yielded sufficient mantle samples for which pressure-temperature determinations can be made to allow construction of vertical 'cores' of mantle rock types and paleotemperatures. The lithosphere-asthenosphere boundary can thus be estimated in some locations. In some pipes, diamonds, garnets and other indicator minerals provide additional geochemical information such as age, and major- and trace element systematics, with depth. These 1-D 'drill hole' arrays provide critical localized calibration for the regional 3-D models.

New compilations of surface geology, improved digital elevation models, and regional magnetic- and gravity-field maps all provide very detailed 2-D knowledge at the surface and near-surface with which to relate the deeper knowledge layers. This surface information can only be extrapolated to the mantle structures that are of primary interest to our project with great care, but is invaluable because of its continuous and higher spatial resolution.

DEVOLUTION OF OIL AND GAS RESOURCES: THE YUKON EXPERIENCE

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In November 1998, Government of Yukon assumed responsibility for oil and gas resources. Over the past 16 years, through land claims, devolution of the majority of other resources and responsibilities, land use planning processes and environmental and socio-economic assessment changes, Yukon has shaped a distinctive regulatory environment for oil and gas. Oil and Gas Resources Branch will share some of the successes and challenges of developing and regulating a northern oil and gas industry.

TARGETED BEDROCK MAPPING, AND NEW GEOCHEMISTRY AND GEOCHRONOLOGY DATA FOR HALL PENINSULA, BAFFIN ISLAND, NUNAVUT

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The Hall Peninsula Integrated Geoscience Program began in 2012 and is led by the Canada-Nunavut Geoscience Office in collaboration with the Geological Survey of Canada, seven Canadian universities and the Nunavut Arctic College. The program has involved two 6-week long field seasons of

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bedrock and surficial geology mapping, regional geochronology and geochemistry, and university thesis projects focused on different thematic aspects of the genetic and metamorphic history of the region. Hall Peninsula is underlain by Archean orthogneiss and Paleoproterozoic metasedimentary and intrusive rocks. These rocks preserve evidence of metamorphism and deformation resulting from the Paleoproterozoic continental collision of the Trans-Hudson Orogen. Regional-scale fold and thrust structures were documented on the northern portion of the peninsula, and amphibolite- to granulite-facies metamorphic assemblages grade from east to west, respectively. Over the course of regional mapping, many sites with mineral exploration potential were identified and flagged for follow-up work. These include gossanous metasedimentary strata, layered mafic-ultramafic intrusions, granitic pegmatites, semi-precious gemstone occurrences, and serpentinite and marble carving stone deposits.

In July 2014, a third and final round of targeted field work was conducted on Hall Peninsula. The objectives of this work included targeted structural mapping, sampling of sites with base or precious metal potential, studying the potential for rare earth element mineralization in granitic pegmatite dykes, and follow-up evaluations at prospective carving stone occurrences. This presentation highlights new field observations of thick-skinned fold and thrust structures, geochemical assay data from gossanous metasedimentary rocks and layered mafic-ultramafic intrusions, and U-Pb zircon geochronology of the Archean and Paleoproterozoic lithologies that underlie Hall Peninsula. These observations and data contribute significant information to the completion of bedrock mapping on Hall

Peninsula, and provide new insights into the geological history of the region and its mineral prospectivity.

AN UPDATE ON THE NORTHWEST TERRITORIES MINERAL DEVELOPMENT STRATEGY

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The Northwest Territories Mineral Development Strategy (MDS) was prepared in partnership with the Government of the Northwest Territories (GNWT) and the NWT and Nunavut Chamber of Mines to establish a framework with the purpose of encouraging investment in mineral exploration and development, while promoting sustainability, enhancing Aboriginal engagement and capacity, enriching workforce development and creating public awareness of the industry.

The NWT MDS Implementation Plan was released in October 2014 and provides resource commitments as well as goals, objectives and timelines focused on specific MDS goals including enhanced geoscience information, increased exploration, evaluation of infrastructure needs, Aboriginal capacity building, and the implementation of new programs to further develop the NWT labour force.

An important component of the MDS, the Mining Incentive Program (MIP), was successfully launched in 2014. The MIP provides funding to prospectors and exploration companies, who propose new exploration projects or are already carrying out mineral exploration in the NWT, in order to offset some of the financial risk

associated with grassroots mineral exploration. Improvements to the program for the 2015/2016 exploration season will include more convenient application dates, as well as greater clarity regarding application and evaluation criteria.

A yearly Implementation Plan and Results Report for the MDS will be produced by the Mineral Resources Division, Department of Industry, Tourism and Investment of the GNWT and will include both forward-looking actions as well as a review of the results achieved over the past year.

THE RISE AND STALL OF KIMBERLITE MAGMA

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The propagation of volatile-rich kimberlite magma through the lithosphere via subvertical dykes, as with all magma types, is dictated primarily by the balance between the driving magma pressure, the tensile strength of the country rock, and the ambient stress conditions. The direction of transport is controlled primarily by the near-tip stress field and, from both theory and field observations, is largely insensitive to pre-existing anisotropy. In extensional regimes, the magma pressure may be sufficient to facilitate ascent to the surface with resultant volcanic eruption. In compressional regimes, the confining stresses tend to stall vertical magma ascent or, at upper-crustal levels, to accommodate lateral propagation in subhorizontal sheets. In near-surface regions characterized by a near-neutral regime (low mean stress), small variations in any of the controlling influences may result in pronounced differences in emplacement depth or style.

Canadian kimberlites have previously been classified into three distinct types based primarily on pipe shape, the internal texture and composition, and on inferred emplacement setting. Of these, the tuffisitic-type is characterized by coherent uniform intrusions, fragmental diatreme textures, and various transitional phases. Archetypical examples include Aviat and Qilalugaq of the Rae craton, the Renard cluster in the Superior craton, and numerous bodies within the southeast Slave craton. In classical terminology, these kimberlites preserve diatreme and root zone components; crater and extra-crater zone components have not been recognized. As noted by others, the textures within tuffisitic pipe-like bodies are compatible with devolatilisation processes in a closed system. Irregular-shaped xenolith-rich bodies, some which expand with depth, and an envelope of intense alteration and brecciation of adjacent country rocks are characteristic. Many of the reviewed kimberlites lack a carrot-shaped morphology and none reveal bona fide indicators of volcanic eruptions (e.g. layered pyroclastic or epiclastic infilling). The common (exclusive?) association with “blind” intrusions and with penecontemporaneous shallow-dipping coherent sheet complexes indicates that vertical magma propagation has stalled or converted to subhorizontal transport at upper-crustal depths. Textures within isolated blind bodies, including the presence of so-called pelletal lapilli, are indistinguishable from those within nearby “pipes” exposed at the current surface. Perhaps many of the pipe-like bodies were originally blind intrusions. It is proposed that the distinctive features of the type examples of Canadian tuffisitic-type kimberlites result from emplacement into a compressional (or near-neutral) stress regime and that many, if not most, of the

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kimberlites failed to breach the paleosurface. If valid, this provocative suggestion that a major class of kimberlite may be intrusive rather than volcanic has numerous implications, including the need for development of effective exploration strategies and for the application of appropriate terminology.

HIGH-SPATIAL RESOLUTION HYPERSPECTRAL IMAGERY: A NEW ANALYTICAL TECHNIQUE FOR OBTAINING COMPOSITIONAL INFORMATION FROM KIMBERLITES (SNAP LAKE, NT) AND KIMBERLITE INDICATOR MINERALS

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With the development of continuous imaging spectrometers, short-wave infrared (SWIR, 1.0-2.5 μm) and long-wave infrared (LWIR, 6.0-11.0 μm) hyperspectral imagery collected from drill core and mineral grains in a rapid and non-destructive manner can be used to obtain high-spatial resolution compositional information.

To investigate the ability of this technique to identify kimberlite dilution by crustal rocks at Snap Lake, SWIR and LWIR hyperspectral imagery was collected from two drill cores: one that provides a longitudinal cross-section of the ore body (~31 meters), and one that provides a vertical profile of the ore body (~4.4

meters). The hyperspectral images were processed to remove spectral noise and to isolate compositional information. Compositional maps were created for each drill core to show the distribution of undiluted kimberlite, diluted kimberlite, and crustal rocks. In addition, the technique was able to accurately distinguish between kimberlite containing micro-dilution and kimberlite containing both micro- and macro-dilution. Accurately evaluating the abundance of crustal rocks in the Snap Lake kimberlite is important because dilution levels can have an effect on diamond grade. To ensure the results were accurate, the compositional maps were compared to the drill core logs, and the results were validated using a full-suite of other analytical techniques.

To develop an analytical procedure capable of identifying kimberlite indicator minerals (KIMs) in mixed-mineral concentrates, which would assist with the accurate and rapid characterization of exploration samples, SWIR and LWIR hyperspectral imagery was collected from several pure and mixed mineral mounts containing KIMs. These images were processed to remove spectral noise and isolate the compositional information. Compositional maps were produced that show the placement of garnet, olivine, quartz, and feldspar in the mineral mounts. Future work will examine larger datasets, with a focus on building an analysis protocol that can identify mantle minerals in an accurate and rapid manner.

There are five main benefits to using high-spatial resolution hyperspectral imagery to obtain compositional information: (1) the technique is sensitive to subtle compositional changes that cannot be visually observed, (2) the resulting compositional maps show full coverage of

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the samples, (3) clast size, abundance, and distribution information can be extracted from the compositional maps, (4) the analyses are non-destructive, and (5) little or no sample preparation is required.

UNEARTHING THE SECRETS OF THE SOUTHERN SLAVE

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Canterra Minerals Corporation is an exploration company focused on diamond discovery in Canada's Northwest Territories. Over the past 20 years Canterra has compiled a proprietary database of kimberlite indicator minerals, microprobe analysis, and airborne and ground geophysical data. This data together with advanced techniques that improve interpretative accuracy, guided the recent acquisition of 6 new properties in the Southern Slave region, an area that continues to deliver significant diamond discoveries. Covering over 72,600 hectares, these properties were selected based on their potential to host diamond bearing kimberlites.

The 2014 exploration program included reconnaissance work at each of the Company's high priority targets, the collection of 656 till samples and ground truthing a number of previously defined airborne geophysical anomalies. Partial results received to date are encouraging with a 1.0 x 1.0 x 1.4 mm off-white, modified octahedral diamond found on the Marlin property, as well as several anomalous indicator minerals including pyropes and chromites. Results from a heliFALCON® gravity survey flown over the northern

portion of the Marlin property and the remaining till samples are pending.

Canterra continues to analyze both proprietary and publicly accessible data to refine targets in preparation for the 2015 exploration season.

Management and Canterra's Board of Directors have extensive northern Canadian and diamond exploration experience; members have been involved with the discovery of the Snap Lake and Ekati Diamond Mines. Canterra's in-house team of geologists and technical advisors include leaders in the fields of geochemistry, geophysics and grain morphology will continue to explore to unearth the secrets of the Southern Slave.

DELIVERING COMMUNITY BENEFITS FROM MINERAL DEVELOPMENT

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Sustainable development does not happen in a vacuum: the ways in which multiple projects and actors interact on a regional scale shapes the impacts and benefits of natural resource development. Communities, government and industry all have a role to play; the benefits of mineral development depend on these and other actors working together to identify, plan for and manage barriers to development.

There are increasing examples of how this can be done. For communities, readiness and wellness studies can result in a vision of what acceptable development looks like, and what is required from the community to both take advantage of opportunities and address

impacts on environment and culture. Government has a role in many areas, from place-based regulatory processes to developing infrastructure. Companies need to collaborate with other actors on supporting local employment and procurement, environmental management and, ideally, community investment.

Identifying the impacts and benefits from mineral development on a regional scale, and the barriers to achieving these benefits, is a first step in the process. With a shared understanding of what is feasible and what has been achieved in other jurisdictions, actors can develop a shared vision of industrial and societal development, and clarify their roles in achieving it.

CHARACTERIZATION OF ARSENIC SPECIES IN LAKE SEDIMENTS SURROUNDING GIANT MINE, NWT

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Roasting of arsenopyrite at Giant Mine released approximately 20,000 tonnes of arsenic aerosols to the environment from roaster stack emissions, 86% of which was released in the first 14 years of operations. Recent studies have shown elevated levels of arsenic in lake sediments beyond the boundary of the property, raising questions about their origin and associated risks to local ecosystems and public health.

The purpose of this study is to determine whether the arsenic present in regional lake sediments is of natural or anthropogenic

origin, and whether these lakes act as a sink (capture) or a source (release) of arsenic in the overlying lake waters. This may be done by assessing the speciation of arsenic in both lake sediments and associated porewaters using dialysis arrays, major and trace elements analysis, synchrotron-based analysis, and advanced scanning electron microscopy. From there we can evaluate the relative stability of arsenic species in these different chemical media, and thus establish the long term trends of arsenic in the aquatic environment, which is an important component in establishing risk assessment.

A field program was completed in July 2014 during which three lakes were sampled: BC-20, Handle Lake and Lower Martin Lake, to the west of Giant mine property, within 3 kilometers of the old Giant roaster stacks. These lakes offer a range of physical and chemical characteristics such as lake depth, organic contents and nature of substrate and immediate catchment. This will allow us to better constrain various physical and chemical parameters of lakes geochemistry in relation to arsenic mobility.

Preliminary results of this program indicate arsenic concentrations in sediment porewaters range from 80 to 1,600 parts per billion, consistently peaking 2-6 centimeters below the sediment-water interface. This might indicate a trend for arsenic to remobilize and migrate upwards through the sediment column after deposition. Whether this remobilized arsenic gets released into the lake water or gets trapped into a more stable mineral phase has yet to be determined.

While there have been several studies designed to evaluate arsenic conditions on mine property and within the City of Yellowknife, there has been limited work in

small lakes adjacent to the mine site. Understanding the sources and behaviour of arsenic in these small lakes is extremely important since First Nations and other local people use the area for hunting and fishing as well as recreational purposes. Such information is very important in helping to determine a potential increase in risks to fish, wildlife and human populations.

ON THE POTENTIAL OF RADAR SATELLITE IMAGES FOR APPLICATION TO WINTER ROAD MANAGEMENT

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In this paper we will present results of an ongoing study that aims to assess and develop the potential of radar satellite images for the mapping and monitoring of ice cover in support of winter road management. The study area is located north of Yellowknife, NWT and comprises the Tibbitt to Contwoyto winter road. This road provides relatively inexpensive seasonal ground-based access to resource industries that are otherwise accessible only by expensive air transport. The study is part of NRCan's TRACS-Project (Transportation Risk in the Arctic to Climatic Sensitivity).

Radar satellites make outstanding tools for collecting up-to-date information on freshwater ice cover thanks to their capability to routinely and systematically

image extensive remote areas independent of weather and daylight conditions. Moreover, during the winter months, radar satellites are capable of capturing information regarding the complete ice column because radar waves penetrate deep into well frozen ice. This capacity of radar waves to penetrate 'dry' ice cover gives radar satellites a competitive advantage over both optical satellites and the human eye.

Following a brief introduction to radar remote sensing and the interaction of radar waves with ice cover, we will address the potential of radar images in support of winter road management tasks such as routing, construction, and maintenance. Specifically, we will demonstrate that radar images of ice cover comprise information related to characteristics such as: ice integrity, ice composition, ice groundedness, and ice thickness. In combination these variables are of great relevance to the trafficability of ice cover.

The radar images studied were acquired by RADARSAT-2 (Canadian) and TanDEM-X (German). Analysis of the images was facilitated by ground reference data collected during February / March 2013. Even though the study is ongoing, results to date show that radar satellite images provide readily accessible and valuable information in support of the mapping and monitoring of ice cover integrity, composition, and groundedness. On the other hand, the application of radar satellites to the mapping / monitoring of ice cover thickness presents challenges in terms of image acquisition / analysis and is complicated by variability in ice cover composition. Radar acquisitions and fieldwork planned for the winter of 2014 / 2015 are meant to advance the development of radar remote sensing for

application to the mapping of ice cover thickness in particular.

INTEGRATION OF REMOTE SENSING-DERIVED TREE SPECIES INFORMATION INTO A NORTHWEST TERRITORIES FOREST VEGETATION INVENTORY SYSTEM

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Natural resource management requires land-cover and tree species identification to support decision making for sustainable resource development, as highlighted by initiatives such as the NWT Biomass Energy Strategy and Boreal Woodland Caribou Action Plan. Satellite remote sensing provides a cost-effective and time-efficient way to obtain this information for the large, remote, and inaccessible northern boreal forests. Because satellite signals are highly mixed due to the presence of tree shadows and understory vegetation in open canopy forests that are typical in the NWT, spectral mixture analysis (SMA) based on analysis of sub-pixel scale components was used to classify Landsat TM imagery and to derive dominant tree species information for each pixel. Stakeholders indicated a specific need for tree species composition estimates (relative abundance of tree species) at the scale of the forest stand, and this study provides an overview of the computation of

this information and its integration into an existing geospatial forest inventory system. The validation process indicated that the image-derived species composition agreed with 56% and 73% of the 48 field plots using a range deviation of 20% and 30% of field measured species proportions, respectively. Work is continuing to improve the species composition estimates through updated image classifications and filtering of erroneous pixels.

UPDATE ON THE MARIAN WATERSHED COMMUNITY-BASED AQUATIC EFFECTS MONITORING PROGRAM

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The Tłichq Government is working together with Wek`èezhìi Land and Water Board ([WLWB](#)) and other partners to develop the Marian Watershed Community-Based Aquatic Effects Monitoring Program. This is a community-based monitoring program that is being developed based on the questions and needs of the Tłichq people.

Tłichq Lands have been under Moratorium since the signing of the Tłichq Agreement in 2005 and on June 1, 2013, the Moratorium was lifted as the Tłichq Wenek`e or Land Use Plan came into force. With the potential for future development of Tłichq Lands, the Tłichq people have expressed concern about impacts on the water and wildlife they are so dependent upon. The objective of the Marian Watershed Monitoring Program is to begin collecting baseline information about the water and fish on Tłichq lands and in

locations the Tł̄chq̄ feel are the most important, prior to any major development pressure (such as the NICO mine by Fortune), and to continue collecting this data over time. Community members are being trained to collect samples, analyze the samples, and report findings back to the rest of the community members.

A pilot project was conducted at Hislop Lake, upstream of the planned NICO Mine site, in the fall of 2013. This project included the training of 8 community members and a field program where the newly trained Environmental Monitors worked with scientists to investigate the concerns of the elders and community members.

A workshop was organized by the Department of Culture and Lands Protection (DCLP) in the spring of 2014 to bring back the results from the Hislop Lake camp and to develop a long term monitoring plan that truly addresses the concerns of the elders.

We identified five important field sites along the Marian River from Hislop Lake to Marian Lake, which will be visited on a four-year cycle. The DCLP organized the second field program this fall at Shotti Lake. Where the freshly trained Environmental Monitors worked with the scientist to investigate the concerns from the elders and communities.

The ongoing program will facilitate enhanced understanding of fish health and water chemistry each year, ensure active monitoring of Tł̄chq̄ waters by Tł̄chq̄ people, and prioritize meaningful communication back to community members.

PRELIMINARY RE-OS AGE, AND PLATINUM GROUP ELEMENT SYSTEMATICS OF THE ~1.9 GA WINNEPEGOSIS KOMATIITE

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As potential geochemical probes of the deep mantle and providing primary evidence for changes in mantle temperature through time, komatiites have long been of significant interest to the geochemical community. In recent years, the variation of Platinum Group Element (PGE) concentrations of komatiites through geological time has been used to investigate the rate of mixing of late veneer components into the deep mantle [1].

This talk will present preliminary geochemical and isotopic data for the Winnepegosis komatiites, from Northern Manitoba. These drill core samples form part of a relatively unexplored ~150 km x 30 km greenstone belt within the Circum-Superior Belt (CSB), adjacent to the Thompson nickel belt. Though sporadically mineralised, with up to 1.6 wt% Ni along certain horizons [2], the widespread preservation of dendritic and spherulitic groundmass phases, and even groundmass glass identifies this komatiite occurrence as one of the freshest on Earth. Their Paleoproterozoic age also gives these rocks great importance in constraining a data-poor portion of the komatiite PGE vs. time curve.

Bulk rock major and immobile trace element data plot along tight olivine control lines, and are used in conjunction with olivine EPMA analyses to calculate parental liquid MgO contents of up to 23 wt%, and liquidus temperatures of up to 1467 °C. These high liquid MgO contents confirm the identification of the Winnepegosis rocks as komatiites, though they fall short of typical MgO contents for Archaean komatiites.

A preliminary 12 point Re-Os wholerock isochron yields an age of 1863 ± 50 Ma, in good agreement with a previously determined U-Pb zircon age of $1864 +6/-4$ Ma for associated basalts [2]. However, our data cannot yet resolve the apparent difference in age between the Winnepegosis greenstone belt and the better studied Thompson Nickel Belt, dated at ~ 1883 Ma [3].

Chondrite normalised PGE patterns are similar to those of other komatiites, though Pd/Ir ratios of $\sim 5 - 12$ are higher than typical for Archaean komatiites [4]. This, along with the lower MgO contents of the liquids and major and trace element compositions that are slightly less depleted than Archaean komatiites, suggests smaller degrees of partial melting or a less depleted source for Proterozoic komatiites.

PGE concentrations fall below the projected PGE vs time curve of [1]. This, combined with with new data for the Barberton komatiites [4], suggest that there has been no resolvable and systematic change in mantle PGE contents since 3.5 Ga, precluding a slow mixing of the late veneer.

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A COMPARISON OF WIJINNEDI-SNARE, COURAGEOUS-MACKAY, AND LAC DU ROCHER/CAMSELL LAKE VOLCANIC BELTS OF THE SLAVE CRATON AND IMPLICATIONS FOR VMS EXPLORATION

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Archean Archean metavolcanic belts occur across the Slave craton and are known to host gold deposits, several volcanogenic massive sulphide (VMS) deposits and numerous VMS prospects. This study provides a comprehensive comparison of three volcanic belts across the southern Slave craton; the ca. 2674 Ma Wijinnedi-Snare volcanic belt; the Courageous-MacKay volcanic belt, with ca. 2810 Ma basement overlain by ca. 2700 Ma Cycle I and ca. 2670 Ma Cycle II volcanic packages respectively; and the ca. 2672 Ma Lac du Rocher/Camsell Lake volcanic belt. Results are anticipated to advance the knowledge of the Slave craton stratigraphy, provide further insights into Archean magmatism, and assist in the identification of VMS prospective volcanic belts.

The three volcanic belts contain varying amounts of bimodal metavolcanic, metavolcaniclastic and metasedimentary rocks. The mafic components of the volcanic sequences are tholeiitic to calc-alkaline and display MORB – BABB

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signatures, with flat chondrite-normalized patterns. The associated intermediate and felsic volcanic components are calc-alkaline and have two predominant chondrite-normalized patterns; the first group shows enrichment in LREE and a steep HREE slope, while the second has similar LREEs, a negative Eu anomaly, and a distinctly flat HREE pattern.

Neodymium (Nd) isotope analyses of whole-rock samples were targeted for individual belts, stratigraphic levels, and relationship to basement material. Intermediate to felsic volcanic rocks from Wijinnedi-Snare belt have ϵNd_i values between +0.9 and +2.1. Lac du Rocher samples have ϵNd_i between +2.0 and +2.5. The Courageous-MacKay belt has a range between ϵNd_i of +0.7 and +5.2. The data indicate that volcanic rocks include a dominant mantle component, with some crustal assimilation.

Within the Courageous-MacKay belt, Cycle I volcanic unit hosts the DEB VMS deposit, while the Cycle II sequence hosts the Tundra, Salmita and FAT gold deposits. The lower stratigraphic felsic unit hosting the DEB deposit are FII rhyolites, referred to a Superior craton-type classification scheme. While FIII rhyolites are characteristic of most large VMS deposits in the Superior, FII rhyolites are host to a number of

Archean VMS deposits. The depositional settings of all three volcanic belts are consistent with a VMS-bearing environment, with VMS-like occurrences recorded at multiple locations. Further exploration will be required to thoroughly evaluate the VMS potential within these belts.

THE NATIONAL ENERGY BOARD'S PARTICIPATION IN FRACFOCUS.CA

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On 27 November 2013 the National Energy Board signed an agreement to join FracFocus.ca which would allow regulated companies to publically disclose their hydraulic fracturing fluids on the FracFocus.ca website. The presentation provides an overview of the National Energy Board's procedures for regulated companies to have their hydraulic fracturing fluid chemicals publically disclosed on the FracFocus.ca website 30 days after their hydraulic fracturing operation has finished.

Abstracts - Poster Presentations

Presenting Author denoted by *

INVESTIGATION OF THE SEDIMENTOLOGY, ICHOLOGY, AND SOURCE ROCK POTENTIAL OF THE MOUNT CAP FORMATION: AN OUTCROP STUDY, MACKENZIE PLAIN, NORTHWEST TERRITORIES, CANADA

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The Mount Cap Formation is middle Cambrian in age and is one of the potential source rocks for reservoirs throughout the Northwest Territories, Canada. However, the distribution of organic-rich facies and sedimentological/source rock characteristics are poorly understood. This is mainly because of the limited number of wells penetrating the formation and the lack of detailed sedimentological and geochemical reports. The purpose of this study is to evaluate the sedimentological/ichnological and geochemical properties of the formation using outcrop observations and samples. The study will provide a detailed analysis of the depositional environments of the Mount Cap Formation and the distribution of organic rich intervals. As the study is in its first stage of execution this report focuses on four outcrop locations in the Mackenzie Mountains approximately 50 km southwest of Norman Wells, Northwest Territories.

The characteristic vertical succession of the Mount Cap Formation consists of

interbedded dolostone and shale, black shale, and dolostone. Bioturbation in the Mount Cap Formation is difficult to observe in outcrop as bedding planes in the black shale are often destroyed when sampling. However, bioturbation tends to be restricted to the lower interbedded dolostone/shale intervals dominated by Planolites.

Two major interbedded dolostone and shale parasequences have been identified in outcrop and represent High Stand Systems Tract (HST) deposits. Planar laminated black shale intervals were deposited during transgression followed by the deposition of carbonate grains as sediment prograded and aggraded. The shale to dolostone cycles represent deposition near shore along a carbonate ramp within a semi-enclosed basin.

The potential source rocks of the Mount Cap Formation are thick accumulations of planar laminated black shale which were deposited during transgression. Rock Eval results from samples collected at the four outcrop locations are currently being analyzed to determine the source rock potential of the black shale.

Detailed sedimentological/ichnological analysis and geochemical work will continue into 2015 to further refine the depositional models and the source rock potential of the Mount Cap Formation.

TILL IN ARCTIC CANADA IS NOT TILL

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By definition, till is sediment deposited directly from glacier ice that has undergone no deformation, remobilization or reworking following deposition by other agencies (e.g., meltwater, gravity). Given this, most the material routinely mapped as till in Arctic Canada is, by definition, not till. Rather, because of extensive near-surface cryoturbation of the active layer, it is more accurately described as frost-churned diamicton. Indeed, a strong argument can be made that till was likely the primary parent material for much if not most of this frost-churned diamicton, given that (1) undeformed till commonly underlies the active frost-churned layer, (2) these sediments, in concert, blanket bedrock topography, and (3) they can contain dispersal trains that trend upslope. However, in places, it is difficult to rule out the possibility that other, younger sediment became cryoturbated into the diamicton following deposition, meltwater-sorted proglacial mud being a prime example, especially where evidence for proglacial lakes exist (e.g., raised beaches) but mud is lacking. Such contributions to the frost-churned diamicton layer may be difficult to detect upon initial inspection, but must be kept in mind when interpreting geochemical data and reconstructing sediment dispersal budgets and pathways.

DISPERSAL TRAINS IN ESKERS VERSUS TILL EAST OF GREAT SLAVE LAKE

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Eskers are commonly sampled for heavy minerals during mineral exploration in glaciated terrain, as is the adjacent till. This has led to several important discoveries, most notably the Lac de Gras kimberlite field. Despite this, a robust conceptual framework for interpreting esker results has not become well accepted, in part because data are scarce: few published studies exist that compare dispersal trains in eskers versus till. Questions therefore remain as to how to best sample eskers during mineral exploration, and how to interpret results.

In 2008 and 2009, 450 esker and till samples were collected as part of a study to evaluate the mineral potential of a proposed national park east of Great Slave Lake. Samples were analyzed for heavy minerals and pebble lithologies. These data image the tail ends of broad dispersal trains (e.g., Dubawnt sandstone pebbles; heavy minerals, likely from an ultramafic source) interpreted to have been transported westward by glacial ice (till), then later reworked by subglacial meltwater (eskers). Several surprising observations are of note. Sulphide minerals and gold grains are abundant in the eskers, even though these elements are commonly perceived as being impoverished in eskers relative to till. Also, the esker and till dispersal trains have similar lengths: the former do not overshoot the latter

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considerably. In many cases, it is difficult to discern which terminate first. A literature review reveals similar trends in previous case studies: overshoot in eskers can range from as little as “zero” (i.e., undetectable in the data) to ~30 km relative to the till. This body of data provides a starting point to help interpret esker results during mineral exploration. It also should be factored into any consideration of how eskers form, which remains a fundamental, controversial scientific problem despite over 100 years of study.

QUANTITATIVE MAPPING OF ESKERS

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Eskers have commonly been mapped manually from aerial photograph as lines (esker ridges) and polygons (sand and gravel). This process is qualitative. To date no method has been deployed that could automatically extract esker extents and quantify esker volumes. A methodology is presented for the quantification of eskers that uses Canadian Digital Elevation Data (CDED), spectral remotely sensed imagery (e.g. LandSat, Spot), and legacy esker line work from Geological Survey of Canada publications. Using ArcGIS and an esker detection module (EDM) coded in Python, the CDED data are smoothed using user defined filter windows. A difference surface is produced that emphasizes ridge areas and is used to create polygons. The legacy esker line work is used as a training dataset to extract ridge areas within a user defined

buffer. Results have been tested against the input training data and a local dataset generated manually from aerial photograph interpretation. Depending upon terrain characteristics the success of the data extraction ranges from 65 to 81% for the esker line work and 35 to 72% for the more limited aerial photograph interpretation. The variable success reflects esker size related to both relief and width in the CDED data.

Ongoing development of this methodology focused on enhanced delineation of low-relief areas of the esker not captured by the digital elevation model (DEM) analysis through incorporation of spectral imagery. A multiclass (80-100) iso-cluster unsupervised classification of SPOT MSS data was completed to characterize the landscape. The iso-cluster classification was then overlain on the esker polygons. The most dominant classes in terms of area are identified and the user can specify the number of classes to be chosen. The originally topographically defined polygons are then merged with the selected intersecting spectral classification.

The ability to extract an esker signature by a semi-automated methodology that generates a dataset for quantitative analysis provides an opportunity to improve understanding of the geometry and sediment landform relationship of eskers. This data is suitable for improving the understanding of heavy mineral sampling programs of eskers and hence could contribute to improved data analysis in mineral exploration programs. The quantification of esker volume could also aid in assessing the aggregate resource potential of eskers.

KIMBERLITE PATHFINDER ELEMENTS DOWN-ICE OF TALMORA

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The Geological Survey of Canada investigated regional geochemistry as a quick and cheap way of exploring for kimberlites. Its effectiveness depends on the chemical contrast between kimberlite and surrounding rock. Kimberlite is characteristically high in Ba, Cr, Co, Fe, K, Mg, Mn, Nb, Ni, P, Rb, LREE (La, Ce, Nd, Eu), Sr, Ta, Th, Ti, Tl and U.

Talmora collected till samples down-ice of magnetic anomalies and Sanatana collected regional till samples surrounding, but mostly down-ice of Talmora. Samples were analyzed for multiple elements and kimberlite indicator minerals (KIMs).

Kimberlite pathfinder elements are anomalous down-ice of three strongest Sanatana KIM anomalies, and are anomalous in a long broad train that includes a cloud of anomalous KIMs down-ice of Talmora. One strong KIM anomaly is related to the Dharma kimberlite and two probably to glacial redistribution of secondary concentrates from basal Cretaceous sediments.

The train down-ice of Talmora is anomalous in Ca and Mg derived from dolomite country rock. It reflects relatively simple ice flow at peak glaciation at the fringe of the Late Wisconsin ice sheet and its 150 to 200 km length indicates a single sustained ice flow to the northwest.

The geology within the train is relatively simple with dolomite at its head and Cretaceous sediments at the tail. There are no known intrusive rocks, but there are magnetic anomalies on the Talmora property that might be weathered kimberlite. Clay recovered from one anomaly is anomalous in many pathfinder elements relative to surrounding tills.

Al, Ba, Be, Co, Cr, Cs, Fe, Ga, Ge, In, K, Mn, Nb, Ni, P, Pb, Rb, REEs (Ce, La, Y), Sn, Ta, Th, Ti, Tl, V, W and Zn show an anomalous relation to the Dharma kimberlite and Talmora areas and a different anomalous relation to the basal Cretaceous sediments. These elements, including kimberlite pathfinders, have almost identical dispersion patterns (histogram equalization). Pb and Zn have low values near Dharma and show a second trend on the Talmora property. Ba, Co, Fe, Mn, Ni, P, W and Zn are not anomalous in the clay, but Fe and Mn are related to a laterite cover. U, Cd and Au are related to the Talmora property, but not to kimberlite.

The "Talmora" train shows normal dispersion of high Ca and Mg values on the dolomite decreasing across the Cretaceous sediments down-ice. However, kimberlite pathfinder elements show the reverse with high values at the tail reflecting initial deep scouring of soft weathered kimberlite and decreasing values up-ice as less and less kimberlite is scoured until equilibrium is reached with the dolomite. The well-studied Ranch Lake kimberlite train has a similar distribution of KIMs and pathfinder elements with peak values 15 to 20 km down-ice of the deeply (60m) scoured kimberlite. A similar distribution of pathfinder elements down-ice of the Dharma kimberlite supports the view that the distribution of kimberlite pathfinder

elements in the Talmora train reflects a cluster of kimberlites on the Talmora property.

FE-TI OXIDES IN KIMBERLITES: IMPLICATIONS FOR KIMBERLITES FROM THE EKATI DIAMOND MINE, NORTHWEST TERRITORIES

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Research is being conducted at Dalhousie University, Halifax examining the potential of Fe-Ti oxides presence, chemistry and morphology as an indicator of kimberlite emplacement conditions and composition and preservation potential of diamond during emplacement of kimberlites. Ekati Diamond Mine (Northwest Territories) was selected as a suitable locality for the study due to the abundance of kimberlites of similar age but variation in lithology (e.g. coherent vs. volcanoclastic facies) and diamond grade. Previous studies have indicated differences in emplacement rates, volatile-content and oxygen fugacity between kimberlites during emplacement. Fe-Ti oxides (chromite and ilmenite) were studied from heavy mineral separates and in thin section from six kimberlites from Ekati. There was found to be a variation in the relative abundance of chromite and ilmenite, composition, zoning and surface morphological features. Chromite was found to be relatively abundant in the volcanoclastic kimberlites (Misery,

Beartooth, Koala and Panda) while only a handful of grains were extracted from the coherent kimberlites (Grizzly and Leslie). Ilmenite was relatively low in all the Ekati kimberlites except for Panda where 68% of oxides extracted from heavy mineral concentrates were ilmenite. Compositional zoning (visible from back-scatter electron images) varied from concentric zones to patchy zones accompanied by spongy pores, with the later being more typical of the volcanoclastic kimberlites. Zoning compositions in chromite reflect the same compositional trends observed in groundmass chromite. In five of the kimberlites, the typical kimberlite chromite trend, from magnesiochromite to a magnesio-ulvöspinel-magnetite (MUM), is observed. Chromite from the Misery kimberlite, which is believed to have had a high volatile content and more rapid ascent during emplacement, reflects a trend from magnesiochromite to a pleonaste composition. Ilmenite was not typically zoned, but instead had rims composed of chromite, MUM spinel, perovskite and titanite. Neither zoning nor rims composed of other minerals was observed on ilmenite from the Panda kimberlite. Morphological surface features on chromite consist of step-like features that reflect the original octahedral morphology and develop towards the edges of crystals causing an overall rounding of the crystal. Sharp to rounded steps with variable degree of crystal roundness are observed on chromite from the volcanoclastic kimberlites, while features are poorly developed on chromite from the coherent kimberlites, but grains are typically rounded making the original octahedral morphology unrecognizable.

The ongoing research is experimentally investigating the stability constraints, zoning and development of morphological surface

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features on Fe-Ti oxides using controlled piston-cylinder apparatus experiments at 1.0 GPa and gas-mixing furnace experiments at 1 atm. Piston-cylinder apparatus experiments are conducted in the experimental petrology lab at Dalhousie University. Gas-mixing experiments were conducted at the Bayerisches Geoinstitut, Universität Bayreuth, Germany. Experiments explored melt compositions within the system: $\text{CaMgSi}_2\text{O}_6\text{-Ca}_2\text{Mg}(\text{CO}_3)_2\text{-CO}_2\text{-H}_2\text{O}$. Preliminary results indicate: ilmenite stability to be related to the oxygen fugacity of the melt during emplacement; style of zoning and surface morphological features is related to the presence of volatiles; and zoning composition can be related to the melt composition and oxygen fugacity.

TECTONIC MAP OF ARCTIC CANADA

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The Tectonic Map of Arctic Canada (TeMAC) presents a tectonic synopsis of all onshore and offshore bedrock areas north of latitude 60°N at a scale of 1:2 000 000. Data sources for TeMAC include regional, territorial and national compilations at scales ranging from 1:200 000 to 1:5 000 000 and new compilation work for Nunavut and Northwest Territories. One hundred and one tectonic domains of Precambrian and Phanerozoic age are documented by TeMAC and include: 5 cratons, 36 basins, 2

platforms, 3 shelves, 2 plains, 1 ridge, 7 cover sequences, 18 accreted terranes, 16 magmatic suites and 11 compressional orogens. In addition, individual map units are coded in terms of the dominant lithotectonic environment of formation.

The lithotectonic variation is expressed by 25 associations, which include nine sedimentary associations (accretionary wedge, back-arc basin, deep water basin, intracratonic rift basin, molasse, stable shelf basin, transtensional rift basin, volcanic rifted margin and sedimentary undivided); seven extrusive associations (alkaline sequence, back-arc sequence, basalt-komatiite sequence, continental arc sequence, flood basalt sequence, mafic sill and dyke complex, and volcanic: extrusive undivided); six intrusive associations (anorthosite suite, alkaline and subalkaline suite, I-type granite suite, S-type granite suite, layered mafic-ultramafic complex, plutonic: undivided); two metamorphic associations (granulite facies gneiss, amphibolite-facies gneiss and migmatite); and an ophiolitic mélangé association.

Standardization of map-unit attributes, including map colours for sedimentary strata, was facilitated by the International Chronostratigraphic Chart (ICS; February 2014 version) with new colour shades added for broader age divisions in the Phanerozoic or to distinguish contrasting tectonic domains of similar age. For Precambrian units, a more nuanced colour scheme than available on ICS was selected in order to adequately portray the rich Canadian rock record and thus discern different Archean cratonic nuclei and various sedimentary basins and cover sequences of Proterozoic age. To differentiate Precambrian or Phanerozoic magmatic suites or accreted terranes from sedimentary strata of a similar

age, unique terrane- or magmatic suite-specific colours were chosen. Colours for onshore and offshore Phanerozoic sedimentary basins are further modified to convey isopach information where available, with saturation increasing with thickness.

Pencil stripe patterns are utilized to effectively indicate the extent of orogenic overprinting with the colour of the stripes keyed to individual orogens. If a region is overprinted by two orogenic events, a paired set of pencil stripes is shown and in cases of three orogenic overprints, a triad of colour stripes is shown. Oceanic crust is present in the Canada basin (Cretaceous) and in the Labrador Sea and Baffin Bay (Paleogene) with a distinct colour scheme based on age range and magnetic chrons.

Identified applications of TeMAC include 1) providing a new tectonic compilation and database context for Arctic Canada; 2) encouraging frontier mineral and energy exploration through wider dissemination of a national data set; and 3) providing general support for the geological framework developed for the delineation of the outer limits of Canada's continental shelf in the Arctic.

NEW GEOLOGICAL COMPILATION MAPS AND SPATIAL DATASETS FOR CANADA'S ARCTIC ISLANDS

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A series of fifteen maps and supportive spatially enabled datasets are being released for the Canadian Arctic Islands of northern

Nunavut and northern Northwest Territories. The map set has been prepared from best available sources and compiled at 1:500,000 scale. Correlation of units has been accomplished by compiling formations and members into 130 tectonic assemblages for the sedimentary and metamorphic rocks and into 12 plutonic assemblages for the intrusive rocks.

The oldest rocks are represented by the Archean and Paleoproterozoic assemblages of Boothia Peninsula, Somerset, Devon and southeastern Ellesmere islands. These are succeeded by late Paleoproterozoic and Mesoproterozoic sedimentary rocks of Victoria and Somerset islands and, above this, the Meso- to Neoproterozoic of the Shaler Supergroup of Victoria Island. Large areas of the Arctic Islands are underlain by platformal Cambrian to Devonian strata which grade northwestward to include Neoproterozoic (Ediacaran) strata at the base and Middle-Upper Devonian foreland basin strata at the top. Dominant features of this succession are basement-cored structures of Boothia and Bache uplifts. These have fringing depositional histories of uplift that range from mid-Silurian (Ludlow) to Early Devonian (Emsian). Otherwise, largely platformal in the south Cambrian to Early Devonian sediments grade to deep water, submarine fan and marine volcanic rocks in the far north. The Neoproterozoic to Devonian package was widely deformed during the Ellesmerian orogeny which relates to the docking of Pearya terrane and a poorly understood accreted terrane (i.e. Crockerland) now situated north and northwest of the Arctic Islands.

Pre-tectonic Upper Devonian and older rocks are succeeded with profound angular unconformity by Carboniferous strata. Diagnostic features in the Carboniferous and

Permian are redbeds, evaporites, carbonate platforms and reefs that grade basinward to shale and chert. By contrast the Triassic to Cretaceous is clastic dominated (proximal coarse clastics grading to submarine fans) and is associated with Cretaceous dyke swarms, evaporite diapirs and other salt tectonic elements. The youngest rocks of the Sverdrup Basin are Paleocene-Eocene foreland basin sediments including uplift associated conglomerates. These and all older rocks were compressively deformed during the Paleocene-Eocene Eurekan orogeny which had its origins in the plate motions of Greenland during sea floor in Baffin Bay and Labrador Sea. The youngest strata of the mapped area are post-Eurekan Miocene and Pliocene strata of the Arctic coastal plain.

DEPOSITIONAL AGES OF NEOARCHAean TURBIDITES ACROSS THE SLAVE CRATON

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Two temporally different Neoproterozoic turbidite packages occur in the western part of the Slave craton. The older is the ca. 2661 Ma Package I greywacke-mudstone turbidites that includes the Burwash Formation. The younger is the ca. 2640-2610 Ma Package II greywacke-mudstone turbidites, which are locally distinctive as they contain interstratified banded iron formation (BIF). Extensive turbidite sequences also exist in the eastern part of the craton, but have poorly constrained depositional ages. Using LA-ICP-MS

detrital zircon U-Pb dating, we demonstrate that these turbidites in the eastern Slave craton can be correlated with the turbidites in the western and central Slave craton.

In the northeastern part of the craton, at Goose Lake, a greywacke sample that contains interbedded BIF yielded a single zircon grain (n=61) with a ²⁰⁷Pb/²⁰⁶Pb age of 2621±18 Ma (1.3% discordant). This is interpreted as the maximum depositional age, and hence, most likely can be correlated to the package II turbidites. Five grains yielded ages between 2670-2660 Ma interpreted to be derived from the Banting Group correlative volcanic rocks. The two largest fractions of the analyzed zircon population fall within ages of the ca. 2690-2670 Ma volcanic belts preserved across the craton and the ca. 2738-2697 Ma Kam Group that is known from the central-western part of the craton and may exist in the Hope Bay belt.

A second greywacke sample from the base of the turbidite succession, which lies stratigraphically on top of the Courageous Lake volcanic belt, yielded four grains with younger than 2641 Ma ²⁰⁷Pb/²⁰⁶Pb ages with the youngest being 2626±14 Ma (9.7% discordance). Twenty grains corresponded in age to the Banting Group ages. As with the Goose Lake sample, a large population of the zircons shows correlative ages with the volcanic belts that are preserved throughout the craton, including stratigraphically below the sample. There is no BIF in the Courageous Lake turbidites suggesting that not all of the young turbidite packages need to contain BIF.

Until now, the depositional timing of the package II turbidites has been based entirely on well-constrained maximum depositional ages from detrital zircons. We discovered a

felsic-to-intermediate ~3 cm thick tuff bed, interlayered with the turbidite-BIF sequence at Slemo Lake in the southwest part of the craton. This tuff yielded a single population of zircon crystallization age of 2620.4 ± 5.7 Ma. This tuff age refines the age of the timing of deposition of these BIF-bearing turbidites and furthermore suggests the existence of an unconformity, yet undiscovered, that should exist somewhere between the Package I and II turbidites.

THE NEW GEOLOGICAL POSTER OF THE NORTHWEST TERRITORIES

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The release of the new Geological Poster of the Northwest Territories (NWT Open Report 2014-010; available as a 15.8 MB PDF download from the Northwest Territories Geoscience Office website) is a significant update to NWT Open Report 2005-007 (Petroleum Resources and Principal Mineral Deposits of the NWT), the previous Geology of the Northwest Territories poster. The latter was based on the only available compilation data at that time, the Geological Survey of Canada Map D1860A (Geological Map of Canada) and NWT-NU Open File 2005-01 (Slave Craton: Interpretive Bedrock Compilation NWT-NU).

The new poster incorporates highly detailed bedrock geology in western mainland NWT and the southern Arctic Islands, including offshore areas and adjacent parts of Yukon Territory and Nunavut. NWT-NU Open File 2005-01 and Map D1860A are still utilized

to fill out the rest of the NWT. Further compilation work is planned for the Churchill and Bear Provinces and the northern Arctic Islands.

Considerably more bedrock geology detail is derived from NWT Open File 2014-01, a GIS-based compilation that uses existing digital geological data to assemble and compile a 1:250,000 scale representation of the bedrock geology for the Cordilleran Orogeny, the Interior Platform, and the southern Arctic Islands. This compilation utilizes all published maps and reports up to 2012 and has a robust back-end database. This NWT Open File is also available for download from Northwest Territories Geoscience Office as an 85.3 MB ZIP containing a file geodatabase.

The poster represents an advertisement and a snapshot of the new GIS-based bedrock geology compilation of the NWT and is intended for display purposes only, designed to illustrate the variety of geologic domains of the NWT. Due to the very large number of geologic units displayed on the map, a legend is not provided with the poster. However, the poster provides all information on where the unit description and map legend information can be found.

The PDF-format poster provides an easy-to-use alternative for users who do not wish to work with the underlying GIS product or who do not have GIS software. Future posters will be published as the digital compilation and its underlying database are significantly updated.

Due to the utility and robust nature of NWT Open File 2014-01, the Northwest Territories Geoscience Office has moved into a new phase of NWT bedrock geology representation. This digital product will

make it easier for stakeholders to incorporate detailed geoscience information into their own work and research. The new Geological Poster of the Northwest Territories is just one example of how this digital product can be utilized.

THE SLAVE VMS PROJECT: AN UPDATE ON THE BEDROCK MAPPING

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This poster presents the results of field investigations that were carried out in the Slave craton in conjunction with the Slave VMS (volcanogenic massive sulfide) project. 1:7,500 scale bedrock mapping was undertaken in 2012, 2013, and 2014 at Sharrie Lake, Indin Lake and at the Snare River. Brief field visits were also made to Fenton Lake and Old Canoe Lake areas.

The volcanic belt at Sharrie Lake lies at the south end of the Sleepy Dragon basement complex and consists of complexly interlayered basalt-andesite (mafic), andesite (intermediate), and rhyolite (felsic). The base of the sequence is not exposed. The nature of the upper contact with the overlying Duncan Lake Group turbidite succession is ambiguous; local structural complexities suggest it is faulted and elsewhere truncation of units imply it is unconformable. Near the bulbous nose of the vertical to steeply NW-plunging antiform, three grab samples from gossans

along a contact between intermediate pillow flows and the ca. 2680 Ma Sharrie Lake rhyolite have yielded from 534 to 43,200 ppm Zn, consistent with this being a VMS target.

At Indin Lake, a 4 km² area of the Burnt Inlet volcanic belt was examined and consists mainly of mafic-intermediate volcanic rocks with thin felsic volcanic units. Quartz-rich rocks, containing combinations of amphibole, garnet, staurolite, or andalusite, are of uncertain protolith and occur between the volcanic rocks and overlying greywacke-mudstone turbidites. Many of the volcanic rocks were metasomatised prior to regional amphibolite facies metamorphism. An assay sample of graphitic slate from an extensive gossan zone at the contact between felsic and mafic volcanic rocks yielded 4340 ppm Zn, consistent with this being a distal component of a VMS mineralizing system.

The Snare River volcanic rocks comprise lava flows and voluminous volcanoclastic rocks that are disposed in a predominantly mafic (basaltic) northern belt and a mainly felsic (dacitic-rhyolitic) southern belt. The northern mafic pillow flows are commonly capped by mafic volcanoclastic units that may represent spatter deposits and interlayering of psammitic and mafic rocks is common at the outcrop scale. In the southern belt, there is a general progression from coherent dacitic-rhyolitic lava flows to increasing volumes of volcanoclastic rocks and cross-bedded carbonate towards the volcanic-turbidite contact. The sediment-volcanic interface of both belts is a common focus for disseminated sulfide mineralization, although to date samples have yielded only slightly elevated Zn contents of up to 739 ppm.

A return visit was made to Fenton Lake in the Cameron River volcanic belt to investigate the gossanous 'kill zone' found in 2012 between the ca. 2690 Ma Fenton Lake rhyolite and the overlying Webb Lake andesite. The exposure consists of sub-crop of massive sulfide and samples from it yielded between 2500-3350 ppm Zn and 1430-3130 ppm Cu.

On the eastern shore of Old Canoe Lake, ca. 2670 Ma felsic volcanic rocks contain thin conformable sulfide-rich zones near the contact with the overlying turbiditic rocks. A sample from one of these zones yielded 1800 ppm Zn. The zones have been previously prospected, but no reports were found of this work in NORMIN.db.

AGE AND ORIGIN OF BASEMENT INLIERS, EAST ARM BASIN, N.W.T.

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Several elongate exposures of Archean basement occur within the East Arm basin of Great Slave Lake, both north and south of the McDonald Fault. However the nature, age and origin of this basement is poorly understood. Possible affinities for the basement include slivers of Slave or Rae cratons or some unknown Archean crustal block. In this study, we investigate origin of the basement using field, petrographic, geochemical and U-Pb geochronological techniques. Fieldwork was conducted in July 2014 and representative samples were collected from eight basement sites. At these sites the basement consisted of a variety of

granitoids including pink two-mica granites, some with centimeter-size muscovite books, megacrystic granites and medium-grained homogeneous grey granodiorites. The granitoids do not show extensive development of a penetrative fabric.

Whole-rock geochemical analysis of nine basement samples have been conducted so far and eight of the samples have similar compositions; 70.6-76.2 wt% SiO₂, 13.9-15.0 wt% Al₂O₃, 3.7-6.3 wt% K₂O, LREE enriched patterns with significant negative Eu anomalies. One intermediate sample has 56.9 wt% SiO₂, 16.4 wt% Al₂O₃ and 2.2 wt% K₂O with an enriched yet flat LREE pattern and negligible Eu anomaly. U-Pb laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS) is in progress on all nine samples. Preliminary age results for two typical granite samples indicate similar dates of ~2.60 Ga. These dates are similar to the age of voluminous Neoproterozoic granite magmatism in both the Slave and Rae cratons. Specifically the new age dates for East Arm basement overlap the 2596 Ma two-mica granites of the Prosperous suite in the Slave craton (Bleeker and Davis, 1999).

Bleeker, W. and Davis W.J. 1999. Timing of plutonism, deformation, and metamorphism in the Yellowknife Domain, Slave Province, Canada. *Canadian Journal of Earth Sciences*, 36:1169-1187.

REMOTE PREDICTIVE MAPPING (RPM) OF SURFICIAL GEOLOGY USING RANDOM FOREST ALGORITHMS: AN AUTOMATED METHOD FOR RAPID AND EFFECTIVE MAPPING OF SURFACE MATERIALS

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Remote Predictive Mapping (RPM) has been used by the Geological Survey of Canada as a mapping strategy capable of quickly mapping large areas at relatively low cost using various archival datasets. RPM efforts have yielded encouraging results in terms of the applicability of the method and the reliability of the mapping results. We summarize some of these mapping efforts and the methodological developments achieved during mapping of surficial materials and landforms for NTS Mapsheets 75M (Mackay Lake) and 76D (Lac de Gras), the latter used as a verification area for the methodology.

The RPM map results from classification of satellite imagery (Landsat ETM+), using training areas to associate distinctive spectral signatures with unique material types. Initial image classification relies on identification of moisture content differences within the landscape. Moisture content is used as a proxy measurement incorporating multiple terrain characteristics

such as topographic position, sediment thickness, and grain size. Moisture content measurements are converted to geologic materials based on a series of rules-based decisions incorporating spectral texture, understanding of glacial landform genesis, landform associations, and topographic position of classified pixels. Image classification was performed using the Random Forest statistical algorithm complemented by additional stochastic training and validation steps. Classification refinements were completed using a heuristic expert system.

The final RPM product is a significant departure from traditional surficial geology maps, and offers three main advantages. First, it is a pixel-based map (30 m pixels) depicting the distribution of bedrock, bedrock-rich areas with surface boulders, and the gradational character of the thickness of glacial sediments on the landscape. The absence of 'hard' (polygon) boundaries offers a more realistic representation of the heterogeneity of surface materials. Second, it is 'scaleable': RPM classifies individual pixels and the map outputs can be viewed at various scales without significant loss of terrain information. An RPM-based classified 1:250 000 scale mapsheet also maps all the constituent 1:50 000 scale mapsheets and, in theory, a much greater number of maps at various scales (defined by the user, though ultimately limited by the pixel resolution). This is not the case with polygon-based maps where generalization of terrain heterogeneity within polygons is scale dependent and precludes the 'nesting' of high resolution large scale maps within smaller scale maps. Third, this RPM method offers map 'derivative' products that depict classification validity (as a percentage of certainty that a pixel represents a particular

material type). This can be depicted for distinct material types and/or for the entire map. Such map derivatives help target areas requiring more detailed mapping and field checking. Within an exploration context, specific materials for sampling can be quickly located (with some certainty) and targeted for exploration/sampling.

POLYMETALLIC CO-NI-AS-BI-SB-AG VEINS IN THE SOUTHERN SLAVE PROVINCE, NORTHWEST TERRITORIES

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Occurrences of Co-Ni-As-Bi-Sb-Ag (-Pb-Zn-Cu) mineralization in the Southern Slave Province, NWT, Canada show multiple stages of hydrothermal vein formation consisting of an early, barren (quartz \pm ankerite) stage, two mineralizing stages forming (i) Ni-Co arsenides (nickeline \pm bismuthinite \pm sulfarsenide solid solution [SSS] \pm ankerite \pm quartz) and (ii) base metal sulphides (pyrite \pm galena \pm chalcopyrite \pm sphalerite \pm ankerite \pm quartz), and a late barren (quartz \pm ankerite) stage. Compared to other deposits of this type in the NWT (Great Bear magmatic zone) and in other localities (e.g., Cobalt, Ontario), the veins are devoid of native Ag and U minerals indicating the relative inability of the hydrothermal fluid to transport these elements, or a lack of these elements in the

original source rocks that the fluids obtained their metal endowment from.

Stable carbon and oxygen isotope analyses of ankerite in the Southern Slave veins show $\delta^{13}\text{C}_{\text{VPDB}}$ ranging from -0.3 to 3.3‰ and $\delta^{18}\text{O}_{\text{VMSOW}}$ from 12.4 to 18.1‰, broadly consistent with data from the deposit at Echo Bay, Great Bear Lake but with $\delta^{13}\text{C}$ values similar to the most ^{13}C -enriched carbonates reported for deposits in Great Bear magmatic zone. Fluid inclusion data (microthermometry and LA-ICP-MS analyses of single inclusions) from quartz- and calcite-hosted inclusions show that an aqueous brine was responsible for metal transport and deposition, with salinity ranging between 25.4-36.6 wt% eq. NaCl and elevated Ca^{2+} (Na:Ca ratios between 1.5 and 5.4). Values of fluid inclusion T_h range from 143-196°C for late, quartz-hosted inclusions and 190-256°C for early, calcite-hosted inclusions. The varying salinities, T_h , and Na:Ca ratios within single vein stages suggests mixing of two fluids (e.g., magmatic and meteoric water). No boiling occurred prior to, during or after ore deposition.

Where the polymetallic veins cross-cut the Caribou Lake gabbro and diorite, determination of fluid composition, P-T of entrapment, and vein age are constrained. First, a comparison of the chemical composition of fresh and altered gabbros/diorites shows that fluid influx caused enrichments in bulk rock Li-Rb-Cs-Tl-Pb-U-Cu-Ni-Bi-Co-Mo-Ag-Sb, but removed Ba, Sr, Zn and V sourced via the alteration of primary feldspars and oxides. LA-ICP-MS analyses confirms this showing that the latest (barren) fluid in the polymetallic veins was highly enriched in K and Ba. Second, primary magnetite-ilmenite intergrowths have been altered to

rutile+ankerite in the alteration selvages of the veins. The relative stability of rutile vs. titanite depends on X_{CO_2} and constraints on this parameter from fluid inclusion analysis, combined with microthermometry-derived isochores, constrains metal deposition between $\sim 325^\circ$ and 250°C at $P < 2$ kbar. Third, a preliminary U-Pb age was obtained from hydrothermal rutile of 1320 ± 80 Ma (discordant; Pb contamination). This age overlaps with the Mackenzie LIP event and Berthoud orogeny, suggesting that (i) resetting of U-Pb isotopes occurred during these periods, or (ii) the mineralized veins formed during regional hydrothermal events during these periods and are actually much younger than comparable mineralization styles interpreted in the Great Bear magmatic zone.

SECONDARY GOLD PRECIPITATION INVOLVING IMMISCIBLE METHANE- NITROGEN-RICH AND AQUEOUS FLUIDS, LUPIN GOLD DEPOSIT, NUNAVUT

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Fluid inclusions in late-stage “ladder” quartz veins in sulfidic BIFs of the Lupin Deposit, Nunavut, preserve $\text{CH}_4\text{-N}_2\text{-H}_2\text{O}$ fluids responsible for secondary gold transport and deposition. Boudinaged, foliation-parallel veins and foliation-suborthogonal, crack-seal/ribbon-textured veins show local high Au grades and are characterized by alteration selvages containing electrum-

arsenopyrite-loellingite-pyrrhotite-grunerite-chlorite.

Three inclusion types are identified in mineralized quartz veins: (i) gas-rich inclusions containing $\text{CH}_4\text{-N}_2$ that cannot be frozen using liquid nitrogen (-196°C), but homogenize to a liquid phase between -113° and -89°C (note they exhibit similar T_h in single trails), thus consistent with a wide range in $\text{CH}_4\text{:N}_2$ ratios or variable P from trail to trail; (ii) liquid-rich inclusions containing a vapour bubble and a saline aqueous fluid that exhibit CH_4 clathrate melting ($T_{m_{\text{clath}}}$) between -4.8° and 8°C and homogenize ($T_{h_{L-V>L}}$) between 254° and 308°C ; and (iii) mixed $\text{CH}_4\text{-N}_2\text{-H}_2\text{O}$ inclusions that decrepitate on heating above $\sim 300^\circ\text{C}$ rather than homogenize and which occur in groups with type (i) and (ii) inclusions. Petrographic and microthermometric characteristics of type (iii) trails are consistent with entrapment of immiscible (coeval) $\text{CH}_4\text{-N}_2\text{-H}_2\text{O}$ fluids, but it is unclear whether the gas-rich and aqueous-rich fluid “end-members” are the products of unmixing or if these two fluid types were derived from separate sources and later interacted at the point of entrapment to produce type (iii) inclusions. An unmixing process could have been associated with the transition from D_2 compression to D_3 unroofing of ~ 2585 Ma granite-cored dome complexes in the region after peak metamorphism.

The results of this study introduce possible mechanisms for localized gold enrichment at Lupin involving decompression-induced unmixing of a primary, single-phase $\text{CH}_4\text{-N}_2\text{-H}_2\text{O}$ fluid, or equilibration of separately-sourced H_2O and $\text{CH}_4\text{-N}_2$ fluids that mingled (immiscibly) – both processes that can destabilize a variety of aqueous complexes which contained gold.

**KIMBERLITE INDICATOR
MINERALS AND GOLD GRAINS
IN TILL FROM THE GREAT
BEAR MAGMATIC ZONE AND
WOPMAY METAMORPHIC
ZONE, NORTHWEST
TERRITORIES, CANADA**

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Kimberlite indicator minerals (KIM) and gold grain counts from near surface till samples (average weight of 16 kg) were collected in 2009 and 2010 as part of an applied Quaternary activity within the IOCG-Great Bear Multiple Metals GEM-1 project in partnership with the South Wopmay Bedrock Mapping Project & Integrated Studies. Till sampling strategy was designed primarily for an IOCG study focused on the Sue Dianne Cu-Ag-Au magnetite to hematite-group IOCG deposit (n=30), the Fab Lake U-Th-Cu magnetite-group IOCG showings (n=23) and the Au-Co-Bi-Cu NICO magnetite-group IOCG deposit (n=13) in the south GBmz but include 39 samples collected across the Great Bear magmatic zone (GBmz) and extending into the Wopmay metamorphic zone and Slave Craton.

Heavy mineral separation (S.G. >3.2) and indicator mineral picking was performed by Overburden Drilling Management Ltd. Potential KIM species identified include; Cr-pyrope garnet, chromite, Mg-rich olivine

and Cr-rich diopside. All reported values are normalized to 10 kg using the table feed (till matrix). The most common species is Cr-pyrope garnet found in 41 samples within the 0.25 to 0.5 mm fraction and in 3 samples within the 0.5 to 1 mm fraction. One Cr-pyrope garnet is present within the >1 mm fraction. Mg-Olivine, Cr-diopside and chromite grains are respectively found in 15, 11 and 8 samples within the 0.25 to 0.5 mm fraction and are rarely present within the 0.5 to 1 mm fraction. The maximum number of grains found in a single sample is 7.1 grains/10kg but 21 samples contain 2 grains/10 kg or more. Samples from the south GBmz are commonly enriched in potential KIM but high grain counts are also present throughout the study area.

The total visible gold grain counts vary from 0 to 38.9 grains/10kg with an average of 3.5. Modified gold grain counts reach a maximum of 13.9 grains/10kg with an average of 0.7. Reshaped gold grain counts reach a maximum of 18.6 grains/10kg with an average of 2.4. Eleven samples contain pristine gold grains (1 to 16.2 grains/10 kg), and these samples all have high contents of modified and reworked gold grains as well. While pristine and modified gold grains are rare, reshaped gold grain contents correlate well with known IOCG systems of the GBmz such as the NICO and Sue Dianne deposits and to some extent, the Fab Lake system in a context of short transport distances. This suggests that the reshaping of gold grains took place either rapidly during glacial transport or in situ caused by wave action from Glacial Lake McConnell. In either case, reshaping of the grains should not be used as an argument to support large transport distances and/or necessarily associating these grains with background values.

- TECHNICAL PROGRAM -

2014 YELLOWKNIFE GEOSCIENCE FORUM ABSTRACTS

EXAMINING DEGREE OF PEGMATITE FRACTIONATION IN THE YELLOWKNIFE PEGMATITE SWARM USING IN SITU GAMMA-RAY SPECTROMETRY

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A swarm of 14 muscovite-biotite granite plutons belonging to the Prosperous Suite have been identified in the southwestern portion of the Slave Province within a 40 x 50 kilometre zone north and northeast of Great Slave Lake. The country rocks are comprised of metagreywacke and metaargillite. Abundant pegmatite bodies have been identified within the granite plutons and the surrounding metamorphic supracrustal rocks. Minerals of economic importance, such as beryl, spodumene, and tourmaline, have been found within these Li-Cs-Ta (LCT) pegmatites. Other commodities that have been identified, such as Sn, Ta, and other REEs, are also important in exploration of these pegmatites. The abundance of these elements is dependent on the degree of fractionation, and rare-element pegmatites represent the final stages of granitic differentiation. A gamma-ray spectrometer (GRS) was used in the field to identify minerals suitable to date by U-Pb methods, as zircons and monazites tend to contain concentrations of radioactive elements. The K, equivalent U (eU), and Th (eTh) were measured on larger clean outcrops; as Th and U are typically

incompatible in fractionating magmatic systems, these elements have the potential to evaluate general fractionation.

Sampling of pegmatites around four granite plutons (Prosperous, Sparrow/Hidden, and Prestige) was completed this summer. During this sampling process, surface GRS measurements were along transects across zones in pegmatites and of the rocks that hosted the pegmatites. The GRS measurements were made using a handheld RS-125 Spectrometer equipped with a 2 x 2 NaI crystal detector with an integration time of 120 seconds. The abundances of eU and eTh are proportional to the abundances of the daughter elements when in a state of radiometric equilibrium (unweathered).

A total of 225 pegmatites and 71 granites were tested, ranging up to 236 ppm eU and 56 ppm eTh for all pegmatites and up to 35 ppm eU and 45 ppm eTh for all granites. The pegmatites at Prosperous had average eU values of 7 ppm and average eTh values of 5 ppm; Sparrow/Hidden had average eU and eTh values of 12 ppm and 4 ppm; and Prestige had values of 10 ppm and 6 ppm, respectively. In general, as crystal fractionation occurs, the eU/eTh ratio will increase since U is more incompatible than Th. The pegmatites intruding the metasedimentary sequence at Sparrow/Hidden had the highest average eU/eTh value of 5.5, and pegmatites intruding the granite had an average eU/eTh value of 4.0. The highest eU and eTh readings occur within the wall to intermediate zones of these pegmatites; conversely, the beryl occurs in or near areas of massive quartz, and other minerals composed of incompatible elements occur within the intermediate to core zones. This indicates that U and Th decrease as fractionation proceeds, which implies a

change in compatibility and/or water saturation during cooling and crystallization of these highly evolved magmas, possibly coupled with oxidative processes, resulting in leaching. This typically affects U abundance to a greater extent than Th abundance, thus a decrease in eU/eTh.

DELINEATION OF WATERSHEDS IN THE MACKENZIE MOUNTAINS

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The Northwest Territories Geoscience Office has been systematically completing a regional stream sediment sampling program across the Mackenzie Mountains, in partnership with the Geological Survey of Canada. To synthesize and interpret the results of the geochemical analyses, a set of detailed watersheds based on stream segment order was required. However, the best publicly available watersheds for the study area are those provided from GeoGratis in the Atlas of Canada, National Frameworks Data, Hydrology dataset at approximately a 1:1,000,000 scale. The detailed dataset required for the sampling program did not exist.

To derive the watersheds for the stream sediment sampling study area, an ESRI ArcGIS geoprocessing model was used (courtesy of R. Fraser, Canada Centre for Remote Sensing). This model requires the ArcHydro Tools and Spatial Analyst extensions for ArcGIS, and uses a digital elevation model (DEM) and hydrology (watercourse and waterbody) data as inputs. A DEM was generated from 1:50,000 scale Canadian Digital Elevation Data (~15m

resolution) and the stream network and waterbody data were downloaded from the National Hydro Network. All input datasets are at a 1:50,000 scale, which is the most detailed existing public data for the study area.

The geoprocessing model first generates a depressionless DEM that is free of sinks, from which flow direction and flow accumulation grids are derived. A raster of the stream network is subsequently generated and used to create a stream order raster. Drainage basins are then delineated for third (or higher) through to sixth (or higher) order of stream segments. Post-modeling efforts on the watershed boundary polygons required significant manual quality control checks. Inherent errors in the input data and minor discrepancies between the stream network raster and vector data resulted in occasionally merging or splitting out watershed polygons. As the process requires a single line network of streams, the abundance of braided streams and alluvial fans in the mountains posed a challenge. Consequently drainage basin boundaries were manually adjusted to encompass the multiple outputs of the alluvial fans and the width of braided streams. The standards employed by the United States Geological Survey were used as a guideline in making these manual changes.

This poster presents the results of the upcoming NTGO publication containing the nested series of watersheds, and highlights some of the process and quality control issues involved. This dataset originally developed for a regional stream sediment sampling program also has the potential to be an important component of water quality, ecological studies, and other environmental research that require detailed watershed boundaries.

- TECHNICAL PROGRAM -

2014 YELLOWKNIFE GEOSCIENCE FORUM ABSTRACTS

INVESTIGATING THE ONSET OF MAGMATISM IN THE EAST ARM BASIN, GREAT SLAVE LAKE

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The Paleoproterozoic Era saw the breakup of the Slave craton from Sclavia, with associated tectonism recorded in its margins. The East Arm basin, a supracrustal assemblage exposed in the Great Slave Lake, consists of well-preserved volcano-sedimentary sequences emplaced during this period in what is interpreted as a rift basin (1). Based on tectonic model, it has long been suggested that the magmatism in the East Arm basin is correlative to that in the Wopmay Orogen, on the western margin of the Slave craton (1,2,3). This is supported by recent geologic mapping and radiometric work, which relate an interval of regional extension (1910-1890 Ma) in both locations (3,4). However, the timing and nature of the onset of rifting in the East Arm basin remain poorly constrained. In particular, only one direct age (1928 ± 11 Ma, U-Pb zircon) exists for the Wilson Island Group (5), which is interpreted as the basal unit. Its stratigraphic relation with the overlying Union Island Group also remains highly interpretive. The paucity of supportive data has been in part due to the lack of reliable radiometric dating techniques for mafic igneous rocks until recent years. To resolve this gap, this study seeks to examine newly sampled mafic magmatic units of the Wilson Island and Union Island groups within a geochemical framework. U-Pb geochronology will be conducted for

gabbroic intrusives (i.e. dykes and sills) to yield high-precision emplacement ages. This will be incorporated with magmatic provenance via whole-rock geochemistry and tracer isotopes to arrive at a temporally-constrained tectonic model. By constraining the initial stages of magmatism in the East Arm basin, this study aims to provide new insights into the regional tectonic history and the evolution of the Slave craton at its margins prior to the assembly of Nuna/Columbia.

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- TECHNICAL PROGRAM -

2014 YELLOWKNIFE GEOSCIENCE FORUM ABSTRACTS

AN UPDATE ON THE DETRITAL ZIRCON RECORD FROM THE PALEOPROTEROZOIC EAST ARM BASIN, GREAT SLAVE LAKE, NWT

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In the East Arm of Great Slave Lake is an exquisitely preserved Paleoproterozoic volcano-sedimentary basin sandwiched between the Taltson magmatic zone to the south and the Archean Slave craton to the north. Post-depositional brittle movement along the McDonald Fault system has dissected the basin into discrete tectonic slices. The East Arm basin consists of four unconformity and structurally bound volcano-sedimentary sequences; from base to top the ca. 1.93 Ga Wilson Island Group, Union Island Group, <1.87 Ga Great Slave Supergroup, and Et-Then Group. All of these sequences have differing sedimentological, volcanogenic, and structural characteristics. The basement to the Wilson Island Group is unknown. The group is dominated by siliciclastic sandstones with locally intercalated rhyolitic volcanic rocks and was metamorphosed, locally up to amphibolite facies. Because of its structural and metamorphic character, the Wilson Island Group was used inferred to be an allochthonous terrane, relative to the Archean Slave craton, and was transported into its current position prior to deposition of the Union Island Group. Distinct from this, the Union Island Group was deposited directly on Archean basement, has abundant

mafic volcanic rocks with rift-like geochemical characteristics, and intercalated sedimentary rocks consist of shelf carbonates and less predominant deeper water black-shale. The group remains undated and has not been observed in contact with the Wilson Island Group but does preserve structural fabrics that have similar trends to those preserved in the Wilson Island Group. The Great Slave Supergroup unconformably overlies Archean basement and Union Island Group, and comprises a carbonate-dominated sedimentary sequence, variably intercalated with mafic volcanic rocks and is intruded by the ca. 1.87 Ga Compton intrusive suite.

Detrital zircons were analyzed from three quartzites from the 'W2' and 'W3' units of the Wilson Island Group and from the Hornby Channel Formation of the Great Slave Supergroup. The heavy mineral separates from each samples were nearly pure zircon ranging in size from 50-400 μ m and exhibit a variety of crystal morphologies from anhedral fragments to euhedral grains. Nearly all of the grains are stained red, likely from the presence of a hematite coating. Cathodoluminescence images of the grains indicate that some have distinct cores with overgrowths, others show multiple domains within the grains, and some grains appear to be metamict. From each sample, 120 zircons were dated by U-Pb LA-MC-ICP-MS, including multiple analyses on single grains with multiple growth zones. The Hornby Channel quartzite shows two distinct age populations on a probability density plot at 2.0 Ga and 2.6 Ga. The W2 quartzite has similar populations, although the 2.6 Ga peak is less abundant. The W3 quartzite only shows a peak at 2.0 Ga.

The three quartzite samples have dominant detrital zircon age populations of 2.0 Ga and

2.6 Ga which are similar in age to the Thelon (2.00-1.99 Ga) and Talston (1.98-1.92 Ga) magmatic zones and to the basement rocks of the Slave and Rae cratons (>2.58 Ga.) and are the likely source areas for these detrital zircons.

LINKING SCIENCE AND COMMUNITY FOR FISHERIES PRODUCTIVITY OFFSETTING IN THE CANADIAN ARCTIC

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Options to offset negative impacts of mining developments on fisheries resources in the Canadian Arctic are limited. If geographically restricted to the remote area of the development, the offsetting measure provides minimal benefits to traditional users of fish. We present a community stewardship option under the recently revised Fisheries Act for a proposed development in the western Kitikmeot Region of Nunavut. The primary objective is to improve a historically significant Arctic Char run in a creek near Bernard Harbour. Previously collected data indicate challenging conditions in the creek, including warm, shallow water, and numerous barriers that impede fish access to the upstream lake used for spawning. Subsequent channel manipulations guided by Traditional Knowledge provided a cost-effective method for improving fish passage at select locations. Based on these results, we predict that complete restoration of the

creek will add at least 100 adults to the spawning lake, or over 320 kg of new biomass per year. Furthermore, we predict that fish production gains may magnify over time when offspring return as adults and greatly exceed losses from the temporary drawdown of a small, low-productivity lake. More importantly, community involvement will be an integral part of the offsetting plan, providing local people with the capacity to continue the work in perpetuity.

CONTAMINANTS IN FREEZING GROUND AND PERMAFROST TERRAIN

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The fate, transport, and transformation of a light non-aqueous phase liquid (LNAPL), a dense non-aqueous phase liquid (DNAPL), chlorinated solvent and metalloids, all legacies of past resource development in the Arctic, is of much concern to agencies charged with safeguarding the health of northern residents. With increasing development in northern regions of the world, much of which is driven by petroleum and mining industry, there is an increasing level of interest in the behaviour of these contaminants in permafrost-affected soils "Cryosols". The release of a thirteen-volume Environmental Engineering Library titled "Contaminants in Freezing Ground Permafrost Terrain" and an accompanying "Contaminated Arctic Soils Database Library" provides the petroleum and mining industry and government agencies with the necessary tools to gain a better understanding of the mechanisms responsible for transformation and transport of contaminants in cryosols founded in

sporadic, discontinuous and continuous permafrost. The engineering library and databases provides an in-depth review of the physical, chemical, biological, and hydrologic properties of cryosols that are responsible for positive or negative impacts of contaminants in northern soils. The engineering library underscores critical aspects of transformation and transport of

these contaminants that should now be reported when undertaking environmental assessment protocol, and will further assist in policy development of guidelines for health and safety in the future development of natural resources in northern regions of the world.

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